MAPPING ONE NICHE OF SOCIAL PALEONTOLOGY’S DIGITAL ECOLOGY: EXPLORING THE PRACTICES OF MYFOSSIL COMMUNITY MEMBERS

By

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To my husband, Andy Nelson, for his strength, support, and encouragement

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CoP	Community of practice
PIT	Paleontological Identity Taxonomy

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Developing and implementing digital spaces that meld social learning and scientific knowledge is needed to increase educational opportunities and research collaborations in the sciences. In order to achieve socially-mediated scientific learning, digital habitats must be examined as they attempt to unite learners from across the spectrum of expertise. The purpose of this study was to explore the knowledge-generating capacity of myFOSSIL as a niche of a digital community of practice (CoP) through identifying which practices lead to participation in and contribution to social paleontology. Two analytical frameworks were employed. The learning activities framework (Wenger et al., 2009) established members' practices, while the Paleontological Identity Taxonomy (PIT) (Lundgren, Bex, & Crippen, 2018) characterized members based on their attributes. In this explanatory sequential mixed methods study, practices were examined first quantitatively, then qualitatively using the findings from the quantitative data analysis. Quantitative analysis complied data using content and social network analysis of the myFOSSIL forums, activity feed, and messages. The qualitative analysis took a multiple case study approach in which

profiles in practice based on member attributes explicated how practice-development occurred.

Community members enacted nearly all practices, including those that were specifically social in nature (e.g., Support) and those that emphasized scientific knowledge (e.g., Problem Solving). Furthermore, practices differed depending website feature (i.e. in forums, activity posts, or messages). Lastly, it was determined that members from different PIT categories (e.g., Scientists, Public, Education and Outreach) enacted different practices. For example, Education and Outreach members were interested in social- and research-specific dissemination of information while seeking support, whereas Public members were problem-solvers and advisors whose focus was on supplying a digital record of real-world expertise.

This study provides empirical evidence for the ways in which practices are enacted within online, scientific CoPs. In particular, how people with different experience and identity with the domain express this within an online environment. The findings can be used to strengthen or support efforts to design, develop, and implement online, scientific CoPs through providing evidence for the ways in which practices can be enacted in such communities.

CHAPTER 1
INTRODUCTION

Background

Ask a person who is unfamiliar with the field of paleontology to tell you what a paleontologist looks like and what they do. Most likely, that person will tell you that paleontologists are dust-laden folks, digging up dinosaur bones in remote locales so those bones can be mounted in museums. In the not so ancient past, this was fairly accurate. Paleontologists conducted field work and lab work without modern tools such as global positioning systems to precisely determine their locations, without megapixel cameras to document specimens, without power tools to remove field jackets and rock matrix from fossil specimens, or without the aid of computers to determine the diversity of extinct species.

Within paleontology and other natural sciences, the future and the past are now digital. Scientists and researchers are establishing digital initiatives that fundamentally change the nature of scientific work. I define digital initiatives as experiments with and developments in new and emerging technologies to aid scientific research. Such digital initiatives can include digitization workflows: common tasks that facilitate efficient and effective practice in the digitization of museum collections (Nelson, Paul, Riccardi, & Mast, 2012) as well as the creation of websites that foment digital and real-world connections between people, places, and things (Crippen, Dunckel, MacFadden, Ellis, & Lundgren, 2015).

Digital initiatives can fundamentally transform natural sciences research leading to new insights about important topics such as climate change, evolution, and biodiversity. A specific digital initiative that has fundamentally altered natural sciences research includes the digitization of museum specimen collections. Digitizing specimens and maintaining them in online databases allows researchers to make new insights that they might not have been able to make without digitized collections (Short, Dikow, & Moreau, 2017). For example, researchers at the University of Alaska recently described a project that centered on digitizing their insect collection. When this digitized collection was combined with other digitized museum entomology collections and compared with data collected by citizen scientists across Alaska, it revealed distributional changes in bumblebee populations over a 110-year period (Sikes et al., 2017). This study and similar studies (e.g. Kerr et al., 2015) show that digitized museum specimens, which can be examined be researchers regardless of space or time, are important to making inferences about species, including information about historic and current species range distributions. The evidence for changes in bumblebee range distribution and other scientific discoveries like it are not possible without the inclusion of digitized museum collections in online databases. Within museums, digital initiatives such as the digitization of museum collections in the natural sciences lead to knowledge generation: the development of scientific ideas based on claims, supported by evidence, and advanced by sound reasoning.

Within paleontology, a natural science field that answers questions about the history of life on Earth via the study of organisms, digital initiatives that enhance the practices of paleontology have been established. Practices are behaviors that people enact to solve complex problems specific to a field, such as paleontology (Wenger, McDermott, & Snyder, 2002). Such paleontological practices include collection, identification, preparation, and curation of fossils. Each of these practices are integral to paleontology; additionally, all are tied to digital initiatives that lead to knowledge generation. Within the practice of fossil collection, digital initiatives have enhanced the ways in which paleontologists document, retrieve, and remove fossils from their surrounding rock matrices. Specifically, digital initiatives that have led to knowledge generation are remote sensing and mapping at paleontological field sites. New technological advances have changed the way fossils are collected, with spatial data accumulated via a technique called Terrestrial Light Detection and Range (LiDAR) in which data is collected and stored in the event of erosion, construction, or other destructive acts (Bates et al., 2008). Before LiDAR, if data were collected at a fossil site that was subject to construction, that became eroded, or that was later destroyed, the only data associated with the site were those data collected via paleontological field notes, photographs, and collected samples. With LiDAR, high-quality scans allow for paleontologists to make more inferences about the site by examining data associated with the site. LiDAR data are often more robust than paleontological field notes or photographs, providing three dimensional views, measurements, and other data points that traditional field methods did not often capture. The advances in the practice of fossil collection provided by digital initiatives such as LiDAR contribute to knowledge generation in paleontology through the data capture capacity that the technology provides.

As with fossil collection, digital initiatives have also made identification of fossils easier, furthering knowledge generation in the science of paleontology. Such digital initiatives include the Digital Atlas of Ancient Life (http://www.digitalatlasofancientlife.org), an online compendium of photographic aids that assist paleontologists in deciphering fossils (Hendricks, Stigall, & Lieberman, 2015). Before free online photographic resources, paleontologists needed to search for fossil identification through studying physical specimens in museums, or seeking information in journal articles that required payment for access (Hartshorn, 2017). With the Digital Atlas of Ancient Life, paleontologists have access to up-to-date, high-quality specimen photographs to assist in their identification processes. The digital initiative of online photograph databases featuring fossil specimens contributes to knowledge generation in the paleontological practice of fossil identification by aiding paleontologists in their identification processes through technological means, providing them access to photographs of specimens that had been previously barred to them either physically or virtually.

A digital initiative in paleontology that is an experiment with technology to aid scientific research is the use of computed tomographic (CT) scanning. CT scans are commonly used in human and veterinary health care to diagnose disease. In paleontology, CT scans are used to determine internal anatomical features of fossils without subjecting those fossils to destruction (Cunningham, Rahman, Lautenschlager, Rayfield, & Donoghue, 2014). One such example of this is a study by Lautenschlager and colleagues (2012) in which the braincase of an herbivorous, bipedal therizinosaur (*Erlikosaurus andrewsi*) was examined. By studying the internal anatomical features of fossils, such as *E. andrewsi*, paleontologists can characterize the evolutionary history of fossilized species leading to insights about past life on earth. In using CT scanning, Lautenschlager and colleagues found that *E. andrewsi* had enhanced hearing, smelling, and equilibrium capabilities, something that was challenging if not impossible to assess using external observation of the fossilized skull. With their study, Lautenschlager and colleagues showed that CT scanning could lead to new insights regarding the evolutionary history about therizinosaurs.

Fossil curation has been positively impacted by digital initiatives that use big data to explore questions concerning extinction geography and evolutionary dynamics through connecting isolated museum collections. For instance, MacFadden and Guralnick (2017) studied how online databases could be used in determining evolutionary dynamics and extinction geography surrounding extinct fossil horses. The authors found that these online databases aggregated over one hundred thousand location records for fossil horses, although most of the records were limited to North America. Their study shows that for fossil species, digital initiatives such as online databases can aggregate museum collections which were once disconnected. However, these online databases are limited in scope by the records that are ingested into the databases themselves.

The use of LiDAR in collecting fossils, the development of digital databases to connect collections, providing access to photos of fossils for identification purposes, and advances in technology that make preparation of fossils easier are all examples of digital initiatives that have led to knowledge generation in paleontology. Across the practices of paleontology, digital initiative integration advances knowledge generation in paleontology through supporting the science’s practices regardless of time or space.

As digital initiatives to support knowledge generation develop, so do efforts to involve the public in scientific research. Public participation in scientific research (PPSR), also called citizen science, includes the public in knowledge generation and occurs when the general public joins scientific research through data collection, analysis, and project creation, delimited by a scale that is referred to as contributory to co-created research (Bonney et al., 2009; Shirk et al., 2012). When citizens contribute to projects, they add data in the form of observations of the natural world (Dickinson & Bonney, 2012). These citizens, also referred to as amateurs, benefit as they generate knowledge while exploring their own interests (Azevedo, 2017; Corin, Jones, Andre, Childers, & Stevens, 2015). Without digital initiatives, many PPSR contributions are not possible. Specifically, in ornithology, amateur bird enthusiasts upload their specimen data to eBird (https://ebird.org), generating knowledge through their species counts and observations, in some cases leading to understandings of population changes in migratory bird species (Walker & Taylor, 2017). In the natural sciences, PPSR has proven to be a valuable asset to knowledge generation.

Within paleontology, digital initiatives have advanced knowledge generation by including amateurs in the science's practices. Although amateur paleontologists' contributions pre-date digital initiatives especially in the case of the Cincinnati region and its' Cincinnati School of Paleontology (Hunda, 2017; Kallmeyer, 2017), with digital initiatives, any citizen with an interest in paleontology can generate paleontological knowledge regardless of time or space. With Zooinverse (https://www.zooniverse.org) projects such as the Smithsonian's Fossil Atmospheres project (https://www.zooniverse.org/projects/laurasoul/fossil-atmospheres) and the Fossil Finder project (https://www.zooniverse.org/projects/adrianevans/fossil-finder), citizens are used as data processors, asked to digitally catalog museum specimens or define, describe, and sort images of fossils. These digital initiatives support knowledge generation, which is documented in terms of numbers of specimens digitized or numbers of images sorted (Soul, Barclay, Wing, Bolton, & Megonigal, 2017). In addition to building up digital repositories and turning citizens into data processors, such projects can enhance skills and knowledge related to the subject matter (Perez et al., 2017; Perez, Leder, Lundgren, Ellis, & Dunckel, 2016).

Although paleontological knowledge generation through the help of digital initiatives is established, there is a dearth of literature that addresses a key facet of such knowledge generation: the development the people who contribute to paleontological knowledge generation as well as the practices they utilize in order to do so. Including people and the ways they learn about and generate knowledge concerning paleontology is called social paleontology (Crippen, Ellis, Dunckel, Hendy, & MacFadden, 2016). Practices are shared elements, both explicit and tacit, with which participation in and contribution within a domain are identified (Wenger et al., 2002). In social paleontology, practices including specimen collection, identification, preparation, and curation are used to understand the natural world (Crippen et al., 2016). To date, social paleontology's landscape of social learning has not been characterized or analyzed. Social learning is defined as being competent within a domain of knowledge, having experiences related to phenomena in the world, and sharing that competence and experience with others (Wenger, 2000). People and their practices are at the heart of social paleontological knowledge generation, yet the ways people develop practices and learn socially within the domain of social paleontology in order to generate knowledge are mostly undescribed.

When social learning in the context of science is described, it focuses on peoples' motivations for participation without delving into the behaviors people enact to do so. Specifically, researchers have considered citizen science as a mode of understanding social learning in science contexts. Some of this research has indicated that the social nature of participating in citizen science is key (Curtis, 2015; Land-Zandstra, Devilee, Snik, Buurmeijer, & van den Broek, 2016; Raddick et al., 2010, 2013). Within this line of research, the participatory nature of citizen science focuses on communal aspects in that by being a community member, participants find fulfilment. While this line of inquiry is important, studying social learning in order to understand the strength of communities misses a valuable aspect: the ways in which community members generate knowledge and develop their own skills within the domain.

Furthering this line of inquiry, studying the social learning processes inherent to these projects can be undertaken by examining them through the lens of communities of practice (Wenger, 1998; Wenger, 2000; Wenger et al., 2002). In such communities, practices unite people. As paleontology and other natural sciences become immersed in the form of digital practice, online communities of practice can help explain the social nature of networked learning, which is the use of information and computing technologies to promote a wide array of learning connections (Goodyear, Banks, Hodgson, & McConnell, 2004). Whereas the contributions of amateur paleontologists' digital practices have been quantified, the ways in which their contributions support their own and each other's learning while generating knowledge has not been studied extensively.

The digital nature of paleontological research has encouraged collaborations across time and space, using numerous platforms for such collaboration, including real and virtual spaces. These collaborations can occur in digital habitats, which are online spaces affording community-building activities regardless of distance or proximity (Wenger et al., 2002). When paleontologists enact practice in the virtual world, they are operating in a digital habitat. Social relationships and community activity can be supported within such a habitat through tools, platforms (also called niches), and features, and the configuration of such tools, niches, and features. In 2015, myFOSSIL (www.myfossil.org) was established to capitalize on the gregarious nature of paleontology in conjunction with building on the turn towards digital data and inclusion of the public in scientific efforts. Within the digital habitat centered on social paleontology, websites and social media sites such as Twitter, Facebook, and Instagram act as niches in which people interested in paleontology can enact domain-specific practices. As a niche, myFOSSIL was a website designed to foment connections between paleontologists from across the spectrum of expertise whereas Twitter, Facebook, and Instagram are social networking sites upon which paleontologists can connect with one another in addition to exploring a range of other social interests (boyd, 2015). As a discipline, paleontology relies on connections between all manner of paleontologist, however, little research explores the social relationships and learning processes among them.

Purpose of the Study

The development of digital spaces that meld social learning and scientific knowledge is needed to increase educational opportunities and research collaborations in the sciences. In order to achieve socially-mediated scientific learning, digital habitats must be examined as they attempt to unite learners from across the spectrum of expertise. A focus on adding knowledge in the form of numbers of specimens digitized or number of specimens donated falls short; therefore, focusing on the social aspects of online communities of practice is necessary. In this study, myFOSSIL was examined through the lens of communities of practice to better understand the ways in which paleontologists from across the spectrum of expertise contribute to and build on paleontological knowledge.

MyFOSSIL has been designed to build community within the science of paleontology by facilitating discussions and creating connections between fossil lovers, amateur paleontologists, and professional paleontologists. The site is focused on practices specific to paleontology, including fossil identification, field work, preparation, digitization, and curation of fossils. While the practices of paleontology are central, so are the people who enact them, including the ways they learn about and generate knowledge concerning paleontology, which is encompassed in the concept of social paleontology. Characterizing social paleontology in a niche such as myFOSSIL can help to alleviate a problem inherent to the field of paleontology: domain-specific knowledge fails to be distributed throughout the whole community of learners.

Accordingly, the purpose of this study is to explore the knowledge-generating capacity of myFOSSIL as a niche of a digital community of practice (CoP) through identifying which practices lead to participation in and contribution to social paleontology.

Theoretical Framework

I approach the problem of characterizing social paleontology within myFOSSIL through the CoP theoretical framework (Wenger et al, 2002). CoPs are defined by domain, people, and practice as three essential elements. The three elements are intricately intertwined, which can lead to them collapsing together, however, they describe distinct aspects of the CoP (Cox, 2005). Wenger and colleagues define a CoP as "a unique combination of three fundamental elements: a domain of knowledge, which defines a set of issues; a community of people who care about this domain; and the shared practice that they are developing to be effective in their domain" (2002, p. 27). A *domain* is the unifying component of CoPs, encompassing the shared interest of the community at hand. The shared interest uniting people within the domain must be complex and long-standing so that sustained learning can occur. The domain is a unifying element of a CoP, as participation within the domain is theorized to occur due to a "sense of accountability to a body of knowledge and therefore to the development of a practice" (Wenger et al., 2002, p. 30). This quote shows that the domain supports another element of a CoP: the *practice*. Practice is qualified as the development of shared elements, both explicit and tacit, Practices are shared elements, both explicit and tacit, with which participation and contribution within an area are identified , including: stories, tools, language, documents, shared world views, and ways of addressing problems (Wenger et al., 2002). The last of the three elements is implicitly connected to the other two elements: the element of community (henceforth referred to as *people*). People are those who engage in activities related to the CoP: having conversations about the domain, participating in the practice of the domain, and helping one another learn about the domain. Within a CoP the people develop a sense of belonging within the community via their interactions, participation in, and contribution to the practices of the domain.

CoPs can be established in the digital and real worlds, emerging naturally, or they can be engineered. Although the term CoP has been recently applied to the ways in which people learn collaboratively, people have been learning informally with one another for centuries (Wenger et al., 2002). In naturally emerging CoPs, communities tend to cluster along geographic lines, as is the case in industries like automobile making; or people group along friendship lines. However, these conditions are not necessarily bound to occur. Wenger et al. (2002) derived seven design principles that demonstrated how design elements coalesced in communities of practice. These design principles were theoretically-grounded and are useful in developing an understanding of the thinking that situated this study. The seven design principles were:

1. Design for evolution
2. Open a dialogue between inside and outside perspectives
3. Invite different levels of participation
4. Develop both public and private community spaces
5. Focus on value
6. Combine familiarity with excitement
7. Create a rhythm for the community

The principles originated from the study of various businesses and the people involved in designing, developing, and implementing communities within them. Scientific communities were not specifically studied as the design principles came to fruition, which establishes a basis for the need to study the knowledge-building capacity of a scientific CoP (i.e. myFOSSIL). Here, I establish the theoretical basis of the design principles (Table 1-1) so that empirical evidence can be added via the study of myFOSSIL. Melding empirical evidence from the study of myFOSSIL will derive evidence-based theory which can strengthen CoPs as a theoretical framework.

The first design principle, design for evolution, is backed by theory in the idea that CoPs change over time (Wenger et al., 2002). Specifically, CoPs go through five stages of development: potential, coalescing, maturing, stewardship, and transformation. The third, fourth, and fifth stages, (i.e. maturing, stewardship and transformation) are of particular interest. The maturation stage entails the movement from "establishing value to clarifying the community's focus, role, and boundaries" (Wenger et al., 2002, p. 97); the stewardship stage relates to sustaining "movement through natural shifts in practice, members, technology, and relationship to an organization" (Wenger et al., 2002, p. 104); and the transformation stage is concerned within the "tension between a community's sense of ownership and its openness to new ideas and people" (Wenger et al., 2002, p. 109). Within these stages, communities can develop strategies for enacting practice, although the ways in which communities do this need further definition and study.

The second design principle, open a dialogue between internal and external perspectives, is based on the idea that members with differential levels of expertise will contribute differently in the CoP. This design principle is based on participative governance, a business-oriented workplace theory that emphasized interdependent relationships, transparent information, and developing workplace competencies (McLagan & Nel, 1995). Within CoPs, dialogue entailed discussion of "the community's potential to develop and steward knowledge" which "often takes an outside perspective" (Wenger et al., 2009, p. 54). Through including components from McLagan and Nel

(1995), Wenger et al. (2002) acknowledge the ways that various perspectives add to the development and design of a CoP.

The third design principle, invite different levels of participation, is supported by the theoretical idea that peripheral participation, or interacting without contributing, is legitimate (Lave & Wenger, 1991). The ways in which members contribute or participate within a CoP can also be broken down by different levels. Wenger et al. (2002) called these the *core group*, the *active group,* and the *peripheral group*. The core group consists of approximately 10-15% of the membership, these members actively identify topics the community should address and determine the learning agenda of the community. The active group consists of 15-20% of the community, and are those who "attend regularly and participate occasionally in the community forums, but without regularity or intensity" (Wenger et al., 2002, p. 56). Lastly, the peripheral group is largest, consisting of approximately 70% of the community. These levels of participation and contribution allow for varied members to coalesce within the CoP, which can also happen within various types of spaces within a digital CoP.

The fourth design principle, develop both public and private community spaces, was theoretically supported by two lines of evidence: the concept of the third place (Oldenberg, 2001) as well as the conceptualization of affordances (Gibson, 1977; Norman, 2013). Third places (also called spaces) are "informal public places…that provide essential context for fostering various interpersonal connections" (Wenger et al., 2009), whereas affordances are the ways in which objects in an environment allow for interaction. These two notions help flesh out the fourth design principle, as the relationships that develop within a CoP can be found in both public and private spaces.

As Wenger at al. (2002) write, “the public and private dimensions of a community are interrelated” (p. 59). Thus, the features of different spaces might afford different interactions and the places in which these interactions occur might influence the people within them.

The fifth design principle, focus on value, lacks a full theoretical backing. Value, according to Wenger et al. (2002) is “a systematic body of knowledge that can be easily accessed” (p. 59), but also, value changes as the community changes. Indeed, in their description of value, Wenger et al. (2002) equate value with practice, writing that “the most valuable community activities are the small, everyday interactions” (p. 60). As such, this design principle is the least theoretically-sound. While value is emphasized, there is very little theoretical backing or description as to what the authors view as value, aside from interactions between members. These interactions were previously described by the authors as *practice*, therefore, it can be determined that value can be equated as practice.

The sixth design principle, which entailed combining familiarity with excitement, is backed by the theoretical notion that variation is a way to denote the strength of the CoP. Wenger et al. (2009) mapped out specific learning activities that could be used by CoPs regardless of the domain in which the CoP operated. These specific learning activities were nested within seven specific higher-level activities. These higher-level categories included Exchanges, Productive Inquires, Building Shared Understanding, Producing Assets, Creating Standards, Formal Access to Knowledge, and Visits. As such, the higher-level activities and their nested specific learning activities were ways for community members to enact the sixth design principle, combining familiarity with excitement by engaging in the activities.

Lastly, the seventh design principle of entails creating a rhythm for the community. This rhythm is based on the theoretical notion that within an online CoP, the rhythm will change based on face-to-face and online activities (Wenger et al., 2002). This design principle is based on evidence derived from workplaces (Gersick, 1988) in which team members in workplaces followed patterns of work that altered between inertia and revolution. This finding allowed Wenger et al. (2002) to determine that events center activity, which led to the design principle of creating a rhythm for the community.

Whereas the design principles are specific for face-to-face CoPs, they can be applied to CoPs that have members who do not live close enough to commune face-to-face. The digitally-connected world affords opportunities to establish digital habitats—knowledge- and community-building CoPs that cross temporal and spatial boundaries. Within digital habitats, people are “enabled by a configuration of technologies,” find one another and meaningfully engage in learning (Wenger et al., 2009, p. 38). The boundaries between people shift as technology extends the confines that CoPs can operate within. Technology both extends and narrows CoPs concurrently. Technological extension enables discovery by nearly anyone with a connection to the Internet. However, technology also narrows CoPs in that private spaces can be easily established for those CoPs that want to limit access to those outside the domain from which they operate. These shifting boundaries influence dynamics related to participation, especially peripheral participation, which is a way for people with less experience to become more immersed in practice (Lave & Wenger, 1991). Digital habitats, like CoPs situated in the real world, are defined by the domain, people, and practice: the interaction of these three components provide potential for people to learn together.

Community relationships are central to social learning, however, the ambiguity in the definitions within the CoP framework has led to ill-structured conceptualizations of the explanatory power of CoPs. Most recent research on CoPs is focused on higher education (e.g. Carroll, 2005) wherein the authors explain that community relationships are key to a CoP devoted to teaching and learning at a university level, yet no empirical measurements support such claims. Qualitatively describing the ways people commune, as well as their dispositions is valuable, but lacking robust analytical frames and empirical descriptions, these narratives lose credence. Theoretically, the CoP framework is important as it adds value to social relationships while bounding those relationships as well as explicates that people enact specific activities within the community for specific purposes.

The theoretical framework used for this study is rooted in socioconstructivist views on learning and knowledge (Wenger et al., 2002, 2009). Digital CoPs frame the study, allowing for the examination of people who exhibit practices within a specific domain of knowledge. The CoP framework grounds my methodology for examining the people and the practices within myFOSSIL, a niche in the social paleontological digital habitat.

Statement of the Problem

Previous research on CoPs is mostly descriptive in nature (Bondy, Beck, Curcio, & Schroeder, 2017). Descriptive studies can be useful, as thick, rich descriptions of contexts highlight the complexity of situations in which learning develops. However, these descriptive studies do not capture the reasons *why* CoPs flourish or fail. The work presented here attempts to both contextualize a domain-specific CoP and present evidence for such a CoP acting as a knowledge-creating space, in which understanding and knowing come about via the interaction between people and their environment.

Many previous attempts to characterize CoPs focus on community aspects in that the foci are about creating *community* versus focusing on how knowledge within the domain can be created by the community (e.g. Wenger et al., 2002; Bondy et al., 2017). In these works, researchers imply that if you build mechanisms for community, the knowledge will come. Shifting the focus of research to emphasize the development of practices that lead to participation in and contribution to the domain allows researchers to establish for whom and under what conditions CoPs meet success.

Research Questions

In line with the CoP theoretical framework, three research questions were proposed to explore myFOSSIL as a knowledge-creating niche of a digital CoP. These research questions will allow me to identify which practices lead to participation in and contribution to social paleontology.

1. What forms of social paleontological practice exist within myFOSSIL?
2. For textual practices, what types of knowledge-creating discourse exist?
3. What forms of practice-development occur within myFOSSIL and how are they related to the attributes of community members?

Significance of Study

The significance of this study is threefold in it that has the potential to rectify issues with CoPs as a theoretical framework; develop theoretical insights for CoPs that are supported with practical, empirically-evidenced statements; and establish what practices exist within the domain of paleontology.

CoP research often focuses on one element within the framework: the community. Research examining CoPs often solely address the concept of community building, exploring the strength of the community participating in the CoP (Kienle & Wessner, 2005; Kimble, Hildreth, & Bourdon, 2008b, 2008a). While CoPs have been conceptualized for formal learning (González-Howard & McNeill, 2016) and within some informal learning environments (Kelly, Cook, & Gordon, 2006), especially those that involve digital niches such as Twitter and Facebook (Stephansen & Couldry, 2014), there is limited research related to the conceptualization of CoPs for scientific fields. The limited literature concerning CoPs within scientific fields will be addressed by this study as I seek to develop theoretical insights that are supported with practical, empirically-evidenced statements. Practices are an integral element to a CoP yet are often removed from focus in favor of studying the element of community. This study seeks to establish what practices exist within the domain of paleontology. By establishing the practices of social paleontology within myFOSSIL using the theoretical framework of a CoP, this study fills a research gap that exists in CoP-related literature and contributes new knowledge related to the ways that CoP members collectively support knowledge-building through their participation and contribution to the domain-specific practices of social paleontology.

Table 1-1. Theoretical support for design principles of a CoP

Design Principle	Theoretical Support
1. Design for evolution	CoPs change over time (Wenger et al., 2002)
2. Open a dialogue between inside and outside perspectives	Based on participative governance, a business-oriented workplace theory that emphasized interdependent relationships, transparent information and developing workplace competencies (McLagan & Nel, 1995). Members with different expertise levels will contribute to an online CoP in differing ways.
3. Invite different levels of participation	Peripheral participation is legitimate (Lave & Wenger, 1991; Wenger et al., 2002)
4. Develop both public and private community spaces	The concept of the third place (Oldenberg, 2001) as well as the conceptualization of affordances (Gibson, 1977; Norman, 2013).
5. Focus on value	Theoretical backing is lacking
6. Combine familiarity with excitement	Variation and usage of different practices highlight the strength of the CoP (Wenger et al, 2009)
7. Create a rhythm for the community	Within an online CoP, the rhythm will change based on face-to-face and online activities (Wenger et al., 2002).

CHAPTER 2
LITERATURE REVIEW

In this study, myFOSSIL was examined through the CoP theoretical framework to better understand the ways in which paleontologists from across the spectrum of expertise contribute to and build paleontological knowledge. Three research questions were utilized to explore myFOSSIL as a knowledge-creating niche of a digital CoP.

1. What forms of social paleontological practice exist within myFOSSIL?
2. For textual practices, what types of knowledge-creating discourse exist?
3. What forms of practice-development occur within myFOSSIL and how are they related to the attributes of community members?

These research questions directed the exploration of the knowledge-generating capacity of myFOSSIL as a niche of a digital CoP through identifying which practices led to participation in and contribution to social paleontology. The significance of this study was threefold in it that had the potential to rectify issues with CoPs as a theoretical framework; develop theoretical insights for CoPs that are supported with practical, empirically-evidenced statements; and establish what practices exist within the domain of social paleontology.

As a well-known and well-funded research agency in the United States, the National Science Foundation acts as a driver for fuller public participation in science, technology, engineering and mathematics (STEM). In social learning, fuller participation refers to building social relationships in order to further develop domain-specific practices (Lave & Wenger, 1991). For the National Science Foundation, fuller public participation in science is regarded with quantitative metrics, which Lave and Wenger would refer to as *complete* participation, as the system contains “measurable degrees of ‘acquisition’” (Lave & Wenger, 1991, p. 37). These measured degrees of acquisition can be enacted through contributing to and participating in authentic experiences with STEM and are built into federal grants through Broader Impacts (BI) initiatives, one of the two criteria considered when grants are under review. According to the National Alliance for Broader Impacts, BI benefit society in a multitude of ways, including strengthening STEM education, increasing scientific literacy, and infusing STEM with a diverse workforce (Retrieved from https://osf.io/jveb7/).

