

Knowledge sharing and boundary conditions within the virtual community: an examination of free and open-source software communities

Juana Du

School of Leadership and Management, Royal Roads University

Email: Juana.Du@royalroads.ca

Hanqing Ding

School of Journalism and Communication, Beijing Normal University

Email: dinghanqingdhq@qq.com

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Abstract

This paper examines knowledge-sharing practices among professionals in the virtual community. It emphasizes the concept of knowledge boundaries and explores the mechanism of knowledge sharing across boundaries within the free and open-source software community. By applying *Bona Fide Group Theory* from a communication perspective, this research identified several key contextual and social factors that impact boundary conditions and knowledge sharing practice. The findings explain the mechanism of interdependence and the impact of contextual and social factors that impact knowledge sharing, an area that has not been studied thoroughly due to its unique nature and emerging complexity of virtual communities. It offers fresh insights into task interdependence and knowledge sharing across the pragmatic boundary with a virtual community, particularly given the advancement of AI technology which reshapes the novelty of knowledge boundary. This research findings offer several important practical implications. First, it highlights the important communication mechanism and its impact on members' commitment to the community. Second, it suggests the need to establish communication protocols with effective tools to accommodate the novelty of boundaries. Third, developing a comprehensive understanding of permeate boundaries helps community members to better collaborate and engage in knowledge-sharing practices. Finally, it suggests establishing sustainable practices and interactions within the virtual community and embracing a positive community culture.

1. Introduction

Scholars have addressed the importance of managing knowledge across boundaries in driving innovation and creative outcomes (Nonaka, 1994). Managing knowledge practices across boundary conditions in virtual communities is vital for fostering collaboration, enhancing knowledge sharing, building trust, and driving innovation. Particularly, researchers have devoted to understanding knowledge transfer across pragmatic boundary conditions, which refer to the specific situational factors that influence how knowledge is shared and utilized. By understanding these boundary conditions, researchers can identify what contextual elements facilitate or hinder effective knowledge transfer, leading to more targeted strategies for improvement and contributing to the overall growth and dynamism of the virtual community.

This research paper examines knowledge sharing practices among professionals in the free and open-source software community. It emphasizes the concept of knowledge community by applying Bona Fide Group Theory (BFGT) and explores the mechanism of knowledge sharing across pragmatic boundaries within the virtual community. From a cross-cultural perspective, this research identified several key contextual and social factors that influence knowledge sharing practices within virtual community. This research offers several important practical insights.

2. Theoretical framework

This research project adopts the Bona Fide Group Theory (Putnam & Stohl, 1990) which features two elements of small groups, including permeable boundaries and group interdependence within its contexts. It provided a framework for understanding the interactions and collaborations within naturally formed groups with special characteristics, such as fluctuations in group member commitment and a shared sense of boundaries (Putnam & Stohl, 1996; Stohl & Putnam, 2005). BFGT posits that bona fide groups operate within environments characterized by permeable boundaries. These boundaries allow for the inflow and outflow of members and information, which is essential for the adaptability and resilience of the group. Permeability facilitates dynamic membership and resource exchange (Stohl & Putnam, 2005). Further, BFGT highlights group interdependence which refers to the mutual reliance of group members on one another to achieve common goals. This feature is crucial for fostering collaboration and cohesion within the group. BFGT recognizes that member commitment is not static but rather fluctuates over time based on various influences, including personal circumstances, group dynamics, and external factors. BFGT provides a nuanced framework for understanding the complexities of naturally formed groups, acknowledging the dynamic nature of group membership, the importance of shared goals, and the challenges of fluctuating commitment. It offers

valuable insights into the functioning of groups in diverse contexts, particularly in relation to emerging trends in virtual collaboration and global networks.

Built upon this framework, this research delineates the mechanism of knowledge sharing and how the knowledge transfer practices impact member interaction and coordination within the free and open-source software community. Particularly, it studies how daily communication and collaboration within the community has been shaped by the recent development of AI technology. The results shed lights on the interdependent nature of the tasks within this shared context of knowledge transfer.

This research provides empirical data to advance the current understanding of Bona Fide Group Theory, and examines its impact on knowledge sharing practices across pragmatic knowledge boundary in the virtual community.

