

Being Present in Online Communities: Learning in Citizen Science

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ABSTRACT

How online community members learn to become valuable contributors constitutes a long-standing concern of Community & Technology researchers. The literature tends to highlight participants' access to practice, feedback from experienced members, and relationship building. However, not all crowdsourcing environments offer participants opportunities for access, feedback, and relationship building (e.g., Citizen Science). We study how volunteers learn to participate in a citizen science project, Planet Hunters, through participant observation, interviews, and trace ethnography. Drawing on Sørensen's sociomaterial theories of presence, we extend the notion of situated learning to include several modes of learning. The empirical findings suggest that volunteers in citizen science engage more than one form of access to practice, feedback, and relationship building. Communal relations characterize only one form of learning. Equally important to their learning are authority-subject and agent-centered forms of access, feedback, and relationship building.

Categories and Subject Descriptors

H.5.m. Information interfaces and presentation (e.g., HCI):
Miscellaneous.

General Terms

Performance, Human Factors, Theory

Keywords

Situated learning, citizen science, sociomateriality

1. INTRODUCTION

How online community members learn to become valuable contributors constitutes a long-standing concern of Community & Technology researchers. Many of these studies draw on the notion of situated learning, which emphasizes learning that is contingent on novices observing and participating in practice as well as interacting with journeymen. For example, research examines how new Wikipedia editors spend their time observing the work of other editors before participating [7, 31], how feedback from experienced editors can predict the quality of long term

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participation [19], and how newcomers' establishment of relations in free/libre and open-source software (FLOSS) projects with experienced participants impacts long term participation [23].

While many projects like Wikipedia fit nicely within such a learning framework by allowing newcomers to interact with journeymen and observe and participate in practice, this model becomes problematic when applied to online communities where there is limited access for observing practice or interacting with journeymen. We are prompted to ask how learning takes place in online communities where newcomers cannot easily interact with journeymen or observe practice and receive feedback.

To explore this question we turn to online citizen science projects where laypeople and researchers collaborate in the production of scientific knowledge. In citizen science projects, participants may gather primary data, such as bird counts in ebird.org, or classify and sort out large data sets (e.g., zooniverse.org). In the project Planet Hunters (PH), the site of our research, participants are asked to analyze light readings from stars taken by the Kepler telescope in the search for evidence of orbiting planets in distant solar systems. Unlike other online knowledge production communities like Wikipedia, participants in Planet Hunters are not able to see the work that other users have done. This lack of access to others' observations is a deliberate design by the project to ensure independent responses, eliminating the possibility that one user's classification decision could affect the decisions of other users. Furthermore, there are a limited number of journeymen in the project to guide the work of new participants. Given the inability to observe work and the scarcity of journeymen in Planet Hunters, we investigated how participants learn to contribute to the project.

Taking our point of departure in practice theory [14, 29] we combine insights from studies of learning in online communities with a sociomaterially informed theory of learning articulated by STS scholar, Sørensen (2009), as a way to consider how situated learning may develop beyond the formation of communities of practice. We begin by reviewing the literature on situated learning in online communities and the consequences of Sørensen's sociomaterial theory on presence and learning. After describing our methods, we introduce a series of vignettes describing Planet Hunters participants' practices and how they constitute different forms of presence and learning. In the discussion, we consider new ways of interpreting the existing literature about learning in online communities. The paper concludes with a discussion about the implications our findings have for the practice of supporting learning in online communities.

2. THEORY

Situated learning takes its point of departure in a practice theory that positions learning in the complex structure of persons-acting-in-world [24, 25, 29]. Learning is situated in practice. It always

involves activities by specific people in specific circumstances. Here, one could imagine a number of changing relations among persons, activities, and a world invoked by learning. In their seminal work, Lave and Wenger (1991) choose to position these relations in communities of practice and see these social formations as intrinsic conditions for the existence of knowledge, not least because communities provide the interpretive support necessary to make sense of its heritage. Communities serve as a structuring resource for learning in practice.

Learning is defined, then, as changes in personal participation in a social context [11]. The learner gradually expands her relations to a community of practice through legitimate peripheral participation. Lave and Wenger (1991) provide the now classic example of apprentices learning among tailors in West Africa. The apprentice begins his learning trajectory by attaching buttons to finished clothing, followed by sewing on details such as pockets. While engaging in these tasks, the apprentice can observe experienced tailors, receive feedback, and build relationships with other participants. Gradually, the apprentice moves backwards through the whole production process to the final stage of the cutting of cloth. This trajectory entails more than the acquisition of competencies in sewing and cutting. It is a matter of becoming a member of the tailor's community of practice.

Not all situations offer the opportunities for observation, feedback, and relationship building as found in the tailor example. Lave and Wenger offer an iconic counterexample of apprentice butchers in a supermarket where the physical layout of the space does not provide access to the work of expert meat cutters. They are literally stuck in a corner performing menial work. There is a lack of transparency, feedback, and opportunity to build relations. While, the design of the physical layout of the supermarket meat department may be bad, we still find many situations where it is not practical or desirable to facilitate a trajectory towards communal participation through open access to practice, feedback, and relationship building. For instance, many citizen science sites build in barriers to observing other people's practices for methodological reasons, to avoid bias in participants' coding of scientific data. In many other crowdsourced environments there are not enough journeymen to go around. Even if the supermarket redesigned their meat-cutting facility to support legitimate peripheral participation, some important practices, such as those that take place offsite or involve other distant, but essential, participants, would remain obscure to the apprentices. For instance, locating the butchers in the ministry of health to master the intricacies of health and safety rules may not be practical.

