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Seeking Shared Practice: A Juxtaposition of the Attributes and Activities of Organized Fossil Groups with Those of Professional Paleontology

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Abstract This study sought to define the attributes and practices of organized fossil groups (e.g., clubs, paleontological societies) as amateur paleontologists, as well as those of professional paleontologists, and explore the potential for these two groups to work collaboratively as a formalized community. Such an investigation is necessary to develop design principles for an online environment that supports this community and encourages communication and shared practice among individuals with different backgrounds in paleontology and who are geographically isolated. A national survey of fossil group representatives and professional paleontologists was used to address the research questions. The results provide a rich description of the attributes and activities of both groups and are discussed in terms of three design principles for supporting the two groups in a form of collaboration and fellowship via a coherent shared practice within an online learning community.

Keywords Community of practice · Design · Fossil · Informal education · Formal–informal links · Paleontology · Public engagement

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Introduction

Throughout the United States (U.S.), citizens form organized groups and participate in the hobby of collecting fossils. These *fossil groups*, including clubs and paleontological societies, are generally recognized as informal or amateur participants in paleontology. Participation by the public in the science of paleontology has a rich history that dates back centuries and has resulted in many important contributions (for example, see Burton 2012). Participation by the public across a wide range of scientific domains has gained attention in recent years as professional scientists increasingly recognize the role citizens can play in furthering scientific understanding (Dickinson et al. 2012). However, despite the long history of amateur paleontology, little is known about the attributes of fossil groups, their members or the very nature of their activities.

This study used a survey of U.S. national scope to begin addressing this issue by defining the attributes and practices of fossil groups as well as the potential for collaboration with professionals under a larger, formalized learning community of our design. The following research questions framed the study:

1. What attributes define the individuals who participate in fossil groups?
2. What activities define participation in a fossil group and how are those activities related to those of professional paleontologists?
3. What experience and interests do professional paleontologists have for working with fossil groups?

By building our understanding of both amateur and professional paleontologists, including how their ways of knowing relate to the science of paleontology, we hope to infer how these practices can be blended into a more

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coherent shared practice within an online learning environment. In addition to improving the potential for generating new knowledge, the effective development of such a networked community would also increase the accessibility of science to the broader public by making the communication and practice more discoverable and transferable. Before describing our research methodology, we detail the construct of community of practice as the theoretical framework guiding this work and provide a review of relevant studies and community examples based upon intentional efforts to engage the public in science. These elements informed the nature and scope of our survey instrument.

Theoretical Framework

Wenger et al. (2002) define a community of practice (CoP) as "groups of people who share a concern, a set of problems, or a passion about a topic and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (p. 4). Within this construct, three characteristics define any CoP—a domain of knowledge, a community of people and a shared practice. In this case, paleontology represents the domain of knowledge and the community consists of amateurs and professionals who are engaged with *understanding the natural world through the collection, preparation, curation and study of fossils.*

Shared practice is the central element in an effective CoP and the principal concern when designing for one (Andriessen 2005; Probst and Borzillo 2008). Practice is a sociocultural construct that includes a repertoire of vocabulary, skills, techniques, stories, symbols and routines (Kienle and Wessner 2005). Practice is embodied in the everyday cultural activity of professional paleontologists, including the social elements (Wenger 1998). This includes: planning for fieldwork, documenting and curating fossil evidence, using this evidence to model past life on Earth, hypothesizing with known fossils, constructing theoretical explanations and communicating this knowledge through publications and presentations. Within a CoP, practice supports the creation of knowledge and is the foundation for future learning (Sadler 2009).

To be part of a CoP, one must participate in the practice, even if vicariously through remote or virtual means. CoP members can be defined along a continuum from novice to expert where expertise involves enculturation in the practice as well as acquisition of cultural capital (Duguid 2005). Amateur and professional participants in paleontology lie along this continuum of knowledge and skills.

Public participation in scientific research describes activities that engage the public in scientific investigations, providing opportunities to both learn about and contribute to science understanding (Bonney et al. 2009). Public participation experiences allow people with varied backgrounds and scientific expertise to contribute their perspectives, ideas, knowledge and values in response to scientific questions or science-related controversies. CoPs based upon public participation in science exist, many of which include effective forms of online support. For example, *Astronomy from the Ground Up* (http://www.afguonline.org/) was developed for informal science educators at a variety of venues to enhance their communication of astronomy to their visitors. Launched in 2007, the *Encyclopedia of Life* (http://eol.org/) serves the general public, amateurs, educators and scientists by providing global access to knowledge about life on Earth. *eBird* (http://ebird.org/), supported by the Cornell Lab of Ornithology, provides news, maps, state and regional portals and species information for people interested in birds.

CoPs are known to evolve through predictable stages that are based upon connections among members (Gongla and Rizzuto 2001). These connections support social learning and involve activities such as the sharing of experiences and future plans (i.e., telling stories), creating norms and building a common vocabulary (Hoadley 2012). For those who are supporting the development of a CoP, knowing the demographics, interests and preferred forms of communication is paramount for building an infrastructure that fosters social learning (Johnson 2001). The existing synthesis of research on CoPs, including those serving domains beyond science and education, indicates the significance of participant attributes and their commitment to core activities as critical elements for success (Johnson 2001; Kraut et al. 2012; Probst and Borzillo 2008). By better understanding the essence of existing activities including the behaviors, motivations, heuristics, tools and resources affords identification of shared infrastructure and activity structures that offer the potential for innovative design and development.

From our collective personal experience, we know that some shared activity already exists between amateur and professional paleontologists and that this activity frequently includes a mutual relationship with at least one museum. These relationships are sometimes characterized as positive, other times as negative. Thus, our understanding of the nature and history of these relationships could be a key variable for success in building a social learning community (Kienle and Wessner 2005). With a CoP as our design goal and these themes and conditions, we identified a national survey of fossil group representatives and professional paleontologists as an appropriate method for addressing our research questions and for formalizing some initial design principles and propositions related to a shared practice and online learning community (McKenney and Reeves 2012).

Methodology

This study uses the perspective of members of fossil groups and professional paleontologists in the U.S. through data collected via a web-based survey to assess the attitudes, knowledge, prior experience and needs related to participating in an online CoP.

Survey Development

We developed two survey instruments—one for designated representatives of fossil groups to characterize the organization to which they belong and the other for professional paleontologists to describe their demographics and the activities that define their practice as well as their interest and capacity for participating in a CoP. Both surveys addressed the following five main themes: (1) demographics, (2) forms of communication, (3) current activities, (4) professional relationships and (5) potential CoP activities. Because of the limited research about the attributes and activities of fossil groups, their survey emphasized demographics (MacFadden et al. 2016), forms of communication and activities. The survey for professional paleontologists focused on their relationships with museums and fossil groups, with an emphasis on current and potential activities.