Fuller public participation in STEM requires strong partnerships among all groups, including scientists, citizens, and amateurs; in many cases such proposed participation can be categorized as short-term outreach, either to the general public or to schools (Frodeman & Parker, 2009; Kamenetzky, 2013; Roberts, 2009). While such initiatives are important, the most effective BI are those that encourage life-wide, life-long learning (Falk & Dierking, 2012). Furthermore, BI initiatives also often focus exclusively on passing on scientific knowledge from scientists to the public, enacting a deficit model of learning in which non-scientists are empty vessels that need to be filled with knowledge to be better citizens (Bucchi, 2014). As such, many BI initiatives fail in their attempts to build unique, valued, and sustainable partnerships.

While it is important for citizens and scientists to have scientific knowledge, the deficit model alone is unable to sustain contribution to and participation in STEM as it is put forth in the BI merit criteria. Thus, the FOSSIL Project aimed to address certain types of BI in the science of paleontology, including: full(er) participation of underrepresented groups in STEM, improved STEM education, increasing scientific literacy, and increased partnerships between academia, industry, and others.

Building on the calls for increased partnerships between all interested parties as well as inclusive science learning at all levels and within all learning environments, I argue in this chapter that collaborative initiatives between practicing scientists and members of the public must tackle the social dimension of learning in addition to addressing the cognitive dimension. I present a review of the literature related to citizen science initiatives, noting trends in goals, outcomes, and challenges, acknowledging the limited number of studies which examine the social aspect of learning inherent to citizen science (Figure 2-1). Following this section, I will present a synthesis of the work on CoPs generally, then focus on studies that address scientific CoPs. I then identify and describe current challenges to creating and maintaining CoPs as I argue for the merit of establishing myFOSSIL as a knowledge-building niche of a digital CoP.

Citizen Science as Social Learning?

According to the Center for Advancement of Informal Science Education, citizen science entails including the public in the myriad activities and processes that are involved in scientific research (Bonney et al., 2009). As such, a number of different pathways towards understanding citizen science exist. The first such pathway is the benefits to science in terms of scientific knowledge, the second, the cognitive benefits that participation has on those who do it, and the third, the affective components of participating in citizen science. To elucidate the differences between these three pathways, I will write about exemplar studies from each.

The first pathway in citizen science often focuses on the scientific outcomes of such efforts. In many sciences, citizens collect data which can clarify poorly-understood phenomena. This pathway focuses on the trend in citizen science in which scientists report on data collected by citizens wherein the data itself is of key importance regardless of the data collector. These studies often indicate that citizen scientists' data allow for scientists to make inferences about specific study species, climatic events, or the nature of the universe.

Examples that elucidate this trend can be found in the sciences that explore the natural world, including biology, ecology, ornithology, botany, and entomology. In one metaanalysis study, it was found that citizen scientists collect data on nearly every essential biodiversity variable, including species monitoring, population demographics, and migratory behavior (Chandler et al., 2017). Indeed, in ornithology, citizen scientists' data is valuable to scientists as these data can indicate changes in birds' lifecycles and migratory patterns (McCaffrey, 2005; Newson et al., 2016). An example of citizen scientists capturing such patterns is from the United Kingdom, where 40 years of citizen scientists' data led scientists to conclude that a changing climate was responsible for the pattern changes (Newson et al., 2016). Other studies that draw on citizen scientists' data collection skills have helped scientists make insights into biological patterns of butterfly species diversity, especially making gains in understanding how environmental conditions shape such patterns (Prudic et al., 2017). Such studies exemplify how citizen science data can aid in understanding and interpreting events concerning the natural world while incorporating more types of expertise in the process.

However, such data collection processes are not without limits, including issues of quality control and length of participation by citizens. The quality of citizen science data has often been called into question, with researchers wondering if the data collected by citizens was on par with the data collected by scientists. Some studies touch upon this issue, as illustrated by literature on validation issues in which training and redundant classification made it so citizen observations were on par with scientist observations (Bonter & Cooper, 2012; Galloway, Tudor, & Haegen, 2006; Swanson, Kosmala, Lintott, & Packer, 2016). Other researchers suggest that data input by non-scientists is often more accurate when participants are tasked with providing general information versus species specific information (Lukyanenko, Parsons, & Wiersma, 2014). For these studies, there is no indication of cognitive or affective outcomes for citizen science participants, but rather, the focus is solely on the quality of data they collected. Other research indicates that citizen contribution patterns are short-term and inconsistent (Sauermann & Franzoni, 2015). These patterns indicate a turn towards an examination of cognitive and affective domains of citizen science, focusing on the ways in which contribution to citizen science affect participants.

To understand the benefits of participating in citizen science, researchers often utilize measures to determine cognitive outcomes of such participation including increased science literacy or content knowledge. Over the last decade, studies that focus on the cognitive benefits for citizen science participation span a wide range of sciences including ecology, where participants monitored invasive species then showed science literacy gains (Cronje, Rohlinger, Crall, & Newman, 2011), ornithology, in which participants showed increased knowledge and attitudes concerning bird biology following their work on the project (Brossard, Lewenstein, & Bonney, 2005), and climate science, in which participants had more defined definitions of weather and climate following use of a citizen science-specific smartphone app (Land-Zandstra et al., 2016). The cognitive benefits of participating in citizen science are often highlighted, indicating that when people participate in citizen science, they gain increased content area knowledge (Cronje et al., 2011; Sickler, Cherry, Allee, Smyth, & Losey, 2014). Conflicting literature is abundant in regards to cognitive learning gains in citizen science initiatives, as illustrated by Druschke and Seltzer (2012), who found that participants had positive affect towards citizen science, but did not learn scientific content in their endeavors. Regardless of conflicting reports, content area knowledge is important as increased science literacy implies an increased understanding about socioscientific issues and ensures that citizens have a stake in science.

The third pathway in citizen science literature is that of studies focusing on affective outcomes. Affective outcomes are defined as interest in scientific topics or motivation to pursue scientific activities (Phillips, Ferguson, Minarchek, Porticella, & Bonney, 2014). In many cases, these outcomes, such as motivation, enjoyment, or attitude towards science, are merged into findings concerning cognitive gains from citizen science participation. Indeed, many studies analyze the motivations of citizen science participants. Such studies have queried participants, finding that some participants enjoy the act of contributing to scientific endeavors (Raddick et al., 2010, 2013). In entomology, college students' attitudes towards science were positively altered by participating in a citizen science project even though content knowledge was not (Vitone et al., 2016). These findings show that the affective nature of citizen science participation has as much of an effect on the people as the people do on the science.

Some efforts to measure the affective outcomes have been successful, however, a plethora of examples exist that highlight failures to engage participants in the affective domain. Brossard, Lewenstein, and Bonney (2005) indicate that while participants' knowledge concerning bird biology was positively impacted by their participation in a citizen science project, their attitudes toward science were not. Similarly, researchers found that participants who collected honeybees in an urban area collected significant amounts of data, yet did not meet any of the prescribed educational or affective goals envisioned by the project (Druschke & Seltzer, 2012). These studies address an important aspect of citizen science research in that not all citizen scientists show affective benefits of participation.

Literature that encapsulates the three citizen science pathways, namely, the scientific data that citizen science participation adds, its cognitive benefits to participants, and the affective outcomes on its participants is valuable, but it fails to account for components that are integral to understanding how people learn: they develop shared practices together and through each other.

Learning together: Communities of Practice

In social learning, people interact with one another in the real world or the digital one; communicate using oral, recorded, or written language; and solve problems collaboratively (Wenger, 1998). Many researchers have described the ways in which people learn collaboratively, including researchers who focus on social development (Vygotsky, 1980) and situated learning through legitimate peripheral participation (Lave & Wenger, 1991). In these lines of research, collaborative learning occurs when more knowledgeable others assist learners who are less familiar with a domain in gaining, developing, and contextualizing information in the world. Specifically, in the case of legitimate peripheral participation, a way of belonging in a community in which learners can engage in social practice via less-intensive action versus centralized action (Lave & Wenger, 1991). Learning and increased understanding via legitimate peripheral participation occurs through growing involvement within an area of interest.

Furthermore, researchers who study social learning envision learners as agents who contribute to learning through interactions with one another (Brown, Collins, & Duguid, 1989). These key pieces of research help inform our understanding of social learning defined as CoPs. The social fabric of the CoP was expressed through shared practices in which community members learn through and with one another to solve problems that are related to a specific domain (Wenger, 2000).

The CoP theoretical framework is well-established within the field of educational research, but carving this niche was an evolving process which took time. The construct of CoPs emerged from work done by Lave and Wenger (1991) on legitimate peripheral participation in which learners grow more involved in community membership through participating more fully within a community. Within the contexts Lave and Wenger examined, participation was contextually dependent on the learning environment. This radical shift decoupled learning from formal school environments, allowing researchers to examine the ways in which learning occurred, focusing on context as it related to the learner. Lave and Wenger specifically addressed learning via conceptualizing legitimate peripheral participation, which can occur at any time and any place and entails the strengthening of a member's involvement in the community through participating in its practices. The legitimacy of participation does not center on *complete* participation within a community, but rather focuses on *full* participation (Lave & Wenger, 1991, p. 36). The term *full* indicates the openness and dynamic nature of relationships that CoPs provide whereas *complete* specifies participation as a closed system with "measurable degrees of 'acquisition'" (Lave & Wenger, 1991, p. 36). This focus reveals an issue that emerges in this work and continues throughout Wenger's development of the CoP theoretical framework: abstaining from the use of metrics for participation within CoPs. Lacking empirically-testable metrics in relation to key CoP components is not isolated to Lave and Wenger's (1991) work on legitimate peripheral participation. Indeed, in later work, the theory is made more robust via additions of design principles as well as stages of development (Wenger et al., 2002), however, these additions do not have empirical measures per se. This issue must be remediated to make CoPs both theoretically and empirically sound.

From the initial work on legitimate peripheral participation, Wenger (1998) further conceptualized CoPs to more fully describe the processes for participating in social learning. Wenger (1998) describes CoPs as ways for people to "[be] together, [live] meaningfully, [develop] a satisfying identity, and altogether [be] human" (p. 134). With this work, Wenger emphasized what CoP membership entailed, specifically focusing on competent membership. Competent community membership was encapsulated with three concepts: mutuality of engagement, accountability to the enterprise, and negotiability of the repertoire. In mutuality of engagement, a person's "ability to engage with other members and respond in kind to their actions, and thus the ability to establish relationships…is the basis of identity for participation" (Wenger, 1998, p. 137). This definition shows that Wenger believed that the ways people communicate with one another are the most important component for participating in a CoP. Wenger then defined accountability to the enterprise as taking responsibility for "enterprise" in a CoP and contributing "to its pursuit and to its ongoing negotiation by the community" (1998, p. 137). With this definition, Wenger bolstered the idea that communication and community relations are the crux of the issue, as when CoP members negotiate (i.e.

create meaning together), they exemplify competence. Lastly, competent CoP membership can be identified by negotiability of the repertoire, or, being able to engage in the practices of the community, especially in its history, as this is the way to "recognize the elements of the repertoire" (Wenger, 1998, p. 137). Thus, Wenger envisioned competent CoP members as those who were well-versed in the past conversations of other members. These conceptualizations that compose competence were community-centric and lacked definition and are difficult to be empirically tested. The engagement with others via interactions such as responding to others' actions or negotiating what enterprise is within the CoP is at the core of this conceptualization of CoPs. As with Lave and Wenger's (1991) definition of legitimate peripheral participation, there were flaws in Wenger's (1998) conceptualization of CoPs. Within this conceptualization of CoPs, competence was described with little evidence-based empirical research. The theoretical positioning is key to creating a social learning system, but without empirical testing of key theoretical elements, the CoP theoretical framework is severely limited in practical applications.

Competence, with its' three nebulously-defined elements, formulate the basis for Wenger's next iteration of the CoP framework (Wenger, 2002), in which Wenger characterized social learning, focusing on refining competence and defining experience. When redefining competence, Wenger writes, "competence is what it takes to act and be recognized as a *competent* member" [emphasis added] of a community whereas when defining experience, Wenger writes that it "is being in the world as a member" (2000, p. 227). Wenger's viewpoint that competence and experience interact to define how people learn socially also require enactment by the people themselves. This enactment, Wenger intones, requires belonging which has, in his view, three modes: engagement, imagination, and alignment. Engagement is the ways in which people do things together; imagination is the way people construct images of themselves and others; and alignment is the steps people take to ensure that learning processes they are involved in connect to their other experiences. Taken all together, Wenger refers to the modes of belonging as ways to enact social learning processes by being a competent member of the CoP.

In order to codify the enactment of such social learning, Wenger describes three "dimensions of progress" in CoPs, specifically "enterprise," "mutuality," and "repertoire" (2000, p. 230). Enterprise is defined as "the level of learning energy" of a CoP, meaning that there should be some measure as to the degree to which members continually centralize learning within the CoP (2000, p. 230). The mutuality of the CoP relates to the "depth of social capital," another measure that emphasizes trust, contribution, and reciprocity (Wenger, 2000, p. 230). Lastly, repertoire covers "the degree of self-awareness" a CoP has. Specifically, Wenger queries, "How self-conscious is the community about the repertoire that it is developing and its effects on its practice?" (2000, p. 230). This self-defined dimension (i.e. repertoire is being self-aware of the degree of repertoire), is problematic as neither practitioners nor theorists can empirically test or build meaningfully upon tautologies. These dimensions of progress provide guiding questions, but not specific metrics, for practitioners interested in developing and maintaining CoPs.

Researchers first focused on describing the management of knowledge within CoPs in order to ensure success in the changeable workforce (Wenger et al., 2002).

The body of literature is bifurcated in that *community* researchers focus on earlier conceptualizations of CoPs from Wenger (1998, 2000) while researchers interested in knowledge management follow the conceptualization of CoPs from Wenger et al (2002). In this next section, I will describe the limitations of the current body of literature on CoPs, namely, how most research on CoPs has focused on community in lieu of describing the practices that community members enact.

Communities of practice as communities

The most common issue with CoP research is the focus on community at the expense of describing other key aspects of the framework. The aspect of community is theoretically examined instead of being subjected to methodical and empirical testing. Theoretical examination of community in CoPs leads researchers to bold claims that establish the strength of CoPs, yet these bold claims are never empirically advanced (e.g. Nistor, Daxelder, Stanciu, & Diekamp, 2015). The community aspect of the three-pronged theoretical framework is endlessly probed in educational research. Researchers claim that the exclusive focus that is paid to community reflects Wenger's (2000) description of CoPs (e.g. Kimble, Hildreth, & Bourdon, 2008a, 2008b). I describe such community-focused research in the following paragraphs and indicate their shortcomings.

In the field of science education, CoPs and situated learning have been explored as ways to engage students in scientific argumentation and preparing them to be scientifically literate global citizens (González-Howard & McNeill, 2016). Specifically, Gonzalez-Howard and McNeill indicate that community is key to establishing classroom science practices including scientific argumentation. In the classroom they examined, classroom membership was transitory, which negatively affected the community and its practices, as every time a new member was added, the community member had to be socialized. This socialization time period coupled with a limited time frame for students to experience legitimate peripheral participation led to a weakened CoP.

Other CoP researchers focus exclusively on the benefits that inclusive communities have on the CoP itself. In their work on academic CoPs, Kimble and colleagues (2008a), emphasize community, or, as they call it, “mutual engagement” (p. 27) as a key component of a CoP. This is a callback to Wenger’s (1998) definition of practice, as he indicates, that “mutuality of engagement” is “the ability to engage with other members and respond in kind to their actions, and thus the ability to establish relationships” (p.137). Within both Wenger’s 1998 conceptualization and Kimble and colleagues’ 2008 conceptualization of a CoP, the people who are acting or learning together are the most important aspect of the CoP but there is a problem: the conceptualization is so vaguely defined, so wide that it can mean almost anything. This key issue within the CoP theoretical framework which makes it useful yet challenging to work with: it has breadth. The breadth makes it widely applicable, but without specific rules, the framework is also difficult to empirically establish. For Wenger (1998) and Kimble and colleagues (2008), inherently, the community is central. There is some emphasis on practice as they indicate that practices have to be mutually shared and agreed upon, offering up examples such as conferences, journals, and relationships. Furthermore, these practices are self-defined by the fact that they are being done by community members. Aside from the indication that community members enact these practices together, Kimble and colleagues do not delve into the ways in which the practices support the community.

Developing CoPs is described in a number of studies in a number of contexts. Specifically, informal and formal classrooms are places in which CoPs are presented as developing. For instance, Sadler (2009) describes theoretical implications for the development of CoPs in classrooms. Specifically, Sadler indicates that CoPs can be utilized in classrooms to develop scientific citizens through authentic practice with science. Cindio and Fiorella (2012) present a framework for designing digital habitats (i.e. CoPs) for community-based dialogues. Tested with citizens in Italy who reported on their street conditions and communicated directly with councilmen on forums, this framework for an online CoP was focused on community in its three-pronged approach. While explicitly an online CoP, it better fits with the community-centric literature review because the three prongs are all community based. Cindio and Fiorella describe the community as a place where interactions occur without specific purposes, leading to a sense of community and mutual trust; yet when purposeful interactions occur, these are centered on shared outcomes and decisions.

Nistor and colleagues (2015) also examined CoPs, focusing on academic CoPs. In this study, researchers developed a scale measuring *sense of community* that correlated socio-emotional knowledge with knowledge sharing. Thus, the intrapersonal relationships (i.e. community) in this CoP were measured in order to determine the knowledge output. This is a key example of a CoP study that focuses on community but does it well, as it indicates the ways in which the community aspect of a CoP adds to the knowledge generating outputs of the CoP.

Another helpful key example is that of Barab and colleagues (2001) who studied mathematics and science teachers in an online professional development environment.

Barab and colleagues used CoPs to explain the ways in which the community aspect of a CoP can account for identities and how those identities can enact change. However, Barab and colleagues found troubles with their community: the most active community members were those who were participating because they were extrinsically motivated (i.e. it was required) instead of participating organically. This is problematic, as Wenger and colleagues (2002) indicate that successful CoPs are those that develop and are sustained because people want to be involved. Community development through practice often relies on proximity: people forming a CoP while in a certain place. However, not all CoPs are constrained by time or place, especially with the development of online CoPs.

Online CoPs: Benefits and Challenges

The sense of community in a CoP has been theorized as constrained by proximity (Brown & Duguid, 2000), yet many researchers have established that online CoPs expand learning boundaries, creating effective learning networks unimpeded by time or space (Conole, Galley, & Culver, 2010; Gunawardena et al., 2009; Hoadley & Kilner, 2005; Wenger et al., 2009). This section will expand upon the topic of online CoPs, citing research that has both theoretically and empirically discussed the benefits and challenges of them. Furthermore, I will differentiate this body of work from the community-based CoP work, as this body of research is often centered in knowledge-management and eschews the community aspect for a focus on individuals or a focus on where knowledge is stored. First, I will describe what knowledge-management is, specifically, the way in which information is maintained, processed, or distributed.

Knowledge includes physical, tangible data such as files or ephemeral, intrinsic structures inside peoples' minds. Researchers who study online CoPs can track knowledge in more tangible ways than researchers who study in-person CoPs, as online CoPs often utilize forums, messaging services, email, and other formats that leave evidence behind. These records of activity within online systems are referred to as digital trace data, and leave patterns and processes that can be analyzed (Howison, Wiggins, & Crowston, 2011). Hoadley and Kilner (2005) developed the C4P framework that explained the ways knowledge is created and disseminated as well as provided a way to analyzed such knowledge. The C4P framework, in which *C4* stands for content, conversation, connections, context and *P* stands for purpose, is important as it established a design for online CoPs. This design centered on contextualizing content through structured conversations with meaningful intent in order to generate knowledge. These pieces are integral to CoPs, especially the aspect of practice, an element that lacked explicit definition and explication in earlier research. Wenger (1998) is specifically vague in this aspect, focusing on the "social production of meaning" as a way to illuminate practice (p. 49). Through new developments in the theory, such as Hoadley and Kilner's description of the C4P framework, Wenger's original conceptualization of social production of meaning begins to take shape.

Gunawardena and colleagues (2009) further the theoretical conceptualizations of online CoPs with the addition of social networking tools. Their online CoP is based on practice, specifically, social networking, which is a practice that expands "knowledge by making connections with individuals of similar interests" (Gunawardena et al., 2009, p. 4). The community discussed by Gunawardena and colleagues is that of higher education researchers whose practice is built through the use of social networking tools. Specifically, Gunawardena and colleagues postulate that social networking sites augmented the ways in which their CoP learned about learning. The augmentations included providing community members with the ability to collaboratively build knowledge and develop their metacognitive knowledge. Through the discussion of practical tools, Gunawardena and colleagues attempt to add to the theoretical basis of CoPs by establishing a basis for the use of social networking tools in online CoPs. However, they fail to provide evidence that social networked CoP of higher education researchers is not contextually bound. Contextual bounding a study is important, as without boundaries, studies fall into a CoP conundrum that is presented in Wenger (1998): describing CoPs too generally and therefore encompassing anything. However, the study by Gunawardena and colleagues is not convincing enough; while it is contextually bound, robust descriptions of practice that are empirically refined are lacking. Describing social networking tools, like Wikis, which were key to building the CoP helps situate the context, however, within the social networking tools, the practices lacked dimension.

Empirical research into the nature of online CoPs build on the theoretical notions established by Wenger (2000), specifically examining CoPs from business-centric viewpoints (Ardichvili, 2008; Pan et al., 2015; Quan-Haase & Wellman, 2005). Ardichvili (2008) indicated that by understanding what factors contribute to the success of online CoPs, human resource developers in businesses could better motivate their employees to contribute to knowledge management endeavors. Motivations included personal benefits, such as career advancement; community considerations, such as establishing ties; and cultural norms, such as leaders who share knowledge within the community. However, Ardichvili also identified barriers to success, such as interpersonal conflict, procedural challenges, technological issues, and cultural problems. This framework was important from a knowledge-management perspective as it mapped CoP-centric ideas to a business model. Within this line of thought, the community aspects were intimately tied to the conceptualization of knowledge-management: to understand the community and their interests was to be able to manage and have access to their knowledge.

Quan-Haase and Wellman (2005) indicated that computers could augment communication, adding trust and building community. However, they also argued that the community structures had to already be in place for computers to augment communication. Therefore, this research was still connected to the community-centered research of CoPs. Pan and colleagues (2015) specifically studied knowledge management systems, finding that social networking enhanced knowledge sharing in an online community. In this study, it was discovered that when people were friends on a social network, they were more likely to exchange information than people who were not friends on a social network. Furthermore, friendships were defined as relational networks in which mutual learning and discussion can occur because of the tie itself. Practices involved in knowledge management, including asking questions and providing answers as well as befriending others virtually, provide structural support for the community. The study by Pan and colleagues is an example of an empirical study that utilizes specific practices to empirically define the ways in which an online CoP functions. Whereas the studies concerning knowledge-management in online environments allow for an understanding of the ways that practices occur, they focused too explicitly on being of use to practitioners, leaving out the ways in which the findings connect to the theoretical framework of CoPs.

In this chapter, I summarized bodies of work about CoPs that are centered on knowledge management and on community building. These lines of research have established CoPs as places where people come together for shared purpose as well as CoPs as communities in which knowledge can be managed, distributed, and stored, especially in workspaces. However, within these bodies of work, there is little evidence for the ways in which members of CoPs, especially digital CoPs can build knowledge. It is important to establish such capacity for digital CoPs, as community building is only one element of a successful CoP. It is known and has been established that CoPs need community to flourish. What is still unknown is the capacity for digital CoPs to build knowledge centered around a domain and based in practice—this study will explore the knowledge-generating capacity of such a digital CoP.

This chapter summarized the literature concerning citizen science initiatives, specifically noting three trends related to citizen science pathways: scientific outcomes from citizen science, the cognitive benefits of participation, and the affective outcomes of participation. Whereas social learning can be encompassed in both cognitive and affective outcomes of citizen science participation, there are limited studies which do so. In order to address this aspect, I establish CoPs as a method with which to do so, especially online CoPs. I presented literature that discusses the bifurcated nature of CoP research, specifically CoPs that focus on knowledge management versus CoPs that focus on community. Lastly, based on the literature, I argued for the merit of examining myFOSSIL as a knowledge-building niche of a digital CoP using the following research questions:

1. What forms of social paleontological practice exist within myFOSSIL?
2. For textual practices, what types of knowledge-creating discourse exist?

3. What forms of practice-development occur within myFOSSIL and how are they related to the attributes of community members?

These research questions direct the exploration of the knowledge-generating capacity of myFOSSIL as a niche of a digital CoP through identifying which practices lead to participation in and contribution to social paleontology.

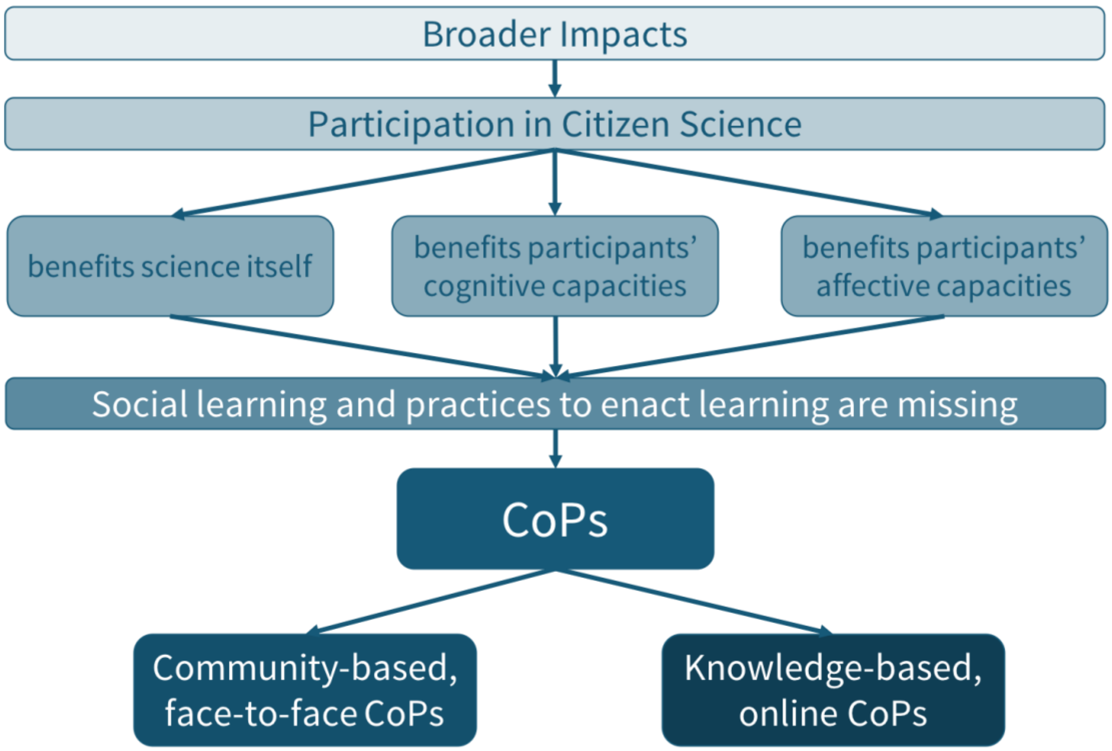

Figure 2-1. Navigating the relationship between Citizen Science and CoPs

CHAPTER 3
METHODS FOR MAPPING PRACTICES WITHIN THE NICHE OF MYFOSSIL

Introduction and Research Design

In this study, myFOSSIL was examined through the CoP theoretical framework to better understand the ways in which paleontologists from across the spectrum of expertise contributed to social paleontological knowledge. Three research questions directed the exploration of the knowledge-creating capacity of myFOSSIL as a niche of a digital CoP through identifying which practices lead to participation in and contribution to social paleontology. This study's significance included the potential to rectify issues with CoPs as a theoretical framework; to develop theoretical insights for CoPs that are supported with practical, empirically-evidenced statements; and to establish what practices exist within the domain of paleontology.

I first present an overview of the research design, giving a basic description of explanatory sequential mixed methods (Creswell, 2011) as well as describe the analytical framework with which I approach my analysis (Figure 3-1). Following that, I provide background into the community of myFOSSIL members that serve as the target population and sample of the study. Then, I will explicate the first phase of research, that of quantitative data collection and analysis. This section includes information regarding the variables included in quantitative analysis as well as how reliability and validity were established. Next, I illustrate the second phase of research, that of qualitative data collection and analysis, including how I established credibility with these data. Following the description of these two phases of the research process, I present the advantages and limitations of taking an explanatory sequential mixed methods approach to research. The final sections of this chapter cover the limitations of explanatory sequential mixed methods, as well as the ethical considerations of my research and the role I take as a researcher.

MyFOSSIL was designed to unite paleontologists in a digital space in the shared practices of social paleontology. This dissertation study was primarily concerned with describing the ways in which knowledge was created in this digital niche. Via three specific research questions, I asked by whom and under what conditions knowledge was created through identifying and describing the practices that led to participation in and contribution to social paleontology. This study followed an explanatory sequential mixed method design as recommended by Creswell (2011), which was appropriate as neither quantitative nor qualitative methods alone were sufficient in capturing both high-level trends and specific details that were found in a digital CoP.