Taking a step back, we might ask if all learning involves a participant's trajectory towards a specific community or context. The notion of trajectory may suggest that the individual learner is hurtling towards the assumed center of a community. We may need to deconstruct situated learning to allow us to account for multiple forms of relations being built by learners, some of which may have little to do with communities.

The notions of materiality and presence come to our rescue. If we see learning as changes in a person's participation in not only a social context but also a sociomaterial world, it opens up a window to multiple forms of learning that include many types of relations, some relying on human interaction and some not. Since the groundbreaking work on situated learning and communities of practice [6, 10, 25, 36] was published, we have seen a lively debate on materiality and sociomateriality emerging out of science and technology studies. While Lave & Wenger saw technology as helpful, it was only if one wanted to understand access to learning

or the history of a practice, because materials carry a portion of a practice's heritage. Largely rendering materials irrelevant made it possible for Lave & Wenger to predominantly focus on one set of relations among persons, activities, and world.

More recent conceptions of technology attempt to avoid a humanist perspective that makes a priori distinctions between humans as actors and things as passive tools or constraints and affordances for action. This allows us to reach beyond studies of meaning, interpretation and identity towards studies of how humans are with materials [18]. In other words, the literature on materiality allows us to reconceptualize situated learning to consider how learning is materially constituted in practice. With no predefined distinction between the social and the material, a sociomaterial perspective frees us to imagine not just one way of being present in our sociomaterial world but multiple.

In an effort to articulate a broader notion of learning among participants in online communities, we turn to Sørensen [34] and her study of learning among school children engaged in a blended learning situation involving traditional classroom situations and virtual worlds. Inspired by Mol and Law [27], Sørensen defines presence as the sociomaterial arrangements through which certain ways of participating is made available (Sørensen 2009:138). If we find multiple sociomaterial arrangements, we may find multiple performances. Drawing on Althusser [1], Asplund [4], and Giddens [17], Sørensen describes three types of presence performed by learners: (1) communal presence¹, (2) authority-subject forms of presence, and (3) agent-centered presence. We will address these in turn.

2.1 Communal Presence

Communal presence forms around a central collective activity, object, or event. All other elements receive their identity through their resonance with the center. For example, at a festival or during a communal celebration, people develop a joint experience or build their relations by resonating with the same event. Learning associated with communal presence takes place as participants join the community and strengthen their relations to the center. Their knowledge is validated through their joint engagement in the practice. We find a similar form of presence captured by the notion of legitimate peripheral participation (LPP). It depicts the changing relations learners experience in regard to a central communal practice as they become part of a group of skillful participants. Socially, they move towards the center of the community as they become sustained participants, increasingly fluent in the tasks, vocabulary, and organizational principles of the community. For instance, the literature on online communities highlights three elements of communal presence that characterize newcomers' learning experience: (1) types of access to central activities, objects, or events, (2) feedback on participation, and (3) the building of social relations.

First, a number of online community studies describe how access to central activities through rich examples of other people's work plays a key role [2, 28]. As newcomers gain access to core

¹ We should note that Sørensen use the term 'collective' while we apply the notion of 'communal.' The concept of collective highlights an activity done by people acting as a group. Communal refers to the common attitude, interests and goals shared among a group of people. The concept of 'communities of practice' bring these two terms together by pointing to collective activities among people with common attitude, interests and goals.

practices and project needs, the benefits of contribution become clear to them. In a Wikipedia study, Bryant et al. [7] observe that newcomers actively gather information about what constitutes proper contribution as they consider taking on more active roles in the project. Hannebauer [20] finds, in a study of FLOSS communities, that without being able to observe others' work, newcomers struggle to learn how to contribute.

Second, feedback on newcomers' evolving practices plays an important role in facilitating communal forms of presence. Feedback has an affirming quality, pointing out to newcomers that their contributions are valued and that the community will benefit by them in some way [3, 8, 37]. In Wikipedia, Halfaker et al. [19] and Zhu [37] found that negative feedback, such as having one's work removed from the project, can have either of two effects: newcomers leave the project altogether, or their subsequent work improves in quality [19, 37]. How tailored the feedback is to the individual also appears to matter, where personalized messages to the newcomer lead to greater newcomer retention than impersonal messages [16].

Third, establishing relations among newcomers and experienced users plays a prominent role in many online communities. FLOSS research suggests that sustained participation is associated with ongoing social interaction with core members [23]. Ducheneaut [12] examines the relationships that newcomers create with established members, and finds that it is not enough for newcomers to simply display their work. They also need the endorsement of established members who are willing to ratify the quality of their code work. In these examples, we see newcomers building their presence in relation to the communal center. While the communal form of presence has received significant attention in the literature, Sørensen suggests that we find multiple forms of presence and with it, situated learning.

2.2 Authority–Subject Presence

Authority–subject presence emerges as sociomaterial assemblages that take the form of regions and sub-regions, each associated with different clusters of homogeneous activities, events, or objects. Sørensen [34] describes the classroom as a region divided into two sub-regions, supporting authority–subject presence: the front of the classroom which is occupied by the teacher and the blackboard, and the rest of the classroom inhabited by students, their desks, and chairs, all organized to face the blackboard and the teacher's sub-region. The separation between students in their chairs and the teacher at the blackboard thus marks two distinct regions, each associated with particular norms for activity. The use of textbooks further reinforces a homogeneous region where the students all work on the same material, allowing the teacher to track their activities and progress. This assemblage of the teacher facing the students, books on desks, chairs facing the blackboard, and the students focusing on the teacher and blackboard perform an authority–subject form of presence. The teacher serves as the authority over his student subjects. Learning happens when true and previously tested knowledge is transmitted from the teacher's sub-region to the students, who will then imitate the teacher's practices to reinforce the transmission. Regions, like the classroom, rarely change. They are immutable. Elements such as students are held in place by their common location and their relation to the authority (the teacher). In other words, authority–subject relation defines the presence by the teacher and the students, each occupying their specific positions.