Prior to use, the survey items were reviewed and revised among the research team for content, consistency and readability. Two of the authors are professional paleontologists with experience working with fossil groups in a collaborative fashion via natural history museums. Due to the exploratory nature of this study, open-response items were used preferably and all closed-response items included an *other* category that was completed as an open response.

Sample

We created a database of U.S. fossil groups—by first listing those already known to the research team and then searching the web and social media extensively for organization names and contact information. Letters were sent to 64 organizations of which 17 did not respond. After further correspondence, we had contact information for 48 individuals who we deemed likely to respond to our survey and capable of accurately responding on behalf of the fossil group (e.g., the president or designated contact). Based on our existing professional contacts, we created a convenience sample of 58 US-based paleontologists working in either university or museum settings. These 106 individuals were sent a URL for the survey, and a total of 64 responses were collected, 30 fossil groups (63 %) representing 19 states and 34 paleontologists (59 %) from 17 states and the District of Columbia (Fig. 1). The overall response rate was 60 %, which is considered an acceptable value for a web-based administration (Manfreda, Bosnjak, Berzelak, Hass, and Vehovar 2008; Shih and Fan 2008). The next section describes the analysis of data, followed by results and a discussion of findings.

Analysis

In order to protect identities, responses were de-identified with a code that included the nature of the respondent and a number (e.g., Group4, Pro6). Research question one was addressed with descriptive statistics for survey responses to closed items involving demographics and forms of communication. These items addressed the age of the fossil group and membership, gender composition, cultural and ethnic diversity and use of resources. Research question two was addressed with descriptive statistics for responses to closed items and a thematic analysis for open-ended items involving current and potential CoP activities. Responses to open-ended questions were first open coded and then refined through a constant comparative method (Lincoln and Guba 1985). Research question three was addressed with a coding of responses to open-ended questions about professional relationships including most rewarding interactions and reasons for engaging/not engaging with a fossil group, as well as barriers and constraints to further interactions between fossil groups and paleontologists. Validity and reliability were addressed by member-checking the responses with attendees of the North American Paleontological Convention (NAPC) as well as against the published information on the websites of the fossil groups. Many of the survey respondents, both amateur and professional, were invited and attended the NAPC meeting where a large subset of the data was presented and discussed on two separate occasions.

Limitations

The survey responses are from 19 states and the District of Columbia. Though geographically diverse, this sample does not support generalization beyond the respondents. Nor did the survey include all individuals in fossil groups or all professional paleontologists. Our reporting of demographics for fossil groups is dependent upon the accuracy and integrity of the individuals who responded on their behalf. In addition, the constructed survey instrument limits our understanding of the nature of activities that were described by respondents. While we included measures to ensure validity and reliability, the resulting data were constrained by the questions we asked and our use of

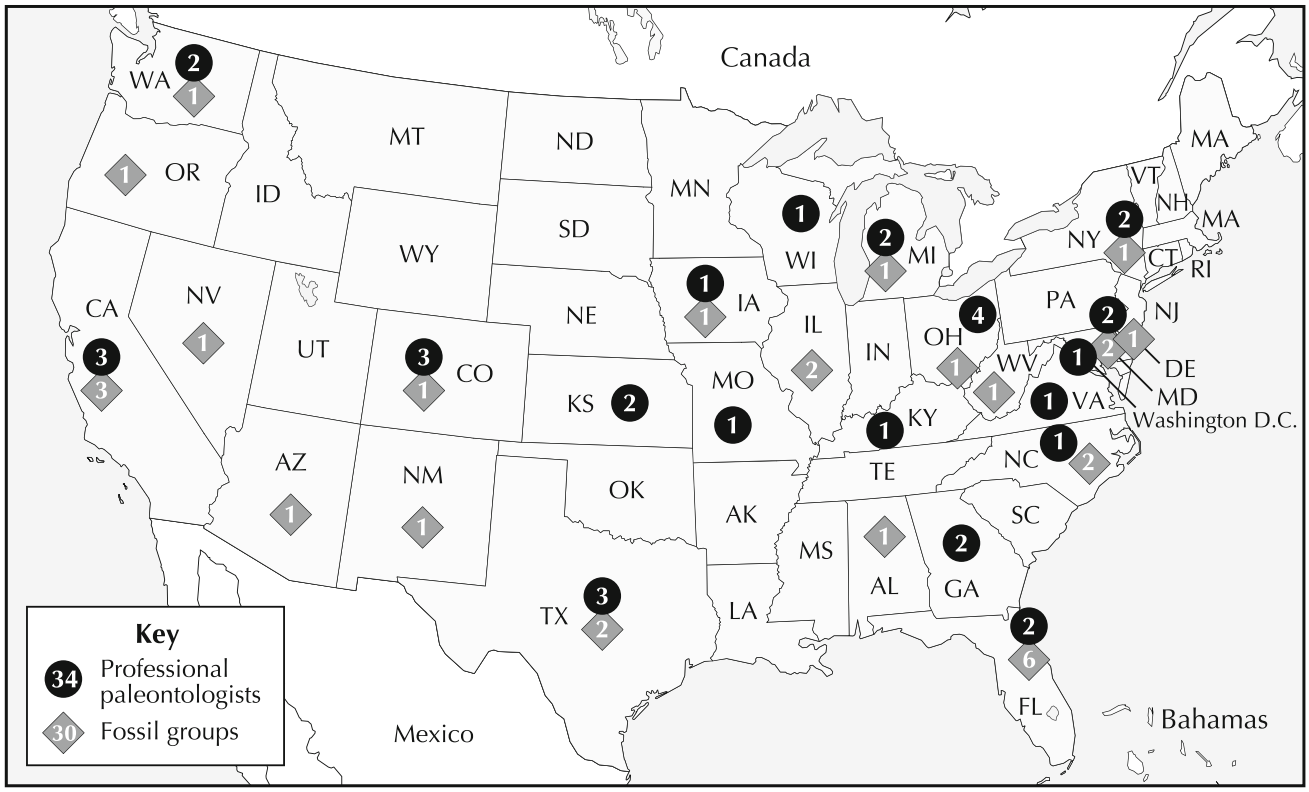

Fig. 1 Survey respondents by state; fossil groups ($N = 30$), professional paleontologists ($N = 34$). The values indicate the number of respondents per state by classification

open-ended responses. Further, there may be unknown variables that were not addressed by this survey that could be used to offer an alternative explanation to that provided here. Despite these limitations, the current study presents an initial front-end examination of the attributes and activities of fossil groups and professional paleontologists in the U.S. and provides the foundation for the development of a CoP. Like the data analysis, the results are presented thematically based upon the order of the research questions. Direct quotes are used to illustrate themes and are attributed to the respondent by the numerical code they were assigned prior to analysis.