Quantitative data collection and analysis were employed to capture generalizable trends concerning myFOSSIL members and their practices, as well as high-level descriptions of practices that occurred in the textual exchanges on myFOSSIL. Qualitative data collection and analysis were employed to capture detailed and nuanced perspectives of members including rich descriptions of practices within the digital CoP, especially the ways these practices related to a member's paleontological identity within the CoP. To analyze practice, the units of analysis ranged from sentence-level to paragraph-level. When used in combination, quantitative and qualitative methods were explanatory, advancing both the understanding of who composed the community within the CoP as well as identifying the practices within the context of myFOSSIL. In this study, as in the custom for those of explanatory sequential mixed methods design, data collection and analysis proceeded in two parts, first with quantitative data collection and analysis then with qualitative data collection and analysis (Creswell & Plano Clark, 2011; Ivankova, 2006). After gaining insights via collecting and analyzing quantitative data, qualitative data was collected using maximal variation sampling (Creswell, 2009) which allowed for purposeful selection of members for three paleontological identity-based case studies These cases were analyzed to determine members' similarities and differences in their enactment of practice on myFOSSIL. After completion of qualitative collection and analysis, the data were interpreted holistically, in that the quantitative analysis allowed for high-level understanding of how members enacted practice while the qualitative analysis provided rich, nuanced descriptions of these occurrences.

This study started with quantitative phase with two forms of data analysis: content analysis (Krippendorff, 2012) and social network analysis which were used to describe the domain-specific practices members enacted on the website (Gruzd, Paulin, & Haythornthwaite, 2016). On myFOSSIL, practices were defined as chains of observable behavior that members enacted and were organized chronologically around specific events (i.e. a forum post, a private message) that other CoP members interacted with in some way. During the quantitative phase, attributes of myFOSSIL members were also collected and analyzed. myFOSSIL members were classified with the Paleontological Identity Taxonomy (PIT) analytical framework (Lundgren, Crippen, & Bex, 2018; Lundgren, Bex, & Crippen, 2018), then classifications were melded with the practice-based, time-bound social network analysis data to give an understanding as to the ways in which practice development occurred within this digital niche. Furthermore, these data provided insight into the ways community member attributes influenced practice development.

Specifically, the explanatory sequential mixed methods research design was used to (1) define the social paleontological practices found on myFOSSIL, (2) delineate a typology of domain-specific discourse that existed within the textual practices on myFOSSIL, and (3) explicate the relationship between community attributes and the development of paleontological practices in a digital space. In the following sections, I fully describe both the target population and sample as well as the analytical frameworks by which I explored the research questions.

Target Population and Sample

The population sampled in this study were those who were established members of the myFOSSIL and/or those who became members of the myFOSSIL during the two-year period between October 2015 – 2017, who consented to participate in the study, and who contributed at least one forum post, message, or activity post during the study period. Although myFOSSIL included members who are under 18, only members who were older than 18 were included in this study. During the specified time period, 63 myFOSSIL members did not consent to participate in the study; these members' data were removed from all data. The total website population included close to 1,000 members (N = 885). However, the focus of this study was on the members who participated and contributed, measured in the form of forum posts, activity feed posts, and messages (i.e. digital trace data). Thus, a sample of the website members, based on data they created, was utilized for the study (n = 263). October 2015 was selected as the start date for this study as it marked the period when myFOSSIL was released from a beta version, opening membership to anyone. The beta phase of the website was not open to the public; during this period the website development team and FOSSIL Project leadership team were iteratively testing pieces of the website.

The two-year time period bounds the study to explore changes within the practices at the whole group (community) level and at the intragroup level based upon PIT classifications. Furthermore, this two-year period was deemed appropriate as a CoP can develop and progress through the life-cycle phases of communities, such as maturing and transformation, in this timeframe (Wenger et al., 2002).

Thirty-eight website beta testers whose profiles were set up by web administrators were included in the data that were collected. These members consented to participate in the study via a paper form but did not fill out the intake survey (Appendix A), in some cases this prevented the collection of demographic data. Examining age ranges of myFOSSIL members revealed an even distribution of age ranges, indicating that myFOSSIL was not limited to a specific age range of people (Figure 3-2). Members' occupations were established using a question from the community intake survey; members mostly described their occupation as related to education in some degree (n = 83), followed by other (n = 46), and for profit (n = 34) (Table 3-1). When asked about educational status, most myFOSSIL members indicated that they held a master's degree (n = 71), followed closely by those who indicated that they held a bachelor's degree (n = 49), followed by those who indicated they had completed some graduate school (n = 32) (Table 3-2).

For the purpose of the first, quantitative phase of the study, all consented, age-appropriate myFOSSIL members who contributed at least one form of data were studied. The emphasis was on their contributions, namely the number of time-based chains of observable behavior that centered on an *organizing event*, such as posting on the activity feed, creating a forum post, or starting a private message chain.

For the purpose of the second, qualitative phase of the study, maximal variation sampling was employed to determine what full participation within the myFOSSIL CoP looked like for members dependent on PIT categories. The quantitative component of the study indicated which members could be highlighted as exemplar cases (i.e. profiles in practice). After quantitative data collection and data analysis, it was determined that one member from each of the following PIT categories could be highlighted as an exemplar case: Public, Education and Outreach, and Scientist. The qualitative portion of the study focused on the chains of observable events each employed while a website member, including the practices that each exemplar member used. Special focus was given to determine the ways in which practice-development occurred and if it occurred over time.

Analytical Framework

In order to fully explicate the methods, two elements of the myFOSSIL CoP, the practices and the people, needed further characterization.

Practice: Development within the Domain

On myFOSSIL, practices were chains of observable behavior that members enacted (Wenger et al., 2002). Within the digital CoP, practices left tangible evidence in the form of digital trace data including friendship connections, public forum and activity posts, as well as private message threads. Wenger et al. (2009) briefly described practices within a digital habitat in terms of *learning activities* that community members could enact; for this reason, learning activities and practices will be used interchangeably.

To further delineate practice, a modified framework from Wenger et al. (2002) was used, which began as a conceptual framework for envisioning the ways in which

CoP members could enact practice was postulated by Wenger et al. (2009). Within this conceptual framework, seven higher-level categories of learning activities were depicted, with specific activities nested in each category (Table 3-3). Such higher-level learning activity categories described by Wenger et al. (2009) were: *Exchanges, Productive Inquiries, Building Shared Understanding, Producing Assets, Creating Standards, Having Formal Access to Knowledge,* and *Visits*. Each of these higher-level learning activity categories had four or more specific learning activities nested within them. As an example of the nested categorization, within the category of Exchanges, community members could enact the specific learning activities of news, information, pointers to resources, stories, tips, and document sharing. Aside from giving name to the higher-level categories and specific learning activities, Wenger et al. (2009) left them undefined.

For this study, each specific learning activity was constructed, with an operational definition as the data were analyzed, leading to an analytical framework (Table 3-4). For example, the six specific learning activities within the category of exchanges were given definitions, then these definitions were operationalized or augmented as the data were analyzed. Augmentation included combining specific learning activities, such as combining news and information to become the specific learning category of *News & Information.* Other combined specific learning activities included: pointers to resources and document sharing (*Pointers to Resources/Document Sharing*), and formal practice transfer, trainings & workshops, and invited speaker being combined into *Formal Practice Transfer/Trainings & Workshops/Invited Speaker.* Additionally, one higher-level learning activity category (*Ungrouped)* was added to the learning activities framework.

Within this category, the specific learning activities of *Support* and *Field Trip Planning* were added. Formal education, including undergraduate education, has been used as a proxy for developing proficiency in a domain (Alexander, 2003). Therefore, within paleontology, proficiency is gained via participation in and contribution to the science via constructing an understanding of the past based in fieldwork and lab work as well as communication of hypotheses via oral and written presentations (Yacobucci & Lockwood, 2012).

In many ways, these practices are digitized or can be ported into digital environments, acting as a basis for social paleontology (Lautenschlager & Rücklin, 2014). Connecting social paleontology-specific activities to the learning activities described by Wenger et al. (2009), I derived practices that myFOSSIL members participated in and contributed to, with the unit of analysis varying from sentence utterances to full paragraphs written by members. The direct relationship between these learning activities and those enacted by members of the myFOSSIL CoP were subject to interpretation and refinement as the data analysis process progressed (Table 3-4). Interpretations were based on iterative coding of the data along with discussions of the codes with a knowledgeable other. This was followed by further iterative coding of the data over a one-month period. Thus, what emerged was an interpretation as to what practices were on myFOSSIL.

People: The Continuum of Expertise

In previous work concerning the FOSSIL CoP, community members have been conceptualized as dichotomous, with *amateur paleontologists* and *professional paleontologists* as contrasting groups (MacFadden, Lundgren, Crippen, Dunckel, & Ellis, 2016). Amateur paleontological status entailed membership in a fossil club or society and professional paleontological status necessitated employment as a paleontologist (Crippen et al., 2016). Furthermore, other work attempted to gradate amateur paleontologists by categorizing their motivations for participation in paleontology (MacFadden et al., 2016; Jones, Anders, Childers, & Corin, 2014). In these interpretations, other people with an interest in paleontology were excluded: those who sought to incorporate paleontology within their educational work, such as teachers. While the dichotomous positioning of paleontologists and the gradation of amateur paleontologists both served to categorize community members, they did not necessarily account for the role of practice. Establishing amateur paleontologists as existing on a gradient moved toward fuller description of the community, however it still did not fully encapsulate notions of paleontological practice.

It was necessary to further the conceptualization of myFOSSIL members existing along a continuum of expertise and eliminate the dichotomous positioning of professional versus amateur paleontologist, especially as some members who did not previously fit into the *professional* category did not see themselves as *amateurs* but rather as *avocational paleontologists*.[1] On myFOSSIL, users filled out a brief survey (i.e. the community intake survey) before becoming members of the site, which asked incoming members to describe their *affiliation* with paleontology, if they had been employed as a professional paleontologist, if they were affiliated with a fossil club or society, and if they collected fossils as a hobby (Appendix A). The responses from this survey allowed for myFOSSIL members to be categorized dichotomously as they have been in recent publications (Crippen et al., 2016; MacFadden et al., 2016), however,

[1] K. Hartshorn, L. McCall (personal communication, March 19, 2017)

when merged with additional membership information gleaned from member profiles, a more complete understanding of members which moved beyond the dichotomy was possible.

To move beyond this dichotomous positioning of CoP members, the Paleontological Identity Taxonomy (PIT) analytical framework was employed. The PIT was first conceptualized with the coding of Twitter profile biographies, proxies by which Twitter users identified their interest specifically in the domain of social paleontology (Lundgren et al., 2018a; Lundgren et al., 2018b) (Figure 3-3). myFOSSIL members' expertise and practice were examined through the PIT which used a three-tiered hierarchy to classify members based on self-described attributes. Members' self-described attributes were determined via examination of front-end surveys as well as the *About* section on members' profiles. The PIT's classification scheme started with *Structure,* which provided a coarse-grain classification of members, and moved to a finer-grained one with the classification scheme of *Category*, followed by the finest grain of classification, *Types*, to describe a member's identity within the CoP. I will use one member, Tom Haverford, to provide an illustrative example of the PIT's classification scheme.

The highest and most coarse-grained tier of the PIT hierarchy was that of Structure—the broadly-defined composition of an entity within social paleontology. Structure consisted of three classifications: Individual, Organization, or Club/Group. Within the CoP, an individual represented a single member. The two other classifications within Structure represented groups of people: Organizations were those members that were described as professionally affiliated; and a Club/Group described amateur-organized or student-led affiliations. In order to determine a member's Structure, I examined the community intake surveys that were submitted, specifically looking for members' names and affiliations. For example, Tom Haverford filled out the community intake survey on October 29, 2015. In his survey, Tom filled out his name, as opposed to the fossil club he belonged to—First Fossil Club. Filling out his own name was an indication that he was representing himself, not a greater entity, making him fit into the Structure classification of Individual.

The second tier was that of Category, a general representation of an entity's identity in social paleontology; it consisted of four distinct classifications: Public, Scientist, Education and Outreach, and Commercial. Members described as Commercial were those that sold or collected fossils for commercialized purposes. Education and Outreach members were those that worked with paleontology in an educational setting, including schools, teaching, or in museums. Scientists were those members who worked in academic disciplines. Lastly, Public described members who did not meet the criteria set forth in the other three Categories. Note that members within the first tier could fit into any classification described in the second tier. Intake survey questions asked members to indicate their occupation, as well as their interest in using myFOSSIL. With these questions, a member's Category could be determined. To return to our illustrative member, Tom Haverford: he indicated his occupation was retired, specifically a retired IT professional. In terms of his interest in using myFOSSIL, Tom wrote,

> I am an amateur paleontologist and fossil enthusiast. I became a member of First Fossil Club in 1991 and since then have assisted professional geologists, sedimentologists and paleontologists in their paleo projects and have equally benefitted from their assistance in advancing my own

> projects. I am the author of [redacted] and want to foster collaboration between amateurs and professions (*sic*) using community.myfossil.org. I am also the designer and webmaster of firstfossils.org and now want to help ensure the success of myfossil.org.

With this answer, Tom's Category of Public was determined. This process was followed to characterize the PIT Category for all members who completed the intake survey.

The last tier of the PIT directly classified members of the second tier into more fine-grained Types, the precisely defined characteristics of a social paleontological entity, which consisted of twenty-five divisions. Members classified as commercial were sorted into three types: Experience, Resource, or Service. Education and Outreach members could have been sorted into 10 types: Blog-Podcast, Conferences-Events, Educational Project-Website, Journalist-Communicator, K12 Teacher-School, Lecturer, Museum Educator, Museum-Science Center-Park, News, or University-College. Scientists were sorted into nine types: Anthropology, Archaeology, Biology, Ecology, Entomology, Geology, Ornithology, Other STEM, and Paleontology. Lastly, Public were sorted into three Types: Amateur Paleontologist, Interested Party, and Paleoartist. On the intake survey, a number of questions helped determine which Type members fit into, specifically questions that asked about status as professional paleontologist, membership in a fossil club, and status as a collector of fossils. On these questions, Tom indicated that he was not a professional paleontologist, that he was a member of a fossil club, and that he had collected fossils as a hobby. With Tom's answers to these questions, I was able place him into the Type of amateur paleontologist.

The PIT directly eliminated the dichotomous positioning of myFOSSIL members as either *professional* or *amateur* paleontologist. Additionally, it has the capacity for adding to our understanding of CoP members by providing more robust explanations of members' self-described attributes.

Members' intake survey responses were used to determine their PIT Categories and Types (Figure 3-3). This classification of myFOSSIL members with the PIT was conducted to highlight the potential for multiple cases. All myFOSSIL members were classified at the Structural level as individuals, who only represented themselves (n = 263). At the Categorical level, all four Categories were present, although there were few Commercial members (n = 5), a higher number of Scientists (n = 44) and Education and Outreach members (n = 62), while members classified as Public made up the majority (n = 151). The finest grain of classification, that of Type, revealed that members classified as Amateur Paleontologist made up the majority of site members (n = 138), followed by members who had a professional affiliation with Paleontology (n = 41), followed by members who were classified into the type K12 Teacher (n = 49). Other categories' types were represented on the site, but in much smaller numbers (Figure 3-3)

With the background information, specifics of the research design, and the analytical frameworks used to analyze practices and people within the CoP defined, I describe in detail the phases of explanatory sequential mixed methods.

Phase I: Quantitative

Variables in Quantitative Analysis

Two of the three research questions sought to determine change in social paleontological practice when either the type of digital trace data or the attributes of community members varied. Additionally, the units of analysis in which the data were analyzed varied dependant on the research question. For research questions one and two, the units of analysis were of variable length, either sentence- or paragraph-length, whereas for research question three, the unit of analysis was based on PIT Category membership. Within the second research question of this study, three categorical predictor variables based on data feature (i.e. forums, activity, messages), were included in this study. The social paleontological practices that members of myFOSSIL developed were considered dependent variables—the outcome or result of the influence of predictor variables.

To examine the ways that myFOSSIL data was connected in a quantitative capacity, social network analysis was used. Social network analysis helped determine which features of the website (i.e. forums, activity feed, or messages) encouraged knowledge-creating discourse. To determine this, I analyzed data by creating a bimodal network in which directed ties (i.e. connections) were created by vertices (i.e. members). In a bimodal network, many activities were related "together in a single analysis" (Hansen, Shneiderman, & Smith, 2011, p. 139). Within this form of social network analysis, the number of data that were contributed to each feature of the website by each member were key variables.

For the third research question of this study, four categorical predictor variables based on the second tier of the PIT (i.e. Commercial, Education and Outreach, Public, Scientist), were included in this study. As with research question two, the social paleontological practices that members of myFOSSIL developed were considered dependent variables—the outcome or result of the predictor variables. Members were classified into one of the four PIT Categories, which were considered predictor variables and were considered such because they influenced or affected outcomes.

Quantitative Data Collection

Data included over 2,500 textual exchanges in the form of activity posts, forum posts, and member messages. These data were collated through the developer interface of myFOSSIL. The three types of digital trace data, or features, that members contributed to were:

- Forum posts: content created by myFOSSIL members that was specific to forums. On myFOSSIL, forums were topic-specific, web-based discussion boards in which members created posts that other members marked as important to them (*favorite*), kept up-to-date with (*follow*), and added additional information to (*reply*).
- Activity posts: original content created by a myFOSSIL member that was situated within an area of the website that was not a forum. Activity posts were stand-alone content or replies to other members' posts.
- Member messages: private correspondences that originated from one myFOSSIL member and were sent to one or more additional myFOSSIL members. The message receivers had the option to respond to the message.

MyFOSSIL was built using the WordPress open-source content management system. I accessed WP Engine, the developer interface of myFOSSIL. Using WP Engine, I then retrieved data from phpMyAdmin, the interface in which all data related to myFOSSIL was stored. Data was collated from this interface, which contained 54 tables were exported as .csv files. Manual searching of these tables revealed one key table that contained information that linked members' login names and their display names with their participant IDs. Participant IDs were solely used within backend website data tables, but not accessible to members who viewed the website as a front-end visitor. An example to help clarify the relationship between login names, display names, and participant IDs: on myFOSSIL, my user login name was llundgren and my display name was Lisa Lundgren, but in the myFOSSIL developer data tables my activity as a member was linked with my participant ID, 9. Therefore, the table that contained

Participant IDs that linked members to their activity on the website was a key table for quantitative data collection and analysis. All other tables were examined, but only five tables were pulled for the quantitative data collection and analysis phase: wp_posts (i.e. forum posts), wp_bp_friends (friendship connections), wp_bp_groups (group names), wp_bp_groups_members (group memberships), and wp_bp_activity (member messages and activity posts).

Quantitative Data Analysis

The research questions were answered on a quantitative level using content and social network analysis. Content analysis was employed iteratively in that the data were examined multiple times in order to ensure that the codes were valid and not merely the result of a cursory examination (Krippendorff, 2012). To analyze the data, it was first exported from the website as spreadsheets. Then, the data were cleaned to eliminate unnecessary page and line breaks, along with other components that could hinder data processing (i.e. commas, apostrophes, and tab stops). These data were copied into Microsoft Word documents and imported to the qualitative research software HyperResearch (version 3.75). After data collection, data were processed, profiled, and cleaned using the open access application OpenRefine (Verborgh & De Wilde, 2013). Data profiling and cleaning were employed to identify duplicative data as well as to remove participants who either did not consent to participate in the research or were under the age of 18. I first read through all data to situate myself within it, then I read through all data with the learning activities framework for reference (Table 3-4). Following this, I systematically coded individual pieces of data in HyperResearch (v. 3.7.5, http://www.researchware.com/products/hyperresearch.html). Data were divided by type (i.e. activity posts were separated from message posts), then each piece of member-created data, which ranged from single sentences to lengthy paragraphs, was coded. Each piece of data was treated individually, however, individual data could be correlated with multiple coded practices. In some cases, a single piece of data was only associated with one practice, but in most instances, individual pieces of data had more than one practice coded within it.

Following a first pass at coding, I took a small sample of the codes and the code book to a knowledgeable other. During this meeting, discrepancies in the coding scheme were discussed to consensus and the codebook (i.e. Table 3-4) was refined. Following this meeting, all data were coded within a month-long period. In addition, intrarater reliability, which is the consistency with which a researcher codes the same set of data at different times, was established (Purzer, 2011). I selected ten percent of each type of data and re-coded them within one month of the original coding. To ensure the widest amount of data from the largest number of members were recoded, I coded every third post until reaching ten percent of the total number of each data type. Furthermore, as each data type was input into the spreadsheets in alphabetical order by member names, I wanted to ensure I coded the widest diversity of members. For forum posts, I started at the beginning of the coded instances, for activity posts, I started in the middle and worked down, and for messages, I started from the end of the coded instances and worked upward. Intrarater coding in this manner resulted in either moderate or substantial agreement between the two analyses, depending on the data type examined (Table 3-5).

To conduct analyses that were based on frequency of the creation of digital trace data (i.e. answering research question 1), I exported data from HyperResearch and processed it. Processing consisted of using the Filemaker database system to re-organize the data so that each code was associated with a piece of data holistically. For example, if a member created a forum post and I coded it with the learning activities Help Desk-Field Trip Planning-Support, within HyperResearch, these three instances counted as three separate codes. To determine how many forum posts were made in summary on the website, I needed to roll these codes back up into their one forum post created by that one specific member. Using Filemaker also ensured that each member's PIT Category was associated with the pieces of data they created to better answer how practices were associated with attributes of community members (i.e. answering research question 3). As another example: if a Scientist created a forum post and the forum post included three different codes (e.g. Collaboration, Boundary Crossing, and Support), each code was associated with that Scientist's forum post individually instead of in aggregate.

Secondarily, social network analysis was conducted, which allowed for an understanding of what knowledge-creating discourse existed within the textual practices on myFOSSIL (i.e. research question two) as well as provided a determination of the ways in which myFOSSIL members contributed to and participated in social paleontological practices on myFOSSIL (i.e. research question three). Social network analysis allowed for practices to be determined at the whole site level as well as the group level. Social network data were examined using a quantitative approach in order to draw more wide-reaching conclusions concerning the members of the site, including descriptive statistics regarding PIT classification of site members. In order to examine forms of practice, digital evidence of practices and their development were tabulated.

Social network analysis was centered on chains of observable behavior, i.e. from the start of a textual exchange to where the exchange ended, either naturally or as dictated by the end of the study. Two factors concerning the chains of observable behavior were analyzed: the members who interacted with the starting textual exchange and the observable behaviors these members displayed. Centrality measures, meaning the ways in which vertices (i.e. community members or time-bound events) were peripheral or predominant within myFOSSIL, were also analyzed at the quantitative analysis phase. Lastly, the Clauset-Newman-Moore clustering algorithm (Clauset, Newman, & Moore, 2004) was applied, which allows for community structures to be more easily identified.

I conducted two forms of social network analysis, one for research question two and the other for research question three. For research question two, the social network analysis followed the method described by Himelboim, Smith, Rainie, Shneiderman, and Espina (2017). First, data from forum posts were exported from HyperResearch into spreadsheets, then into Filemaker, where they were sorted and matched. Specifically, the forum post data were cleaned so the time-bound, nested nature of forum posts and replies was emphasized. Forum posts were chosen for the social network analysis because of the inherent nature of forum posts: they were threaded, and chains of behavior were most easily observed in them. Furthermore, forum posts were the most observed form of digital trace data on myFOSSIL, therefore, their abundance allowed for a robust understanding of the knowledge-creating discourse that existed.

The time-bound nature of the forum posts entailed connecting multiple codes from individual forum posts to other multiple codes to replies to original forum posts.

These data followed patterns similar to those found when conducting interaction analyses, therefore, an adjacency matrix, based on work by Crippen and Sangueza (2013) was created from these data (Figure 3-4). Adjacency matrices highlight the number of times that two entities connect within a bounded system. For instance, if one member used specific learning activity of Help Desk within their forum post and other person responded to their post with the specific learning activity of Tips, the relationship would be counted once, although if this relationship was found to occur again, it would be counted a separate time. The number of times relationships occurred between two distinct specific learning activities was therefore calculated. The adjacency matrix provided the structure to create an edge table for use in NodeXL for the social network analysis. Edge tables include two columns in which the relationship between two items can be displayed. For instance, if a forum post started with the specific learning activity *Stories,* and a reply to that forum post included the specific learning activity *Exploring Ideas,* there was a *directed edge* between Stories and Exploring Ideas. I summarized the total number of directed edges, which gave me the metric of edge weight, a determination of the most prominent practices that occurred on the myFOSSIL forums. This type of social network analysis also emphasized density (i.e. overall connectedness), eigenvector centrality (i.e. influence), betweenness centrality (i.e. control of information) and closeness centrality (i.e. individual connectedness) as dependent variables. Following conducting these analyses, the network was visualized in NodeXL using the Harel-Korel fast multiscale graph, within which an algorithm situates vertices so that closely-related vertices are positioned closer to one another, which provides another way to measure the relationships between them.

The second form of social analysis I conducted was for research question three. For this question, social network analysis followed the methods employed by Hansen, Shneiderman, and Smith (2011) for thread networks. Data were collated with emphasis on member's PIT Categories and the number of times each member contributed to the forums, made activity posts, or sent/replied to a message. These data were collated into a bimodal graph.

For the third research question, I also conducted a time-based analysis of the data to determine the ways that members from different PIT Categories contributed to myFOSSIL during the study period. After processing in HyperResearch, I used the open source program OpenRefine to facet the data at two different time points. Faceting was based on counts of members' names. All data were examined at these two points to determine the ways that practices developed or were distributed over the course of the data collection period. The first point collated data from the beginning of the data collection period to the midpoint of the data collection period (October 1, 2015 – October 1, 2016), the second point collated data from the midpoint of the data collection period to the end of the data collection period (October 2, 2016 – October 31, 2017).

Reliability and Validity

In quantitative research, reliability and validity checks are important to decrease errors that arise from measurement problems. In this research, reliability related to the concept of data capture, namely how myFOSSIL website data were aggregated and how these data were then pulled from the system for analysis. When I originally exported the data concerning textual exchanges and chains of observable events, the data tables containing all information relating to members were linked with only with numerical participant IDs. To ensure my data were reliable, Filemaker was used to replace participant IDs with their display names across all five key tables, with two researchers working collaboratively to ensure that the correct columns were chosen to be replaced in each table. Furthermore, the data were subject to constant appraisal concerning the relationship between the usage of system labels and actual usage within the system. For instance, within each data table *id* was an internal data table reference, which indicated an event's place within the data table, instead of a reference to a participant ID or other form of identification. Familiarity with these nuances within the data tables helped ensure that no errors related to messy data occurred (Broman & Woo, 2017).

Validity issues with social network analysis and digital trace data centered on two main issues: the data were found data and event-based (Howison et al., 2011). The first issue, that these data were found as opposed to produced data, meant that the data were a by-product of activities. To alleviate validity issues associated with found data, this research addressed non-links as both a limitation and as a potential avenue for further research. Such non-links were forms of paleontological practice or practice-development that did not seem to occur on myFOSSIL and/or did not seem to be enacted by certain Categories of PIT members. *Structural holes* (Burt, 1995) within the membership network of myFOSSIL's CoP could have indicated places in which there were missing links between members that could have been strategically filled by new members with specific attributes. However, these data were considered carefully as the non-links might have been indications of such practices or practice-development occurring in ways that could not have been adequately measured in the collected data, for example, those who read forum posts, but did not post replies, and then enacted paleontological practices gleaned from forum posts at face-to-face paleontological events.

Similarly, structural holes could have been created by the researcher when removing members who did not provide consent or were under the age of 18. This problem was minimized as the amount of data removed in this way was examined and found to be a miniscule percentage—less than two percent of all total data. In total, only 62 pieces of data were removed from analysis due to member non-consent or age. Within activity posts, eight pieces of data were removed, six posts by members under the age of 18 and two posts from non-consented members. Within forum posts, 21 posts were removed, 1 post by a member under the age of 18 and 20 posts made by non-consented members. Within messages, 11 pieces of data were removed from analysis, 5 made by members under the age of 18 and 6 by non-consented members.

The second issue, that the data were event-based, was an issue for digital trace data, as within the literature, these data are often presented as dichotomous (Howison et al., 2011; Lampe, 2013). The dichotomy is most often represented as high interaction versus low interaction, for example, more than five interactions with another member of the network equals a strong relationship and less than five interactions equals a weak relationship. The emphasis of the quantitative portion of the study was on describing the practices broadly, therefore understanding what practices were present was generally important, the dichotomy of high versus low interactions was minimized by focusing on the holistic characteristics of members' practices.

Phase II: Qualitative

Qualitative Data Collection

The second, qualitative phase in this study focused on explaining the results of the analysis done in the first, quantitative phase. After a high-level, quantitative analysis concerning the amount of practice-centric digital traces was collected in phase I, phase II of the research sought to further characterize these practice-centric digital traces, especially linking social paleontological practices with PIT attributes of community members via in depth analysis. Furthermore, textual exchanges were examined to establish a typology of knowledge-creating discourse within the social paleontological practices based on member's PIT Categories. A multiple case studies design (Stake, 1995) was used for collecting and analyzing qualitative data.

Case studies are designed to explore *bounded systems* (Merriam, 2009) in which a single unit with defined limitations is studied. For a multiple case study, a single unit with defined limitations is still the central focus, although it is studied from multiple perspectives. For the purposes of this study, the case (i.e. *single unit*) was that of social paleontological practice on myFOSSIL. Using maximal variation sampling (Creswell, 2009), multiple perspectives were employed to explore the case in depth, determining what full participation on myFOSSIL looked like dependent on PIT Categories (e.g. Scientist or Public). Within these Categories, one member acted as an exemplar of practice, focusing on the chains of observable behavior members employed, emphasizing similarities and differences by PIT Category.

The primary technique was collecting all intake survey data and data from forums, the activity feed, and messages that each of the selected members created. Triangulation of data sources, a key feature of case study analysis, was used to examine cases (Creswell, 1998), these data were examined for similarities and differences, with specific emphasis given to the open-ended survey questions, comparing members' answers with the data collected. Furthermore, I used a process of quantifying qualitative data in that the number of data created by each member were counted to avoid using terms such as *most* or *many* as well as ensuring that patterns I saw were, in fact, patterns (Maxwell, 2010; Sandelowski, Voils, & Knafl, 2009).