2.3 Agent-Centered Presence

Agent-centered presence is associated with fluid relations compared to the stable structures found in authority–subject and communal forms of presence. There is no central focal point drawing people's attention in agent-centered presence. For example, in Sørensen's study, the students not only participated in regular classroom activities focused on the blackboard and their teacher, but also took part in a virtual world where they could create buildings and form communities of virtual participants. Sørensen notes how this highly mutable environment forms a spatial dynamic without fixed spatial relationships. This flexibility makes it difficult to create bounded regions or fixed focal points around specific objects, therefore making it hard for the teacher to use the virtual environment as a space where she might define the boundaries of the students' activities as she does in the classroom.

When performing in an agent-centered presence, the students in Sørensen's study operated sometimes in isolation and sometimes in intimate collaboration with their peers and system features. Referring to the work of Turkle [35] and Lévi-Strauss [26], Sørensen describes how the activity of the students reflects a form of bricolage, where they piece together elements of their participation as they move through the virtual environment. They try one thing and then another, making connections and bringing disparate components together. This playful exploration is not guided by an outside authority or the collective, but rather by the process. The fluid learning typically associated with agent-centered presence involves ongoing mutations of the knowledge that the participants master and the spaces and times in which they do so. It is a process where the last step influences the next and thus gradually mutates over time as the participants extend their sociomaterial relations, and new spaces emerge. In contrast, authority–subject forms of presence tend to imply an increase in relations between the individual and references to authoritative knowledge. Learning in communal presence happens when new participants join the community and the network of relations becomes more and more robust.

These three forms of presence are not mutually exclusive. The same infrastructure, such as a class or crowdsourcing site, can “host” multiple forms of presence. For instance, an academic department can be carefully bounded into sub-regions supporting authority–subject forms of presence. Think of the lecture hall. The same place can serve the central activities and objects associated with a communal form of presence, which may spread the word about a faculty's research findings. Likewise, a person can change the form of presence guiding their performances. As a person learns to perform in an online community, their type of presence is likely to change and with it the type of sociomaterial assemblages they engage. Newcomers start out performing to the best of their abilities in particular assemblages of technologies, people, and activities. The type of presence they can successfully perform gradually changes. They may no longer be confined to particular regions or resonate with a specific object as part of a collective. New forms of learning and knowledge may become relevant and with it, specific forms of authority and interpersonal relations. Sørensen's work allows us to more pointedly ask: What forms of presence characterize newcomers' learning in crowdsourced environments? Do we see evidence of authority–subject, communal, and agent-centered forms of presence?

3. METHODS

To explore our research questions, we analyzed data from our ongoing study of the citizen science project, Planet Hunters.

Participants in Planet Hunters are asked to identify transiting planets in light curve images taken by the Kepler space telescope. Volunteers do this by scanning an image to see if there are any anomalous dips in the light reading of a star, as such dips may reflect the presence of a planet orbiting the star. As of this writing, over 300,000 participants have contributed to classifying 20 million light curve images, and the project has confirmed the discovery of several planets.

Our analysis of Zooniverse projects finds that they are built on two system feature typologies: science and communal. The science features remain under the control of science teams and the project developers who manage the project. These features include the annotation function, the site guide, and help. The annotation feature is the interface where participants analyze light curves. The annotation feature guides participants through the process of analysis by prompting them to identify a range of characteristics, focusing in particular on the presence of dips that may indicate a transiting planet. Each image must be analyzed multiple times by different participants, and the technical architecture of the system prevents interaction with other participants during this task so as not to bias the decisions of annotators. This task is most important to the science team because it draws attention to data objects that science teams will explore in greater depth. The Help feature provides content developed by the science team and represents an immutable knowledge source for participants to consult during the process of annotating images. The Site Guide, which is accessible outside of classification activity, provides access to a tutorial, a description of the science behind the project, and an FAQ page.

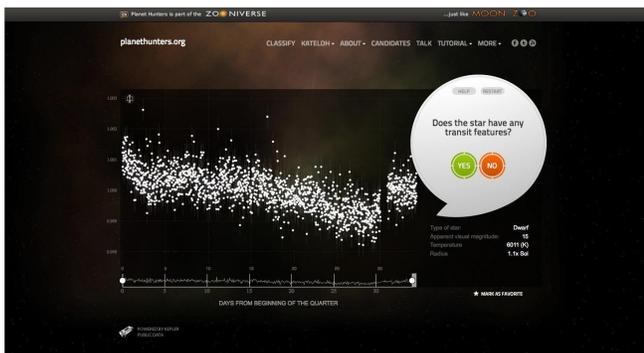


Figure 1. Planet Hunters classification interface

The second set of features is described as communal as they allow volunteers to collectively organize and further analyze the content. Where the science features were built as part of the original infrastructure of the system when the project began, the communal features were an add-on supported by WordPress software. Communal features include talk, discussion, collections, and private messaging. The opportunity to make comments in the project is presented in talk and discussion features. After submitting an annotation, participants can make comments on data objects by selecting Talk. Talk comments have a 140-character limitation while Discussion has no restrictions. Discussion allows participants to pose general questions to the community on topics not related to specific data objects. Users of the discussion interface often post links to outside resources, which answer participant questions and can be accessed by the community. Collections allow participants to pin images in a named collection that is made public to other participants. Participants have used the feature to collect images related to certain discoveries like those possessing *weird curves* or *eclipsing*

binaries. These collections and their descriptions are a valuable repository for images with interesting features.