Results and Discussion

Attributes of Fossil Groups

The participating fossil groups have been in existence for quite some time, with an average reported length of 29.6 years (SD 16.5; range 6–65 years). The average reported membership was approximately 170 people, but there is considerable variability in size (SD 139) with groups ranging from 12 to 600 members. The demographic is older (average above 50 years), male (59 %) and not perceived by the respondents as culturally or ethnically diverse. However, 17 of the groups (57 %) reported a youngest member under 10 years of age, while 25 groups (83 %) reported an oldest member over the age of 80 years. It is not clear whether the groups recognize their lack of diversity as an issue, but they do recognize their average age and lack of youth as an issue. For example, Group3 commented, "numbers keep going down due to 'old age'. No young members." Members are more likely from suburban and urban areas compared to rural areas, and they overwhelmingly prefer the descriptor of *amateur* to the title of paleontologist (57 %), over other terms such as *vocational* (17 %) or *citizen* (10 %).

The mission statements of the fossil groups provided an interesting perspective on the values and intent of these organizations (Table 1). If enacted as described, most of the themes could have direct and important implications for developing a more formal CoP. Themes such as *promotion of paleontology*, *promotion of earth science* and *dissemination of findings* are consistent with what one might expect of a professional society of scientists. Others such as *preservation of the fossil record*, *support of the local museum* and *collaboration with other organizations* are consistent with the role of a community service organization that values its presence in the everyday lives of the people that it serves.

Table 1 Top ten coded themes from the mission statements of fossil groups

Theme	Rate (%)	Operational definition	Coded examples
Inquiry and learning	70	The study of fossils, new discovery, increasing knowledge, promoting understanding, advancing science or engaging in education of the public	…to increase our present level of knowledge, wherever possible, in all branches of the earth sciences… (Group11) …to stimulate interest and promote education at all levels… (Group13)
Promote paleontology	40	To advocate or support the science of paleontology by name or definition	To promote the scientific study of fossils. (Group27) …promote paleontological efforts… (Group23)
Curation	33	The collection, preservation and presentation of fossils or other physical evidence of past life	…laboratory preparation and collection curations… (Group2) Participation is invited in the program to collect, preserve, and study paleontological material (Group6)
Dissemination of findings	30	To formally and publicly communicate the results of group activities	…provide opportunities for members to display, discuss, and identify their fossil finds (Group8) To publish and distribute educational information. (Group10)
Study of the local area	30	The group's activities are focused on a region or natural resource in the immediate area	…protection of the {natural resource} as a National Monument… (Group17) To explore and preserve {state name}'s past… (Group15)
Amateur and professional collaboration	27	Working or cooperating with a professional paleontologist on research	…to assist the professional in locating new outcrops or collecting areas, and with the identification, characterization, and preservation of new types or species of fossils, minerals or artifacts… (Group12)
Promote earth science	20	To foster or support an interest or encourage engagement in a formal study of Earth's natural environment	…members interested in the studies of Archaeology, Mineralogy, Micromounts, Paleontology, and the Lapidary Arts (Group20)
Collaborate with another organization	20	Working or cooperating with another recognized formal institution	To assist other individuals, groups, and institutions interested in the various aspects of Paleontology (Group19)
Preservation of the fossil record	20	To advocate for the safeguarding of fossils and the natural environment in which they are found	…preserve the paleontological heritage… (Group28) To encourage responsible stewardship of Earth's paleontological resources… (Group29)
Support the local museum	20	Providing financial support, working with or promoting a local museum	…activities that promote paleontological efforts of the museum… (Group23) Support the {Name}Museum… (Group7)

Most encouraging for the development of a shared practice are the themes of *inquiry and learning*, *curation* and *amateur and professional collaboration*. These strongly suggest the potential for a shared purpose and practice related to the CoP's domain of knowledge. However, the explicit focus on the *study of the local area*, consistent with previous literature indicating the importance of place-based learning (Braund and Reiss 2006; Rennie et al. 2003), will need be considered and respected in any efforts to develop national initiatives involving fossil groups, as a national focus might be perceived as inconsistent with the mission and scope of some groups' local activities.

Given the central role that online communication will play in the design of our CoP, we were interested in the fossil group members' facility with the Internet. An estimated 80 % or better of all group members have access to the Internet and e-mail. A high percentage of respondents indicated that at least some members of their groups use the Internet to access museum websites (93 %), online scientific articles (93 %), fossil group websites (their own and others) (90 %) and online image galleries (77 %). Other online resources used by fossil group members include Facebook, newspaper articles, maps and forums.

Fossil group information is shared predominately at face-to-face group meetings (90 %), but also via e-mail

(90 %) and newsletters, often in hard copy (70 %). Although all but two participating groups have a website, only about one-quarter of representatives reported that 75 % or more of their members use it. A small percentage reported having communications with other fossil groups (35 %) and, on the occasion that it occurred, was accomplished with e-mail or a phone call. Their reported preferences for communicating with other groups include e-mail, a joint website, shared field trips, a newsletter and Facebook.

The fossil group representatives reported their members to be knowledgeable across a range of topics, but most knowledgeable about *fossil collections in relation to U.S. natural history museums* and *evolution based upon the fossil record* (Fig. 2). The representatives also reported that members have a high interest across these topics, with higher interest than knowledge in all areas except *climate change interpreted from the fossil record*. This differential suggests a capacity for using these topics as themes for engaging them in a CoP.

Activities of Fossil Groups

Seventy percent of the fossil groups meet on a monthly basis, and some groups meet only during the winter months. The primary activities reported were field trips (100 %), lectures and talks (97 %), newsletters (83 %), website (83 %), fossil fairs and festivals (57 %), training workshops (53 %), social activities (50 %) and fundraising for scholarships for university students. Other activities mentioned include a grant program for specific kinds of paleontology research, kids' programs, museum tour trips, symposiums, publications and work with a local museum.

The club representative responding reported that most fossil group members keep a personal fossil collection and do so for display (e.g., at home, schools, fossil fairs) (83 %), for the enjoyment of organizing their discoveries (77 %) and for trading with others (53 %). A smaller percentage collects to sell fossils or to contribute fossils to research or specific museums or parks.

The majority of respondents did not feel there are barriers to working with professional paleontologists, but those who did cited a lack of trust (e.g., "many paleontologists only contact fossil groups when they need help with their own research and funding needs"—Group11), a lack of time (e.g., "Most have contracts they are fulfilling and do not have the time to spend with amateurs"—Group17) or a lack of will (e.g., "They could be more willing to present programs at club shows or small fossil festivals"—Group7). However, the lack of trust clearly was fostered by some amateurs as respondents also acknowledged the role of bad behavior. Group21 answered, "I think the barriers have mainly to do with amateurs over collecting sites, not collecting enough peripheral data with the finds, selling fossils, etc." Many of the respondents who indicated that there were no barriers also described specific local or regional professionals who provided time and resources or advocated on the fossil group's behalf.