Qualitative Data Analysis

For the qualitative analysis phase, data collection and analysis proceeded simultaneously (Merriam, 1998). Data were exported as .csv files and converted into text files, then coded and analyzed for themes using HyperResearch. Focusing on research question three, the steps in qualitative analysis included: (1) preliminary exploration of the data through reading each member's contribution to and participation in social paleontological practice and writing memos; (2) connecting and interrelating codes within and across the cases; and (3) constructing a narrative (Creswell, 2001).

In this multiple case study approach, data were analyzed at two levels: within each case and across the cases (Stake, 1995). For this study, each case of the PIT was analyzed for themes concerning paleontology-specific knowledge-creating discourse. Then, all cases were analyzed for themes concerning paleontology-specific knowledge-creating discourse that were similar or different to show the extent to which identified attributes of community members related to practice-development. This analysis approach allowed for the practices that were used in the exchanges of myFOSSIL website members to be categorized into practice-based discourse. This discourse pertained to the ways in which myFOSSIL community members modified the state of domain-related knowledge within the CoP.

Establishing Credibility

The criteria for judging credibility of qualitative research differ from that of quantitative research. For phase II of this study, trustworthiness and reliability were established through triangulation of data, writing with rich, thick descriptions, and using intercoder agreement (Creswell, 1998). Triangulation was used when converging the different sources of information—digital trace data and intake surveys—as well as intercoder and intracoder agreement were all used to ensure credibility while analyzing data. When conveying findings, rich, thick descriptions that detailed the setting and the participants was employed to determine whether findings can be transferable within contexts with shared characteristics.

Advantages and Disadvantages of Explanatory Sequential Mixed Methods Design

The merits of mixed methods design studies have been discussed, with focus on the ways mixed methods allow for data collection and analysis at multiple levels (Creswell, 2009; Ivankova, 2006). Specifically, there are three advantages of explanatory sequential mixed methods design. First, a lone researcher has the ability to implement it with fewer difficulties as it sequentially proceeds from one phase of research to the next. The ease of implementation is advantageous to those seeking doctoral degrees, as dissertations are meant to be solitary pursuits. Secondly, using an explanatory sequential mixed methods design allows for quantitative results to be explored in more detail, meaning that the quantitative, numerical data does not necessarily have to stand alone. With the qualitative research phase, results from the quantitative research phase can be explored with purpose. Thirdly, explanatory sequential mixed methods design can explicate unexpected results that arise from quantitative analysis. The results do not merely have to become a footnote or oddity, they can be explored in depth with the qualitative phase of the research.

Research Permissions and Ethical Considerations

Ethical issues, including Institutional Review Board (IRB) permissions for conducting research was obtained following all regulations of the IRB. An IRB consent form affiliated with a survey was used to register members. This form stated that participants were guaranteed certain rights, that they agreed to be involved in the study, and acknowledged that their rights were protected (Appendix B). All members who consented within the proposed two-year time period were considered participants. The anonymity of participants was protected by de-identifying participants and providing them pseudonyms following content and social network analysis. Whereas it was important to contextualize the data during the qualitative analysis phase by writing thick, rich descriptions, it was also paramount to protect the identities of myFOSSIL members. Therefore, occupations of community members, membership in fossil clubs, and names were masked or changed. In some cases, the fossil specializations or interests of members chosen for qualitative analysis were also masked or changed, as including these may have de-identified members. All electronic study data was kept on a password-secured computer that was either with the researcher or kept in the researcher's locked office. Electronic study data will be destroyed after seven years. Summary data will be distributed to participants and the professional education community. This research was conducted as part of the FOSSIL Project, a National Science Foundation-funded grant (No. DRL-1322725). Any opinions, findings, and conclusions or recommendations expressed in this material were those of the author and do not necessarily reflect the views of the National Science Foundation.

Role of the Researcher

During the majority of data collection and analysis, I was affiliated as a graduate student research with the Fostering Opportunities for Synergistic STEM for Informal Learners (FOSSIL) Project (No. DRL-1322725), a National Science Foundation-funded grant. The FOSSIL Project was the vehicle through which researchers like myself were studying social paleontology. Five niches within the digital habitat—myFOSSIL, FOSSIL Project Facebook, Twitter, and Instagram pages as well as the myFOSSIL YouTube channel, were specifically designed under the input and guidance of researchers to enhance communication among paleontologists, as opposed to developing spontaneously without guidance. I was a registered member of myFOSSIL, however, I sought to approach this topic from an etic standpoint, so I examined myFOSSIL from the perspective of a participant-observer (Stake, 1995).

Limitations

There were limitations to explanatory sequential mixed methods design research. Most of these limitations were associated with the fact that two forms of collection and analysis were utilized in the study. For example, additional time is often needed to complete mixed methods studies as two forms of data collection and analysis are being completed instead of one which is traditionally the case. Often, additional resources are also required to complete explanatory sequential mixed methods design studies as well. With this dissertation study, these limitations were mitigated, as data collection in the form of digital trace data was completed early in the study, which alleviated some of the time and resources devoted to that component of the study.

Summary

In order to explore the practices related to social paleontology within the niche of myFOSSIL, I approached this study with the theoretical framework of CoPs. I used three research questions to explore practice-development within social paleontology, which were analyzed using both quantitative and qualitative means, including social network analysis of myFOSSIL members and their activities, content analysis of textual exchanges, and discourse analysis of practice-centered activities on myFOSSIL. All of these elements were considered to understand which practices contribute to the development of a knowledge-centric CoP.

In summary, this study sought to establish the knowledge-generating capacity of myFOSSIL as a niche of digital CoP. The research methodology, that of an explanatory mixed methods design, was explicated. The study focused first on collecting and analyzing quantitative data in the form of digital traces of myFOSSIL members, who were classified by the PIT to determine their status within the CoP. Applying social network analysis to the digital traces of these members created a temporal map of the paleontological practices conducted, as well as highlighted the relationships that developed from these practices. Following completion of quantitative data collection and analysis, cases based on PIT classifications were determined, then analyzed qualitatively. Maximal variation sampling was employed to explore each case in depth, determining what full participation within the myFOSSIL digital CoP looks like dependent on PIT Categories (e.g. Scientist). These cases were analyzed using thematic analysis and discussed in both within-case and cross-case descriptions. Within these categories, one member acted as an exemplar of practice, focusing on the chains of observable behavior members employed, which emphasized the similarities and differences by PIT Category to establish the practices within a niche of a digital habitat.

Table 3-1. myFOSSIL member occupations (N = 263)

Occupation	Number of responses
Education	83
Other	46
No response	37
For Profit	34
Student	25
Non-profit	19
Government	14
Health Care	5
Total	263

Table 3-2. myFOSSIL member self-reported level of education (N = 263)

Level of education	Number of responses
Master's degree	71
Bachelor's degree	49
No response	38
Completed some graduate school	32
Doctoral degree	31
Completed some college	19
High school graduate	9
Some high school	6
Associate's degree	5
Other	3
Total	263

Table 3-3. Conceptual framework for behavior and domain-specific learning activities (Wenger et al., 2009)

Learning activity category	Specific learning activities
Exchange	News, pointers to resources, information, stories, tips, document sharing
Productive Inquiries	Broadcast inquiry, exploring ideas, case clinics, project reviews
Building Shared Understanding	Hot topic discussions, reading group, joint events, joint response
Producing Assets	Documenting practice, collections, problem solving, learning projects, boundary crossing
Creating Standards	Mutual benchmark, models of practice, warranting, external benchmark
Formal Access to Knowledge	Formal practice transfer, help desk, trainings & workshops, systematic scan, invited speaker
Visits	Guests, visits, filed trips, practice fairs

Table 3-4. Behavior and domain-specific learning activities and practices on myFOSSIL

Learning Activity Category	Specific learning activity (Practice)	Operational definition within myFOSSIL	Evidence
Exchange	News & Information	Story about paleontology presented for a lay audience or a general resource for paleontology, such as a geologic map or dissemination of recent organization activity, links to blogs	“Let’s start things out with some exciting news from my area of SoCal! Pleistocene-aged fossils, specifically a mammoth skull and tusks, have been discovered during construction of a tunnel for LA Metro (our version of a subway)! These fossils were uncovered by mitigation paleontologists and were located right next to the La Brea Tarpits! Once again, not many places in the world where you can find actual fossils in the middle of urban sprawl. href=*http://www.latimes.com/local/lanow/la-me-ln-ice-age-20161130-story.html” (Scientist, Activity Post #11523)
	Pointers to Resources Document Sharing	Distribution of PDFs, PowerPoint presentations, journal articles or other domain-related materials to the CoP; reposting or shifting location of posts on the website	“Cockburn Town Fossil Reef, San Salvador, Bahamas, Pleistocene: see http://www.geraceresearchcentre.com/pdfs/2ndgeology/Curran&White1984.pdf” (Scientist, Activity Post #5429)
	Stories	Person-centered account of social paleontological practice	“Cool find! Makes me jealous, because I used to live along Rattlesnake Creek in Gainesville. All I ever found were shark teeth, which are interesting in their own right, but not as interesting as a dugong (note my bias as a mammalian paleontologist).” (Scientist, Forum Post #9790, Web #576)
	Tips	Members providing advice or best practice information to other member/s concerning social paleontology	“Its hard to know for sure what kind of rodent it is because the teeth are diagnostic.” (Scientist, Forum Post #7098, Web #7093)
Productive Inquiries	Exploring Ideas	Brainstorming about the domain, not necessarily seeking answers	“Let’s start a forum related to Texas fossils and events. My friends at the Goldcrest Paleontology Society taught me a lot about the local fossils which I can share.” (Public, Forum Response #3303, Web #1579)
Building Shared Understanding	Joint Events	Creation of meetups, conferences, or other such events that support all member classifications	“Hey folks, we are happy to announce our first PaleoBlitz, scheduled for March 18-20, 2016, at the University of Florida! Just check our calendar for further information. We look forward to creating an interesting and fruitful Blitz for you and hope to make some great new connections. Initially we have planned to invite 12 individuals from different paleontology clubs/organizations to participate in this weekend-long workshop, but because of the overwhelming interest we are thinking about planning multiple events with different topics.” (Scientist, Forum Response #3325, Web #1945

Table 3-4. Continued

Learning Activity Category	Specific learning activity (Practice)	Operational definition within myFOSSIL	Evidence
Producing Assets	Problem Solving	Communication concerning solutions related to the domain	“Hi [Public member]--If we could get a group of Pleistocene mammals (optimally at least 6 specimens for statistics), like Equus, from [redacted] then these could be compared to the chemical fingerprint of the supposed early Miocene fossils from the same site. This uses rare earth elements.” (Scientist, Forum Response #2237, Web Response #1585)
	Collaboration	Swapping of resources or information to create domain-specific partnerships	“I collected some Tamiami fossils for you. I’ll try to bring them by the department tomorrow or Friday.” (Scientist, Message #442)
	Boundary Crossing	Individuals demonstrating activities that are not consistent with their PIT categorization	“As an example, I recently gave a one hour illustrated talk to [redacted] volunteers on the History of Ancient Horses and was very gratified with their interest. I was able to enmesh the topic of evolution within my presentation and what better way than through the history of horses. I will also be giving a talk on the Ancient Forces and Ancient Life of the Salton Basin to a naturalist club in the near future.” (Public, Forum Post #24463, Web #1579)
	Documenting Practice	Creation of digital artifacts that highlight real world experiences or ways to participate in and contribute to social paleontology	“2) You mention using Play Doh or modelling clay to stabilize the fossil for photography. I know that modelling clay is oil based and can leave an oily residue on the fossil. I don’t know about Play Doh. I use a product that I have heard called Ticky Tack. When I buy it the name is always different. I get it a Hobby Lobby. It looks and works like modelling clay but is stickier. It is not oil based and leaves no residue. It is meant for temporarily holding objects.” (Public, Forum Post #3370, Web #1752)
	Learning Projects	Undefined	Not found
	Collection	Undefined	Not found
Creating Standards	Models of Practice	Members taking an authoritative stance when describing the practices within social paleontology	“So I screen for museum-worthy fossils and bring those to the attention of the Collections and Research Center. I’m also aware of what research our local professionals are conducting and keep an eye open for what they need. So I collaborate and donate fossils for educational purposes.” (Public, Forum Post # 18851, Web #12976
	External Benchmarks	Information concerning best practices of digitization of specimens	“Having apparently successfully used https://www.myfossil.org/audubon-core-wizard/ do I expect that the wizard generates the Audubon Core (AC)? If so, how do I fetch it? If on the other hand I am expected to provide the AC, how do I do so and how is it subsequently fetched? On the third hand, perhaps the wizard has nothing to do with https://terms.tdwg.org/wiki/Audubon_Core_Term_List ?????”

Table 3-4. Continued

Learning Activity Category	Specific learning activity (Practice)	Operational definition within myFOSSIL	Evidence
Formal Access of Knowledge	Formal Practice Transfer; Trainings; Workshops and Invited Speakers	Presentations, conference papers, or webinars that provide access to some aspect of the practice that were created by the member of the CoP who is sharing them	[@commercial member], [@scientist member] [@education and outreach member] Here is our FAQ page with info on how to create a group! http://www.myfossil.org/faq/#make_org.>http://www.myfossil.org/faq/#make_org (Scientist, Forum Post #16095, Web #13921)
	Help Desk	Inquiring about domain-related topics—most often, the identification of specimens	My students dug through some matrix from the Pawnee Museum (thanks for the tip [Public member]!!) There was only one tooth we couldn.t identify from the chart. My second grade student is eagerly awaiting your help! (Education and Outreach, Forum Post #28354)
Ungrouped	Support	Members thanking others for contributing, acknowledging a contribution or being otherwise social without adding to knowledge per se	"Wow, that sounds like a great program! I really like the idea of teaching skills in conjunction with the subject matter." (Public, Message #394)
	Field Trip Planning	Discussion of events that relate to domain-specific outings	"Hey guys, This Wednesday's lunch meeting will be very important to attend. We will be discussing the [redacted] agenda and the roles we will be taking, as grad students, concerning the hikes we will go on each day. See you then: [@scientist member, @scientist member, @education and outreach member, @education and outreach member] (Education and outreach, Scientist, Activity #16034)

Table 3-5. Intrarater Reliability for Digital Trace Data

Digital Trace Data Type	N	N recoded	κ (level of agreement)
Forum Posts	1950	195	$\kappa = .57$ (moderate)
Activity Posts	1297	129	$\kappa = .70$ (substantial)
Messages	848	84	$\kappa = .61$ (moderate)

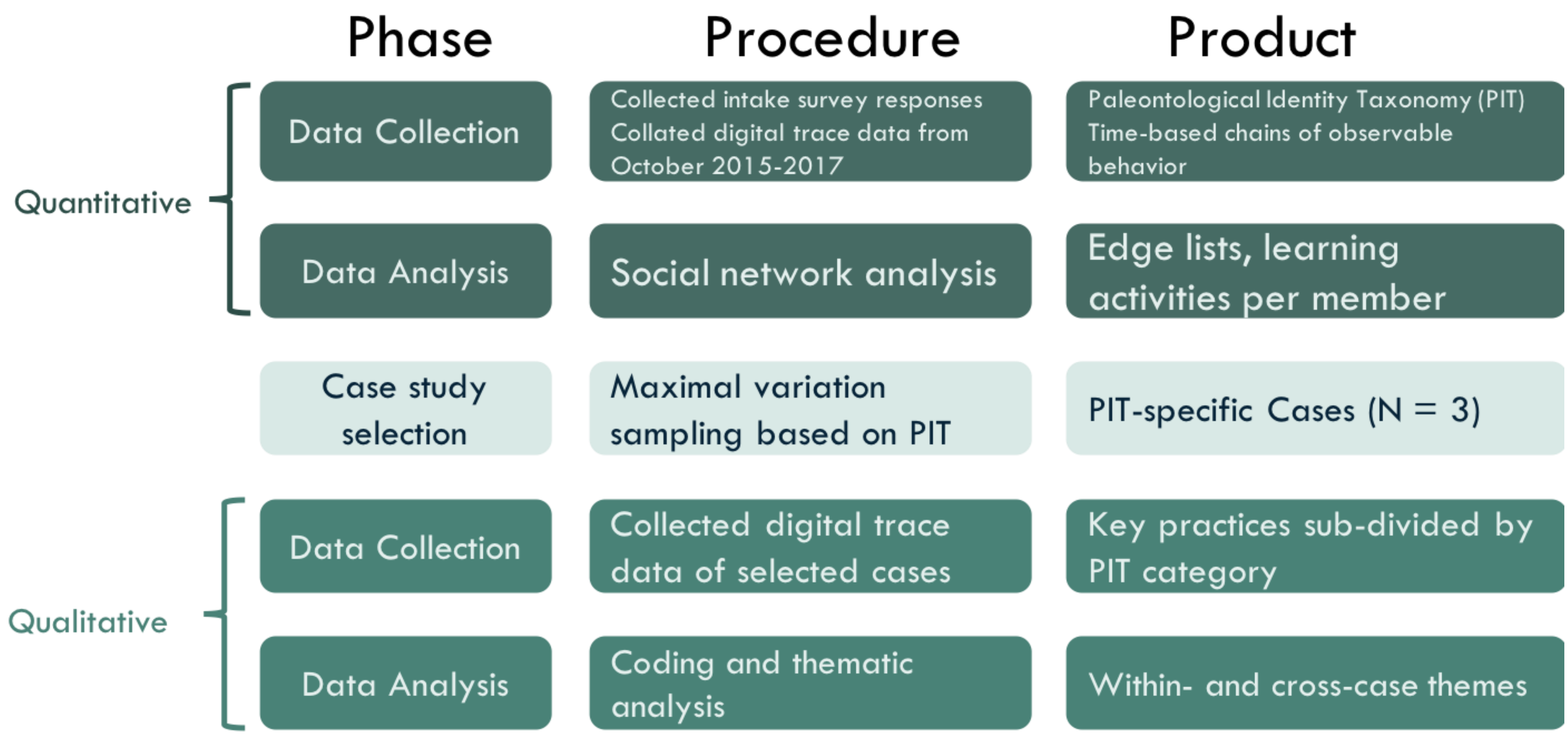

Figure 3-1. Visual Model for Explanatory Sequential Mixed Methods Design

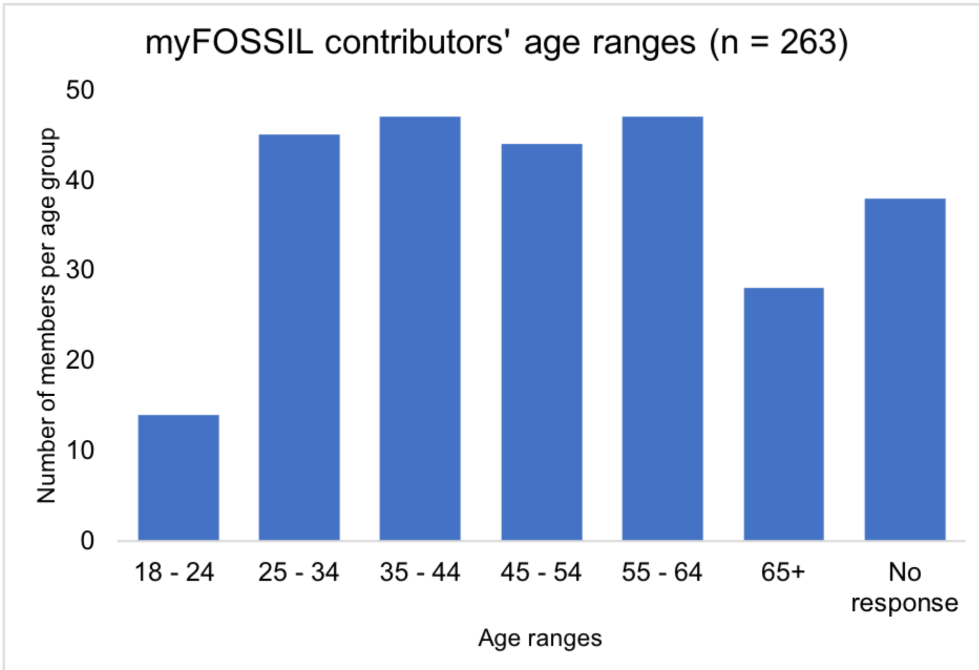

Figure 3-2. Age range of myFOSSIL members shows a fairly even distribution across the age groups (n = 263)

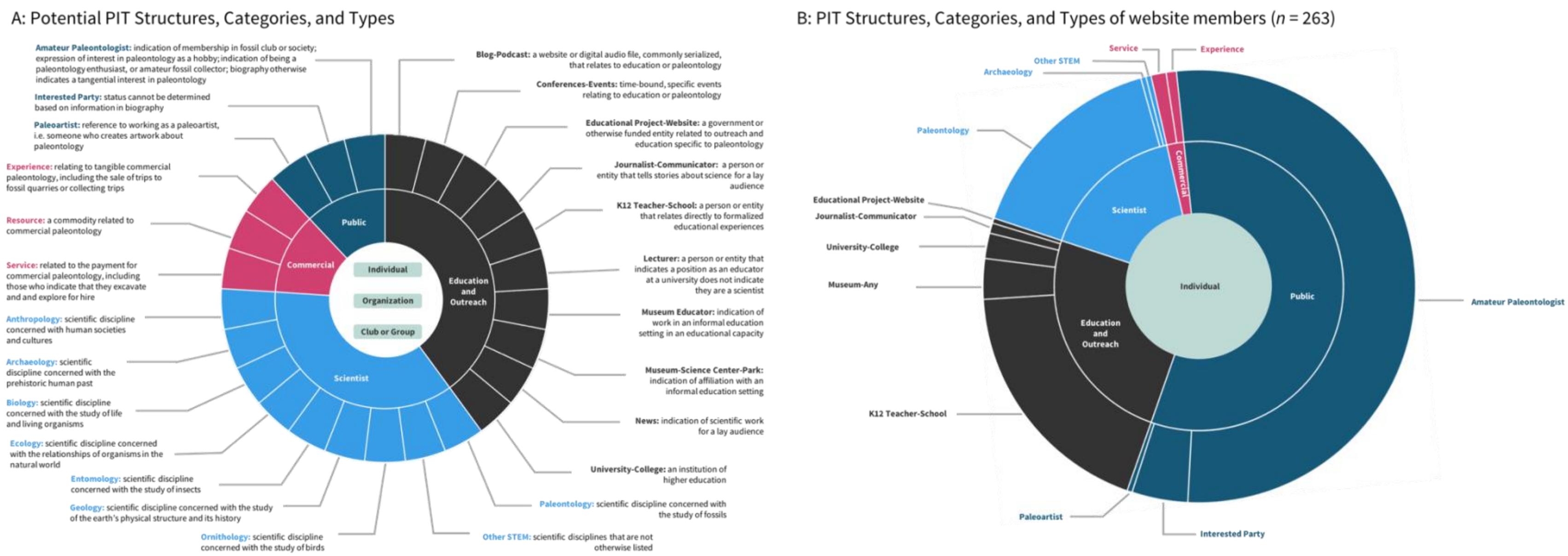

Figure 3-3. The three-tiered Paleontological Identity Taxonomy (PIT). The PIT is used as an analytical framework for classifying myFOSSIL members. A) Descriptions of the third tier (types). B) The makeup of active myFOSSIL members

Starting Activity (columns) / Trailing Activity (rows)

Trailing Activity	News and Information	Pointers to Resources / Document Sharing	Stories	Tips	Exploring Ideas	Joint Events	Documenting Practice	Collections	Problem Solving	Collaboration	Boundary Crossing	Models of Practice	External Benchmarks	Formal Practice Transfer / Trainings and Workshops / Invited Speakers	Help Desk	Support	Field Trip Planning
News and Information	20	4	11	6	19	6			1	1		1			3	2	
Pointers to Resources / Document Sharing	31	31	20	12	18	5	3		12	3		3			30	2	
Stories	29	22	58	7	30	28	2		9	2		3		1	11	3	1
Tips	17	13	18	22	10	6	3		20	4	2	1			87	1	
Exploring Ideas	39	8	13	1	46	7	7		4		1	4		2	4		
Joint Events	18	1	2		6	20			11						4	2	
Documenting Practice	7	31	7	4	5	7	8		6	3		2		4	9	1	
Collections																	
Problem Solving	21	19	14	18	19	10	6		16	15		3	1	4	30	1	
Collaboration	6	21	2		6	1			4	3		1			2		1
Boundary Crossing	4	7		4	3	2			5			1		1	2	3	
Models of Practice	3	10	4	5	2	1			5			6		1	10		
External Benchmarks					3												
Formal Practice Transfer / Trainings and Workshops / Invited Speaker	3	5	1		5	2	4		1			1		2	2	2	
Help Desk	13	8	8	25	9	8	5		12		1	3			41	1	
Support	40	32	17	19	36	16	5		19	5	3	1		4	53	5	2
Field Trip Planning	2				1												4

Figure 3-4. Adjacency matrix of the ways learning activities were connected on the myFOSSIL forums. The adjacency matrix provided the basis for creating an edge list that was used for social network analysis

CHAPTER 4
FINDINGS

This chapter presents the findings for each of the research questions. This was an explanatory sequential mixed methods study and as such, I first address the quantitative findings, then present findings from the qualitative data. The first research question sought to characterize the forms of social paleontological practice that exist within myFOSSIL. The second, to describe the types of knowledge-creating discourse, and the third to elucidate practice-development in relationship to community member attributes. To this end, the following questions framed the study:

1. What forms of social paleontological practice exist within myFOSSIL?
2. For textual practices, what types of knowledge-creating discourse exist?
3. What forms of practice-development occur within myFOSSIL and how are they related to the attributes of community members?

The quantitative dimension of this study collected digital trace data from a two-year period from myFOSSIL. Three types of data were collected and analyzed during this phase: members' forum posts, activity posts, and private messages. A more robust description of these data that were collated is as follows:

- Forum posts: content created by myFOSSIL members that was specific to forums. On myFOSSIL, forums were topic-specific, web-based discussion boards in which members created posts that other members marked as important to them (*favorite*), kept up-to-date with (*follow*), and added additional information to (*reply*).
- Activity posts: original content created by a myFOSSIL member that was situated within an area of the website that was not a forum. Activity posts were stand-alone content or replies to other members' posts.
- Member messages: private correspondences that originated from one myFOSSIL member and were sent to one or more additional myFOSSIL members. The message receivers had the option to respond to the message.

Phase I: Quantitative Findings

Forms of Social Paleontological Practice in Aggregate

Data were analyzed using the learning activities analytical framework (Table 3-4). Connecting social paleontology-specific activities to the learning activities described by Wenger et al. (2009), I derived practices that myFOSSIL members participated in and contributed to. Therefore, I describe the specific learning activities as *practices.*

Answering the first research question required holistic data analysis, without regard to the feature (i.e. forum post, activity post, or message) from which the data originated. As such, the unit of analysis for answering the first research question was individual posts, regardless of feature. The length of posts that were created by individual members varied from sentence to paragraph length; each member-created post was subject to analysis. These data were collected and then analyzed to answer the first research question, namely, *what forms of social paleontological practice exist within myFOSSIL?* I describe the findings regardless of website feature to provide a holistic overview of the practices that existed on myFOSSIL. The findings indicate that nearly all of the specific learning activities created by Wenger et al. (2009) plus three additional learning activities that were specific to myFOSSIL, existed on the website, although some were more prevalent than others (Table 4-1). Two specific learning activities from the framework were not found during the coding: *Learning Projects* and *Collections*; they remained uncoded and undefined as data analysis concluded. Therefore, there were 16 total learning activities that were coded across data on myFOSSIL. Note that in some components of the analysis, namely the Chi-Square tests, that the specific learning activities were collapsed into their higher-level learning activity categories. For example: *Models of Practice* and *External Benchmarks* were collapsed into *Creating Standards; Support* and *Field Trip Planning* were collapsed into *Ungrouped*. This was done to ensure that the Chi-Square tests conducted without issue (Yaeger, K., 2018, SPSS Tutorials: Home, https://libguides.library.kent.edu/SPSS, September 2018).

Regardless of data type, the main social paleontological practice that existed on myFOSSIL took the form of *Support* (Table 4-1). Support, which entailed members thanking others for contributing, acknowledging a contribution or being otherwise social without adding to knowledge per se, was added following preliminary data analysis. There were 693 instances of support expressed by myFOSSIL members. Support often took the form of a simple *thanks!* or expressions of gratitude to other members for posting, such as this activity post created by a myFOSSIL member who fit the PIT Category of Scientist: “It is helpful! Thanks for sharing, [@member!]” (activity post ID #17880). In data that were coded as Support, the focus was on social niceties.

The second most frequently observed practice was *Tips*, which occurred when members provided advice or best practice information to other member/s concerning social paleontology (n = 495). An illustrative example of Tips came from a Commercial member who responded to a query concerning uploading fossil specimens, “Hey [member]. Yeah but I don’t have any of them, and the industry photos are business confidential until released in an EIR or other final environmental report” (forum post ID #2827). In this post, the Commercial member explained why they could not provide photos of fossil specimens, explicating a part of commercial paleontology that was perhaps unknown to the member who had asked to see such photos.