To explore the learning experience of newcomer participants in Planet Hunters, we draw on the practice perspective in social theory by focusing on the work practice of both new and experienced volunteers. We pay particular attention to data that reveals how they make sense of the task at hand, how they work through obstacles of participation, and how their work practice changes over time. In doing so we are able to see the nexus of social and material entities that are entangled in the contribution to citizen science collaboration.

Our data collection drew on virtual ethnography [21] and trace ethnography [15]. We used virtual ethnography to emphasize participation in the online environment while trace ethnography highlighted the history of participant activity as it appears in the system logs of the online platform. Combining virtual and trace ethnography allows researchers to identify and trace practices as they emerge by analyzing visible participant comments, comment timestamps. Trace data was gathered by observing comments as they appear on the platform as well as running data base queries on nine accounts so as to observe a volunteers history of making classifications and comments. In using virtual ethnography, we conducted 21 semi-structured interviews with newcomers and experts. Each interview lasted approximately one hour. We asked volunteers how they conducted their work and engaged various tools and social interactions in the process, and how their work changed over time. Six months of participant observation data was collected by the researchers. As participant observers, we signed up for user accounts, completed all tutorials, reviewed help resources that newcomers are prompted to review, participated in the task of classifying light curves, and interacted in the social spaces of the project. Over the six months of observation, researchers visited the site a few times each week, spending between one and three hours participating and observing during each visit.

Drawing on the practice perspective in social theory [32, 33], we conducted a qualitative analysis of the participant observation data, trace data, and interviews, focusing on the nexus of participant work practice in which social and material entities are entangled. Data from the ongoing study were independently analyzed by three doctoral students and then compared to identify themes about newcomer enactment of learning. These findings were discussed at weekly research meetings where results from the various data sources were triangulated.

As researchers, we are grounded in LPP and expect to view learning as being a function of situated and relational knowledge. As expected, we noticed the traditional trajectory of participation where newcomers started out on the periphery, moved their way towards more impactful practice, and sought access to observe other participants' work. However, in our data, we noticed that participants repeatedly described the integral role of information from such artifacts as a tutorial or FAQ in their work practice. Most noticeably, there were few journeymen to guide and assist newcomers, a critical feature of the LPP framework, perhaps prompting what we observed as a reliance on knowledge artifacts. Our data analysis therefore highlighted how important both artifacts and people were to the enactment of learning. In particular, we focused on data from interviews, traces, and observations that reflected the changing role of artifacts and people as participant practice changed over time. In the following section, we draw on our various data sources to explore these

shifting configurations of artifacts and people in the learning experience of volunteers in Planet Hunters.

4. FINDINGS: SHIFTINGS FORMS OF PRESENCE

We present our findings first as vignettes comprised of data from multiple users with experience ranging from a novice in the project to having been with the project for a long period of time. Each vignette represents a particular form of presence performed by project participants (all participant names are fictitious). After each vignette we analyze the way in which the presence is performed, providing more examples from specific respondents.

4.1 Performing Authority–Subject Presence

Caroline is a kindergarten teacher who has always been fascinated by astronomy. When she first heard about Planet Hunters on her favorite science television show, she seized the opportunity to engage in a new outlet to pursue her love of the stars. Caroline is new to Planet Hunters and has only made a few contributions to the project using the classification interface. Upon logging into the Planet Hunters website, Caroline heads over to the tutorial for a quick refresher on how to hunt for planets before she starts classifying again. After selecting the option “Start Classifying,” she is presented with the first question that asks her to match up visual characteristics of the light curve with a series of images that reflect the “noisiness” of the star. Since she has only gone through the tutorial once, she is still uncertain about how to answer the question, so she clicks on the “help button” for a reminder about what characteristics to look for. After answering this question, she is presented with a second question that asks her to match yet another visual characteristic of the star to another series of images that relate to whether the pattern of the light curve is variable, regular, or irregular. Finally, she is asked to scan the image for the presence of transiting planets in the light curve, which appear as V-shaped dips in the light curve reading. This last question reflects the entire mission of the project, and the pressure she puts on herself to “give the right answer” compels her to step away from the classification process and visit the site guide where she finds FAQs and descriptions about the science of identifying transiting planets in light curve readings. After browsing the site guide, Caroline returns to the classification interface to provide an answer to the last question. With the completion of the classification, the interface asks Caroline whether or not she would like to “discuss this star.” Caroline selects “yes” and is brought to the Talk page where the light curve she classified is presented along with an option to leave a comment that is less than 140 characters. Caroline observes that other volunteers have left comments, some pointing out what they believe to be the presence of transiting planets at particular points in the light curve. As a newcomer, Caroline finds such comments to be a valuable learning opportunity because they demonstrate what other volunteers pay attention to when classifying light curves. While Caroline would like to leave a comment, she finds that the existing comments exhibit a degree of expertise that she is not proficient with. Unsure of how to write the comment in the talk space, Caroline returns to the classification interface and observes another light curve.

4.1.1 Searching for Authority–Subject Presence

In addition to responding to questions from the classification interface, we see the production of an authority–subject presence between the citizen scientists and the project scientists when newcomers express a need for expert guidance on how to contribute. For instance, we see Caroline referring to content

produced by the science team in the site guide and the help features when she needs to answer questions about classifying light curves. The reference materials are described as beneficial since participants do not always know what to look for; having exemplary images to compare light curves with gives new participants the opportunity to learn which features of the light curve are important to further inspect. One newcomer pointed out how she would move back and forth between the task of classification and the help and tutorial features.