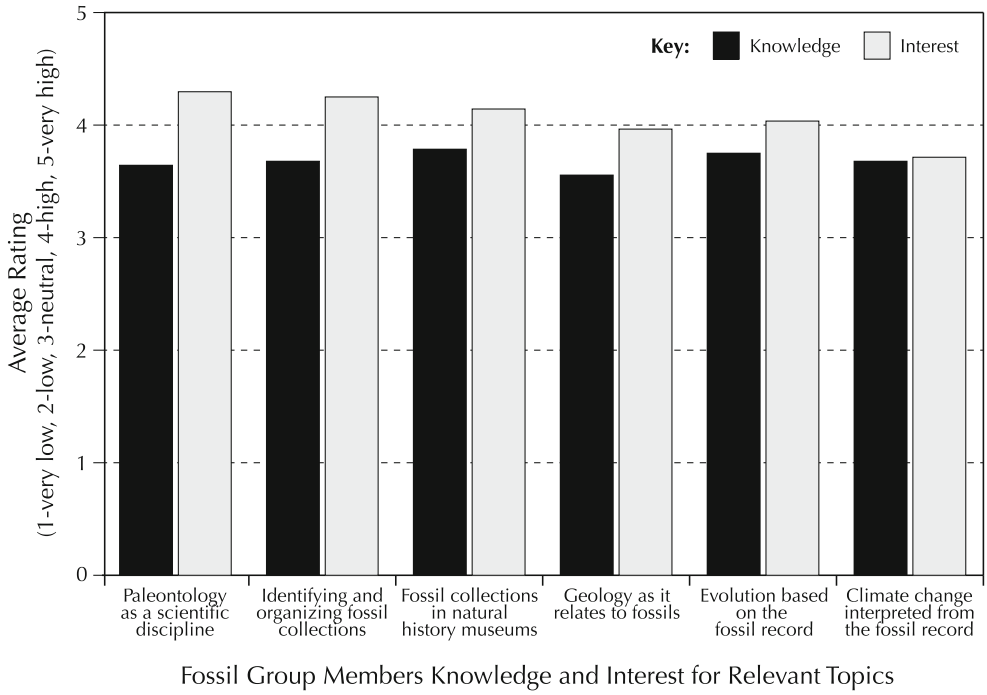

Fig. 2 Reported level of knowledge and interest for fossil group members in relation to assumed topics of interest

There was a positive response to the idea of access to digitized fossil images (63 %), and fossil groups indicated that members would use these as a resource for identifying their discoveries. Respondents noted that participating in a networked CoP could be useful for younger members interested in learning more about potential colleges and careers as illustrated by this comment, "A national network would be very beneficial to those members who cannot regularly attend meetings due to scheduling or physical disabilities preventing travel; the webinars and virtual field trips would provide new opportunities to reach people that would otherwise not be exposed to paleontology"—Group11.

When provided with a list of activities that a CoP could facilitate, respondents indicated an interest in all of them, but expressed the greatest interest in: a) field trips, b) identifying and organizing fossils and fossil collections, c) a speaker series, d) resource materials for meetings and e) ask a paleontologist and/or other kinds of interactive activities. Member-produced newsletters seem to be an important cultural element and communication vehicle with fossil groups and most respondents indicating that they would be interested or very interested in receiving and/or contributing to an e-newsletter sponsored by the CoP (86 %). This level of interest was also expressed for web-based video seminars (i.e., webinars).

When asked about additional ideas for how groups could participate in a CoP, their responses focused on four themes: (a) sharing information (e.g., "We also can share field guides and collecting localities for people visiting the area."—Group8, "trade specimens from other areas of the country"—Group19, "Ideas for speakers"—Group23), (b) field trips (i.e., learning about localities where fossils could be collected), (c) access to identification services (i.e., people or databases that can be queried in order to identify a fossil) and (d) the potential for an expanding the knowledge base.

One of the survey items proposed the idea of an annual face-to-face meeting for the CoP, and 94 % of respondents indicated that their group would be interested or very interested in sending a representative. Given a list of possible activities for this meeting, respondents indicated interest in: (a) information on new paleontological discoveries, (b) practical workshops about how to identify and catalog fossils, (c) reports on group activities and (d) how to use the web to connect to other groups and online collections. These interests mirror their suggestions for the kind of information they would like available on the CoP website—namely: (a) links to organizations, (b) a calendar of events, (c) news from the world of science (i.e., new discoveries and publications), (d) newsletters and (e) links to websites with resource information, including a suggestion for "a database of fossils found in other collections rather than just links to fossil collections on line. It would be nice to do one search for a fossil and have it search multiple databases for you"—Group4.

Formal Learning Activities of Paleontologists

The professional paleontologists reported an average of 19.6 years of experience (SD 10.5) with most (62 %) describing their role as curator or manager of a collection. Nearly all explicitly mentioned research activities as a major part of their responsibilities. The types of paleontological collections the professionals curate include invertebrates (47 %), vertebrates (44 %), paleobotany (38 %), microfossils (25 %) and general paleontology (16 %). Only a small fraction of these collections were reported to be searchable from the web. The majority of the professionals who responded were affiliated with a museum (82 %); of these 53 % were affiliated with a university, while 25 % were affiliated with institutions supported by government (e.g., state, city or federal) funds.

The majority of professionals who responded to the survey (82 %) reported interacting with fossil groups and their members, of these 27 % rating their level of involvement as "significant" and 15 % as "moderate." When asked about what they found rewarding about working with fossil groups, nearly 80 % cited the enthusiasm and knowledge of group members, as well as the opportunities to interact with young people, "Many members are highly motivated collectors and want to not only learn about paleontology but want to make an impact on the science through their observations and collecting efforts"-Pro6. In general, the professionals reported being motivated by opportunities to share their interests and excitement for the field of paleontology. Due to the time and money constraints associated with being a professional, they rely on amateurs to be in the field collecting fossils and to volunteer in a variety of collection-related functions back in the collections or museums. When asked about obstacles to working with groups, 33 % cited a lack of time, while 23 % indicated geographical distance.

Half of the professional respondents reported having fossil group members currently assisting with their collections, and the majority (88 %) believe that properly trained amateurs could assist with the digitization of those collections. Nearly, all professional respondents (94 %) indicated that they work with students and, to some degree, those students are involved with fossil groups—mainly in the form of giving presentations (44 %), identifying specimens (19 %) and facilitating fieldwork (14 %). About half of the groups are supporting these students financially in the form of scholarships or small grants for research. The vast majority (90 %) of professional paleontologists who responded to the survey expressed strong interest in participating in a CoP.