2.1 Knowledge transfer and pragmatic boundaries

Knowledge transfer is an intricate process through which knowledge actors purposefully learns from another. It consists of a series of sub-processes including search, access, assimilation and integration. Studies examined different approaches to manage knowledge transfer across boundary conditions to achieve innovation (Carlile, 2002, 2004). Three progressively complex boundary conditions have been identified: syntactic, semantic and pragmatic (Carlile, 2004). Transferring knowledge across syntactic boundaries requires the establishment of a shared and stable syntax to enable the processing of information; Within conventional organizational research, this approach to boundary spanning has been dominant, resting on the assumption that increased information and communication invariably enhance knowledge transfer. In contrast, transferring knowledge across semantic boundaries requires considerations of individual and context-specific aspects of knowledge creation (Nonaka and Takeuchi, 1995). The third perspective, the pragmatic approach, emphasizes the importance of understanding differences in the practices of actors involved in knowledge transfer and the consequences of these differences, which may give rise to additional costs (Van der Meer et al., 2013). This approach further underscores that knowledge is embedded and localized within practices, drawing on Polanyi's insight that tacit knowledge resides in the performance of activities. It also assumes that conditions of difference, dependence, and novelty are simultaneously present and necessary within the broader process of transforming existing knowledge. Consequently, the pragmatic boundary represents the most complex context, within which creative outcomes are most likely to emerge (Du & Wang, 2019). Therefore, knowledge transferring across pragmatic boundaries calls for a more engaged and deeper sharing to better suit the specific situation, rather than a simple transfer or translation of knowledge between different contexts (Carlile and Reberich, 2003).

Three complex knowledge transfer processes have been examined that suit different boundary conditions of knowledge transfer. Those are transfer, translation and transformation (Carlile, 2002).

These distinctions further indicate that the level of novelty within a situation influences the nature of boundary conditions. Novelty refers to the degree of newness or unfamiliarity perceived by individuals in a given context (Carlile, 2004). As the level of novelty increases, boundary-related challenges become more complex and difficult to address. High levels of novelty are typically associated with pragmatic boundaries, whereas

moderate and low levels of novelty correspond to semantic and syntactic boundaries (Du & Wang, 2019).

Discussions of pragmatic boundaries emphasize that managing knowledge transfer across such boundaries necessitates the creation of new knowledge (Carlile, 2004; Du & Wang, 2019). Consequently, existing knowledge at the boundary must be negotiated and transformed. The development and maintenance of such complex transformation processes are inherently challenging, as they require actors to identify and represent differences and dependencies across domains. Crossing pragmatic boundaries thus entails that all involved actors recognize these differences and interdependencies, negotiate alternatives, and collaboratively transform existing knowledge to support solution development (Carlile, 2002, 2004).

From this perspective, scholars advocate for a repetitive and iterative approach to building boundary capacity. This process involves experimenting with new alternatives, testing knowledge in practice, and accepting that certain forms of knowledge may be discarded (Carlile, 2004). As a result, knowledge at pragmatic boundaries evolves into a "transformed mixture" composed of elements considered valuable and consequential within a specific context (Carlile, 2004, p. 559).

This body of literature further underscores that the approaches of knowledge transfer must be aligned with the type of boundary encountered. Under conditions of novelty, knowledge actors often attempt to reuse existing knowledge due to pressures for efficiency. However, such tendencies frequently result in mismatches, as novelty is difficult both to recognize and to articulate. These mismatches are exacerbated when one group perceives novelty but is unable to convey its implications to others. Addressing this challenge requires groups to actively construct and explore knowledge gaps, whereby practical capabilities are integrated with efforts to transform and generate new knowledge at the boundary (Du & Wang, 2019).

This issue becomes more significant in virtual community where there is a high degree of uncertainty and risk taking in knowledge transformation processes of professionals. Members of distributed teams as knowledge actors often need to share knowledge across geographic, cultural and linguistic boundaries, which all contribute to the level of novelty of boundary conditions. Those differences are often associated with asynchronous communication channels, a variety of platforms and different practices, which as a result, increases the novelty of knowledge boundaries.

