Avalanche Beacon Parks: Skill Development and Team Coordination in a Technological Training Ground

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ABSTRACT
High-risk outdoor recreation allows its enthusiasts to reach unprecedented levels of adrenaline; it also contains risks and requires specific training (in part technological). In particular, its participants must be ready to react efficiently during an emergency or in response to an accident. *Technological training grounds* can simulate particular contexts and emergency situations as a place for recreationists to train and practice. In this paper, we use the practice of *avalanche companion rescue* as a case study to explore how technological training grounds support recreationist training. Our results offer insights into how avalanche beacon training parks support skill development and team coordination training. We also present strategies to orient the design of technological training grounds beyond avalanche companion rescue.

Author Keywords
Avalanche rescue; avalanche beacons; training in context; simulation; communities of practice; team cognition.

ACM Classification Keywords
H.5.3 [**Group and Organization Interfaces**]: Computer supported cooperative work; H.1.2 [**User/Machine Systems**]: Human factors.

INTRODUCTION
In the past years, there has been an increase in high-risk outdoor recreation activities, sometimes labeled as extreme sports, 'modern outdoor activities' [37], 'skilled adventures' [6] or risky forms of recreation [4]. Those sports have been characterized as "specialised, highly technological and demanding a high degree of preparation, and are associated with individual endeavour, risk, speed, and excitement" [37:36]. Examples include climbing, skydiving, mountain biking, big wave surfing, BASE jumping, white water kayaking, kite boarding, heli-skiing, and backcountry skiing. Such sports are also characterized by 'communities of interest' [4:12], comprising people who participate in those activities, use specific areas in the outdoors, and use particular equipment. Members of these communities demonstrate a desire for risk-taking, while at the same time cultivating a high knowledge for the sport they practice, including its risks and dangers [6].

As sports and recreation continue to develop into the more extreme and risky spheres, there is also a growing need for ongoing simulated practice and training for recreationists and outdoor enthusiasts. That need is even more important for situations within the practice that happen rarely but that can be life threatening. Examples include rappel rescue techniques for rock-climbing accidents, canyon extraction for canyoneers, swiftwater rescue for paddlers in danger, and avalanche rescue for backcountry skiers. Yet unlike professional guides, the typical recreationist training relies on a few short (and possibly superficial) courses. Furthermore, they are rarely exposed to real situations requiring that training. Thus even 'trained' enthusiasts can become quite rusty over time. At the same time, digital technology is becoming increasingly incorporated into many of these activities, particularly through the use of portable devices running specialized apps. As these devices are integrated into those activities, they need to be included as part of the training program. For example, GPS devices are critical both for routine route finding in the backcountry, and for deciding on alternative routes when problems occur (e.g. [14]). Personal satellite trackers (e.g., the SPOT GPS Messenger, www.findmespot.ca) allow people to check in periodically to inform others not only about their location and well-being, but to send out a distress and location signal when they require rescue. Various apps and devices let people monitor specialized environmental forecasts and bulletins in order to help their decision making, such as extreme changes in weather during backcountry travel, winds when skydiving, potential for flash floods when canyoneering, and local avalanche conditions when backcountry skiing (e.g., www.avalanche.ca). Some devices are solely dedicated to handling particular emergency situation, such as avalanche transceivers (beacons) that help people locate victims buried in an avalanche [13].

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For these devices to be used effectively, recreationists need to understand how to use them within the context of their real-world activity. This goes beyond reading the user manual. While one can read about the functions of (say) a GPS unit or an avalanche transceiver, their actual use during the high-risk activity demands far more knowledge and expertise. The consequences of misuse or inefficient use can be extremely serious. Misreading a GPS while skiing on a glacier during a whiteout can lead the group to extremely hazardous terrain. Inefficient use of an avalanche transceiver can lead to delays during rescue, resulting in suffocation of the buried victims before they are found [12].

The challenge is that people need to learn how to use these devices and the best practices around them within their recreational context. Yet learning while actually doing the activity is often impractical due to the inherent danger and time constraints of the activity, and the relative rarity of critical events. Hence, training often occurs in specially crafted physical settings - *technological training grounds* - that simulate particular contexts and emergency situations.