The professional respondents were most interested in teaching group members about topics related to paleontology as well as providing training and development. The majority indicated an interest in participating in an annual meeting with the amateurs (79 %) and in receiving and/or collaborating on a newsletter (76 %). Their ideas for CoP activities focused on a one-way flow of information that involved using their expertise to inform or train amateurs in techniques, procedures and ethics. For example, Pro23 suggested "Training and certification programs for amateurs through prep lab and/or field work." or as Pro20 suggests, "workshops on teaching taxonomy, systematics, curation etc. and training how to handle specimens, photography, Photoshop and other tasks that involve curation and digitization of specimens." Yet, their comments also uniquely echoed the need of the research community for techniques that preserve the value of any fossil, such as "the need to capture locality information for maintaining integrity of the specimen and research value."-Pro20.

The Potential for Working Together

Collaboration already exists among amateurs, professionals and museums. For example, 82 % of the professionals indicated that they have interacted with fossil groups and describe the nature of this relationship as predominately giving presentations, identifying specimens and advising. A fraction of respondents indicated that they engage amateurs in fieldwork or in some other form of their research. Professionals responded that sharing information, engaging with fossil groups via inquiry and learning and the fellowship of paleontology were the most rewarding parts of working with them. As for the fossil groups, 28 out of 30 groups (93 %) reported having a relationship with a museum or similar institution. And, 27 of 30 (90 %) reported an existing association with a professional paleontologist where the role of the paleontologist was described as: (a) identifying specimens, (b) giving talks, (c) participating as an active member, (d) being an advisor, (e) leading field trips and (f) serving as officer or member of the fossil group leadership. Yet, many professionals also indicated that they were not aware of any fossil groups in their area.

Ten groups (36 %) reported doing collaborative activities with other groups; 57 % of these activities involved joint field trips as well as some cross-promotional activities. While there is some evidence for the existence of cooperation and collaboration, it seems to occur on a very limited and geographically constrained basis. One example of collaboration that has been in existence for nearly a decade involves members of the Southwest Florida Fossil Society and their involvement in the Aurora Fossil Festival in North Carolina. However, this kind of collaborative activity seems limited.

The survey responses provide evidence for two primary channels of how information is shared: (1) unidirectionally from professionals to amateurs and (2) unidirectionally from amateurs and from professionals to museums. Professionals responded that the flow of information to amateurs largely takes the form of giving talks and presentations, but also includes some genuine mentorship (i.e., "Being able to encourage their interest by showing respect for their expertise and interest."-Pro7). However, as illustrated by this quote from Pro6, some professionals also recognize that the activities of fossil group members have the potential for advancing science and thus could make the flow of information more bidirectional, "Many members are highly motivated collectors and want to not only learn about paleontology but want to make an impact on the science through their observations and collecting efforts."

Field trips were an often-cited activity that offers tremendous potential for collaboration among amateurs and professionals. However, there is evidence that the two groups have differing opinions about the nature and purpose of this activity. Amateurs view field trips as a means of collecting, for collaborating with other groups and for building membership in their group. Nevertheless, they acknowledge that field trips can serve as a way to involve professionals and to help collect data for the scientists' research projects. The professionals generally share this enthusiasm for working in the field and report having engaged in this activity with amateurs. However, scientists' time is limited and they view the role of fieldwork (their term) very differently than do the amateurs. For example, when asked about the least rewarding aspects of working with groups, the comments of professionals were focused on time (i.e., amount and, in some cases, nature of what was involved), the difference between science and collecting, a lack of awareness regarding the scientific value of specimens among some amateurs and trust. The disparity in perspective with regard to fieldwork seems to be rooted in the beliefs and motivations that define the different practices of the two groups—namely, being a collector versus being a scientist. For example, Pro7 describes the differences between collecting and science and the resulting tension that is created:

> There seems to be little understanding of the way science actually works at the level of the professional - that fossils are to many professionals a means to understand process - the old "how the world works" business - not an end in and of themselves. This can result in misunderstandings about the importance of their fossils finds, or the amount of attention we are

> able to devote to them and their ideas about things. (Pro7)

For many amateur fossil collectors, the act of discovering a fossil specimen and the fossil itself are their focus. In contrast, for the professional paleontologist, the discovery of a new fossil is the beginning of the scientific process to better understand *what* and *how* we know about past life. The fossil is but one component in the structure of scientific knowledge, the evidence used in support of a knowledge claim. This fundamental epistemological difference in the two practices tends to put professionals and amateurs at odds, creating a "divergence in goals"-Pro16. This philosophical difference, while not necessarily known or acknowledged by the two parties, can explain the noted issues related to trust and ethics. For example, Pro34 describes how the lack of trust may be propagated by the activities of both parties:

> The greatest barrier to productive interaction is mutual mistrust. Amateurs can be very wary of professionals and are readily intimidated. Similarly, professionals are sometimes mistrustful of collectors and do not respect their interests and motives, which are often fundamentally different from those of the professional. It is important that there be mutual respect and a recognition of common goals and interests. When an effort is made to create an environment where collectors are respected it is far easier to establish synergistic relationships that are mutually beneficial.

As a structured process that is communicated and learned via the formal educational system and promoted by professional societies, professional paleontology has developed an ethical basis and set of procedures that are intended to protect the knowledge and objects produced by the activity of paleontology. For example, this includes the proper permitting, documentation and eventual donation of all scientifically significant fossils to a museum (SVP Ethics Committee 2014). Professionals typically expect amateurs to operate within the ethical framework of formal science. As Pro25 describes, for professionals, the ethic differences are perceived to relate to dire consequences "…interests of amateur collectors is a difficult barrier to overcome; they have everything to gain and I have everything to lose in interactions." However, amateur paleontology—by nature an informal activity—lacks such a formal process or centralized ethical basis or authority (i.e., groups and individuals are free to define and operate on their own set of ethics). Thus, paleontology, as a formal practice, stands at odds with many of the activities of amateurs and results in secondary issues that on the surface, appear to be the result of a lack of communication, but in actuality, may be rooted in the philosophical underpinnings of the two practices. Many professionals—as well as amateurs—cite commercial collecting (i.e., the sale of fossils) as a prime example of this dissonance.

Museums were cited by both parties and described in ways that suggest they can play a fundamental role in supporting any relationship between amateurs and professionals. For example, all but two groups reported having a relationship with a museum that revolved around: a) amateur and professional collaboration (e.g., research activities), b) sponsoring joint ventures (e.g., fossil fairs or exhibits) or participating in a museum event (e.g., provide displays), c) volunteering (e.g., basic museum operations) and d) donation of specimens. Most professionals who responded to the survey were already affiliated with at least one museum and described their collaborative work there in forms that are consistent with the interests of fossil group members. Professionals and amateurs alike value and participate in disseminating the results of their activities as a well as outreach and recruitment. In addition, museums develop and offer programming that can potentially incorporate the activities of amateurs and professionals as well as recognize their contributions and expertise. Because of their mission and audience, museum events can promote amateur collecting as well as the formal science of paleontology.