The third most frequently coded practice was that of *Problem Solving* (n = 452). Problem Solving, whose definition was *communication concerning solutions related to the domain,* occurred regardless of data type. Often times, these communications were a mixture of domain-specific topics and questions regarding the website, as exemplified by a member who wrote, “additional photo that didn’t load, back of previous tooth” (forum post ID #2996). In this post, a member attempted to convey domain-specific identification information, but also indicated that they attempted to upload a photo a second time, as their attempt was unsuccessful the first time around. A further exemplar of Problem Solving was from a Scientist who was discussing the identification of a trilobite (an extinct arthropod) with another member. In his post, the Scientist wrote,

> “I was assuming the entire fossil to be a pygidium, but now I take your point that it comprises the whole thorax plus the pygidium. And that makes it an excellent match for the thoracopygidium of *Thaleops ovata*. It also helps explain the outline that appears anterior to the thorax. It’s a cross-section through the cephalon. I note the especially robust right gena” (forum post ID #17132).

In this forum post, the Scientist described specifics for trilobite identification, creating a solution to a domain-specific problem—the identification of a trilobite. By explicating reasoning, this member was exemplifying the practice of Problem Solving, however, a member reposting a photograph of a tooth was also an example of the practice, which shows the breadth of contexts the practice spanned.

Another frequently seen practice was that of *Stories,* defined as *person-centered accounts of social paleontological practice* (n = 413) (Table 4-1). Stories were often long-form accounts of members’ interest in paleontology, or reminiscence concerning fossil hunting. An example of this was from a Scientist who posted on the activity feed about some fossilized specimens that she appreciated, writing “Very adorable inarticulate [brachiopod]! We don’t get the variety around here that you find in the Cincinnatian. I think I have only found Pseudolingula here, I prefer the encrusting ones.” (activity post ID #18099). This quote shows the personal connection this Scientist had with paleontological specimens. In calling a fossil specimen adorable and relating them to her personal collecting experience by saying that they had low variety where she was, this Scientist was personalizing paleontology to her experiences with it. Another example came from a Public member who described her fossil specimens from a recent collecting trip, “I’ve only been to [collection site] a few times, and only have found small shark teeth, I believe. I did find a horse tooth at [collection site] a few years ago, but it is probably Pleistocene.” (forum post ID #3059). In this post, the Public member recalled her past experiences at a specific collection locality, explaining which specimens she found when she collected there. These two quotes highlight the ways in which members created personalized narratives regarding paleontology, specifically describing specimens or trips that were taken to collect fossils.

Across all three data types, the learning activities of Support, Tips, Problem Solving, and Stories occurred more frequently than the other learning activities. Support was the most coded practice, representing 18.1% of the total coded responses (n = 693). The second most coded practice was Tips (n = 495), which made up 12.9% of the total coded data. The third most coded practice, with 11.8% of the total coded data, was that of Problem Solving (n = 452). The fourth most coded practice, and one with more than ten percent (10.7%) was that of Stories (n = 413). Overall, this shows that the forms of social paleontological practice that exist on myFOSSIL were personal, related to sharing advice, and concerned with producing or at least explored new ideas related to social paleontology.

Across all data (N = 3825), the least frequently coded practice was that of *External Benchmarks,* defined as information concerning best practices of digitization of specimens consisting of 0.1% of all coded data (n = 4). The practices of *Formal Practice Transfer* (n = 47) and *Boundary Crossing* (n = 47) were also rare, each consisting of 1.2% of all codes on myFOSSIL. The scarcity of these practices indicated that either myFOSSIL members did not use the website to discuss these activities or were perhaps unaware of External Benchmarks for social paleontology. In terms of social paleontological identity, both Formal Practice Transfer and Boundary Crossing , which entailed members either transferring information that they had expertise in or crossing the bounds of their specific identity, were rare occurrences on the website with members tending to display their PIT identities versus expanding beyond them.

Identifying the forms of social paleontology that existed on myFOSSIL provides a holistic view, however, it was also important to understand the ways in which different practices emerged on features of the website, and what kinds of discourse existed within the textual practices. Therefore, I examined data within forum posts, the activity feed, and messages individually.

Forms of Practices and Knowledge-Creating Discourse within Website Features

I sought to determine the differences in practices use by website features (i.e. forum posts, activity posts, and messages). Examining data in this manner required data analysis in which each feature was examined, without regard for the other two types. As such, the unit of analysis was individual posts, with emphasis on the feature. As was done with the analysis of practices regardless of feature, the unit of analysis was individual posts, which varied in length from sentence to paragraph; each member-created post was subject to analysis. I illustrate the results of analysis in three parts: giving an overview of what was found using descriptive statistics, presenting the results of the Chi-Square test of Independence to highlight the overall differences within the data types, and describing the results of the social network analysis.

Descriptive statistics

Practices divided by data type were analyzed to make comparisons between each data type (Table 4-1). The data type of forum posts had the highest number of coded instances (N = 1858). Within forum posts, the practice of Support occurred most frequently, consisting of 14.3% of the total practices within forum posts (n = 265). *Stories* represented the second most frequently coded practice, consisting of 12.4% of the data (n = 231). Following Stories was the practice of *Tips,* which were the third in their prevalence, at 12.3% of all coded forum data (n = 228). *Problem Solving* (n = 201) and *Help Desk* (n = 189) were the only other learning activities occurring with frequencies higher than ten percent (10.8% and 10.2% respectively). These percentages show that within the data type of forum posts, myFOSSIL members were focused on providing non-scientific, community-based support to one another, telling personal paleontological accounts about paleontology, and producing solutions to domain-specific problems through advice, communication, or the distribution of domain-specific materials.

Activity posts, or those data which occurred in public spaces of myFOSSIL with the exception of forums, followed similar patterns to forum posts. Overall, 1,300 coded passages were found in the data type of activity. The most frequently coded practice was that of Support, consisting of 21.9% of all coded instances (n = 285). The second most frequently coded practice was Problem Solving, although the percentage drops to 13% of all activity posts (n = 169). The third most frequently coded practice was *Exploring Ideas,* a practice in which members brainstormed about the domain, and did not necessarily seek answers, which consisted of 11.1% of activity posts (n = 145). The only other practice that occurred in a frequency higher than ten percent was that of Tips, which made up 10.5% of all coded instances in activity posts (n = 137). These percentages highlight the ways in which members used the activity feed of myFOSSIL: as a place to appreciate one another socially and to brainstorm, communicate, and advise others about the domain of paleontology.

Lastly, the data type of messages followed a similar pattern to the other two types. Overall, 669 coded passages were found in messages. Similar to the other two types, Support was the most frequently coded practice, accounting for 21.4% of all coded instances (n = 143). Following Support was the practice of Tips, accounting for 19.4 % of codes (n = 130). The only other coded practice which showed up with regularly was that of Problem Solving, appearing 12.3% of the time (n = 82). These data show that within the digital trace type of messages, myFOSSIL members were explicitly focused on providing advice to one another, perhaps in lieu of other learning activities.

In examining the data to determine what knowledge-creating discourse occurred on myFOSSIL, the data showed that overall, most members were explicitly focused on bolstering one another’s contributions to the domain of paleontology purely in a social sense as seen by the frequency of data coded as Support. However, members were also expressly interested in the domain of paleontology, as they also frequently gave one another guidelines or ideas about identifying specimens and other domain-specific problems.

Chi-Square Test of Independence

In order to conduct a Chi-Square test to determine the statistical differences in practice use and data type, the specific practices were collapsed into seven broader learning activity categories. These categories were based on the original conceptualization of learning activities as dictated by Wenger et al. (2002) (Table 3-4). The specific learning activities of News and Information, Pointers to Resources/Document Sharing, Stories, and Tips were collapsed into the category of *Exchange.* Exploring Ideas was categorized as *Producing Inquiries.* Joint Events was categorized as *Building Shared Understanding.* The specific learning activities of Problem Solving, Collaboration, Boundary Crossing, and Documenting Practice were collapsed into the learning activity category of *Producing Assets*. Models of Practice and External Benchmarks fell into the broader category of *Creating Standards.* Formal Practice Transfer; Trainings; Workshops and Invited Speakers, and Help Desk were categorized as *Formal Access of Knowledge.* Lastly, the three specific learning activities that were emerged from the study data, Support and Field Trip Planning were grouped into their own broader learning activity category of *Ungrouped.*

A Chi-Square test of Independence was performed using the statistical software program SPSS Statistics (v. 25). There was a significant association between data type and learning activity use on myFOSSIL, X^2 (12, N = 3825) = 102.52, $p < .001$, $R^2 = .16$. As it was important to determine the differences between data type, pairwise comparisons were then performed. The pairwise comparisons show significant differences in the ways that learning activities were used on forums and activity, X^2 (6, N

= 3158) = 64.89, $p < .001$, $R^2 = .14$; on forums and messages, X^2 (6, N = 2525) = 50.75, $p < .001$, $R^2 = .14$; and on activity and messages, X^2 (6, N = 1967) = 23.31, $p = .001$, $R^2 = .11$. That is to say that myFOSSIL community members enacted social paleontological practices in different ways dependent on data type. These results indicate that the knowledge-creating discourse that exists on myFOSSIL was different depending on the data type. For example, the ways in which members enacted the broader learning activity category of Exchange might have been different whether the members created messages or forum posts. These data are somewhat contradictory to the descriptive statistics in which practices were generally similar across all forums, activity, and messages. This means that at a higher level, the discourse varied dependent on the features of myFOSSIL.

Social network analysis of data types and knowledge-creating discourse

This component of the quantitative analysis was completed to provide a better understanding of the chains of observable behavior that occurred on myFOSSIL. While it was useful to understand the general practices that occurred, it was imperative to understand how they developed and related to one another. This analysis was conducted on the forums, as they contained the greatest amount of data. In addition, the chains of activity were discernable within forums. Within the activity feed, the backend data did not parse chains of behavior, instead all data, regardless of member, originated from the activity feed.

The practices were therefore analyzed on the forums using methods as outlined by Himelboim et al. (2017). First an adjacency matrix was created (Figure 3-4) then used to create an edge table that was imported into NodeXL (Smith et al., 2010). These data reveal the structure of the discourse that occurred on the forums. In social network analysis, the emphasis on the flow of connectedness from one entity to another without the necessity or possibility of reciprocation is called directed connections (Hansen et al., 2011). Therefore, the network graph created during this stage of analysis was a *directed graph* (Figure 4-1)*.* The directed graph showed the connections, specifically, the differences that emerged between these connections, that occurred between the 16 practices on the website (Figure 4-1, Part A). The content of forum posts was classified by the practices and the connections between them, namely which practices occurred first, and the practices that followed them. The seven higher-level learning activity categories (e.g. Exchange) and their associated nested specific practices were visually depicted on a social network graph with seven different colors (purple, wine, pink, peach, marigold, pea green, and brown) (Figure 4-1, Part B). Within the social network analysis of myFOSSIL, individual practices were represented as single vertices, the connections between vertices were called edges.

The social network of practices on forum posts was high density ($\rho = 0.610$), meaning that the practices within the network were fairly interconnected. Furthermore, modularity of the network, measured on a range of value from 0 to 1, was low ($Q = .027$) (Himelboim et al., 2017). These metrics reveal that the network structure of the myFOSSIL forums was unified.

Calculating centrality measures allowed for an understanding as to the way information flowed within the network. Degree centrality explicated the total connections that linked to a vertex. The most basic of these measures were in-degree and out-degree. In-degree measured the number of connections that flowed towards a vertex while out-degree was the number of connections that radiated outwards from a vertex

(Hansen et al., 2011). Visually, this was depicted by increasing the size of vertices with higher out-degrees (Figure 4-1, Part C).

Betweenness centrality was used to determine through which practices information flowed through on myFOSSIL, or rather, which practices served as bridges (Hansen et al., 2011). Within this network, the practices of Exploring Ideas and Problem Solving had high centrality measures, with Exploring Ideas equaling 20.68 and Problem Solving equaling 14.31. News and Information had the next highest betweenness centrality, at 5.68. Another centrality metric, closeness centrality, indicated the average distance between one practice and all others in the network. On myFOSSIL, all practices had closeness centralities that were less than one, meaning that the average distance between all practices was short. The last centrality measure, that of eigenvector centrality, indicated the connectedness of connected vertices. For instance, a practice could have a high eigenvector centrality if the practices it was connected to were highly connected. On the myFOSSIL forums, eigenvector centrality ranged from .010 to .071, with External Benchmarks featuring the lowest eigenvector centrality (.010) and Exploring Ideas representing the highest (.071).

Understanding the structure of the myFOSSIL forums helped explicate the ways in which the practices were connected to each other. Another way to do this was to determine number of times a relationship occurred, which can be described as edge weight (Hansen et al., 2011). Visually, increased edge weight was depicted by increasing the width (or thickness) of an edge (Figure 4-1, Part D). An example of a relationship with increased edge weight was that of Help Desk leading to Tips. This relationship occurred 87 unique times and was assigned an edge weight to depict this.

Other learning activities which had high edge weights included Stories-Stories (i.e. one forum post that included the practice of Story often led to another forum post that included the practice of Story), Help Desk-Support, and Exploring Ideas-Exploring Ideas. Relationships that occurred fewer times than this (e.g. Models of Practice-Exploring Ideas), were depicted with a thinner edge weight. These connections and the structure of the learning activities on the myFOSSIL forums therefore illustrated the knowledge-creating discourse that existed. Indeed, the myFOSSIL forums showed high connectedness between the practices, as well as high numbers of connections between certain practices, which showed the way that people created knowledge on myFOSSIL.

General connectedness was also shown through the process of grouping. Grouping (i.e. clustering) indicated the collection of vertices that were more connected to each other than they were to other vertices (Hansen et al., 2011). On the myFOSSIL forums, there were three distinct groups. These groups were visualized in a social network diagram in that associated vertices were given similar shapes (Figure 4-1, Part E). Group 1, shown with the shape of a disk, included Tips, Documenting Practice, Collaboration, News and Information, Stories, Field Trip Planning, and No Connection. Group 2, depicted as a solid triangle, included Formal Practice Transfer, Joint Events, Help Desk, Models of Practice, Pointers to Resources/Document Sharing, and Boundary Crossing. Group 3, depicted as a solid square, included Exploring Ideas and Problem Solving. I examined these groupings to determine if the included practices were divided into their higher-level learning activity categories (Wenger et al., 2009). Aside from determining that three of four specific learning activities (i.e. Tips, News and Information, and Stories) from the higher-level learning activity of Exchange were included in Group 1, there were no other associations. This shows that the associations between higher-level learning activities and their specific learning activities were not as strong. Therefore, the conceptual framework determined by Wenger et al. (2009) (Table 3-3) that was modified for the coding scheme (Table 3-4) was modified further by changing the higher-level learning activities from seven to three higher-level categories, as determined by the social network analysis grouping on myFOSSIL's forums (Table 4-2).

Forms of Social Paleontological Practice, PIT Identity Breakdown

The third research question, what forms of practice-development occur within myFOSSIL and how are they related to the attributes of community members, was answered quantitatively in three ways. First, the total number of practices, regardless of PIT Category, were tallied at the mid-point of the data collection period (October 2, 2016) and the end point of the study (October 31, 2017) to determine the ways that practices developed or were distributed within the myFOSSIL community over the data collection period, therefore, the unit of analysis for this component was each piece of digital trace data. Then, members' PIT Categories and the data were summarized with descriptive statistics, meaning that the unit of analysis was individual pieces of digital trace data. Lastly members' PIT Categories and their relationship to the data that was created by members within each Category was analyzed using the Chi-Square test of Independence and pairwise comparisons, meaning that the unit of analysis was member-based.

Practice-development over time

Overall, the number of practices on the website increased and became more evenly distributed among members (Table 4-4). This occurred regardless of data type.

For example, from October 1, 2015 – October 1, 2016, 79 unique members contributed to activity whereas from October 2, 2016 – October 31, 2017, 119 unique members contributed to activity. For forums, from October 1, 2015 – October 1, 2016, 70 unique members contributed whereas from October 2, 2016 – October 31, 2017, 108 unique members contributed. Lastly, for messages, from October 1, 2015 – October 1, 2016, 40 unique members contributed to activity whereas from October 2, 2016 – October 31, 2017, 80 unique members contributed.

The distribution of practices was then examined based on the different PIT Categories, specifically the PIT categories of Public, Scientist, and Education and Outreach. Commercial members' practice-development over the course of the study period was excluded from this analysis due to the rarity of this Category of members contributing. Two practices across three PIT Categories increased: Support and Help Desk. For Support, the increases were: Public (+57), Education and Outreach (+37), and Scientist (+19). For Help Desk, the increases were: Public (+65), Education and Outreach (+25), and Scientist (+14). Tips increased for members categorized as Scientist (+97) and Public (+72) For both Education and Outreach and Scientist, the practice of Joint Events exhibited static growth (+2) whereas it decreased for the Public (-28).

Following this, I sought to comprehensively determine the ways in which members of different PIT Categories established practices on myFOSSIL. To determine if members associated with specific PIT Categories created digital data at higher frequencies than other PIT Categories, coded data were subdivided by PIT Categories. I first determined the makeup of contributors via the application of the PIT, then examined what practices were present and how these practices varied by PIT Categories using social network and content analyses.

In examining data created during this time period, 263 members created at least one form of data; these members were the sample chosen for analysis (Table 4-4). Within the time period of the study, most members contributed only activity posts (n = 69), followed by contributing to just the forums (n = 57). Thirty-seven members contributed all data types, whereas 34 contributed to forums and activity and 33 contributed to activity posts and messages. Members who contributed only messages (n = 23) and forums and messages (n = 11) were the least frequent combinations seen.

Descriptive Statistics

A visual representation of the differences in PIT Categories' varied usage of practices was needed (Figure 4-2). A bimodal graph of the three data types and members who contributed to them was created. Vertex shape (square, solid diamond, solid circle, and solid triangle) was used to depict the different PIT Categories. Increased vertex size was used to indicate the amount of data each member contributed. The graph does not depict very many differences between member Categories, although it does highlight the lack of Commercial members (i.e. pink circles) and as well as the fact that Public members contributed across all types of data on myFOSSIL in increased numbers. The graph showed that members who contributed to all three data types contributed more than those members who contributed to only one data type. What this means is that members were more prone to contribute across all data types than they were to contribute prolifically to one data type.

Only five Commercial members contributed some form of data. Two contributed to only the activity feed, one of the only contributed to the forums, another contributed activity and message posts, while the last contributed to all three forms of data.

Forty-five Scientists contributed some form of data. Most Scientists contributed to only forums (n = 15), followed by only contributing to the activity feed (n = 8). Seven Scientists contributed to forums and activity as well as to all data types. Only messages (n = 4), activity and messages (n = 3), and forums and messages (n = 1) were contributed to infrequently by Scientists.

Sixty-two Education and Outreach members contributed some form of data. Education and Outreach members most frequently contributed to only the activity feed (n = 17), followed by contributing to the forums and activity (n = 11), then only forums (n = 10). Fewer Education and Outreach members contributed the combination of activity and messages (n = 8), only messages (n = 7), all data (n = 6), or to both forums and messages (n = 3).

One hundred and fifty-one Public members contributed some form of data. The largest majority of Public members contributed to only the activity feed (n = 42), followed by only forums (n = 31), all data (n = 22), then activity and messages (n = 21). Fewer members who fit the PIT Category of Public contributed data in the form of forum and activity posts (n = 16), only messages (n = 12), and forums and messages (n = 7).

Public members most frequently created data that included the practices of Support (n = 322), Stories (n = 232), and Problem Solving (n = 223) whereas Scientists often created data that included the practices of Support (n = 266), Tips (n = 257), and Problem Solving (n = 185).

Education and Outreach entities created less data overall than both Public members or Scientists. Education and Outreach members' data entailed only 12.7 percent (n = 487) of coded instances, whereas Scientists created 41.3 percent (n = 1,581) coded instances and Public members created 44 percent (n = 1,684) of the coded instances. Education and Outreach members most often created data that included the practice of Support (n = 85), *News and Information* (n = 58), which was defined as a story about paleontology presented for a lay audience or a general resource for paleontology, such as a geologic map or dissemination of recent organization activity, links to blogs, and *Help Desk* (n = 55), a practice defined as inquiring about domain-related topics—most often, the identification of specimens.

Commercial members, although a miniscule percentage of website members (1.9 percent), most often created data that included the practice of Support (n = 20), Stories (n = 17), and Problem Solving (n = 9), a pattern that was similar to members who fit into the PIT Category of Public.

Chi-Square Test of Independence

Using the statistical software program SPSS, a Chi-Square test of Independence was conducted, followed by pairwise comparisons. For this analysis, the Category of Commercial was excluded due to the small amount of data that were contributed by this PIT Category. As was done with the Chi-Square test of Independence for determining the relationship between knowledge-creating discourse and data type, practices were collapsed into their higher-level learning activity categories as determined by Wenger et al. (2002). There was a significant association between PIT Category and learning activity use on myFOSSIL X^2 (12, N = 3752) = 47.49, $p < .001$, $R^2 = .11$. Pairwise comparisons show that, specifically, there were differences in the ways that Education and Outreach members implement learning activities versus Public members X^2 (6, N = 2171) = 26.44, $p < .001$, $R^2 = .11$, and versus Scientists X^2 (6, N = 2068) = 34.65, $p < .001$, $R^2 = .13$. There were no significant differences in the ways that Public and Scientist members used learning activities on myFOSSIL X^2 (6, N = 3265) = 15.34, $p = .018$. This means that for the Categories of Public and Scientist, they implemented practices on myFOSSIL in similar ways, but those members categorized as Education and Outreach enacted practices differently. The differences between Education and Outreach and the other two Categories could have implications for the development of digital, scientific CoPs.

Quantitative Data Summary

The data analysis conducted during the quantitative part of this study emphasized the practices that led to participation in and contribution to social paleontology. Namely, regardless of PIT Category or data type, Support, a practice that was defined as members thanking others for contributing, acknowledging a contribution or being otherwise social without adding to knowledge per se, was the most frequently seen practice. This meant that on a website devoted to social paleontology, the members focused most often on the social aspect versus the scientific aspects. The second most frequently coded practice, Tips, in which members provided advice or best practice information to other member/s concerning social paleontology, indicated that in addition to providing social encouragement, members contributed to the scientific practice of social paleontology on myFOSSIL. The high frequency of Tips indicated that members viewed each other’s queries about paleontology and responded to them. Problem Solving, defined as communication concerning solutions related to the domain, indicated a more robust or in-depth exploration of the topic of social paleontology than

Tips. The prevalence of Problem Solving indicates a sense of ownership to the knowledge created on myFOSSIL. Members were interested in having discussions that centered on being creative and flexible in the face of domain-related issues (Wenger et al., 2002).

Phase II: Qualitative Findings

As this was an explanatory mixed methods study, the qualitative phase of research followed the quantitative phase. During this phase of research, I explored in depth the forms of practice development that occurred for three myFOSSIL members. Members were selected based on the quantitative findings from research question three using maximal variation sampling in which individuals were selected based on their specific characteristics (Creswell, 1998). Members who created large quantities of data were first examined. Then, members whose contributions were consistent with the most frequently coded practices were chosen as exemplars of social paleontological practice on myFOSSIL, henceforth called *profiles in practice.* Commercial members were excluded from these profiles in practice, as their contributions to the website were minimal. Therefore, the three profiles in practice were chosen: Chris Traeger (Scientist), Ron Swanson (Public), and April Ludgate (Education and Outreach) (Table 4-5).

Each case is described, including basic information such as their PIT classification, occupation, and website member profile to give a rich description of the member as a representation of the Category. To protect the identities of each member chosen as a profile in practice, certain details, including their names, paleontological specialties, fossil club membership, and locations have been modified. Exchanges between the exemplar members and other myFOSSIL members were also modified to protect identities, for example, individual nuances, including the ways that members signed their names to the end of posts or included emoticons, were also removed as these could reveal identities of members. Following descriptions of members, each member’s contributions to myFOSSIL are described, with their contributions quantified to indicate patterns (Maxwell, 2010). After each case has been described in this way, I will provide comparisons of the ways in which each case contributed to social paleontology.

Profiles in Practice

Scientist

Chris Traeger: As per the PIT, Chris was classified at the structural level as an Individual, at the Category level as a Scientist, and at the Type level as Paleontology. During the study period he was a researcher at a natural history museum affiliated with a large university in the United States. His research foci were marine vertebrate paleontology and paleobotany. Additionally, Chris had interest as well as expertise in the digitization of fossilized specimens, which he often discussed with other members on myFOSSIL. Chris was between the ages of 35-44 and had been a member of myFOSSIL since the beta testing phase. Chris had traveled extensively for paleontological research, including many locations in Europe and across the United States.

Chris contributed to all three forms of data, specifically he created a large number of forum posts (n = 140) and some activity posts (n = 46), but rarely sent messages (n = 1). Chris used the following practices across all his contributions: Support (n = 51), Tips (n = 30), Problem Solving (n = 25), Collaboration (n = 7), and Exploring Ideas (n = 5). As an exemplar of the PIT Category of Scientist, Chris was a social supporter who sought to solve domain-specific problems, which I will explain in the following sections.

First, Chris most often offered Support to his fellow members, either by thanking them for contributing or was social without adding knowledge about the domain per se (n = 51). A poignant example of this occurred when Chris commented on a fossil specimen posted by Ron Swanson, the exemplar Public member, who will be described more fully in a later section. Ron had uploaded a fossil specimen to highlight how ammonium chloride can be used to whiten fossil specimens, making it easier to see details after photographing them. Chris wrote, “I really like the whitened pic, the surface is perfectly showing every detail! Good job! Excellent example for how a good pic should look” (Chris, Scientist, forum post ID # 3139). With this post, Chris acknowledged Ron’s contribution, ensuring that Ron felt encouragement for posting a picture of his specimen, as well as provided feedback regarding the quality of the image. In another instance, Chris created a tutorial for cleaning and curating fossils. A Public member indicated that the tutorial was helpful, and Chris responded, “Thank you so much for your feedback, I really appreciate it and feel very pleased. That is just the right reward for all that work. Once again: Thank you very much!” (Chris, Scientist, forum post ID # 3424). With this forum post, Chris exemplifies the notion of Support, indicating that he was glad for feedback. This kind of response is not domain-specific, but still important for a digital CoP: it acknowledged the response of one member, which helped to build community as individual member input was recognized.

Chris also provided many Tips (n = 30), which supplied other members with advice or best practice information. For example, in one post concerning cleaning and whitening specimens in order to ensure that they photographed well, Chris indicated a technique that he used then advised, “I forgot to mention that you should not look into the bright white flame…but I’m sure you already know that” (Chris, Scientist, forum post ID # 2267). With this post, Chris explicitly provided other members with domain-specific advice. When he provided this advice, he was responding to a forum post that was started by a Public member. When Chris indicated in his post that the member *already [knew] that*, the playful, teasing tone indicated a familiarity with the other member, showing both the ability to provide advice while being friendly. In another instance, a Public member asked for clarification concerning a fossil specimen. Chris responded, “it is definitely the skull fragment of a whale or dolphin, better identification will take some more time, but it is definitely a whale skull” (Chris, Scientist, forum post ID # 3248). With this post, Chris did not explicate *why* he knew the specimen was a whale skull fragment, instead he provided base-level information: he knew it is a whale skull just by looking at the photo. In his posts about best practices for getting quality photographs as well as his identification posts, Chris rarely provided background information or explicit reasoning for his responses, he simply provided the answer, a quality that was exclusively tied to the practice of Tips.

Chris contributed many posts that were coded as Problem Solving (n = 25) in which he communicated with other members about solutions related to the domain. Specifically, Chris had a serious interest in securing high quality digital images of specimens. Chris often responded to other members concerning the practice of digitization, offering solutions. For instance, some members posted in a forum, indicating their interest in using cell phone camera attachments to take photos. Chris responded, indicating,

> “concerning the extra macro cell phone lenses, I would suggest that the quality of a $500 Pro lens is way better but we have to think about that not everybody is able to spend that much money just for a lens. We invite everybody to be part of this community and as long as we can help to make the quality of images better even with not so expensive tools ($40-70 is still a lot of money, it depends on your pocket) we would like to do it. But you are right it might be very interesting to find out how good these accessories are compared with the pro stuff, maybe it will be a big surprise and we all can [save] a lot of money so stay tuned for upcoming output btw: I have fixed the sound problem and will upload it soon ... hopefully it will make it easier to follow my instructions (Chris, Scientist, forum post ID #2620)

This quote highlights the way that Chris thought about the community. He applied his expertise in photography while considering the ways in which other community members could contribute. After this post, another member responded with concerns about image distortion in a specimen photograph taken using a cell phone camera attachment. Chris then replied, writing,

> Hey [member] now I see the failure ... yes you are absolutely right the distortion at the edge is quite high but the pics from [member] are not so bad and give me the feeling that there is a way to make them even better. I know that these set ups will not reach the level of a professional camera with special macro lens but we always have to think about the budget. I will try to [test] different models. Maybe I can figure out which one should be recommended and which [ones] we can forget (Chris, Scientist, forum post ID #3138).

With this response, Chris further exemplified the practice of Problem Solving. Namely, Chris identified issues (i.e. the distortion in an image) and indicated that there was a possible solution (i.e. testing cell phone camera attachments). In considering budget, Chris was being a good community member by being mindful of the ways that anyone could continue to contribute to the community.