Our goal in this paper is to understand the use of these technological training grounds and how to better design them. We chose to study the case of backcountry skiing and the specific practice of the *avalanche companion rescue protocol* within *avalanche training beacon parks* (both will be described shortly). Avalanche companion rescue training is particularly interesting to both HCI and CSCW because its success relies on several aspects: how each rescuer masters the skills of using his or her tools during particular emergency scenarios (including technology such as an avalanche transceiver), how the rescuers as a team are able to collaborate and coordinate on scene while using that technology, and how people support the training of others through facilitation and mentorship.

In this paper, we take on the dual roles of being CSCW researchers as well as backcountry skiing recreationists. One of the authors and observers is a professional avalanche education specialist. Another author is a recreationist with considerable experience running avalanche simulations: he was once completely buried in an avalanche, and had to be found and rescued by his team (see account in Part I, [7]). The third is a recent convert to the activity and who has run through training sessions herself. While we use the observations we made of our participants to ground our analysis, we also interpret and extend what we saw to our own in-depth experiences of similar situations done 'in the wild'.

After describing related work, we present the two parts of our research: 1) an observational study of recreationists training in the avalanche beacon training park with subsequent semi-structured interviews, and 2) our reflections on maintaining a beacon park. We report our results under the themes of skill development, team coordination training, and designing beacon parks as a technological training ground. To foreshadow, our main findings articulate the value of a progressive difficulty scale of scenarios, the importance of levels of fidelity, finding a balance between skill development *vs.* team coordination training, and the challenges in supporting communities of practice in simulations for recreationists.

RELATED WORK

Team cognition and team training

Training, and specifically training of non-professionals to work as an ad-hoc team in critical situations, is central to our work. Previous research has articulated in great details team cognition, cross training, and the importance of shared mental models. We present a very brief summary of this more general work and will come back to concepts mentioned here in the presentation of our results.

Team training

Teams are understood to be "social entities composed of members with high task interdependency and shared and valued common goals" [36:541]. Moreover, teamwork requires the ability to adapt coordination strategies by communicating and orienting the team towards reaching their goal [38]. Achieving successful and efficient teamwork is not easy and requires team training. In addition to mastering one's role and tasks, it has been argued that each team member should also gain a shared mental model of the team goals, tasks, and needs. Shared mental models are particularly useful for people working in teams because it allows individuals to predict and explain what is happening around them and further allows them to make decisions about what to do [32].

In avalanche companion rescue, a *group* of recreationists must quickly become a *team* when they have the shared and valued goal of rescuing one of their companions. However, unlike most teams discussed in the literature, the group is *ad hoc*. Some may not have met before, they may not have trained together, and the level of training and practice between team members can vary considerably. As well, individuals may not be familiar with each other's skill level, which can affect how roles within the team are assigned and how well they are carried out.

Thus we find particular value in the concept of cross training (specifically, *positional rotation* [8]): a strategy in which each team member learns about and is trained on the other roles and tasks within the team [30,42]. This allows each team member to gain a better mental model of the team's work and can lead to enhanced implicit coordination in the team (by reducing the need for overt communication and explanations) [29] and to more seamlessly exchanging roles ad hoc within the team.

Team training through simulations

CSCW has focused on the collaborative aspect of training in emergency situations. Examples include observational studies of air traffic control [11], health care [3], firefighting [21,39,40], avalanche rescue [13] and real-world emergencies [27]. Researchers have also created new systems to better support training, often focusing on collaborative practices. Proposed solutions include tabletop systems [11], wearables [9,22], games [27,40], and virtual environments [28].

The literature on simulations and training discusses the different dimensions and types of simulation. For example, Beaubien and Baker [3] offer three types of simulation (case studies/role plays, part task trainers, and full mission) and three dimensions of fidelity in simulations (environment, equipment, and psychological). The authors articulate how each training exercise or facility can offer more or less fidelity on each dimension, which can reflect particular sub-areas of a more complex practice. However, they also state: "although the three fidelity components are inter-related, psychological fidelity [the degree to which the trainee perceives the simulation to be a believable surrogate for the trained task] is generally considered to be the most essential requirement for team training" [3:i52]. Literature on simulations also proposes that some aspects of practices can be learned without a complete simulation [40] and that in fact a full simulation can be unnecessary [35].