2.2 Communication mechanism in virtual teams

Scholars proposed Bona Fide Group Theory to study group dynamics from a communication perspective (Putnam & Stohl, 1990). This conceptualization provided a framework to develop a comprehensive understanding of the interactions and collaborations within naturally formed groups with special characteristics. Those features include fluctuations in group member commitment and a shared sense of boundaries (Stohl & Putnam, 2005). According to this theory, Bona Fide Group have three unique features. First, it examines groups with permeate boundaries, in the sense that group boundaries are permeable as membership changes regularly, and internal dynamics are influenced by the social context; Second, it highlights the feature of group interdependence, which captures the dynamics that groups relay on and are influenced by their surrounding environment. For instance, other groups or organizational

structures may provide resources or define tasks for studied groups; Third, members of Bona fide Group are often members of multiple groups simultaneously, and this creates competing loyalties and influences how they act in any given group.

From a communication perspective, Bona Fide Group principles are used to study how communication shapes a group's ability to make decisions, manage conflicts and socialize new members. It also provides a way to look at how group identities are formed and maintained within larger organizational and community context and could be extended to study communication and coordination among task-oriented teams or virtual teams. In this study, we have drawn upon Bona fide Group theory which captures the unique dynamics of task-oriented groups in free and open-source community, as professionals naturally form groups to provide solutions on given issues and tasks. Those groups will dissolve once the tasks are completed and group members are usually associated with multiple groups simultaneously.

To develop a comprehensive understanding of the complex knowledge boundary conditions and approaches of knowledge sharing in virtual community, given the unique features of task oriented virtual teams, this research examines the following research questions:

RQ1. What particular features of boundary conditions and knowledge transfer approaches have been demonstrated in the context of virtual teams and community?

RQ2. What is the communication mechanism for knowledge transfer given the identified boundary conditions of the virtual community in the age of Artificial Intelligence? RQ3. What contextual factors impact knowledge transfer in the context of free and open-source software community?

3. Methodology

3.1 Data collection

The authors conducted 30 semi-structured, in-depth interviews with professionals working within free and open-source software communities worldwide. The interviewees all have been working in the areas of geographic information systems, data science, and information technology. All of them have bachelor's degrees, and several of them have post-graduate degrees. The first round of interviews is conducted in face-to-face settings during the 2025 Euro free and open-source software for geospatial (FOSS4G) conference in Mostar, Bosnia and Herzegovina. The second round of interviews are conducted online. Each interview lasts from 60-80 mins. Interviewees are asked about the communication and collective experiences of collaborating with working professionals working with FOSS4G technologies. Particularly, the individual motives and collaboration experiences from the cross-cultural perspectives are examined. Questions around the impact of recent advancements in AI technologies on virtual work collaboration and community building are explored. Further, interviewees were also asked to describe their experiences in the free and open-source software community and how their personal experiences impacted their perception of community and community culture.

3.2 Data analysis

All interviews are conducted in English and recorded with the consensus of interviewees. The interview transcripts are analyzed with the software of MAXQDA. Emerging themes are identified from initial data analyses. Several propositions are further developed with those main themes and discussed in the following session.

4. Findings

The research results contribute to the current literature of knowledge sharing and, particularly, to the current understanding of boundary conditions and knowledge transfer approaches in the context of virtual communities. First, the results highlight several contextual and social factors which impact knowledge sharing across different boundary conditions in the context of free and open-source software communities. The findings explain the communication mechanisms of knowledge transfer and the impact of contextual and social factors that impact knowledge transfer approaches and practices. Second, it offers fresh insights looking into task interdependence and permeate boundary of virtual teams from the perspective of Bona Fide Group Theory, and extend the conceptualization to the virtual teams. Finally, the research findings examine the impact of the recent advancement of AI technology on coordination mechanism in this virtual community, and identify trust in AI as an important factor impacting knowledge transfer.

Several propositions have been developed around the main themes and are discussed below.

4.1 Proposition 1. Pragmatic boundary with a high degree of knowledge novelty provides the condition for knowledge sharing in the virtual community.