In addition to Chris' propensity to provide support, offer best practice information, and to problem solve, Chris' posts were coded as Collaboration in which Chris swapped resources or information to create domain-specific partnerships (n = 7). Chris exchanged or responded to Ron Swanson (PIT Category: Public), with regularity during the study period. In these posts, the thread of Collaboration is apparent. Specifically, Chris and Ron intertwined Documenting Practice and Collaboration while responding to one another. Chris was interested in creating video tutorials concerning preparation and cleaning of fossilized specimens. Ron uploaded a specimen he prepared; following this, Chris indicated that documenting the ways in which Ron prepped his specimen would be interesting to the community at large. Then, Ron and Chris began responding to one another on the forums and in the activity feed, discussing how to best do this. An example of the collaboration can be seen in this post from Chris, which contained other practices, such as Support, but the overall thread of the post was an attempt to encourage Ron to collaborate with him via creating and uploading his own preparation techniques:

> Hey Ron, Thanks for your comments. The recommendations I gave were multifarious and not just related to Vertebrates. In our cleaning tutorial I mentioned that cleaning methods are depending on matrix, fossil material and how fragile or stable your fossil is. I also cleaned a bivalve and gastropod shell and recommended some DIY advice for making even finer instruments like tiny spatulas for very delicate structures and tiny objects. I also pointed to specific tutorials about fossil preparation where I will focus on fragile objects, different fossil material and matrix. These tutorials are not finished yet. At the moment I am just about to finish the photo tutorial, then the one about preparation comes next. I do all this on top of my scientific work, and as you may understand it takes time. The preparation tutorial will also cover the use of different chemicals (different acids, H2O2, etc.), the use of sandblasters, Dremel tools, ultra sound bath and many more. The problem is that not everybody has the possibilities of using a sandblaster or an ultra sound. We have to be focused on techniques that everybody can use. I truly appreciate your helpful

> comments and I think it is a good idea to present your preparation techniques within this forum as a special section. Please do so. You can also create your own little tutorials and upload them if you like. That would be great!!! (Chris, scientist, forum post ID # 3344)

This post shows how Chris provided Ron with a reason to collaborate: so that myFOSSIL could be a place where everyone could find techniques to prepare fossils. The collaboration that Chris encouraged was that of Documenting Practice, the act of creating a digital artifact about preparation techniques, but Chris was interested in helping with this process and encouraged Ron to do it.

In another series of activity posts which was started by Bobby Newport (PIT Category: Public), Chris explicitly sought to create a domain-specific partnership. Bobby uploaded a scientific paper about the relationship between shark teeth and body length to myFOSSIL, Chris read the paper then responded to Bobby, writing that the paper interested him and that they should work together to solve problems set out by the previous research: “Maybe we can find a way to work on that with more tooth sets (also with some carcharinid sets as extra control groups) and publish it…” (Chris, Scientist, activity post ID # 2107). After this post, Bobby responded affirmatively, then Chris responded back, “it is definitely worth publishing…with some improvements. I look forward to [working] on it with you.” (Chris, Scientist, activity post ID # 2776). Chris’ interest in working together to understand domain-specific problems is seen in this series of posts, as he acknowledged the problem Bobby brought up (shark teeth and body length estimates), then indicated a way to swap resources or information to create a partnership.

Lastly, Chris used the practice of Exploring Ideas (n = 5), defined as brainstorming about the domain, not necessarily seeking answers. Specifically, Chris asked other members questions, sometimes about their collections or specimens. These questions were not necessarily seeking solutions, but rather, ways to interact with other members. An example of this occurred in a forum post in which Chris queried Dennis Feinstein (PIT Category: Public),

> Hey Dennis @dennis.feinstein, I know that you have done some work in digitizing shark teeth, do you also have mounted teeth sets from Great White Sharks with known Body Length? That would be very interesting [to] me. (Chris, Scientist, forum post ID # 4794)

In this quote, Chris asked another member about their past experiences with paleontology, as seen by asking about this member's past digitization efforts. Chris then indicated that the information that his fellow member would provide would interest him. Aside from the knowledge that Chris is interested in shark paleontology, his reason for asking about this information is unknown. By examining these data, we can infer that Chris' interest in Dennis' digitization expertise was potentially related to the collaboration that he was attempting to set up with Bobby Newport—Chris was looking for solutions related to shark teeth and body length. In asking these questions, Chris was attempting to solve his domain-specific problems by expanding his search to other myFOSSIL members.

Public

Ron Swanson: As per the PIT, Ron was classified as an Individual at the Structural level, as Public at the Category level, and as Amateur Paleontology at the Type level. Ron was a member of a fossil club that was based United States and joined myFOSSIL as a beta tester. Ron was retired, over 65 years of age, and had an interest in invertebrate fossils and photography. Over the two-year period of the study, Ron contributed to the forums (n = 121), to the activity feed (n = 52), and to messages (n =

13), meaning that he contributed all forms of data on the website. Most often, Ron created data that included the practices of Problem Solving (n = 45), Tips (n = 43), Support (n =30), Documenting Practice (n = 20), and Stories (n = 5). As an exemplar of the myFOSSIL membership category of Public, Ron was a problem-solver and adviser whose focus was creating a digital record of real-world expertise.

Ron often sought to communicate about domain-specific solutions (i.e. Problem Solving) when posting on myFOSSIL (n = 45). An example of this occurred in a forum post that centered on discussing ways to photograph specimens. Chris, a Scientist, created a tutorial explaining best practices for specimen photography. Ron responded with feedback that he though could improve the tutorial particularly focusing on areas he thought he could troubleshoot,

> "I have a few of comments. 1) You mention using a color checker. That's a very good idea and I wish I had thought of it. You didn't show this close up and I would like to get one. Can you tell me more about it?" (Ron, Public, forum post ID # 2925).

In this post, Ron was interested in the technique Chris explained, but needed more information as to where to find tools to help him better photograph his specimens. Ron also was interested in fossil preparation, and often discussed this with the myFOSSIL community. In one forum that centered on fossil preparation, Ron listed off a number of ways to clean fossils, focusing on a chemical that he knew some other members had used. Ron lamented that the chemical could not be found in the United States. Upon seeing this post, Chris indicated that he would look into ways of obtaining the chemical outside of the United States, as he had ideas, due to his extensive travels. After not hearing from Chris for a while, Ron created a forum post that moved the conversation along in the forum, writing, "I'm hoping Chris (@chris.traeger) will get back to us about [chemical] when he returns from his travels” (Ron, Public, forum post ID # 3001). In doing this, Ron was attempting to solve a domain-specific problem, specifically that of finding a good chemical to clean fossils. Both of the aforementioned posts exemplify both the practice of Problem Solving, as they focused on a domain-specific problem (e.g. finding a chemical used to prepare fossil specimens), and the role that Ron played as a Public member on myFOSSIL. He was able to speak knowledgably about fossil preparation and curation techniques then communicate with others concerning those domain-specific problems, moving along conversations about those problems by tagging others and following up with additional information.

Ron further indicated his expertise in regard to fieldwork, identification, and curation in his responses that were coded as Tips (n = 43). In these posts, Ron gave identification information that could help members further their knowledge of specimens. Ron gave Tips to members of any PIT background. For instance, one member who was a Scientist posted a photo of a fossil specimen, then tagged Ron, who had extensive experience with invertebrate fossils, asking for his help in identifying it. Ron responded, writing, “Orin, Ann, these are indeed Graptolites. [Redacted] is the most commonly found Graptolite in this area. Orin you might consider joining First Fossil Club if you are collecting in this area. We have a member who is an expert on Graptolites and can help identify your specimens” (Ron, Public, forum post ID # 2266). Ron also provided identification to another member who asked about their specimen, writing, “Definitely a [redacted]. It looks too big for Ordovician. More likely Mississippian.” (Ron, Public, forum post ID # 3937). With both these posts, Ron used his expertise with invertebrates while filling the role of a Public member: he offered both advice about fossil specimens but also social aspects related to paleontology, including joining a club. His level of expertise was acknowledged by those who tagged him in posts related to his interests which include invertebrate fossils as well as fossil preparation and curation techniques.

Ron was very responsive to his fellow myFOSSIL members, often providing critical feedback followed by messages of Support (n = 30). Whenever another member followed up with Ron indicating that they gained something from their interaction with him, whether it was an identification, feedback on curation techniques, or corrections to geologic time periods, Ron quickly followed up, writing responses like "Glad I could help (Ron, Public, activity post ID # 5764), "No problem, you're welcome!" (Ron, Public, activity post ID # 16931), and "We're always willing to communicate with others about the great Paleozoic materials!" (Ron, Public, activity post ID # 2108). Ron responded regardless of members' PIT Categories: he did not seem to send more messages of Support to Scientists over other Public members or Education and Outreach members.

Ron was also explicit about praise for other members, creating posts like "Chris, I think your video was really good. I was impressed with the range of information that you covered" (Ron, Public, forum post ID # 3394) and "I found the webinar quite interesting, by the way" (Ron, Public, activity post ID # 16978). These posts highlight Ron's responsiveness to other myFOSSIL members as well as his role in the community. Aside from being a prolific content creator, he was also interested in creating a community, which entailed a friendly, open, and good-natured demeanor.

Ron was also eager to share his knowledge in an online environment. Specifically, he explicitly created digital artifacts to highlight his real-world experiences with paleontology, the definition of the practice of Documenting Practice (n = 20). In one case, Ron was attempting to obtain membership in an organization that recently changed its' regulations to allow amateur paleontologists at a reduced rate. Ron posted on the activity feed, alerting a prominent member of the organization about an issue with registration. Ron indicated a chain of people with whom he communicated to resolve the issue:

> "@mark.brendanawicz, Mark, I originally spoke to [redacted] about this so he knows there is an issue they didn't anticipate. Greg sent me to Jennifer Barkley who then referred the problem to Marcia Langman at [redacted]. Marcia manually fixed my situation and she is the one who have me the instructions I relayed here." (Ron, public, activity post ID # 10481)

Documenting real-world domain-specific events via the creation of activity posts is a specific example of Documenting Practice. Furthermore, a number of examples of Documenting Practice were from a forum that focused on curating one's collection. Ron had extensive experience in photographing invertebrate fossils, which often presents problems as they are either very small or very flat, making photography challenging. Ron responded to a video tutorial that a Scientist, Chris, created indicating the ways he fixed the issues with photographing invertebrates:

> "A photo of a trace fossil from around here with flat lighting would end up invisible. So maybe it depends on the subject as to what lighting technique you use. I use a single flash as a main light source and a white card reflector as balance/fill. The card has to be positioned so that it softens the shadows without completely eliminating them. When photographing trace fossils I sometimes use no fill at all along with very strong side lighting (image of Phycodes flabellum trace attached)" (Ron, Public, forum post ID #2787).

In another instance, Ron expounded in a lengthy forum post upon the 11-step technique he employed to cut and polish different fossil specimens: "…my methods are labor intensive but fairly easy to do. 1) Unless you collect a specimen that is flat, you will need to cut the specimen…11) Note that not all specimens will exhibit a mirror finish" (Ron, Public, forum post ID # 4361) This digital documentation of the real-world experiences that Ron had in relation to preparation of fossils highlights the way that Ron used myFOSSIL: as an online repository for fossils as well as a way to share his experiences.

Lastly, Ron exemplified the PIT category of Public with a propensity to make paleontology person-centered (Stories) (n = 5). In these posts, Ron describes experiences he has had with volunteer work, collecting fossils, and buying and selling fossils at fossil shows. In one forum post, Ron talks about being tricked by someone selling fake fossils at a fossil show:

> “This is being sold as a ‘sand stromatolite’. It is in reality a concretion and not a stromatolite at all. I was duped when buying this myself and didn’t find out until later what it actually is. It is an interesting form but since stromatolites are becoming popular collector’s items, anything remotely resembling a real stromatolite that has any layered structure is being misrepresented in the market.” (Ron, Public, forum post ID # 4611)

Ron indicated that this experience was formative, as he used to have less understanding about fossils, especially ways of identifying fake fossils. He then described the fossil in detail and indicated that he wanted others to be more informed. Earlier on in this post, Ron had written that he wanted to help others identify fossils so they did not have same experiences he had. By sharing his personal experience, Ron had hoped to help others better understand and contribute to the paleontological community. In another post in a forum that centered on sharing paleontological field stories, Ron describes an experience he had in the field:

> Off hand I could only locate one photo of me in the field. It’s a great shot of me working with Professor Lindsay Shay. I’m removing about 25 mm of soft shale that was below a concentration of crinoids. The shale was wet screened later and yielded thousands of phosphatic microfossils. This is a [redacted] site. (Ron, Public, forum post ID # 3062)

This post is representative of Ron’s propensity for centering domain-specific knowledge, even within posts that are person-centered. Even when describing a past experience that was included a nice photograph of him the in the field, Ron maintained the sense that paleontology, enacted by people, was central, describing the formation, the type of fossils found there, and the fieldwork steps he enacted. In summary, Ron exemplified the PIT Category of Public when he posted data that included the practices of Problem Solving, Tips, Support, Documenting Practice, and Stories. These practices that Ron used made him seem like a member who was interested in problems related to the domain, who cared about creating a community, and who was helping to share information with others.

Education and Outreach

April Ludgate: As per the PIT, April was classified as an Individual at the Structural level, as Education and Outreach at the Category level, and as Museum Educator at the Type level. April was affiliated with a museum on a university campus. April was interested in integrating photogrammetry techniques and paleontological concepts in classrooms. April’s age range was between 35-44. She joined myFOSSIL as a beta tester. April contributed to all forms of data, including activity (n = 49), forums (n = 36) and messages (n = 2). She most often contributed posts about News and Information (n = 15) and Pointers to Resources (n = 12). She also sometimes made posts that employed the practices of Support (n = 5), Stories (n = 5), and Help Desk (n = 5). As an exemplar of the membership Category of Education and Outreach, April was interested in social- and research-specific dissemination of information, while seeking social- and research-specific support.

April mostly created activity posts or made forum posts regarding integrating of paleontology and education, regardless of grade level. Within these data, she created many News and Information posts (n = 15). These posts were stories about paleontology presented for a lay audience, dissemination of recent organization activity, or links to blogs. Through these posts, April indicated that she read many blogs about paleontology and graduate education. For example, April wrote, “Hi all, I thought you would like to read this regarding impact factor: (link)” (April, Education and Outreach, activity post ID # 51). She also disseminated information from projects that she worked with, such as distributing pictures, writing, “hello wonderful [redacted] group members. Here’s a picture of all of us ☺” (April, Education and Outreach, activity post ID # 17345). In another instance, April indicated the occurrence of events, and wanted to spread the word about them, writing, “Thanks @jessica.wicks. We will be piloting some photogrammetry in K-12 during 2016,17, and 18. We hope to increase student motivation and to collaborate with teachers on technology integration” (April, Education and Outreach, forum post ID # 2847). The focus of these posts was to disseminate activity from groups, meaning that April sought to spread the word about the group’s successes without providing context, information, or follow up concerning the work the group was doing. April’s inclusion of a large amount of News and Information posts was exemplary of the PIT Category of Education and Outreach. These members often sought to use myFOSSIL to connect to one another through the inclusion of domain-specific topics, although these posts were not always centered on scientific practice, instead, they featured the sharing of events that Education and Outreach members participated in.

Sometimes, Education and Outreach members shared Pointers to Resources; April was no different (n = 12). These posts centered on linking to research articles, PowerPoint presentations or other domain-related materials. Specifically, April often posted links that clarified or added to domain-related experiences she had. For example, she attended a webinar, then posted a link to it, writing,

> Hey guys, here's a recording of the NSF webinar Mark and I attended yesterday. It was more about the introduction of a journal that looks for papers bridging the gap between informal and formal STEM education. Perhaps this is a good venue for the paper about [redacted]. Here's the link to the recording: (link) (April, Education and Outreach, activity post ID # 13122)

With this activity post, April shared a resource that others could utilize, namely, a link to a webinar clarifying the scope of a new journal. In other instances, April was willing to provide resources to others that would be of interest to members who cared about paleontology education and outreach. For instance, April linked to a scientific journal article about mobile devices in the classroom, writing, "This study might be of interest to some of you. Instead of bringing people to the museum, it brings the museum to the classroom…" (April, Education and Outreach, activity post ID # 15493). April also provided links to resources for graduate students, writing, "hello grad students, take note of this webpage that compiles graduate-level statistics courses across the university (link)" (April, Education and Outreach, activity post ID # 14778).

On the forums, April often created posts that provided members information about photogrammetry. In a particularly compelling example, April linked to nine different resources that could be used by members interested in getting started with it classrooms or in informal science learning environments (April, Education and Outreach, forum post ID # 3669). April also provided direct links to resources, such as fossils, including a horse ankle bone, as seen in her forum post here: “see first attached image of a horse metatarsal” (April, Education and Outreach, forum post ID # 13265). The sharing of these resources relates to April’s member status of Education and Outreach: she sought to disseminate research-specific information to other members, perhaps at the expense of creating other forms of data.

April also created an equal number of posts that contained each of the following practices: Support, Help Desk, and Stories posts (n = 5 per practice). April’s posts that were Support-specific thanked others for contributing, such as a post in which she wrote “this is super exciting” in reference to the ability to add 3D fossils to myFOSSIL (April, Education and Outreach, forum post ID # 13454), or when she wrote “that’s awesome!” when learning about a new event (April, Education and Outreach, activity post ID # 8004). These posts showed an interest in acknowledging the contributions of other members, without adding to domain-specific content to the website.

The posts that were coded as Stories centered on April’s outreach efforts, such as creating guides for using photogrammetry in classrooms, for example: “Right now, I am producing 2 [guides] outreach in [redacted] and an art class in [redacted]” (April, Education and Outreach, forum post ID # 15605),“There is a high school in [redacted] who is raising funds …Once students become proficient in photogrammetry, they can potentially contribute to the national digitization effort…” (April, education and outreach, forum post ID # 1854).

Whether interested in raising funds for photogrammetry in classrooms or providing guides, April’s Stories always centered on the ways she was involved. Her involvement and advocacy for education extended to the practice of Help Desk when she inquired about domain-specific topics. Namely, April related back to teachers and classrooms, for example, “Hello, I am working on a series of mini screen capture video tutorials on how to use 3DF Zephyr. Anyone on this group currently using 3DF Zephyr?” (April, Education and Outreach, forum post ID # 11087). In another example of photogrammetry and the practice of help desk, April queried about adding to the website by integrating more photogrammetry-friendly options, such as larger file sizes and 3D rotation of fossils (April, Education and Outreach, forum post ID # 18928). These quotes demonstrate April’s propensity for relating her posts on myFOSSIL to her interest in the intersection between paleontology, teachers, and education.

Comparing Profiles in Practice

The ways that these exemplar members interacted with other members have similarities and differences that allow for understanding the forms of practice-development that existed on myFOSSIL. The members chosen for profiles in practice were exemplars for the ways in which their PIT Category contributed to myFOSSIL. For members that fit the PIT Category of Public, problem-solving and advising others as well as supplying a digital record of their real-world experiences in paleontology were key. Those members categorized as Scientist focused on social support and seeking to solve domain-specific problems, and those categorized as Education and Outreach were interested in disseminating social- and research-specific information as well as seeking social- and research-specific support.

Comparisons between the Exemplar Public and Scientist

In comparing the ways that Chris (the exemplar Scientist) and Ron (the exemplar Public) interacted on myFOSSIL, patterns emerge in which both are using the same practices, yet these members approach the practices in distinct ways. Chris, the

Scientist, valued contextualization, Ron, the Public, valued other peoples' definitions. Both Chris and Ron often sought to solve problems related to the domain of paleontology. They often traded forum posts rapidly, responding to one another and other members within a day or two. An example of this is a forum topic in which one member asked about the difference between molds, casts, and steinkerns, which are all different types of fossils. The member who created this post tagged both Chris and Ron, asking for their thoughts on the matter. Three Scientists responded with their interpretations of what molds, casts, and steinkerns were, as did Ron and Chris. A lengthy discussion about semantics followed, with Ron and the original poster rapidly replying to one another. Finally, Ron wrote that the member who created the post originally was "over complicating this" by attempting "to improve these definitions. The definitions of molds and casts were made very simply at the beginning of this thread and that's all you really need" (Ron, Public, forum post ID # 3745). Chris then indicated that the solution was to "decide from a contextual basis" (Chris, Scientist, forum post ID # 3694). Both of these responses were coded as Problem Solving, as members were communicating about solutions related to the domain. However, the approaches each member took differed. Ron's solution was to refer to information found earlier in the forum post thread; Chris' was to make inferences on a case-by-case basis. These were both ways to problem solve but seemed to emerge from different ways of viewing the world, which could have been tied to each member's PIT Category.

Another example of the differences that emerged between Chris and Ron's approaches to developing practice on myFOSSIL was that of Ron's proclivity for Documenting Practice. Whereas Ron often created posts that highlighted his real-world experiences with paleontology, Chris rarely did this. Ron sought to provide a clear record of his experiences with paleontology, his posts in which he explains how he prepared or polished fossils were examples of this. By comparison, Chris also sought to create digital artifacts, but these were expressed differently. Chris created multiple video tutorials about fossil photograph and preparation, but, because these were videos that were hosted on an external site (i.e. YouTube), they acted as Pointers to Resources. The difference between these two members' data that documented real-world practice were in the way they presented them. Chris presented video tutorials as a way to improve practice, writing responses like "you said you would like to improve your skills in photography-just check the video tutorial under resources here at myFOSSIL" (Chris, Scientist, forum post ID # 4793). Ron wrote long forum posts that described the ways he prepared and photographed fossils. These differences were likely related to their PIT Categories of Scientist and Public. As a Scientist, Chris provided insight into how scientists envisioned social paleontology, but these insights were rarely written out, instead they were linked from external sources. As a Public member, Ron explicated his experiences which indicated his practice-based expertise with social paleontology.

While some differences in approaches were seen, in many ways Chris and Ron developed their practices in similar manners. Both Ron and Chris provided other members with Tips, or advice or best practice information in a similar way, especially in terms of things they were interested in. Ron was especially interested in curating fossils whereas Chris was focused on photography.

Ron specifically asked for a forum to be created that centered on curating fossils, then wrote extensively about the ways that he curated his fossils. The Tips that he provided included phrases such as, “so, when thinking of your own curation system, consider what kind of disaster could make your system fail and your specimens become curiosities. Once you’ve done this you can modify your system to compensate” (Ron, Public, forum post ID # 11467). By comparison, Chris offered photography tips, “Would you like to get images with a camera?…the easiest way is to buy a regular camera tripod. You can get some…for around $10…[this] makes it much easier to get blur free images.” (Chris, Scientist, forum post ID # 2049). In both these forum posts, each member offered information to other members to ensure good experiences with social paleontology.

Comparisons between Exemplar Scientist, Public, and Education and Outreach Members

myFOSSIL offered members the ability to post to forums, on the activity feed, or within messages. Within these features, members expressed different practices and different interests emerged. For example, there were different topics within the forums, such as the topics of digitization, 3D printing, and specific fossils or localities (e.g. fossil horses). It can be assumed that people will participate in and contribute to forums that are within their areas of interest (Wenger et al., 2002). April created the majority of her forum posts within the forums that were centered on photogrammetry and paleontology education. Sometimes, April would give other members Tips about her interests. One example occurred when April described numerous reasons why a photogrammetry could go awry (April, Education and Outreach, forum post ID # 4295). April’s Tips about photogrammetry were similar to posts created by Ron and Chris in that the Tips were centered within the domain of social paleontology; however, April’s interests of photogrammetry and education were very different than Ron and Chris' interests of photography and curation.

Ron and Chris, the Public member and the Scientist, both used practices in a different way than April, the Education and Outreach member. April sought to use myFOSSIL to disseminate information; Ron and Chris utilized it to solve problems. April exhibited few similarities to Chris and Ron in her development of practices on myFOSSIL. April was explicitly focused on her own interests, teachers and paleontological education, which were not of similar interest to Ron and Chris.

Summarizing Quantitative and Qualitative Data

In summary, the purpose of this study was to explore the knowledge-generating capacity of myFOSSIL as a niche of a digital CoP through identifying which practices led to participation in and contribution to social paleontology. The three research questions were answered using explanatory sequential mixed methods in which quantitative data were collected and analyzed, then qualitative data was collected and analyzed based on the results from the quantitative phase.

The quantitative phase of this study revealed that the most prevalent practices on myFOSSIL were that of Support, Tips, Problem Solving, and Stories. These practices provided the CoP with social foundations as well as a place to discuss topics related to paleontology. In examining the discourse within the textual practices, it was found that the practices varied dependent on being posted in forums, the activity feed, or in messages. For forums, Support, Tips, and Stories were often seen; for activity, Support, Problem Solving, and Exploring Ideas were common; and for messages, Support, Tips, and Problem Solving were prevalent. During the quantitative research phase, social network analysis provided empirical evidence for reducing the seven conceptual categories as identified by Wenger et al. (2009) to three. The three categories highlight the ways that practices grouped together on myFOSSIL. Lastly, the quantitative analysis explicated the differences between PIT Categories on myFOSSIL. Namely, members within the Category Commercial were rare contributors; Education and Outreach members contributed in different ways than members categorized as Public and Scientist, however, the Public and Scientists did not significantly differ in their practices on myFOSSIL.

The quantitative findings informed the qualitative phase of the explanatory sequential mixed methods study as maximal variation sampling was used to choose exemplar members from three PIT Categories. These exemplar members were called profiles in practice, Ron was a Public member, Chris was a Scientist member, and April was an Education and Outreach member. Ron was a problem-solver and advisor whose focus was supplying a digital record of real-world experience. Chris was a social supporter who sought to solve domain-specific problems. April was interested in social- and research-specific dissemination of information who also sought social- and research-specific support. Profiles in practice allowed for rich, thick descriptions of the practices that were identified in the quantitative phase of the research. Conclusions about these data and how they relate to current literature on CoPs will be described next.

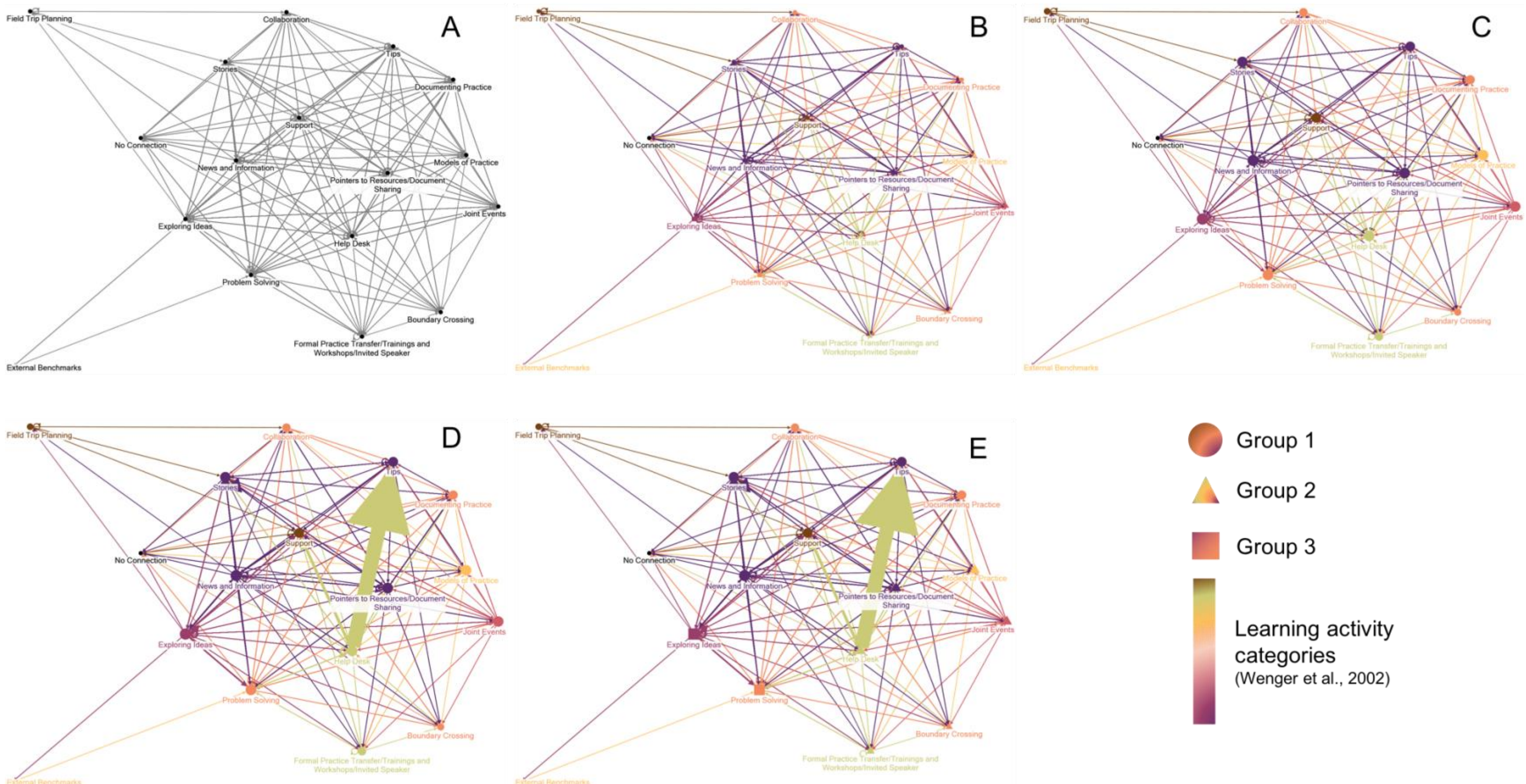

Figure 4-1. Social network analysis of myFOSSIL forums. A) Original social network graph of myFOSSIL forums. B) Colorized edges and vertices showed learning activity categories (Wenger et al., 2002). C) Increased vertex size highlighted increased out-degree of specific vertices. D) Edge weight depicted via increased edge thickness. E) Depiction of practice grouping on myFOSSIL: Group 1 (disk), Group 2 (solid triangle), or Group 3 (solid square)

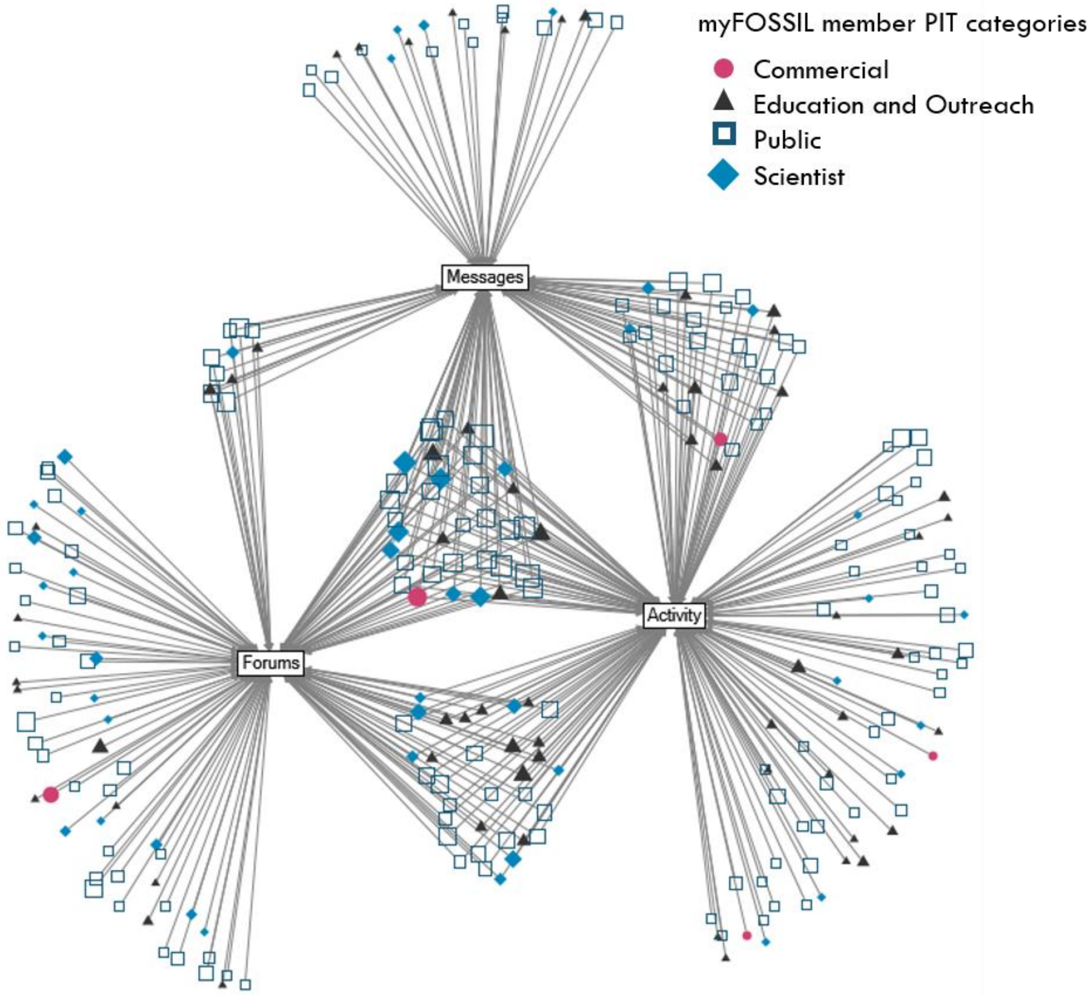

Figure 4-2. Digital trace data contributions and PIT categories. Size of the vertex indicated the number of pieces of data that each member contributed.