The activities and themes that were identified through analysis of this survey data are evidence for the potential of a shared practice that supports a distributed, online CoP composed of amateur and professional paleontologists. To achieve this end, we distill the findings into design principles (Bell et al. 2005; van den Akker 1999), or specific guidelines and heuristics that define the characteristics and procedures of a CoP.

Design Principles for an Online CoP for Paleontology

To design an online CoP composed of amateur and professional paleontologists, three design principles are proposed. Each design principle is buttressed by a collection of propositions that emanate from a combination of the results of this study as well as the existing literature related to successful CoPs. These principles were developed in order to address the elements described by Hoadley and Kilner (2005) that define how knowledge is generated in a CoP: *Content*—the shared knowledge repository, *Conversation*—the two-way exchange of information that represents the knowledge transfer and generation, *Connections*—the interpersonal contacts among people that represent relationships, *Information Context*—the circumstances related to information that is used to determine its

relevance to the CoP and *Purpose*—the reason that people associate with the CoP. In our description of each design principle, we attempt to distinguish the activities of the CoP from the technology that would be used to enact and support it. Recognizing that in context, these elements often blend together and become indistinguishable (Wenger, White and Smith 2009).

Design Principle 1 Honor amateur collecting and professional paleontology by supporting individual and collaborative practice related to the full range of inquiry.

This principle is intended to respectfully recognize and define the attributes of and engagement with a shared practice residing in the expressed mutual interests and commitment to inquiry, learning and collaboration, one of the essential elements for a successful CoP (Wenger et al. 2002). By improving the capacity to collaborate and disseminate findings of a shared practice, the online CoP would directly support the mission statements of most fossil groups as well as the work of paleontologists. Fossil groups indicate a strong interest, valuable experience and capacity for engaging in fieldwork. Via collaborative inquiry with other members, this potential volunteer workforce could boost the research capacity of paleontologists. In addition to the potential for knowledge gains, engaging the public in this fashion can serve the CoP by expanding and diversifying the demographics of the participants, a long-term goal of fossil groups and professionals. Since amateurs and professionals operate from very different backgrounds, interests and motivations, open communication and mutual education are critical attributes of this principle.

This principle implies a knowledge sharing and knowledge building conversation. The themes of geology and evolution expressed through the fossil record would be key ideas for organizing and seeding this conversation (Fig. 2). Such forms of collaborative discourse would encourage engagement and participation, make the production of scientific knowledge explicate and accessible, and allow participants to reflect on science as a way of knowing. These attributes have been recommended for informal science learning environments (NRC 2009) and can be supported with technology (Lin et al. 2009). Thus, this design principle provides the basis for the process of legitimate participation (sensu Lave and Wenger 1991) by affording entry into the community as well as access to structures that can support the building of trust and identity with the practice (Hoadley 2012).

Technology has an important role to play supporting the forms of communication and education that are associated with a shared practice. Pursuing this as an avenue for the CoP is supported by the high degree of Internet access reported by survey respondents. Using technology, members could propose or solicit challenges or problems for the community to address collectively. To encourage teamwork and democratic collaboration, the participation of members in these activities, whether it be collecting and digitizing fossils or tagging and discussing the images of others, may be prominently recognized and promoted (Dickinson et al. 2012). The result of this collaborative problem solving could be made available for other members to explore and learn from, or be used as a promotional tool for encouraging membership (Gutiérrez 2008; Rubin and Doubler 2009).

Information sharing should be encouraged with forms of technology that allow for hyperlinking to existing social media outlets such as Facebook that the majority of potential members report using. This continued sharing and re-sharing of information would increase avenues for and degrees of individual participation while also providing the community with new information (Muller 2003; Rubin and Doubler 2009). The technology should afford the use of rich media such as photographs and videos and the sharing of newsletters with other groups and to all members of the community (Gutiérrez 2008). This design principle improves the accessibility of the communication, practice, and cultural tools and products, providing a window into the practice (Wenger et al. 2009).

To successfully enact this principle, the online CoP needs to increase awareness and conversation related to the differences between the cultures and practices of amateurs and professionals while supporting a shared practice that is accessible and explicit. Such an emphasis will help to address the documented issue of trust and misunderstanding. This implies social learning opportunities related to collecting and understanding formal paleontology along with recognition of expertise (Eveleigh et al. 2014; Everett 2011; Wenger et al. 2002). This includes training to build knowledge and skills, as well as new opportunities to contribute to a range of activities that serve the community's purpose. For example, the CoP could provide *amateur development* (analogous to professional development) on topics such as organizing and maintaining a collection or identifying and cataloging types of fossils, thereby helping amateurs maximize the scientific value of their collections (Kienle and Wessner 2005). Traditional forms of communication, like newsletters, need to be maintained and recognized alongside newer forms, such as social media. The participation of members in shared practice, like digitizing collections or collective community challenges, needs to be recognized and highlighted appropriately (Hoadley and Kilner 2005; Muller 2003). In addition to contributions to the science of paleontology, this recognition also includes contributions to the interests, focus and purpose of the CoP, such as developing strategies for recruitment or models and materials for working with schools.

Free information and resources should be made available for guests (i.e., those who are not formal members) and structures, and strategies are needed to encourage their transition to membership (Everett 2011). The free resources, such as K12 lesson plans and materials for outreach in informal settings, should reflect the values, practice and diversity of the CoP. Members should be encouraged to create personal stories, including virtual field trips with digitized fossils, and to provide feedback to other members on their contributions (Eisenhart and Edwards 2004; Muller 2003). The stories and interactive field trips support the interests of CoP members while offering a vicarious and interactive experience for guests. Digitized fossils (images and scans) are the key scientific specimens that provide a foundation for this online CoP.

Design Principle 2 Support the documentation, identification, cataloging and sharing of digitized fossils as valid, interactive forms of scientific data.

This principle recognizes the objective importance of fossils, related contextual information and skills associated with providing relevant digital information for the purpose of the online CoP. From an epistemological point of view, fossils represent the central objective knowledge of the CoP. Providing high quality and sharable digitized forms of these objects is critical for building scientific knowledge. Though physical fossils will continue to be of significant importance to the CoP, the results of this study suggest that amateurs and professionals alike are interested in the digitized form, indicating an understanding of the utility of such a form for identification and curation.