“Well when you start looking over the images you can always have a click back on the help button, so you can have a few images where you know what you’re doing and then you’ll have one that will bring up something different and then you can always go back and really go through some of the quick tutorials then you can understand what you’re looking at.” -Alexandra

Newcomers also perform authority–subject presence in the social spaces of Planet Hunters. For those that viewed the Talk space as containing knowledge valuable for making annotations, participants described how they like to watch and learn from the expert participants that contribute to the space. This learning opportunity is seen in newcomer Emily’s experience when she indicates that she always found the conversations in Talk to be interesting and would click on the “discuss this star” feature as a way of learning how to participate.

“most of the threads that have people posting targets to them, they are already vetting from other targets that other people found, so instead of just going to the very small, basic tutorial you get through the interface there, you can actually go check and see, ‘Oh this is what a bigger transit looks like, oh this is what a smaller transit looks like, oh this is what a not-transit looks like.’ And just kind of figuring out, with examples if what you found is something worthy or not.” -Emily

The motivation to use Talk as a resource for learning was also described as being due, in part, to a perception that the contributions to Talk came from expert participants. One respondent, Pauline, commented that the talk space was a valuable source for learning how to participate. She noted that, “*There were certain people . . . who seemed to be the expert and when they commented I took their comments as a learning experience.*”

Emily, now an experienced participant, described how she used the talk and discussion features as a newcomer to seek out long-term dialogues with experienced members so that she might learn how to conduct more extensive analysis of the data. While she was still new to the project, Emily built up her social network with other core members after she posted a discussion topic about a potential transit she believed might be a planet candidate. Appealing to core members to learn what else she might do to take the analysis of this object forward, Emily received lots of information and resources that she needed to advance her participation in the project.

While many respondents viewed the social spaces as potential sources for observing expert work, we did encounter individuals that exhibited a distrust of the content on Talk and therefore did not use it as a learning resource. In one interview, a respondent noted that they did not understand why anyone other than members of the science team should be trusted. “If they are not part of the science team, then they are just like me, a novice. Why should I listen to what they have to say? It is like the blind leading the blind!” Such an example of distrust illuminates the fact that the characteristic of authority for any space or content on the

Planet Hunters platform is a mutually constituted phenomenon that depends as much on the expertise of the comment's author as it does on the citizen scientists recognizing the authority of such expertise. As Sørensen states, "The existence of the authority is dependent on the subject's recognition of it as such. And this mutual recognition is dependent on the socio-material assemblage in which its elements are entangled." (Sørensen, 2009: 154)

Much like a classroom, we find the science team promoting an authority–subject presence in their relation with citizen scientists, not through textbooks and blackboards, but with the help and site guide features. The citizen scientists imitate and reference this tested knowledge in their annotation work. The science team keeps tight control over this immutable region, which then allows them to make scientific knowledge claims as they turn the citizens' work into scientific articles. In addition, many newcomers position themselves in the authority–subject relation when viewing comments of experienced participants in the talk and discussion features. In doing so, they frequent Talk not as a place to build communal relations but observe expert practice and receive validation of their own work. In this case, the authority is not the science team's comments, but more experienced users' comments on specific images that the newcomers have also encountered. As such, we observe that newcomers, like the students in Sørensen's classroom, have their attention uniquely oriented towards experts and instructions from the interface and do not interact with other newcomers or non-experts as they learn how to contribute.

4.2 Performing Communal Presence

Carl, a retired cardiologist, has over 2000 classifications to Planet Hunters under his belt. Like many active participants in Planet Hunters, he holds a subscription to a science magazine and is an avid viewer of television shows on astronomy. We find Carl after he has just completed answering the three questions that the classification interface has asked him. Finally prompted to "discuss this star" in the interface, Carl accepts the invitation. In the talk space, Carl types a comment that describes the presence of a possible transit by referencing the markers on the X and Y axis in the image to indicate where he sees the transit. Leaving a question mark at the end of his comment, Carl hopes to elicit a response from other volunteers or science team members to discuss his observation. Returning to the classification interface, Carl moves quickly through the set of questions. Again accepting the invitation to discuss the star, Carl writes "#binary." By placing a hashtag in front of his comment, Carl utilizes a function in the platform software that moves any comment with a hashtag into a list generated around similar text. In doing this, Carl has added an additional layer of classification that appears in a list of trending hashtags that other volunteers and scientists can browse for further analysis. After adding another light curve to the #binary list, Carl decides to take a break from the classification feature and browse the #binary list to see light curves that other volunteers have highlighted.

4.2.1 Building Collective Knowledge and Seeking Consensus

Whereas some participants appears to limit their work to answering a set of questions predetermined by the classification interface, some, prompted by their own curiosity, expand their range of activity by leaving comments and questions in the talk and discussion features. In our interviews, we found that for some participants, the talk feature played a role in what they describe as an indirect collaboration with the science team by building and

organizing knowledge artifacts that are useful for the scientists. To these participants, Talk serves as a space where they present their evidence and reasoning to other participants about why particular data objects may be worthy of further investigation. In an interview with Isaac, who has contributed over 30,000 classifications, we learned that a select group of users sort through Talk looking for already classified objects that match their personal interest in Planet Hunters. Isaac argued that without this relationship between the comments left on the talk pages and this select group of users, there would not as many planet discoveries as have been made thus far.