Table 4-1. Total Numbers and Percentages of Data

Code	Forums n	Forums %	Activity n	Activity %	Messages n	Messages %	Total n	Total %
Joint Events	72	3.8	47	3.6	15	2.2	134	3.5
External Benchmarks	4	0.2	0	0.0	0	0.0	4	0.1
Models of Practice	54	2.9	9	0.7	6	0.9	69	1.8
News + Info	82	4.4	62	4.8	7	1.0	151	3.9
Pointers to Resources	140	7.5	53	4.1	6	0.9	199	5.2
Stories	231	12.4	114	8.8	68	10.1	413	10.8
Tips	228	12.2	137	10.5	130	19.4	495	12.9
Formal Practice Transfer	33	1.7	12	0.9	2	0.3	47	1.2
Help Desk	189	10.2	69	5.3	80	11.9	338	8.8
Boundary Crossing	36	1.9	10	0.8	1	0.1	47	1.2
Collaborations	53	2.9	44	3.4	63	9.4	160	4.2
Documenting Practice	99	5.3	70	5.4	18	2.7	187	4.9
Problem Solving	201	10.8	169	13.0	82	12.3	452	11.8
Exploring Ideas	161	8.6	145	11.1	37	5.5	343	8.9
Field Trip Planning	10	0.5	74	5.7	9	1.3	93	2.4
Support	265	14.3	285	21.9	143	21.4	693	18.1
Total	1858	100.0	1300	100.0	667	100.0	3827	100.0

Table 4-2. Revised learning activities framework

	Specific learning activity (Practice)	Operational definition within myFOSSIL
Group 1	Tips	Members providing advice or best practice information to other member/s concerning social paleontology
	Documenting Practice	Creation of digital artifacts that highlight real world experiences or ways to participate in and contribute to social paleontology
	Collaboration	Swapping of resources or information to create domain-specific partnerships
	News & Information	Story about paleontology presented for a lay audience or a general resource for paleontology, such as a geologic map or dissemination of recent organization activity, links to blogs
	Support	Members thanking others for contributing, acknowledging a contribution or being otherwise social without adding to knowledge per se
	Stories	Person-centered account of social paleontological practice
	Field Trip Planning	Discussion of events that relate to domain-specific outings
	No Connection	Social network analysis group that emerged from practices that had no responses within myFOSSIL forums
Group 2	Formal Practice Transfer; Trainings; Workshops and Invited Speakers	Presentations, conference papers, or webinars that provide access to some aspect of the practice that were created by the member of the CoP who is sharing them
	Joint Events	Creation of meetups, conferences, or other such events that support all member classifications
	Help Desk	Inquiring about domain-related topics—most often, the identification of specimens
	Models of Practice	Members taking an authoritative stance when describing the practices within social paleontology
	Pointers to Resources Document Sharing	Distribution of PDFs, PowerPoint presentations, journal articles or other domain-related materials to the CoP; reposting or shifting location of posts on the website
	Boundary Crossing	Individuals demonstrating activities that are not consistent with their PIT categorization
Group 3	Exploring Ideas	Brainstorming about the domain, not necessarily seeking answers
	Problem Solving	Communication concerning solutions related to the domain
	External Benchmarks	Information concerning best practices of digitization of specimens

Table 4-3. Time-based practice development on myFOSSIL

	PIT Types			
	Public	Scientist	Education & Outreach	Commercial
	October 1, 2015 – October 1, 2016			
Joint Events	43	22	6	0
External Benchmarks	0	0	0	0
Models of Practice	10	13	1	0
News + Info	13	25	10	1
Pointers to Resources	34	49	26	3
Stories	108	51	17	5
Tips	67	80	8	2
Formal Practice Transfer	3	15	3	1
Help Desk	51	51	15	0
Boundary Crossing	18	9	2	0
Collaborations	33	48	6	1
Documenting Practice	50	38	13	3
Problem Solving	88	94	6	6
Exploring Ideas	66	74	11	3
Field Trip Planning	0	9	1	0
Support	133	123	24	9
Total	717	701	149	34
	October 2, 2016 – October 31, 2017			
Joint Events	15	28	18	3
External Benchmarks	1	3	0	1
Models of Practice	24	18	2	1
News + Info	22	31	48	1
Pointers to Resources	42	56	35	5
Stories	124	54	42	12
Tips	139	177	16	5
Formal Practice Transfer	10	11	4	1
Help Desk	116	65	40	0
Boundary Crossing	14	3	1	0
Collaborations	24	32	13	1
Documenting Practice	37	37	8	1
Problem Solving	135	91	29	3
Exploring Ideas	66	97	24	2
Field Trip Planning	7	35	41	0
Support	190	142	61	8
Total	966	880	382	44

Table 4-4. Contributions by PIT category and type

PIT Category	PIT Type	N	% of total contributors
Public	Amateur	138	52.5
	Interested Party	11	4.2
	Paleoartist	1	0.4
Education and Outreach	K12 Teacher	49	18.6
	Museum	8	3.0
	University-College	5	1.9
	Journalist-Communicator	2	0.8
	Educational Project-Website	1	0.4
	Lecturer	0	0
Scientist	Paleontology	41	15.6
	Geology	0	0
	Biology	0	0
	Other STEM	1	0.4
	Archaeology	0	0
Commercial	Service	3	1.1
	Experience	2	0.8

Table 4-5. Demographics of myFOSSIL members chosen as profiles in practice for the qualitative phase of explanatory sequential mixed methods research

Pseudonym	Age range	Education Level	Number of data contributed	PIT Category	PIT Type
Chris Traeger	35-44	Doctoral Degree	187	Scientist	Paleontology
Ron Swanson	65+	Master's Degree	186	Public	Amateur Paleontologist
April Ludgate	35-44	Completed some graduate school	87	Education & Outreach	Museum Educator

CHAPTER 5
DISCUSSION

Overview

CoPs have been touted as being both an easily-employable strategy for building relationships between people (Wenger et al., 2009) as well as being a well-defined and sound theory for understanding social learning processes (Wenger, 2000). Despite these proclamations, there is limited evidence to support these claims especially when online, scientific CoPs are examined. This explanatory sequential mixed methods study of an online, scientific CoP aimed to explore the knowledge-creating capacity of myFOSSIL, a niche of a digital CoP, through identifying which practices led to participation in and contribution to social paleontology.

To frame this inquiry, data were collected and analyzed to answer three research questions:

1. What forms of social paleontological practice exist within myFOSSIL?
2. For textual practices, what types of knowledge-creating discourse exist?
3. What forms of practice-development occur within myFOSSIL and how are they related to the attributes of community members?

The research questions were explored first quantitatively, with content analysis of data collected from forums, messages, and the activity feed of the website, as well as with social network analysis, followed by qualitative analysis of cases. Qualitative data were examined using a multiple case study analysis in which cases were chosen using maximal variation sampling (Merriam, 2009). After choosing the cases and describing them with vignettes and examples of each case’s usage of practices on myFOSSIL, the data were examined holistically as profiles in practice.

In this section, I revisit topics that framed the study, namely the ways that paleontological practices have been defined in the real world and the need for defining practices as enacted by people. I also describe how the findings relate to existing research on CoPs. I illustrate the relationship between the seven design principles for CoPs and the empirical evidence that emerged for these design principles on myFOSSIL. Furthermore, I will describe how this work shifts the focus of CoP-centered research to the development of practice, which allows researchers to examine for whom and under what conditions CoPs meet success.

Synthesizing Findings with Previous Literature

Identifying Forms of Social Paleontological Practice

In paleontology, scientific work has been centered around the practices of collection, identification, preparation, and curation of fossils (Crippen et al., 2016). While each of these is integral to paleontology as it is experienced in the real world, with the shifting emphasis to digital initiatives, the ways in which *people* are integrated with these practices and their contributions to paleontological knowledge generation has been missing. The results from this study explicate the integration of real world knowledge generation in paleontology with the development of people's practices within an online environment. If paleontological knowledge generation in the real world has been centered on the practices of collection, identification, preparation, and curation of fossils, myFOSSIL provides an indication of the paleontological knowledge generation that was developed, shared, and maintained within an online environment. Implications can be identified by examining previous research that discussed what *practice* entailed within a CoP. Such previous literature includes studies on CoPs on social media (Liberatore, Bowkett, MacLeod, Spurr, & Longnecker, 2018) as well as CoPs that are business-centric and virtual in nature (Pan et al., 2015). In these studies, practice has been defined in terms of knowledge exchange (Pan et al., 2015) or in terms of social media interactions (Liberatore et al., 2018) with CoP members writing, discussing, and commenting to one another. While these high-level depictions of practice are useful, they fall short as they do not classify nor clarify the specific ways in which CoP members contribute. With this study of the myFOSSIL CoP, these shortcomings were addressed, as the content that people posted (i.e. recording that a post contained the practice of support) as well as where they posted it (i.e. in forums, the activity feed, or messages) were collected and analyzed. The first research question indicated that the most common practices that existed on myFOSSIL were Support, Tips, Problem Solving, and Stories, meaning that members were most often interested in encouraging or acknowledging one another's contributions, providing advice to one another, communicating about domain-specific solutions, and describing paleontology in a person-centered capacity. Analyzing the ways in which people contributed through analyzing the specific content helped to provide a fuller understanding of practice within a CoP. This kind of information was necessary, as the content within posts, not simply understanding that posts were made can help researchers determine how a CoP functioned.

In previous studies on CoPs, researchers have addressed how CoPs provide their members with social structure and support (e.g. Bondy et al., 2017; Nistor et al., 2015). On myFOSSIL, I found that two of the four most common practices were socially-motivated as opposed to domain-motivated. For example, when members enacted the practice of Support, they created content in which members acknowledged one another's contributions. Members enacted Support to foster interactions, providing one another with "mutual respect and trust" (Wenger et al., 2002, p. 28). Extensive research into online communities has found that social interactions, including posting questions "to instigate personal conversations that extend well beyond factual information exchange…[increases] people's willingness to contribute" (Harper, Moy, & Konstan, 2009; Kraut, Resnick, & Kiesler, 2012). Trust, idea sharing, and belonging have been found to be integral to the development and sustainability of a CoP (Wenger et al., 2002). In this way, the practice of Support was important to the myFOSSIL digital CoP. The other socially-motivated practice was that of Stories. Stories can be thought of as socially-motivated, as they were person-centered accounts of paleontological practice, such as a member recounting a recent fossil collecting trip they took. This practice, like Support, promoted the sharing of similar ideas, yet brought "individual perspectives" which created "a social learning system that [went] beyond the sum of its parts" (Wenger et al., 2002, p. 28). This was seen in the social network analysis of forums in the recursive nature of Stories leading to more Stories: members were interested in hearing about each other's Stories and in sharing their own. In sum, the socially-motivated practices of Support and Stories allowed members to coalesce in a more fluid manner.

Other practices, namely Tips and Problem Solving, were firmly rooted in the domain of social paleontology and these practices established solutions to domain-specific problems. In previous work on CoPs, domain-specific practices were established through conducting interviews and distributing surveys (Carsten Conner, Perin, & Pettit, 2018; Forbes & Skamp, 2013, 2014, 2016). These methods were useful for studying face-to-face CoPs, *ex post facto* techniques such as interviews and surveys allow for data capture that is challenging in real time: conversations are easy to miss and recording conversations can change the nature of them (Lave & Wenger, 1991). With digital data, members' practices were more readily traced. As such, these data established an understanding of "the existing body of knowledge and the latest advances in the field" of paleontology (Wenger et al., 2002, p. 38). Members communicated about paleontological topics including the proper method for curating fossils, best fieldwork practices, and identification of unknown specimens. Furthermore, specific practices such as Pointers to Resources/Document Sharing progressed domain-specific knowledge, allowing for both the tacit and the explicit knowledge of social paleontology to come to the forefront of discussion. The practice Pointers to Resources/Document Sharing often ported real-world experiences, including fossil preparation techniques or collections curation, into the digital one. Members indicated the sources, or bodies of knowledge, that they knew of, creating digital records of these in-the-world experiences. In creating messages that used the practices of Tips or Problem Solving, members were enacting domain-specific practice. This study was one of the first of its kind to firmly establish the social and domain-specific practices that were enacted by community members in a digital, scientific CoP.

Identifying Knowledge-Creating Discourse

The results from the second research question indicated the knowledge-creating discourse that existed on myFOSSIL, specifically, that the different features encouraged different practices. Furthermore, when chains of practices were examined on the forums, there were relationships between particular practices, such as Help Desk and Tips, but weaker relationships between others. These findings tie to literature on the nature of affordances (Gibson, 1977; Kaptelinin, 2013; Norman, 2013) as well as to one of the seven design principles for CoPs derived by Wenger et al. (2009): *developing public and private community spaces*.

Affordances are possibilities for interaction that are provided to people by the environment (Gibson, 1977). Norman (2013) expanded on the theory defined by Gibson, indicating that affordances can be perceived, especially in human-computer interaction and design. Martinez and Peters Burton (2011) have hypothesized regarding the affordances of the cyberinfrastructure (i.e. the informational network with connects to data sensors and tools to permit data analysis), noting that there could be six cognitive affordances, two of which, *distributed expert networks* and *forums for public discourse,* apply to this study. With the affordance of distributed expert networks, Martinez and Peters Burton indicate “information networks thereby support social networks that share common intellectual goals, which is apparent when examining the websites of any of the cyberinfrastructure groups because of the organization of information” (Martinez & Peters Burton, 2011, p. 21). This affordance relates to the finding that within myFOSSIL, different PIT Categories contributed different practices, but all these practices were aligned with the domain of social paleontology. On myFOSSIL, different PIT Categories often contributed different practices, yet, these practices were still related to the CoP holistically. Whether providing social support, as was done by many Public members, or answering inquiries regarding identification of fossil specimens, as was common for Scientists, the domain- and community-specific emphases of the CoP were apparent. Martinez and Peters Burton (2011) indicate that the cognitive affordance of forums for public discourse was hypothesized to allow for the illumination of “the iterative nature of the scientific enterprise through social discourse” (p. 23). Within the myFOSSIL forums, the discourse between members demonstrated the nature of scientific enterprise, however, it was limited. This is especially apparent when examining the most common practice: Help Desk-Tips. There was little iterative discourse that occurred in this practice, rather, one member indicated that they had a question, another member responded with the answer. Creating an environment that moves beyond this dichotomous discourse to reach Martinez and Peters Burton’s (2011) cognitive affordance of forums for public discourse would be a fruitful future research endeavor.

The discourse on myFOSSIL was often focused on community-based ideas; it is worthwhile to note the ways in which the features of the website brought forth differential practices. Each feature on myFOSSIL could be said to have unique affordances. Forums, for example, afforded threaded conversations between multiple members, regardless of PIT Category. Messages afforded privacy, and allowed members to enact practice or show vulnerability (i.e. members could create collaborative agreements or ask simple questions). The activity feed afforded possibilities for interaction that were familiar to members who had experience with other social media sites, such as Facebook, since the activity feed was designed to allow members to create updates that other members could respond to in some way. When members interacted with these different features of myFOSSIL, they enacted different practices. Forum posts were used to provide Support, tell Stories and Problem Solve. When members interacted on messages, they most often used the practices of Support and Tips, and on the activity feed, members most often Explored Ideas, Solved

Problems, and Supported one another. Significant differences were found in the practices that were enacted on each, which indicates that each feature afforded members a different interaction experience. This is important to note as this research can provide evidence for continuing to meld work on interaction design with the development of CoPs. Indeed, one of the seven design principles of CoPs is “to develop both private and public community spaces” (Wenger et al., 2002, p. 59). On myFOSSIL, there were established areas for public interaction (i.e. forums and activity) as well as for private interaction (i.e. messages). These varied spaces afforded different types of interactions to occur, which is key to developing and maintaining a strong CoP.

Discourse was more fully explored on the myFOSSIL forums using social network analysis. Social network analysis has been used in regards to CoPs, most often in knowledge management research, where such analysis allowed “executives to visualize the myriad relationships either facilitating or impeding community effectiveness” (Cross, Laseter, Parker, & Velasquez, 2006, p. 32). Whereas this utilization is important, as it bridged a gap between the knowledge management and community-building components of CoP research, social network analysis regarding the content of digital, scientific CoP had not yet been undertaken. Establishing what practices looked like with such a CoP is an important direction for CoP research, as it moves beyond community-building, and brings research from knowledge management into a scientific context.

On myFOSSIL, social network analysis revealed that there were centralized, key relationships between certain practices, including between Help Desk and Tips. What this entailed was members posting questions they had, most often about identification of fossils, then other members responding with exactly what the specimen was. In this way, the Help Desk-Tips discourse centralized distribution of knowledge from more knowledgeable others to those with less knowledge. While this is not inherently problematic, within certain contexts it can become an issue. In the fields of science communication and citizen science, this form of providing scientific knowledge is labeled the deficit model in which scientists bring knowledge to a passive public "whose default ignorance and hostility to science can be counteracted by appropriate injection of science communication" (Bucchi, 2014, p. 58). I argue that supplying members with information regarding specimens without contextualizing this information or describing the method by which identification was made is akin to establishing a form of the deficit model of science communication within the domain of social paleontology. Providing correct knowledge in the form of identifying a specimen for a member only served to provide information to that person, it did not allow for an understanding as to why their specimen was identified the way it was—what characteristics led to the identification? The ways in which knowledge-creating discourse was occurring on myFOSSIL, therefore, were somewhat shallow in regards to Help Desk-Tips. This discourse allowed for answers to be given, however, there was no way for the member who created the Help Desk request to understand *why* they were given the answer they were, merely that they *were* given the *correct* answer.

Identifying prevalent discourse such as Help Desk-Tips on myFOSSIL can help researchers identity the strengths and weaknesses of digital, scientific CoPs so that they can develop, implement, and test CoPs within other domains. On the forums, the discourse that occurred was highly centralized on the relationship between Help Desk and Tips. Research into online communities reveals that the question asking-answering dynamic is powerful in that both informational questions and conversational questions get answered, but only informational answers have high value to others (Harper et al., 2009). CoPs need both types of questions to thrive, as community-building is essential to a *community* of practice, but without domain-specific knowledge, the CoP is merely a group of friends (Wenger et al., 2002, 2009).

Creating a higher-level, useful question asking-answering relationship can be tied back to research on traditional science education, in particular work on Science Talk Moves (Michaels & O'Connor, 2012). Michaels and O'Connor's research developed Science Talk Moves in order "to facilitate discussions that support reasoning and deepen student understanding of complex material" (2012, p. 1). This goal, while tied to classrooms and formalized education, can be discussed in terms of myFOSSIL and the discourse that occurred within. Whereas on myFOSSIL the most common relationship was that of the Help Desk-Tips, implementing strategies like those identified within the Science Talk Moves framework could help to expand the types of discourse that exist within digital, scientific CoPs. The most prevalent form of discourse was that of help-seeking and help-giving practice—a narrow form of communication. Implementing strategies that encourage the development of scientific reasoning could widen the discourse. Indeed, Michaels and O'Connor (2012) established goals for students to develop scientific discourse including deepening reasoning through "asking for evidence" as well as asking for expansion or clarification (p. 11). Implementing these Talk Moves would require buy-in from CoP members who regularly respond to others' queries. Encouraging member buy-in is a strategy that has been encouraged by CoP practitioners as well as designers of other online communities (Kraut et al., 2012; Wenger & Synder, 2000; Wenger et al., 2009). Studying the development and delivery of these Talk Moves within another digital, scientific CoP could be the focus of future research.

Each feature of myFOSSIL afforded the development of different practices. Specifically, on the forums, it was found that the most common practices that connected to one another were Help Desk-Tips. Furthermore, analysis of the forum posts showed that the seven conceptual categories identified by Wenger et al. (2009) were reduced to three empirically-deduced categories. These three categories highlight the relationships that existed between the various practices on myFOSSIL. Acknowledging the developing of these different practices is novel—in the exhaustive literature search that was associated with this study, there were no references to differences in practice-development based on website features. Awareness of the affordances and barriers within myFOSSIL can enable the development of sustainable digital, scientific CoPs. This study has given understanding to the practices that members enact within a digital, scientific CoP, an insight that has previously been unidentified. Understanding these differences allows researchers to develop strategies for further advancing such practice-development in online, scientific CoPs through implementing strategies identified found in formal science classrooms.

Practice-Development and Community Member Attributes

The results of the third research question indicated that there were relationships between the attributes of community members and practice-development. In the quantitative analysis phase, a Chi-Square test of Independence followed by pairwise comparisons showed differences, as well as similarities between three PIT Categories.

For the Categories of Public and Scientist, they implemented practices on myFOSSIL in similar ways, but those members categorized as Education and Outreach enacted practices differently. Then, members from three of the four PIT Categories were chosen for case study analysis: Chris Traeger, a Scientist, Ron Swanson, from the Category of Public, and April Ludgate, from the Category of Education and Outreach. Chris Traeger was a social supporter who sought to solve domain-specific problems, while Ron Swanson was a problem-solver and advisor whose focus was on supplying a digital record of real-world expertise, and April Ludgate was interested in social- and research-specific dissemination of information while seeking social- and research-specific support. I attempted to describe each case in a robust and meaningful way to provide a full picture as to what contribution to myFOSSIL entailed for members within each PIT Category. I found that, in alignment with the quantitative analysis, there were similarities in the ways that Ron and Chris contributed to the website, whereas April seemed to have a slightly different focus in her use.

There are implications for the fields of science communication based on the findings from this study, specifically, in the finding that there were no significant differences in the ways that Scientists and Public members contributed to myFOSSIL. The aforementioned deficit model of science communication (Bucchi, 2014) emphasizes the gulf between scientists and an ignorant public. In the case of some myFOSSIL members, there was no gulf. Members of the PIT Categories and Public and Scientist contributed to myFOSSIL in equally meaningful ways. This implies that for the field of paleontology, the emphasis of science communication should not be on how little members of the public know, but rather, on how much they can add to paleontology as they have previous knowledge, experience, and expertise that can add to scientific understanding. The findings of this study add evidence that the deficit model of science communication is ineffective.

Interestingly, there were differences in the ways that Public and Scientist members and Education and Outreach members contributed to myFOSSIL. Forbes and Skamp (2016, 2014, 2013) provide insight into why these differences exist. Their initiative, called MyScience, entailed the collaboration between scientists and teachers in a CoP to develop science teaching in schools. Their initiative, which took place in Australia, crossed grade bands, including primary and secondary school. Forbes and Skamp (2014) indicate that the teachers involved in MyScience "viewed their role as providing support to students" as well as "fostering students' interest and enthusiasm in science" (p. 22), which is similar to the ways that April Ludgate, the Education and Outreach member on myFOSSIL, chose to contribute. By asking for social- and research-support, she was filling the same role that the teachers were in the study by Forbes and Skamp (2014). Indeed, Forbes and Skamp (2016) indicated that partnership was fruitful because of the various viewpoints that emerged when scientists and teachers came together in a CoP. These partnerships stimulated a sense of belonging as evidenced by the participants' perceptions of science learning, teaching, and interactions. Within myFOSSIL, there were differences in contributions by Education and Outreach members and others, however, these differences could have engendered collaboration. Further investigation into the notion that educators might seek out or contribute to CoPs in a manner that is distinctive or separate from members who are not educators is needed.

Implications of the Research in Total

Holistically, the research questions that were examined in this study have implications for the design, development, and study of digital, informal learning environments. Whereas each of the research questions individually have had implications for the design and development of CoPs, I widen my lens to examine the ways in which the findings can relate to the field writ large. Therefore, I turn to the field of informal learning, in particular informal learning as theorized by Marsick and Watkins (Marsick & Watkins, 1990, 2001; Marsick, Watkins, Callahan, & Volpe, 2009; Watkins, Marsick, Wofford, & Ellinger, 2018). While the majority of this body of literature is focused on informal or incidental learning as it occurs within workplace environments, the definitions that the authors provide for informal learning are well-defined and well-understood. Indeed, Marsick and Watkins (1990) define informal learning as that which occurs “outside formally structured, institutionally sponsored, classroom-based activities (pp.6-7), and incidental learning is informal learning, with the addendum that it is “a byproduct of some other activity, such as task accomplishment, interpersonal interactions, sensing the organizational culture, or trial-and-error experimentation” (pp. 6-7). These definitions of informal and incidental learning are echoed by the National Research Council Report (Bell et al., 2009) in which informal learning was broadly categorized, then divided into strands of learning that could be assessed. The relationship between Marsick and Watkins’ theoretical notions of informal learning and the development of assessment strategies for informal science learning can relate back to the ways in which practices were explored on myFOSSIL. Indeed, Marsick and Watkins (2001) indicate that lack of “external facilitation or structure” can weaken informal learning as it occurs, which makes “it imperative that we teach strategies to adult learners to make this kind of learning both more visible and more rigorous" (pp. 30-31). Implications from this statement related to this study emerge: namely, that external facilitation and structure could be facilitated through the CoP framework used in conjunction with Science Talk Moves (Michaels & O'Connor, 2012), and, that informal learning can be made more visible via the design and development of online, digital CoPs in which members are able to engage in social- and domain-specific discourse.

The implications for informal, digital science learning seem to be that members of a scientific, digital CoP are willing to both provide both social and scientific support to other members and that websites such as myFOSSIL provide a structure that seeds the development of a CoP. myFOSSIL provided affordances as well as barriers to the development of a CoP. Affordances included the design of the website itself, which provided distinct spaces for public and private conversations, while barriers were comprised of an online-only environment that did not necessarily allow for the development of face-to-face connections.

Furthermore, the PIT and learning activities analytical frameworks that were created for this study can be applied to other domains. Specifically, the PIT, while created to classify community members within the domain of paleontology, could be modified for usage in other scientific domains. Scientists have been previously been classified on Twitter (Collins, Shiffman, & Rock, 2016; Ke, Ahn, & Sugimoto, 2017), however, Twitter is populated by more than scientists (Lundgren et al., 2018a). The ability to nimbly classify the diverse members of online, scientific social networks can heighten the interactions that occur amongst these members as identifying people with their varied interests can widen discourse. Heightening these interactions relates to the

National Science Foundation's initiative regarding Broader Impacts. The explicit purpose of Broader Impacts initiatives is "communicating with the public rather than at the public on scientific research" (National Science Foundation, 2015, p. 4). Therefore, identifying and classifying the people who contribute to and participate in scientific discussions within online social niches is important: understanding the people and their interests can lead to more fruitful discussions (Azevedo, 2017). Engaging wider audiences in the process of scientific research also increases scientific literacy, as evidenced by Falk and colleagues (2016), who found that there was a significant correlation between science center visitation and scientific literacy. This correlation may also hold with those who interact on online, scientific, social spaces; this study is a step in that direction.