To successfully enact this principle, technology must support the language and representations of digital curation (i.e., digitization), a recent shift in paleontology and informatics (Higgins 2011). This includes the ingestion of digitized fossil specimen data, comprising taxonomic classifications and geo-referenced locales as metadata. Informed by the findings and coupled with predictions for the rapid evolution of technology, digitization should be supported for any form of networked computing device (e.g., tablets, smart phones) (Johnson 2001; Johnson et al. 2013).

CoP members must be able to add and use digitized fossils to construct personal collections that can be shared within the community and beyond. In order to have the potential for contributing to the big data initiative for paleontology (Zgorski 2012), the digital fossils should be constructed using the formalized protocols of paleontology. In this way, the CoP could add to the related *iDigBio* Project that is attempting to aggregate 100 million digitized fossil specimens (images and related data) in the collections of U.S. natural history museums (non-federal) (http://www.idigbio.org/). Technology could be used to provide training for CoP members (e.g., workshops, webinars) to build and improve their skills. The community could recognize and encourage this practice with formal credentials, such as certificates and badges (Wenger et al. 2002). Having the capacity to share and repurpose digitized fossils and other forms of community knowledge is a core requirement for affording community growth and knowledge creation.

Design Principle 3 Support the discovery of new relationships among participants, institutions, information resources, physical specimens and geographic location.

This principle is intended to build the connections among CoP members, the locations of their work and the scientific specimens that facilitate shared practice. The lack of such connections is recognized as one of the primary reasons for CoP failure, and enacting this principle addresses the survey finding that existing fossil groups have only limited contact with other groups and with paleontologists (Probst and Borzillo 2008). This principle would build the CoP network by increasing the number of connections while strengthening existing ones. It also would emphasize connecting the CoP to other networks with similar interests or attributes, forming a community of communities (Gongla and Rizzuto 2001).

Technology has an important role to play in better connecting members, locations and scientific specimens. The technology must be deployed such that it creates a unique site of work (Bhabha 1994; Gutiérrez 2008) and clearinghouse for the community's knowledge building activities (Eisenhart and Edwards 2004; Muller 2003). This unique site of work should highlight the attributes of common practices and facilitate the transition from amateur to professional. As a repository of content products, the technology should provide access to past and current newsletters, guest speaker information, video material that includes lectures on current topics of paleontology, interactive field guides for locations of interest, protocols for activities (e.g., fieldwork, digitization, working with schools) as well as information pertaining to the ethical and legal dimensions of fossil groups (Eveleigh et al. 2014). This information should be presented so it demonstrates the formation of shared goals among members, recognizes the different forms of expertise involved in creating the resource, affords communication about the resource and encourages and recognizes participation in the shared practice (Hoadley 2012; Wenger et al. 2002).

Members should be able to find, contribute, discuss and share information socially by rating or tagging the contributions of others (Azevedo 2012; Muller 2003). According to the findings from the survey, amateurs are interested in learning from guest speakers and finding other locations to dig fossils. Professionals are motivated to share their

interests and enthusiasm for paleontology with amateurs. For both groups, connections among these interests can be enhanced using technology. Participation in the digitization of both public and private collections is a vehicle for public participation in science. The technology should afford discovery by matching members with information based upon shared attributes (Everett 2011). This principle could then support any subsequent learning practices resulting from the discovery of related elements.

Maps are another significant cultural artifact for the CoP, and a digital version can be generated nearly instantaneously with technology. Using the metadata that is included by addressing Design Principle 2, technology affords new connections to be made among people, institutions and scientific specimens. Using metadata, the results of a member-initiated search and/or computational matching of elements (e.g., members to members, members to institutions, members and institutions to specimens and information resources) could be displayed visually on a map. In essence, a virtual map with geo-located people, information resources and specimens could serve to mediate the shared activities of the CoP. Thus, participants can find each other by interest, location or some other shared attribute (Rubin and Doubler 2009). For example, groups could discover other groups with similar interests or issues, professionals could discover amateurs in specific locations, and amateurs could find professionals with expertise related to certain types of fossils or find projects to help with (Probst and Borzillo 2008; Wenger et al. 2011).

Finally, it is important to note that we view these design principles as theoretical knowledge and thus subject to refinement and modification with additional evidence—in particular, trace evidence of actual member activity as well as specific feedback from amateur and professional paleontologists about design choices related to technology. Such evidence may allow us to further disentangle and distinguish the activities of the CoP from the technology and to understand how the purposeful integration of the two has afforded or constrained the evolution of the online CoP.

Conclusion

The results of this study contribute to the fields of paleontology and science education in two very important ways. First, they offer a more robust understanding of the participants and forms of participation that lie along the continuum of formal and informal science learning in the domain of paleontology. Second, with the three design principles developed and discussed above, we have a greater capacity for supporting collaboration and fellowship via a coherent shared practice within an online workspace. This is particularly important for more effectively engaging amateur paleontologists in scientific research and thus contributing to our understanding of past life on Earth. The next phase in our development of a CoP involves selecting and developing technology that supports the design principles in an online environment in order to create what Wenger et al. (2009) define as the digital habit, "where community and technology intersect" (p. 11). With the increased volume, coordination and focus that is afforded by a highly functional CoP in a digital habitat, tremendous potential exists for increasing: (a) meaningful scientific discovery, (b) the number and quality of informal science experiences for amateurs, (c) the value of outreach activities related to paleontology and (d) the diversity of participants engaged in the science of paleontology.

In addition, this research also has the potential to inform other efforts to build collaborative communities that blend the practices of formal and informal science learning and engage the public in scientific research. Some of the critical issues to be addressed include the optimal mechanisms for promoting dialog and building networks among those with similar interests, effective practices in engaging the emerging community in learning broadly defined (e.g., science and outreach) and how to balance the need to value informal practice while simultaneously increasing participation in, as well as contributions to, formal science.