In the performance of communal presence, participants break from the isolated activity of authority–subject presence and reorient their attention towards a setting in which participants become mutually aware of each others' work and work towards building upon each others' efforts. For example, in the shift towards seeking consensus through interaction in the talk interface, we observed that some participants move beyond an authority–subject presence towards a communal presence. However, in some talk situations, we found that the same participants may oscillate between authority–subject and communal presence. For example while many experienced users see a significant decrease in their use of Help and the site guide, Amy, a participant with over 10,000 classification, occasionally refers to the site guide as a reminder of project practice rather than as a learning resource. Other shifting relationships include how the classification interface remains the workplace monitored by the authority of the science team, but also becomes a source of images around which discussion and talk can resonate.

4.3 Performing Agent-Centered Presence

In this vignette we meet Deborah, a journalist with a lifelong love for astronomy. Where we focused on participant activity at a particular point in time in the two previous vignettes, here we examine Deborah's practice across an expanded temporal scope so that we can address her learning as a function of bricolage, aggregating a multitude of resources that supports her evolving project practice. As such, we see that Deborah, who is driven by an interest in the discovery of other planets, has taken courses in astrophysics and participated in a university astronomy club, using the university's telescope to observe the stars. Today she is an active member in her local astronomy club, holds a number of subscriptions to science journals, stays current on discoveries in astronomy and other sciences, and is an avid viewer of television shows on science. Indeed, it was while viewing her favorite show on astronomy that she first heard about Planet Hunters. Beyond her broad interest in astronomy, her motivation to participate in Planet Hunters comes from an excitement in the opportunity to be part of the scientific community and support ongoing research. With Planet Hunters, astronomy research is no longer the strict domain of professional scientists; now she too can be part of the scientific process instead of only being an enthusiastic observer.

When she started using the classification interface, Deborah reviewed the tutorial, read the Planet Hunter's blog written by the project scientists, and reviewed a range of other material provided by the science team. While all of this helped her make sense of the classification process, she describes how the experience of witnessing the transit of Venus in front of the sun helped her understand what a transit is and what the changing brightness of a star implies on a light curve reading. Deborah describes how her primary obstacle in the project was when she encountered the technical language used by participants in the talk space. It was at this point that she began to feel like an outsider, however she used

this feeling as motivation to learn more about astronomy. Using the technical language in the forums as a starting point, Deborah scoured Wikipedia and Google, watched science documentaries on YouTube and various other science-themed websites to better understand the science behind the terms being used by other participants. Open online courses at a number of universities were also a helpful resource for learning more about the science driving the Planet Hunters project. Inspired by the opportunity to apply what she has learned, Deborah has taken her newfound understanding of the science behind planet hunting and applied it to conversations with other participants about the data on Planet Hunters. While Deborah feels she has a firm grasp on the basics of the project, she does occasionally return to the site tutorial and science-based resources for a quick refresher on the basics of the project.

While terminology is one obstacle that Deborah successfully addressed, the extensive analysis performed by expert users on data objects goes far beyond what is asked of participants and indeed requires some degree of technical ability. Because she is excited at the prospect of expanding her contributions to Planet Hunters, Deborah is in regular contact with some of the active expert contributors on the site in order to learn how to perform analyses that involve downloading the light curve data across multiple quarters, plotting the data in a spreadsheet program, and analyzing the plot for evidence of transiting planets.

4.3.1 Situating Planet Hunters within the Practice of Amateur Astronomy

By taking part in Planet Hunters, many of the longtime amateur astronomers encounter aspects of astronomy research that they are not familiar with. Referring to the tutorial on using the classification interface or reading the site guide to learn more about the process of planet hunting is helpful, but many of the participants we spoke to use such moments of unfamiliarity as opportunities to expand their knowledge about astronomy. As described in the vignettes, some users will use Google, visit Wikipedia, or go to the astronomy education website hosted by a large state university to examine key terms. Some go so far as to take open online courses to address particular facets of the Planet Hunters project and then return to apply what they have learned. Volunteers may also seek out the advice of experienced participants to learn how to perform more advanced modes of analysis. In all of these examples, we observe how Planet Hunters motivates participants to learn more about astronomy so that they can be more knowledgeable about the project they are participating in.

Learning to participate in Planet Hunters is therefore not uniquely bound to the authority of the Planet Hunter scientists that manage the project. Rather, in the broader practice of amateur astronomy and citizen engagement in scientific research, we observe the newcomer as bricoleur, building their learning experience across multiple sources in a variety of settings, such as in interpersonal interaction with other citizen scientists, searching the web for definitions of terminology, and taking open online courses. This activity of bricolage is what Kallinikos would describe as a “playful exploration” in which the bricoleur draws on past solutions and a “miscellaneous toolbox” to address new problems and challenges [22].

When we observe how Planet Hunters is situated within a broader practice of amateur astronomy, we decenter our focus on the project and find the agency of participants as it relates to their motivation to learn more about, and contribute to, astronomy

research. In such a setting, we find that participants in Planet Hunters are not defined solely as citizen science volunteers functioning within the project platform; rather, they are amateur astronomers, moving back and forth within the project to learn more about their passion and apply what they know.

Much like Sørensen’s example of students taking part in an online virtual world environment, newcomers to Planet Hunters perform agent-centered presence by building their own path through collaborative and individual efforts, towards making contributions to scientific research without any one individual or authority determining their actions.

5. DISCUSSION

In this section, we return to the broader notion of learning to discuss how unique modes of presence come together in a participant’s general learning experience in Planet Hunters. We follow this discussion about learning in Planet Hunters with a broader consideration about learning in a crowdsourced phenomenon, followed by a discussion about the practical implications of our findings.