From in-depth interviews, emerging themes describe the high novelty as an important feature of boundary condition in knowledge transfer practices in the virtual community. Professionals from free and open-source software community are working online world widely and collaborating on team projects daily. The geographic dispersions usually mean that professionals must work in different time zones and often it is challenging to coordinate synchronous communication and online meetings. As a result, a variety of online communication tools are used to coordinate daily tasks. Those communication tools provide both synchronous and asynchronous communication opportunities, which help the professionals, as knowledge actors, to present and discuss their questions via multiple formats. Although it is a common practice to respond to an inquiry regarding programming and software tools, often those questions are complicated in nature, as it involves developing and applying the programs in a new knowledge context. Therefore, there is a high level of novelty associated with the knowledge transfer across the boundaries. For instance, one of the interviewees described her experiences of sharing knowledge as below:

"We used GeoServer tools for open map developing for my community in Tanzania during the time of flooding. GeoServer is an open-source server written in Java that we can share and edit geospatial data to get maps. I am a community developer rather than a programmer and feel we are benefited by using those open-source tools. I ask questions online and could get quick responses which helped my community work."

This knowledge transfer practice of applying the GeoServer tools requires to generate new knowledge to understand the world by generating open maps for community. The new context of applying knowledge involves high novelty, which requires understanding the differences in practices of actors (e.g. community developers in Tanzania) and the consequences of knowledge transfer (e.g. to generate open maps in flooding time). To effectively manage knowledge transfer across pragmatic boundaries in this case, it calls for a more engaged approach of knowledge sharing, rather than a simple transfer or translation of knowledge between different contexts (e.g. the context of developing knowledge of GeoServer tools and the context of

applying the knowledge of GeoServer tools). This knowledge sharing practice is quite common in the virtual community, given the differences between local contexts that the knowledge actors are situated.

Due to the high level of novelty presented at the pragmatic boundary conditions, knowledge actors are required to commit significant resources (e.g. time in this case) as there is often risk (e.g. failure) involved in the knowledge transfer practices. The process of transferring knowledge across a pragmatic boundary is a dynamic and complicated one, as actors in different local contexts might have multiple and even contradictory interpretations, which could result in equivocality and ambiguity. The lack of understanding cannot be addressed by simple practices alone; instead, it necessitates an iterative process of continuously developing and shaping alternatives in response to evolving circumstances. Therefore, developing an iterative and interactive process to help reduce ambiguity and equivocality at pragmatic boundaries is essential.

4.2 Proposition 2. Task-interdependence serves as a communication mechanism in the virtual community, which brings group members to exchange knowledge across pragmatic boundaries.

One of the most important features of this virtual community is that professionals often form task-oriented teams to work on a solution or project. In this sense, the daily communication and coordination are largely organized around a particular task which creates interdependent working relationships among those professionals located geographically dispersedly. Members working on the tasks often need to meet a specific goal collectively and are under time pressure. As a result, the team members exchange information and knowledge across pragmatic knowledge boundaries on a daily basis. This task interdependence feature facilitates communication among team members by creating a shared context to exchange knowledge to complete the specific goal. It also serves as a mechanism to bring talents and resources together which reduced the level of risks in the process of knowledge transfer.

As one of the free and open-source software developers described:

“Working on an open-source software project team helps to pull resources, get access to talents and we can better combine resources as a way to share the risk. Working with professionals from different parts of the world often lead to better social impact as our project may serve a particular goal for the locals.”

This shared context facilitates knowledge transfer among professionals as knowledge actors, as they share similar knowledge backgrounds and professional experiences. Using the same type of professional language also help to overcome the communication barriers due to the cultural and linguistic diversity presented in those task-oriented teams. The high level of task-interdependence also leads group members to establish communication protocols and use shared communication platforms. This also contributes to creating shared context to facilitate knowledge transfer among professionals in this virtual community.

4.3 Proposition 3. Common interests and professionalism created a dynamic context for knowledge sharing practice, given the high novelty feature of pragmatic boundaries

During the interviewees, “open”, “collaborative” and “professionalism” have emerged as the most common themes for those professionals to describe their experiences working in the free and open-source software community. This represents the unique nature of free and open-source software work, that applications are free to use and the source code is available for anyone to view, modify and distribute. Those themes also reflect the perceived community culture that has connected and brought professionals to work within this virtual community. Underlying this community culture is the common interests in innovative practices which were shaped by professional values that constitutes the context for knowledge transfer to cross the pragmatic boundaries. Those shared values are aligned with the open and collaborative principles that benefits everyone, and creates a vibrant community spirit that encourages benevolent behaviours and mutual communication. Those serve as the foundation to develop communication protocols and norms for sustainable practices.