Findings and CoP Design Principles

The myFOSSIL CoP was able to provide empirical evidence for the seven design principles theorized by Wenger et al. (2002), an important development as the majority of literature concerning CoPs mentions design principles as components of the building process, however, they are not revisited (e.g. Baker & Beames, 2016; Boud & Middleton, 2003). The myFOSSIL CoP provided evidence that within a scientific CoP, these design principles were evident (Table 5-1). I will revisit the seven design principles and indicate how findings from myFOSSIL strengthen them.

The first design principle was to *design for evolution*, which entailed the concept that CoPs have the capacity to change over time. Wenger et al. (2002) indicated that CoPs experience five stages of development: potential, coalescing, stewardship, and transformation. This study was time-bound by a two-year period within which timeframe the community had time to progress through the stages (Wenger et al., 2002). Based on the results of this study, the myFOSSIL CoP was within stage 2 (coalescing). This is evidenced by the establishment of practices including *Joint Events* (n = 134) and *Field Trip Planning* (n = 93*)*, which, when combined consisted approximately six percent of all website practices. The usage of these practices by members indicated that "community building has begun" which allowed "members to build relationships, trust, and awareness" (Wenger et al., 2002, p. 82). When the time period was subdivided, and practices were examined before October 2, 2016 and thereafter, the number of practices was found to be disbursed throughout members. It was also found that the practice of Help Desk increased, which relates to the stage of coalescing, as during this stage members "develop the habit of consulting each other for help. As they do this, they typically deepen their relationships and discover not only their common needs, but also their collective ways of thinking, approaching a problem, and developing a solution" Wenger et al., 2002, p. 84). The results from myFOSSIL therefore indicate that during the time period, the community was well-within the coalescing stage as identified by Wenger et al. (2002).

Within other studies concerning the development of CoPs (e.g. Gongla & Rizzuto, 2001), stages of community development were identified and studied via participant observation, activity measures, and structured interviews. In some ways, these stages were similar to those identified by Wenger et al. (2002), Gongla and Rizzuto note that in their model "a community can mature and dissolve at any one of the stages beyond the initial formation level," (2001, p. 846), which Wenger et al. (2002) also note, indicating, "some communities go through one stage rapidly; others spend much time in the same stage…some do not make it all the way through" (p. 70). Gongla and Rizzuto's (2001) stages included *potential, building, engaged, active,* and *adaptive.* Within the potential stage, connection was key, in that individuals with a common interest (i.e. a domain-specific interest) needed to coalesce. Within the building stage, a core group creates "a structure and processes for how the community will operate, and how members will work together over time" (Gongla & Rizzuto, 2001, p. 847). In the face-to-face CoPs that Gongla and Rizzuto (2001) studied, stages were not bound to an evolutionary perspective as in Wenger et al. (2002), but rather moved between stages, or plateau at one stage. Indeed, within myFOSSIL there was evidence for the stages identified by Gongla & Rizzuto (2001), as community members who participated consisted of a core group. During the time period of the study, the website had 841 consented participants, yet only 263 of them contributed any form of data. Therefore, the core group on myFOSSIL consisted of these 263 members who created forum posts, activity posts, and messages. CoPs do not need for all members to be active participants, indeed, that is the reason for legitimate peripheral participation, which is defined as occurring at any time or place, entailing the strengthening of a member's involvement in the community via taking part in CoP activity (Lave & Wenger, 1991). However, creating structures could entice or encourage differential participation by members who are peripheral. Such structures need to revolve around building trust and creating a community, which myFOSSIL was capable of developing, as evidenced by the high number of Support posts.

The second design principle, *open a dialogue between internal and external perspectives*, was seen on myFOSSIL when examining the practices enacted by members of different PIT categories. I found that Education and Outreach members contributed differently than Public or Scientist members; their practices were more focused on disseminating information in lieu of discourse. The differential contributions of members from different PIT Categories has implications for this design principle, as do the similarities in usage. The differential contributions by Education and Outreach members supports the second design principle, as “good community design brings information from outside the community into the dialogue about what the community could achieve” (Wenger et al., 2002, p. 54). With Education and Outreach members bringing in information and disseminating it, they acted as harbingers of information, which could have strengthened the community. This study also showed that members within the PIT Categories of Scientist and Public were similar in their myFOSSIL contributions. For these members, there are wider implications. These implications have to do specifically with the idea of science communication. Within science communication, there is the concept of the deficit model, in which experts deliver content to novices who do not understand a topic (Bucchi, 2014). Furthermore, the deficit model highlights the belief that knowledge exists in those with credentials—that knowledge must be passed to those without. For paleontologists in this study, traditional novices (i.e. Public members or amateur paleontologists) and traditional experts (i.e. Scientists) did not display differences in their use of the website. This shows that these groups can be equally competent at delivering and receiving scientific content. In relation to design principles, this meant that designing for members from different backgrounds was important, but practitioners and researchers should recognize that in many cases, members who can be subdivided into different categories on the outset may be able to contribute to the CoP in nearly the same manner from one another.

The third design principle was *invite different levels of participation*. Different levels of participation can be envisioned as both legitimate peripheral participation as well as levels of participation. Although legitimate peripheral participation was not studied in-depth in this study, some commentary on it is worth noting, especially as during the time period studied, only 263 of 841 registered, consented website members were active contributors to the forums, activity feed, and messages. This indicates that myFOSSIL had differential levels of participation, as members who did not contribute could have been legitimate peripheral participants. In order to study this more in-depth, peripheral participants would need to be queried regarding their experiences with myFOSSIL. As for the active members, members from different PIT Categories seemed to leave differential amounts of digital trace data. Indeed, Commercial members created less than one percent of all data and Education and Outreach members created only 12.72 percent, whereas Scientists 41 percent and Public contributed 44 percent. With this in mind, it could be said that the member Categories of Education and Outreach and Commercial were more prone to be peripheral participants who were in the interstices between their Categorical life and their position as CoP members. In this manner this could afford or prevent “articulation and interchange among communities of practice” (Lave & Wenger, 1991, p. 36), in that Commercial and Education and Outreach members might be attempting to bridge the gap between their external lives and their lives as CoP members. In order to make this gap more manageable, supports for these members could help. The legitimate peripheral participation that was enacted by certain member Categories on myFOSSIL suggested “growing involvement” within the CoP (Lave & Wenger, 1991, p. 37).

Indeed, legitimate peripheral participation in the form of lurking is still a form of being a member of a CoP (Nonnecke, Andrews, & Preece, 2006; Yeow, Johnson, & Faraj, 2006). Lurking is defined as reading content, or looking at websites without contributing in a traceable manner (Nonnecke & Preece, 2000) Lurkers read, however, because they did not add to digital trace data, their practices were less easily seen. Wenger et al. (2002) identified three different levels of participation and contribution within CoPs: peripheral groups, active groups, and core groups. The ways in which myFOSSIL members moved from, or if they moved across these levels of participation was not tracked for this study, which could be a path for further research. This is something that could be tracked in future studies with the breakdown of website data, although challenges could arise in determining which members were lurkers and which were merely inactive. For this study, I determined that some PIT Categories were more active that others, namely, that Public members and Scientist members contributed more data than others. This is aligned with other research into scientific CoPs (Lundgren et al., 2018a; Lundgren et al., 2018b). Indeed, in this research, it was found that Public and Scientists also were more frequent contributors than Education and Outreach members. This shows that within the digital habitat of social paleontology, there is a trend towards differential levels of participation, which leads into the development of a new design principle that is tied to design principle three.

This suggested addition of a sub-design principle that was attached to design principle three, which I call design principle 3-a: Invite and *design for* different levels of participation, particularly for education-based members. Education and Outreach members contributed to myFOSSIL less than Public or Scientist members, lurking and ingesting content. This ingestion was then perhaps used in unique ways outside of the digital CoP (Forbes & Skamp, 2014). In order to encourage education-based members to move from their peripheral locations within the CoP, the CoP needs to be designed to meet their needs. For the digital, scientific CoP of myFOSSIL, this could entail developing Category-specific elements that would encourage fuller participation by education-based members, such as social- and research-specific dissemination of information.

Information dissemination regardless of PIT Category occurred on all features of the website, both public and private. These private and public places were developed and can account for design principle four: *develop both public and private community spaces*. On myFOSSIL, the ways in which members contributed to the website features varied. Forums, activity posts, and messages were all significantly different from each other. For the scientific, knowledge-building community of myFOSSIL, the public spaces (forums, activity posts) featured more Support and Stories, whereas the private space (messages) featured more Tips and Problem Solving. These findings support the fourth design principle in that the variety of community spaces encouraged the orchestration of activities "in both public and private spaces [to strengthen] individual relationships" (Wenger et al., 2002, p. 59) This means that the practices enacted within myFOSSIL positively affected the community.

Design principle five was *focus on value.* Within the myFOSSIL CoP, members from different PIT Categories displayed that they had somewhat different values, which Wenger et al. (2002) defined as different bodies of knowledge they wanted to be easily accessible. With the practices that they enacted on the website, summaries of each PIT

Category’s values were extrapolated. Members of the public valued solving problems and advising others, supplying digital records of their real-world experiences. Scientists valued social support and solving domain-specific problems. Education and Outreach members valued disseminating social- and research-specific information as well as seeking support in these topics. Designing for value has been envisioned in other CoPs as well, including online, scientific CoPs, in which value was expressed via group identity (Liberatore et al., 2018). For Liberatore et al. (2018), who studied bird enthusiasts, increased interaction with different components of a Facebook page indicated value. For myFOSSIL, the various practices that were expressed within different website features and by different PIT Categories indicated the values were held within the CoP.

The sixth design principle was *combining familiarity with excitement.* To combine familiarity with excitement, members discussed domain-specific topics while providing each other social encouragement. To explicate this, the learning activities framework from Wenger et al. (2009) was used. Within the myFOSSIL CoP, nearly all the learning activities were used by members. In their usage, the patterns varied, with Support (n = 693) used the most, followed by Tips (n = 495). The least used included Boundary Crossing (n = 69) and External Benchmarks (n = 4). These differences in usage highlight the notion of combining familiarity with excitement, as the variation denotes that on myFOSSIL, community members were thanked for their contributions (i.e. Support), or they contributed to the social paleontological conversation via taking an authoritative stance when describing the practices within social paleontology (i.e.

Models of Practice). The CoP found on myFOSSIL actualized the sixth design principle when members used a wide variety of practices to communicate with one another.

The last design principle was *create a rhythm for the community.* This principle was ill-defined by Wenger et al. (2002), who merely indicate that similar to “our everyday lives…vibrant communities of practice have a rhythm” (p. 62). Therefore, the design principle of creating a rhythm for the community can be tied to the stages of community development. myFOSSIL was in the coalescing stage, in which community members were integrating and coming together to discuss their ideas. For this study, the data were collected from October 2015 – October 2017, a two-year time span that should allow for a CoP to move through the stages of development (Wenger et al., 2002). In looking at the time-based data, including the numbers of practices per member at the beginning of the study versus the numbers of practices at the end of the study, it was shown that members contributed throughout the study period and practices disbursed throughout community members. Members’ acknowledgement of contributions encouraged idea sharing, belonging, and trust. Idea sharing can be measured by the total number of content that was created by myFOSSIL members. This content increased and became disbursed, indicating that idea sharing was occurring on the website. Furthermore, the disbursement of practices among members indicated that more members contributed, indicating a level of trust within the CoP. This has been seen in other research of online communities, such as within Twitter, where mutual trust has allowed and extended contributions by teachers and students (Stephansen & Couldry, 2014). Members’ contributions can provide an idea generally of the ways in which the community rhythm changed overall, another way to determine the ways in which the community rhythm developed is through examining the ways in which the online data matched with the face-to-face data of the myFOSSIL community. Because the online community website is only one part of the myFOSSIL community, one piece of the rhythm of the community is missing. In order to further explicate the rhythm of the full myFOSSIL CoP, interviews with members concerning their interactions and practices during October 2015 – October 2017 could help further explicate the rhythm of the community.

The seven design principles set forth by Wenger et al. (2002) were theoretically established, however, they had not been empirically established in online, scientific CoPs. Via a study of the practices that developed on myFOSSIL, the design principles were empirically developed, which gave them theoretical and empirical grounding.

Limitations of the Study

One limitation inherent to explanatory sequential mixed methods work is the lengthiness of data collection and analysis. This limitation was alleviated due to the time-bound nature of dissertation studies. The feasibility of resources can also be a limitation or concern with this type of study. As the data were collected from digital trace data on a website, the resources inherently associated with this sequential explanatory mixed methods design were all digital, which limits the conclusions that can be made regarding the CoP writ large as digital practice comprise only one half of the story. Face-to-face practices comprise the other half and can be captured using interviews and other data collection techniques. This was not done for this study, which limits the findings. Digital data collection prevented the loss of paper copies of artifacts, although, aside from their limited data collection quality, these data also came were their own issues, namely version control of spreadsheets and ensuring the prevention of errors in spreadsheets. These issues were avoided via the use of best practices for data management in spreadsheets (Broman & Woo, 2017).

This study was limited by the choice of a single context, that of myFOSSIL. The participants were not chosen at random, but were selected due to their agreement to participate in the study as well as their posting of data on myFOSSIL. The study itself was not conducted with an experimental design in mind, instead, it was a natural research setting from which data were collected ex post facto.

Limitations related to the collection and analysis of quantitative data include digital data capture, including how data were aggregated and pulled from the system for analysis. To ensure data were valid and reliable, I worked with a knowledgeable other to input data into spreadsheets appropriately as well as followed best practices as recommended by Broman and Woo (2017). Another limitation concerned the reliability of data as intrarater, instead of interrater reliability, was conducted. Intrarater reliability by definition includes the coding of data multiple times by a single coder (Purzer, 2010). As such, biases from the researcher could be high. To alleviate these biases, I blind coded ten percent of all data to ensure that the codes attached to data were not influenced by prior coding, leading to substantial agreement (Table 3-5). Additionally, I brought the codes to a knowledgeable other to ensure that personal biases were accounted for. The qualitative component of the study also was subject to limitations, including the issue of case selection bias, cherry picking of data, and other limitations that are often associated with qualitative data collection and analysis (Merriam, 2009). I attempted to alleviate these limitations through providing evidence for the choices I made in terms of case selection, by discussion of cases and their data with an informed other, and through providing descriptions of the cases in the form of vignettes. The data were then examined holistically, as it recommended for mixed method research (Creswell & Plano Clark, 2011; Ivankova, 2006). These steps were taken to ensure that the data were examined in an appropriate manner, in that the data collected from both the quantitative and qualitative stages were aligned.

Conclusions

The purpose of this study was to explore the knowledge-generating capacity of myFOSSIL as a niche of a digital CoP through identifying the practices that led to participation in and contribution to social paleontology. The findings highlighted the practices used on myFOSSIL, namely ones that promoted social cohesion as well as scientific knowledge generation. This work also characterized the ways that members contributed differently dependent on the digital trace data, as well as dependent on PIT Categories, with the PIT Categories of Scientist and Public having more similarities than Education and Outreach. In addition, this study contributes to the body of literature concerning CoPs, in that the seven conceptual categories developed by Wenger et al (2009) were collapsed into three empirical categories. Furthermore, this study specifically adds to our understanding of the processes under which online, scientific CoPs mature. These findings are of import to researchers and practitioners who seek to design, develop, and implement scientific CoPs.

Table 5-1. Empirical evidence from myFOSSIL for design principles of CoPs, with additional suggested design principle(s)

Design Principle	Empirical Evidence on myFOSSIL
1. Design for evolution	The number of members on myFOSSIL increased and as it did, contribution in the form of practice spread throughout those members (information was no longer siloed)
2. Open a dialogue between inside and outside perspectives	Members from different PIT Categories, specifically Education and Outreach, contributed differently that Scientists or the Public, however, there were no significant differences between the scientist and the public
3. Invite different levels of participation	Commercial and Education and Outreach members contributed far less than Public or Scientist members, indicating that peripheral participation was occurring.
3a: Invite different levels of participation, particularly for education-based members	Education and Outreach members were prone to contributing less and in vastly different ways than other member Categories, designing CoPs to capture their interests is needed.
4. Develop both public and private community spaces	There were significant differences in practices dependent on data type
5. Focus on value	Members from different PIT Categories contributed to myFOSSIL in different ways
6. Combine familiarity with excitement	Nearly all of the practices from Wenger et al. (2009) were observed on myFOSSIL, though their patterns of usage varied
7. Create a rhythm for the community	Time-based data showed that people contributed throughout the study period, although the practices became disbursed.

APPENDIX A
COMMUNITY SURVEY

Consent

The FOSSIL Project is funded by the National Science Foundation (DRL-1322725) to research the creation of a national network of fossil clubs and professional paleontologists. The knowledge gained from FOSSIL will enlighten informal and formal STEM educators about how to effectively engage the public with scientific data.

myFOSSIL is our online community space and a key component of our research and service to the community of people who are interested in fossils and paleontology. Choosing to participate in this research improves myFOSSIL as well as our understanding about how to design similar communities. **Please consider choosing to participate.** If you have any questions or concerns about this you may contact Dr. Kent Crippen at kcrippen@coe.ufl.edu or (352) 273-4222 or Dr. Betty Dunckel at bdunckel@flmnh.ufl.edu.

For you to use myFOSSIL, we must be able to verify your first name, last name, valid email address and genuine interest in our community.

If you've already filled out this survey and haven't yet received an email with your login, then contact at kcrippen@coe.ufl.edu for help.

Your First Name:

Your Last Name:

Your Email Address:

What is your affiliation (are you part of club or society; do you work at a museum, college or university)?

Briefly describe your interest(s) in using myFOSSIL.

Which of the following best describes how you learned about myFOSSIL?

- through social media (e.g. Facebook, Twitter, etc.)
- from a member of a fossil club or society
- from a college or university professor, researcher or museum representative
- from a member of the FOSSIL Project team
- by participating in an event that was sponsored by the FOSSIL project (e.g., mini-conference, paleoblitz, etc.)
- by searching and/or browsing the Internet
- other

FOSSIL Project
Florida Museum of Natural History
University of Florida
Project Description and Informed Consent

Study Description:

FOSSIL is creating a national network of fossil clubs and professional paleontologists. The project team is very interested in your experiences, interests, needs, and feedback about the development and effectiveness of FOSSIL in creating a network for amateur and professional paleontologists and providing opportunities for members to learn science, contribute to science, and promote informal science learning. Participant feedback informs the on-going project development and implementation of FOSSIL.

Procedure:

If you choose to participate in this study, you are allowing us to use information that is collected during the normal, iterative development activities for FOSSIL. The following types of information may be collected:

- Survey: A variety of means may be used to document your perspective, experiences, interests, and needs.
- Artifacts: A variety of artifacts may be collected to document your perspective, experiences, interests, and needs. These may include but are not limited to communication artifacts.
- Online archives: Comments and responses that are posted on the myFOSSIL website.
- Observations: Observation data in the form of field notes, video recordings, or audio recordings may be collected to document your interactions during focus groups, workshops, or the annual FOSSIL meeting.
- Interviews: Interviews lasting approximately 20 minutes may be conducted to gain insight into your perspective, experiences, interests, and needs. Interviews will be audio or video recorded and transcribed. Interviews will focus on the following kinds of questions:
    - Describe your participation in FOSSIL.
    - What elements of FOSSIL are most effective in creating a network among amateur and professional paleontologists? Please explain.
    - How do digitized collections impact the practices of the network?
    - How does your participation in FOSSIL influence your science learning, contributions to the science of paleontology, and promotion of informal science education?
    - What types of components should we include in the myFOSSIL website? Please explain.
    - Are the FOSSIL programmatic activities and training effective? Please explain.
    - Is the communication among FOSSIL participants effective? Please explain.
    - How do the FOSSIL amateur and professional paleontologists share practices and skills?
    - How does networking the clubs improve the outreach, resources, and capabilities of the individual clubs?

An anonymous coding scheme will be applied to all information collected and prior to analysis. Data will be analyzed and reported in an aggregated fashion and participants will not be identified by name in any reports of our research.

Risks and Benefits of Participation:

There are risks involved in all research and evaluation studies. However, minimal risk is envisioned for participating in this project. You will not be identified by name in any reports of this research; pseudonyms will be used. There are no direct benefits for participating in the FOSSIL project research and evaluation. However, future participants may experience benefits in the form of a more effective FOSSIL project in providing a network for amateur and professional paleontologists that fosters science learning, contributions to the science of paleontology, and informal science learning.

Time Required and Compensation:

The study will occur over the course of the FOSSIL project and we anticipate requiring a total of 60 minutes annually of your time to complete the surveys. There will be no compensation for participating in this study.

Confidentiality:

All information gathered in this study will be kept confidential to the extent provided by law. No reference will be made in written or oral materials that could link you to this study. All records will be stored in a locked file cabinet in the Principal Investigator's office. When the study is completed and the data have been analyzed, the information will be shredded and/or electronically erased.

Voluntary Participation:

Your participation is strictly voluntary. Non-participation or denied consent to collect some or all of the data listed above will not affect your participation in FOSSIL. In addition, you may request at any time that your data not to be included.

Contact Information:

If you have any questions or concerns about the study, you may contact Dr. Kent Crippen at kcrippen@coe.ufl.edu or (352) 273-4222 or Dr. Betty Dunckel at bdunckel@flmnh.ufl.edu. For questions regarding your rights as a research participant in this study you may contact the UFIRB Office, Box 112250, University of Florida, Gainesville, FL 32611-2250; ph (352) 392-0433.

Participant Consent:

I have read the above information and agree to participate in this study. I am at least 18 years of age. Download a PDF copy for your records here.

Do you consent to participate?

- ◯ Yes!
- ◯ No

Demographics

Please provide a candid response to each of the following approximately 10 questions that will help us understand your background and ideas related to the content of myFOSSIL. This information is very important for helping us optimize the function and usability of myFOSSIL for all members of the community.

Which best defines your age?

- 17 or under
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65+

Which of the following options best describes your occupation?

- For profit
- Non-profit (religious, arts, social assistance, etc.
- Government
- Health Care
- Education
- Student
- Other (Please describe)

Choose the option that best describes your **highest level of education**.

- Some high school, no diploma
- High school graduate, diploma or equivalent
- Completed some college
- Associate degree

Bachelor's Degree

Completed some graduate school

Master's Degree

Doctoral Degree

Other

Are you currently or have you ever been employed as a professional paleontologist?

Yes

No

Are you or have you ever been a member or consider yourself affiliated with a group of people who collect fossils (i.e. a fossil club or society)?

Yes

No

Do you or have you ever collected fossils as a hobby?

Yes

No

Social Media Use

Do you use social media (i.e. Twitter, Facebook, Instagram)?

Yes

No

Which best describes your use of social media?

- Almost Never
- Every few days
- Daily
- Multiple Times Daily
- I'm always online

Which social media networks do you use? Check all that you use.

- Facebook
- YouTube
- Twitter
- Pinterest
- LinkedIn
- Instagram
- Blogs
- Fossil Forum
- Other (Please Name)

Which tools do you use to access social media? Check all that you use.

- Computer
- Android Phone
- iPhone
- iPad
- Other tablet computer

Estimate the number of connections that you have on social media:

- 0-50

- 50-100
- 100-200
- 200-1,000
- more than 1,000

Which of the following sentences best describes your personal use of social media? Choose the Best.

- "I don't check social media because I don't find it worthwhile."
- "I check social media, but I don't post a lot of things."
- "I use social media to exchange information and check in with people."
- "I use social media to read news and stories."
- I use social media to post about my day, I check in with others. I'm always keeping up."
- "I don't want to miss anything, so I'm always checking my social media."

myFOSSIL is based upon the concept of **Social Paleontology**. In your own words, what does this idea mean to you? Please be descriptive.

APPENDIX B
IRB CONSENT FORM

UF | Institutional Review Board
UNIVERSITY of FLORIDA

PO Box 112250
Gainesville, FL 32611-2250
352-392-0433 (Phone)
352-392-9234 (Fax)
irb2@ufl.edu

DATE: January 23, 2015

TO: Bruce J. MacFadden, PhD; Kent Crippen; Betty Dunckel, PhD
Shari Ellis, PhD; Austin Hendy
PO Box 117800
Campus

FROM: Ira Fischler, PhD; Chair
University of Florida
Institutional Review Board 02

SUBJECT: **Renewal of Protocol #2014-U-0077**

TITLE: Full-Scale Development: FOSSIL - Fostering Opportunities for Synergisic STEM with Informal Learners

SPONSOR: National Science Foundation - DRL - Informal Science Education, Program Solicitation NSF 12-560

Your request to continue your research protocol involving human participants has been approved. Participants are not placed at more than minimal risk by the research. You are reminded that any changes, including the need to increase the number of participants authorized, must be approved by resubmission of the protocol to the Board.

Re-approval of this protocol extends for one year from the date of the review, the maximum duration permitted by the Office for Human Research Protection. This approval is valid through **January 27, 2016.** If this project will not be completed by this date, please telephone our office (392-0433) at least four weeks prior to this date so that we can discuss the renewal process with you. If you complete the project on or before the date please submit the closure report to our office. The report can be located at http://irb.ufl.edu/irb02/irb-02-forms.html

It is important that you keep your Department Chair informed about the status of this research project. In addition, if your project is funded, you should send a copy of this project renewal notification to the Division of Sponsored Research, Awards Administration, P.O. Box 115500.

ISF:dl

Approved by
University of Florida
Institutional Review Board 02
Protocol # 2014-U-0077
For Use Until January 27, 2016

FOSSIL Project
Florida Museum of Natural History
University of Florida

Project Description and Informed Consent

Study Description:
FOSSIL is creating a national network of fossil clubs and professional paleontologists. The project team is very interested in your experiences, interests, needs, and feedback about the development and effectiveness of FOSSIL in creating a network for amateur and professional paleontologists and providing opportunities for members to learn science, contribute to science, and promote informal science learning. Participant feedback informs the on-going project development and implementation of FOSSIL.

Procedure:
If you choose to participate in this study, you are allowing us to use information that is collected during the normal, iterative development activities for FOSSIL. The following types of information may be collected:

- Survey and questionnaires: A variety of means may be used to document your perspective, experiences, interests, and needs.
- Artifacts: A variety of artifacts may be collected to document your perspective, experiences, interests, and needs. These may include but are not limited to communication artifacts.
- Online archives: Comments and responses that are posted on the myFOSSIL website.
- Observations: Observation data in the form of field notes, video recordings, or audio recordings may be collected to document your interactions during focus groups, workshops, or the annual FOSSIL meeting.
- Interviews: Interviews lasting approximately 20 minutes may be conducted to gain insight into your perspective, experiences, interests, and needs. Interviews will be audio or video recorded and transcribed. Interviews will focus on the following kinds of questions:
    - Describe your participation in FOSSIL.
    - What elements of FOSSIL are most effective in creating a network among amateur and professional paleontologists? Please explain.
    - How do digitized collections impact the practices of the network?
    - How does your participation in FOSSIL influence your science learning, contributions to the science of paleontology, and promotion of informal science education?
    - What types of components should we include in the myFOSSIL website? Please explain.
    - Are the FOSSIL programmatic activities and training effective? Please explain.
    - Is the communication among FOSSIL participants effective? Please explain.
    - How do the FOSSIL amateur and professional paleontologists share practices and skills?
    - How does networking the clubs improve the outreach, resources, and capabilities of the individual clubs?

An anonymous coding scheme will be applied to all information collected and prior to analysis. Data will be analyzed and reported in an aggregated fashion and participants will not be identified by name in any reports of our research.

Risks and Benefits of Participation:
There are risks involved in all research and evaluation studies. However, minimal risk is envisioned for participating in this project. You will not be identified by name in any reports of this research; pseudonyms will be used. There are no direct benefits for participating in the FOSSIL project research

and evaluation. However, future participants may experience benefits in the form of a more effective FOSSIL project in providing a network for amateur and professional paleontologists that fosters science learning, contributions to the science of paleontology, and informal science learning.

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The study will occur over the course of the FOSSIL project and we anticipate requiring a total of 60 minutes annually of your time to complete the surveys. There will be no compensation for participating in this study.

Confidentiality:
All information gathered in this study will be kept confidential to the extent provided by law. No reference will be made in written or oral materials that could link you to this study. All physical records will be stored in a locked file cabinet in the Principal Investigator's office. Digital records will be stored on a secure server on the UF campus. When the study is completed and the data have been analyzed, the information will be shredded and electronically erased.

Voluntary Participation:
Your participation is strictly voluntary. Non-participation or denied consent to collect some or all of the data listed above will not affect your participation in FOSSIL. In addition, you may request at any time that your data not to be included. And participants can withdraw their consent at any time without penalty.

Contact Information:
If you have any questions or concerns about the study, you may contact Dr. Bruce MacFadden at bmacfadd@flmnh.ufl.edu or (353) 273-1937, Dr. Kent Crippen at kcrippen@coe.ufl.edu or (352) 273-4222, or Dr. Betty Dunckel at bdunckel@flmnh.ufl.edu or (352) 273-2088. For questions regarding your rights as a research participant in this study you may contact the UFIRB Office, Box 112250, University of Florida, Gainesville, FL 32611-2250; ph (352) 392-0433.

Participant Consent:
I have read the above information and agree to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

______________________________ ________________
Signature of Participant Date

____
Participant Name (Please Print)

Approved by
University of Florida
Institutional Review Board 02
Protocol # 2014-U-0077
For Use Until January 27, 2016

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BIOGRAPHICAL SKETCH

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