5.1 Learning Online in Citizen Science

We find that all three forms of learning associated with distinct forms of presence take place in the learning experience of participants in Planet Hunters. These distinct forms of presence however are not mutually exclusive; rather, they coexist throughout the individual’s learning experience. While the forms of presence do not occur as a neat trajectory where one follows another throughout the participant’s learning experience, we do find evidence that the authority–subject form of presence is more prevalent earlier on in a participant’s career, and the communal forms of presence tend to dominate later on. Agent-centered presence takes place all of the time. We speak to each form of presence in turn.

In our description of agent-centered presence we decenter participant practice in Planet Hunters and place it within a broader assemblage for the practice of amateur astronomy. In doing so we observe agent-centered presence as participation that spans the boundaries and authority of the Planet Hunters project, weaving together a range of other activities relating to amateur astronomy. For example, participants take open online courses to improve their skills, refer to science magazines, or draw on the work of their astronomy club. The description of volunteers drawing on a range of resources reflects the theme of bricolage that Sørensen ascribes to agent-centered presence. As Sørensen describes in her example of students in a virtual world, the students draw on various media and social interactions in the creation of their own unique learning experience.

Most newcomers in the project performed authority–subject presence as they worked to make sense of a new setting. In these examples, learning, while situated in the practice of classifying light curves, was a solitary experience, where newcomers interacted primarily with knowledge artifacts produced by the science team or observed comments about work that expert participants left on the talk page. Here we find distinct regions defined for the authority of the science team and the subject position of the participant. However this form of presence was not unique to newcomers. More seasoned volunteers like Amy and Deborah also performed authority subject presence when they needed to remind themselves about aspects of project practice by referring to the site guide or tutorial.

Similar authority–subject arrangements can be seen in OSS communities where newcomers are relegated to performing bug reports before they are allowed to become developers [12]. Bug reporting systems, typically consisting of forms with predefined fields, frame the range of possible contributions a newcomer can make. Like the regions that form around the assemblage of the classification interface in Planet Hunters and the detailed instructions on how to participate seen in the tutorial and site guide, Østerlund and Crowston [30] point out that the bug reporting space in one OSS project is accompanied by detailed instructions on how to file a report. Here the authors conclude that, compared to the code commit spaces of the OSS project that feature virtually no instructions on how to participate, bug report spaces require detailed instructions due to the fact that many people committing bug reports are new to the project [30]. Like the detailed instructions and predefined fields in a bug reporting form, the classification interface, site guide, tutorial, and other features contribute to new participants performing authority–subject presence as they learn the basics of contributing to Planet Hunters.

Communal presence, on the other hand, was mostly performed by more experienced participants seeking consensus around the classifications they had made. Through an awareness of the project terminology, experienced participants are better equipped to resonate with other participants around data objects as they seek consensus about what they have all observed together. While experienced participants were more likely than newcomers to seek consensus with other participants in the talk and discussion spaces, newcomers, despite a familiarity with project terminology, ventured occasionally into the talk space in hopes of interacting with other participants to discuss their work.

We turn now to a consideration of how our findings contribute to existing research on newcomers to online communities.

5.2 Access, Feedback, and Social Relations

Validating existing research, we found access to practice, feedback, and relationship building to be important elements of learning in Zooniverse. As we previously mentioned, these themes draw on the situated learning literature, which focuses on social learning as it occurs between people. As such, our findings extend beyond the communal-oriented modes of access to practice, feedback, and relationship building as we observed such themes performed also as authority–subject and agent-centered presence. In this section, we revisit the themes in the literature in light of our findings and Sørensen’s modes of presence.

5.2.1 Access to Practice

Our vignettes describe moments of communal presence when participants sought out comments in the talk space where other participants talked about their work. However our findings departed from the previous literature when we observed participants referring to such artifacts as the site guide or tutorial to learn how to participate. In such examples, volunteers are able to observe examples of practice curated by the science team and can classify simulation data that provide immediate feedback to the volunteer indicating whether the work was done correctly. In such cases, volunteers are observing and engaging practice in a well-defined region that features homogenous entities of knowledge intended to define the boundaries of newcomer practice. Here we find Sørensen’s theme of authority–subject presence to be a valuable analytical lens not only for analyzing our findings, but for repurposing previous research on newcomer learning. For example, where findings in Bryant et al. [7] are

framed by Lave and Wenger’s Legitimate Peripheral Participation [25], their findings on the role of rules and policy for newcomer learning, viewed through a lens of authority–subject presence, demonstrate how the newcomer learning experience is not a distinctly intersubjective and situated experience.

Access to practice was also performed as agent-centered presence when we observed participants going outside of Planet Hunters, looking at examples of amateur astronomy in contexts that the Zooniverse team does not have control over. Visiting other Zooniverse projects or other citizen science projects also informed how volunteers do their work in Planet Hunters. Furthermore, for those participants engaging in analysis of data that falls outside the basic light curves classification task, examples of how such analysis is conducted through resources outside the Planet Hunters website may inform how they perform their practice in Planet Hunters. Such findings expand our current understanding of newcomers to online communities in that, where previous research bounds itself to the experience of newcomers as it plays out on a single platform, we observe such experience as being a product of activity across multiple platforms.