One of the new members who just started to work within this community described her experiences to learn about the expectations and working manners:

“I think it is professionalism that serves as the shared assumptions for us to work collectively online. We expect and also assume that once an inquiry is made, an answer or solution from a community member will be posted in a timely manner. This helps to reduce the uncertainty by working with individuals across cultural and geographic boundaries. Although many of us have multiple memberships with groups and associations, and no matter what workplace culture we are part of professionalism hold us together and create a shared sense of responsibility that we are working on common good for the society and community.”

Those points have been repeated by interviewees, as the assumption of professionalism serves as a norm of practice that invites actors to openly share knowledges. As a result, professionalism as a community practice embraces professional identities of individuals working with free and open-source software community. This also make community members to further commit to the work for common good, as they may face tension between volunteer-based work and employer-initiated tasks. As one of the interviewees puts:

“Sustainable community practices is one of the major issues we are facing nowadays. How to invite more young members to join our community requires more careful thoughts and creative approaches, particularly for those young talents to join our community.”

Although the community has developed communication protocols and working procedures over time, it is important to orient young talents to this community culture for more inclusive and sustainable practices in the long run. In addition, the underlying assumptions for professionals to openly share knowledge and practices are still lessons for young talents to learn once they join the community work.

4.4 Proposition 4. Recent advancement of artificial intelligence (AI) tools contributes to generating shared contexts that facilitate knowledge transfer, by presenting difference and dependence at pragmatic boundaries.

Interviews are invited to describe their recent experiences with AI tools during the interviews. It seems there is a very mixed voices regarding the potential impact of AI tools in the long run. It has achieved consensus that AI tools help to gather and analyse

information to improve efficiency, while concerns have been expressed during interviews as well.

One of the benefits of AI tools is to help create a shared context that facilitates knowledge to transfer across pragmatic boundaries. Knowledge actors need to present both differences and dependences of knowledge at the pragmatic boundaries. Differences in knowledge have been demonstrated in two different aspects, which include both the amount of knowledge has been accumulated and the types of domain specific knowledge accumulated (Du & Wang, 2019). As differences in knowledge increase, knowledge actors must continuously assess and share their knowledge. The dependence among knowledge actors reflects the dynamic process of knowledge sharing arising from the interdependent nature of tasks. In this context, knowledge actors must also consider the goals of others in order to create a shared understanding that facilitates knowledge transfer.

Although the results of using AI tools not always meet expectations of software developers, using AI tool helps to create a shared context of same language (e.g. write prompts to use AI tools in this case) that crossing cultural and linguistic boundaries to a large extent. In addition, using AI tools could help to solve some basic issues in a timely manner, which lead to bridging the differences in knowledge and help to transfer knowledge across pragmatic boundaries. As one of the interviewees puts:

“I used different AI tools, including ChatGPT and Gemini, to seek answers to my questions, and find it is quite helpful. Although I don’t use them directly for software development, the answers from those AI tools help me to further work on software programming and provide me some computer languages to communicate my problems with collaborators in other continents.”

4.5 Proposition 5. Trust of artificial intelligence (AI) technologies impacts coordination mechanism among professionals in the virtual community, and consequently, reshapes the knowledge boundary conditions.

Although there are mixed voices regarding the impact of advancement of AI tools in free and open-source software work and community, there is an increasing use of AI-assisted communication tools in this virtual community. Besides the benefits of using AI-assisted communication tools and platforms, interviewees commented on the enhancement of self-efficacy by using those tools, which lead individual knowledge actors to be more actively engage in knowledge sharing practices by both asking questions and providing feedback. During the interviews, interviewees also expressed their cautious attitudes towards AI technologies. Trust of AI technologies emerges as a main theme. As one interviewee described his experiences as below:

“You don’t really know whether the question was posted by a real person in front of the desktop, or it is a question generated by AI tools online as there are increasing number of junks online. It made people to doubt about how serious are those questions? I feel this may pose threats to the sincerity of engaging in community work and make people more hesitate about those questions.”

While building trust is a long-term effort, it raises questions on how trust of AI technologies could impact knowledge transfer practices within virtual teams and community. Further, trust is a context and culture-specific topic, as individuals from different

cultural origins and backgrounds may hold very different attitudes towards trust in AI. This brings further inquiries to understand the dynamic process of building trusts in AI-human interactions and knowledge transfer practices.