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Appendix

Survey for Fossil Groups

1. What is the name of your fossil club? How long has it been in existence? {demographics}
2. How would you describe the mission and/or purpose of your fossil club? Or, if you have a written mission statement, include it here. {demographics}
3. If there is a club website, please provide the URL. {forms of communication}
4. How often does your fossil club meet? {demographics}
5. Approximately how many members belong to your fossil club? {demographics}
6. What is the approximate age of your youngest member? Your oldest? {demographics}

7. Please estimate the percentage of your club members that fall into the following age categories. {demographics}
8. What percentage is male and female? {demographics}
9. Please estimate the percentage of your members that fall into each of the categories listed below. {demographics}
10. Please rate the cultural and ethnic diversity of your fossil club. {demographics}
11. Please share your ideas for ways to reach out to various groups and expand membership in fossil clubs. {forms of communication}
12. What percentage of your members would you estimate use email and/or the Internet? {forms of communication}
13. What kinds of fossil-related Internet resources do your members use? {forms of communication}
14. Of the names below, what do you think would be the preferred way members of your club would like to be referred to? {demographics}
15. Do many of your club members maintain their own personal fossil collections? If so, what would you describe as the reason(s) for their collections? {current activities}
16. What kinds of activities does your club coordinate? {current activities}
17. What percentage of your members would you estimate use your website? {forms of communication}
18. How do members of the club typically communicate with one another and how is information shared among members? {forms of communication}
19. Does your club include or have an association with any professional paleontologists? {professional relationships}
20. What role(s) do the professional paleontologists play in your club? {professional relationships}
21. Does your fossil club have a relationship with a museum or other informal science institution (e.g., nature or science center)? {professional relationships}
22. Please describe the nature of the relationship between your club and the museum or other informal science institution. {professional relationships}
23. If professional paleontologists were more accessible to the club, how would you envision their participation in club activities? {professional relationships}
24. Do you think there are barriers to interactions between professional paleontologists and fossil clubs? If so, briefly describe those barriers and suggestions for how they can be overcome. {professional relationships}
25. Please rate your members' knowledge of the topics below. {demographics}
26. Please rate your members' interest in the topics below. {demographics}
27. One of the goals of the FOSSIL project is to network fossil clubs. Does your club currently coordinate any activities with other fossil clubs? {professional relationships}
28. Please indicate the kinds of joint activities your fossil club does with other clubs. {professional relationships}
29. How do you currently communicate with other fossil clubs? {forms of communication}
30. Please give us your ideas for the ideal methods of communication between your fossil club and other clubs. {forms of communication}
31. Do you see any potential benefits of joining a network of fossil clubs? Any drawbacks? {potential CoP activities}
32. How interested do you anticipate your club would be in joining a network (envisioned to be no cost) of fossil clubs? {potential CoP activities}
33. Another goal of the FOSSIL project is to network fossil clubs to provide access to online ("digitized") specimens and their related data from museum collections. Would your members be interested in accessing these resources? If so, how might you envision your club using them? {potential CoP activities}
34. Below are other possible activities that the FOSSIL project could support. Please rate your members' likely interest in each. {potential CoP activities}
35. The FOSSIL project plans to develop a website with a focus on communication and networking with fossil clubs, plus have a link to fossil collections on line. What kinds of things would you like to see on the home page of this website? {potential CoP activities}
36. In addition to the FOSSIL website, we are considering developing an e-newsletter that would be sent, for free, to interested members of fossil clubs. How interested would your members likely be in receiving and/or contributing to this e-newsletter? {potential CoP activities}
37. One FOSSIL project activity might be an annual meeting for fossil clubs and professional paleontologists with expenses paid for one representative from participating clubs. How interested would your club be in sending a representative? {potential CoP activities}
38. What kinds of activities would you like to occur at this annual meeting?{potential CoP activities}
39. Another FOSSIL resource may be interactive, web-based video seminars (webinars) for fossil clubs.

How interested would your club be in web-based video seminars? {potential CoP activities}

40. Please share any other suggestions and or comments you may have regarding the FOSSIL project. {potential CoP activities}

Survey for Paleontologists

1. How many years have you been a professional paleontologist? {demographics}
2. Briefly describe your position and/or the nature of your work. {demographics}
3. During your time as a professional paleontologist, have you interacted with fossil clubs and their members? {professional relationships}
4. Please indicate your role with the club or clubs with which you have interacted. {professional relationships}
5. How would you rate the extent of your involvement with fossil clubs and their members? {professional relationships}
6. What aspects of your interactions with fossil clubs and their members do you find most rewarding? Least rewarding? {professional relationships}
7. What is/are the name of the club(s) with which you have had either the most recent, or most extensive, interaction? {professional relationships}
8. How would you describe the leadership of the club or clubs? {professional relationships}
9. Please rate the cultural and ethnic diversity of the fossil clubs with which you interact. {professional relationships}
10. Are there specific reasons (e.g., lack of time, geography, philosophical differences) that have kept you from engaging with fossil clubs? {professional relationships}
11. Do you think there are barriers to interactions between professional paleontologists and fossil clubs? If so, briefly describe those barriers and suggestions for how they can be overcome. {professional relationships}
12. Please share your ideas for ways to reach out to various clubs and expand membership in fossil clubs. {professional relationships}
13. Are you affiliated with a museum? {professional relationships}
14. Which of the following best describes your museum? {professional relationships}
15. Are you a curator and/or manager of a paleontology collection of any kind? {current activities}
16. What kind(s) of collection(s) do you curate or manage? {current activities}
17. What is the approximate size of the collection(s) that you list above, in terms of total number of catalogued and/or uncatalogued specimens or lots? {current activities}
18. How much of your collection(s) is/are available in a searchable format on the web? {current activities}
19. If a set of the club members were properly trained, do you think they could help an effort to digitally catalog your fossil collections? {potential CoP activities}
20. Do the fossil club members you are associated with have the opportunity to visit or access the physical collections at your museum? {current activities}
21. Do any of the club members currently volunteer in your collection, or assist with related activities (e.g., field work)? {current activities}
22. Please estimate the number of volunteers that work in the collections or assist in other ways each year or the most recent year (2012). {current activities}
23. Please estimate the number of hours in total volunteers contribute to your paleontological program over the course of one year. {current activities}
24. What kinds of tasks do your volunteers perform? {current activities}
25. Do you work with university students? {current activities}
26. Do the students participate in activities with the fossil clubs and their members? {current activities}
27. Do the clubs ever provide financial support (e.g., small grants, scholarships) for these students? {current activities}
28. Briefly describe the kind of financial support the clubs provide for students. {current activities}
29. Given the goals described at the beginning of this survey, would you be interested in participating in the FOSSIL project–at an appropriate level given your other professional activities? {potential CoP activities}
30. Please rate your level of interest in participating in the possible FOSSIL activities listed below. {potential CoP activities}
31. One FOSSIL project activity might be an annual meeting for fossil clubs and professional paleontologists with expenses paid. How interested would you likely be in participating? {potential CoP activities}
32. The FOSSIL project team is considering developing an e-newsletter that would be sent, for free, to professional paleontologists and interested members of fossil clubs. How interested would you likely be in receiving and/or contributing to this e-newsletter? {potential CoP activities}
33. The FOSSIL project plans to develop a website with a focus on communication and networking with

fossil clubs, plus have a website link to fossil collections on line. What kinds of things would you like to see on the home page of this website? {potential CoP activities}

34. Please share any ideas you may have for other activities we might include in the FOSSIL project. {potential CoP activities}
35. Please describe any other potential ways you think professional paleontologists might engage fossil clubs. {potential CoP activities}
36. Please share any other suggestions and or comments you may have regarding the FOSSIL project. {potential CoP activities}

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