5.2.2 Feedback

The theme of feedback in research on newcomer learning in online communities was also evident in our findings, however, we noticed that our findings identified forms of feedback as part of the performance of both authority–subject presence and communal presence, whereas the existing literature described it solely in terms of authority–subject presence. For example, our findings showed newcomers performing authority–subject presence when they sought out feedback in social spaces to affirm whether or not their work was done correctly, while more experienced participants performed communal presence when seeking feedback to produce consensus on what they believed they discovered. Drawing on the theoretical lens of Sørensen, we find that existing literature on feedback can also exemplify authority–subject presence where newcomers are either actively seeking the insight of experts or are told by experts that their work is correct or incorrect. In such examples, we see the creation of a subject position where the newcomer is functioning within boundaries of practice defined by experts. As such, while the literature may view these as examples of social learning, the production of authority–subject presence is also indicative of a well defined region of knowledge that is imposed rather than uniquely co-constructed between newcomers and experts.

While we have not observed this, sources of feedback can occur in open online courses or social media platforms where volunteers discuss their broader work or involvement with Planet Hunters. Such feedback may then support the work volunteers perform in the project.

5.2.3 Relationship Building

The theme of relationship building in the newcomer research literature demonstrates a phenomenon where the career of participants is deeply entangled with the social networks they establish [13, 23, 31]. While we observed this phenomenon, we also found that the building of relationships is not a uniquely social phenomenon, but also includes relationships being built with various platform features and other artifacts that factor into the configurations of participant practice.

Our story about Emily, an experienced participant who established a social network with core members as a newcomer, aligns well with findings in existing literature that such relationships are associated with long term participation [13, 31].

In particular, it was Emily's initiating a discussion about a potential planet candidate that drew the attention of core members, as it seemingly demonstrated her value to the community [9, 23]. Such examples are reflective of communal presence in that relationships are built around communal witnessing of a data object as well as communal building of knowledge. We also found examples of asynchronous relationships being built where participants added hashtags to data objects in the talk space so that other participants might pick them up for further analysis. Here we witness a group of volunteers converging around a common data object, building an asynchronous relationship in order to analyze it together. In these examples we note that convergence around a common object was also constituted by a range of material entities like orbital calculation tools, Excel spreadsheets, and the use of the discussion and talk spaces on Planet Hunters. In highlighting the role of artifacts, we observe that relationship building as it relates to changing modes of participation is not a uniquely social phenomenon as the current literature describes. Rather, it is also a form of relationship configuration with tools in such a way that may reflect either new or expert practice.

While we have not observed this, agent-centered forms of relationship building may occur in open online courses or social media platforms where volunteers discuss their broader work and involvement with Planet Hunters, establishing a bricolage of relations beyond the boundaries of the project that may impact how they participate.

6. IMPLICATIONS FOR RESEARCH AND PRACTICE

The existence of not just one, but multiple and overlapping forms of presence in crowdsourcing environments, calls for additional research into the particular ways participants tie together their presence in and across those settings. First, most participants string together their engagement in one project (e.g., Planet Hunters) with activities in other contexts, some online, others not. It should encourage researchers to operate with more than one unit of analysis as they explore participants' learning. In other words, they may analyze learning from the unit of the individual as well as the unit of the community. One does not exclude the other. For instance, future research in Planet Hunters could investigate how participants engage more broadly in science. What are the places they go to, and how do they bring those together with their communal and authority-subject forms of presence? For instance, several participants described how they stumbled upon Zooniverse and Planet Hunters as part of their interest in science, which involves a continuous exploration of various resources and settings, including magazines, news media, web resources, articles, and local astronomy clubs. An outside authority does not guide this playful exploration, but rather, it is their process. In short, further research is required to fully understand how participants manage to integrate multiple forms of presence to stimulate their desires and goals.

Second, distinct types of access, feedback, and relationship building support each form of presence. This means that system features do not support one but multiple forms of presence. While the examples we draw from Sørensen may suggest that, for example, a classroom supports only authority-subject forms of presence, and a virtual world, a fluid agent-centered presence, our research clearly shows that system features may support more than one form of presence, depending on the type of sociomaterial spaces people form and the type of presence performed in them.

To further explore this range of system feature uses, we have planned a series of experiments with the talk feature in Planet Hunters that will allow us to better understand which posts participants find helpful and from which modes of presence. For instance, one may give participants the option to indicate why they want to Talk. They may want to get an answer to a question from the science team, or share an interesting finding with other members of the community, or engage in Talk as a way to build their own collection of items pertaining to their particular interest in, for example, eclipsing binaries. Likewise, one might allow participants to indicate what Talk posts they find helpful. These choices could then be reflected back to the participants in a number of different ways. Science team members may look for people seeking answers. Newcomers could seek likeminded participants or look over their mutating collections of images, hash tags, or external resources. Participants can see what Talk posts other people find helpful or look in their profile to see which of their own posts other participants enjoyed.

Our research also has implications for practice. As designers of crowdsourcing infrastructures, we should be wary of building features with the goal of supporting just one form of presence. Instead, we may approach individual features, e.g., Talk, as open-ended artifacts that support multiple forms of presence. Each feature does not create a set boundary or determine a dominant form of presence [5]. Features such as Talk should support not only community building but also newcomers' pursuit for authoritative forms of access to practice, feedback, and relationships. Likewise, a feature such as Talk may not indicate a meaningful boundary from which to understand these practices. Learners are likely to bring their engagement in Talk together with other features from within or outside Planet Hunters and Zooniverse. As designers we should strive to support dynamic boundaries that allow newcomers to weave multiple forms of presence together in their ongoing learning effort.

7. ACKNOWLEDGMENTS

Without the Zooniverse volunteers who worked on the projects and took the time to answer our questions there would be no paper. Many thanks to Stuart Lynn and the Zooniverse team for access to PH data. Several colleagues and anonymous reviewers offered invaluable feedback. This material is based on work supported by the National Science Foundation under Grant No. IIS 12-11071.

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