Another theme emerged from interviews around AI technologies deals with security vulnerability issues of free and open-source software and related practices. As one of the interviewees states:

“For free and open-source software, we depend on copyright as a legal tool to enforce our open-source licensing. When it comes to using AI, it becomes more complicated because it is unclear whether the output of using AI can be placed under copyright. Without that legal tool, we lack the power to enforce our free and open-source licenses to set up the terms and conditions of using software. In that sense, it may challenge the assumptions that the foundation of our free and open-source community was built upon.”

It is a common practice for free and open-source software developers and professionals to share and assemble source codes to capture value. The popularity of using AI and having the access to source codes offers alternative way to capture value over time, which set some competitions with free and open-source software community. It requires further studies to understand how the use of AI tools pose challenges of the current practices and assumptions of sharing knowledge in free and open-source community. Further, the involvement of AI tools may help to reduce differences in knowledge while increase dependence among knowledge actors across pragmatic boundaries, as AI tools assisted analysing and synthesizing information by bridging differences in knowledge. Meanwhile, it creates the context for more collaborations and increases dependences among knowledge actors. Therefore, it is important to further study how the involvement of AI reshapes knowledge boundary conditions.

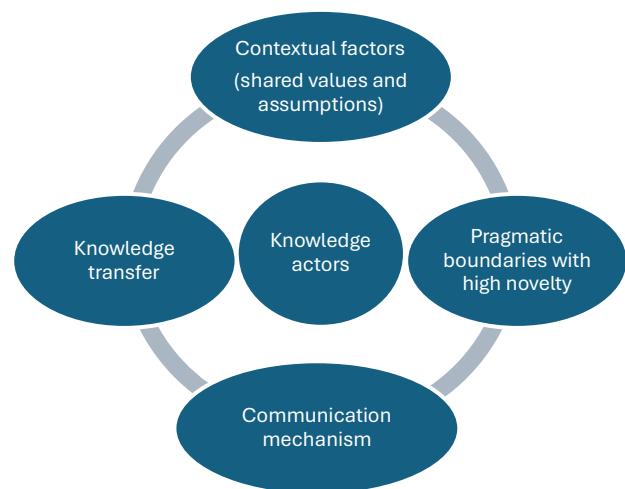


Figure 1. A conceptual model of knowledge transfer across the pragmatic boundaries in virtual community

5. Conclusions and practical implications

This research offers several important practical implications for professionals operating within virtual communities. Using empirical data collected specifically from the free and opensource software (FOSS) community, the study investigates the communication and coordination mechanisms utilized by distributed teams in a virtual environment. The findings yield several significant practical implications.

First, enhancing member commitment: The research highlights crucial communication mechanisms and their subsequent impact on member commitment to the virtual community's work. Understanding these specific mechanisms can inform strategies aimed at developing and solidifying stronger member commitment within FOSS contexts.

Second, developing adaptive protocols: The findings suggest the necessity of establishing effective protocols through appropriate communication tools designed to accommodate the inherent novelty and dynamism of virtual boundaries for knowledge transfer.

Third, fostering collaboration: A deeper understanding of the permeable boundaries inherent in virtual teams can significantly enhance community members' ability to collaborate effectively, engage in robust knowledge-sharing practices, and contribute positively to the overall and sustainable development of the community.

Fourth, improving young talent onboarding: The study advocates for providing clear roadmaps to orient new members to the virtual community. This structured onboarding process facilitates rapid learning of established community communication protocols and helps new members to learn the norms and expectations, thereby fostering a more sustainable and positive community culture.

Finally, guiding environmental design: Ultimately, insights derived from this study can serve as a practical guide for community leaders and designers in creating virtual environments that optimally facilitate effective knowledge sharing and seamless collaboration.

This research provides qualitative insights from professionals engaged in the FOSS community, elucidating the mechanisms of knowledge transfer within virtual communities. Future studies could adopt quantitative data collection methods, such as surveys, to investigate the interaction patterns of knowledge sharing across various boundary conditions. Additionally, subsequent research may explore the dynamics of knowledge transfer in different forms of virtual organizations and communities. Particularly, developing a comprehensive understanding of how interdependence is unfolded in team task settings, as well as virtual teams and communities, could contribute to current understanding of boundary conditions and knowledge transfer practice. We anticipate that future investigations will build upon the current findings and address these questions in the emerging era of AI, where knowledge practices have become pervasive across a wide range of organizational and community contexts.

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