However, it is important to note here how our work differs from the above. As mentioned, the training and simulations typically studied in CSCW are oriented towards professionals and experts in emergency management and rescue. That audience is distinctly different from high-risk recreationists (such as the companion rescuers in the case of an avalanche [13]). Unlike professionals, they do not necessarily commit or have the time to commit to extensive formal training. Unlike professionals, recreationists often form ad hoc groups for each outing *vs.* stable teams that work together over time. Thus no single group learns how to work together as a team during emergencies. As well, a particular group may include strangers and/or people of quite different (and perhaps unknown) levels of expertise. These distinctions are at the center of the motivation for this paper: how are technological training grounds used by these recreational groups, and how can they be designed to best train people to respond to the life or death situations inherent in their practices?

Ad hoc and volunteer teams

CSCW has an established tradition in studying and designing for disaster communities and emergency response groups, with a particular focus on ad hoc and improvised collaborative volunteer work. Past research has addressed the important role of social media (e.g. [19,20,33]) and virtual communities (e.g. [31,38]) in disasters and mass emergency events. Improvisation and ad hoc teaming resonate very strongly with the practice of avalanche companion rescue since it is impossible to know who will be part of the rescue team and what role everyone will need to play (as we will describe in the Our Study section). However, avalanche companion rescue has its own unique characteristics that differ from this past work, mostly because of the immediacy of the event. Expertise cannot be called in, as the remote areas involving backcountry skiing means there is often no wireless or cellular network access, and thus no access to social media or virtual communities. All the teamwork has to be performed on site, with only the people who are present as rescuers, with only the equipment immediately available, and within a short period of time. Even if people can communicate to the outside world, the arrival of additional parties is often far later than the critical time required for finding and unburying the victim alive.

Communities of practice and situated learning

Most high-risk recreational activities occur in a social context, where its players strongly identify with a community of like-minded people. Formal and informal clubs are common, specialized social media sites develop, open invitation social gatherings abound, and courses are offered by both professional and lay people [4]. Similarly, training is often part of a social event.

This social structure is captured by the concept of *communities of practice* as developed by anthropologists Jean Lave and Etienne Wenger [24,43]. These communities refer to groups of people who share a passion, a craft, or a profession. Central to these communities is how learning is situated in the social, where practitioners share knowledge and experience of their field of the practice, and thus learn from each other [23]. Communities of practice display a shared repertoire of experience, stories, best practices, and equipment and tools, all which help inform its members. The act of learning is further situated in the real world [24], as it often occurs as they perform their shared practice. Wenger [43] argues that it is by being part of a community of practice and by practicing alongside 'old timers' (people with considerable experience) that newcomers can learn the skills, techniques, values and norms of a community of experts. This process takes time and 'repeated and enduring exposure' is necessary for learning to happen [25].

In the case of backcountry skiing recreationists, some aspects of the practice are passed on via this *situated learning* as they are performing the activity. Examples include the selection and review of appropriate equipment by members at the start of the activity, route finding and terrain choice discussion while travelling, and even critique and fine-tuning of skiing techniques. The practice of avalanche companion rescue does not benefit as much in situated learning. Since avalanches are rare but serious occurrences, learning must happen in different ways, such as through reading and instructional videos, and by taking formal courses. While simulations can occur in the field (e.g., by one member of a group burying a transceiver while others try to find it), they are rarely and often hastily done: people would rather ski.

We are thus particularly sensitive to the notion of communities of practice, where we see it as one way to better understand the use of technological training grounds by outdoor recreationists, both in terms of skill development and team coordination.

OUR STUDY

Our study took place in a dedicated area at Mount Baker Ski Area in Washington, U.S.A. Our study comprised 2 parts: an observational study with interviews of participants using the beacon park, and a reflection on our own practice of installing and modifying the beacon park in response to what we observed. As the two parts of the study happened simultaneously and influenced each other, we continuously evolved and refined our research questions. Two of the authors, a CSCW researcher (also newly a backcountry skier) and a professional avalanche education specialist were on site to install, maintain a wireless beacon park, and conduct the study for 4 weekends, one day per weekend. The education specialist served a dual role, where he acted as both as an observer and as a facilitator for those requiring or asking for help.

Before we go further, we provide necessary background information on backcountry skiing, companion rescue and the functioning of avalanche beacon training parks. A detailed description of the avalanche rescue protocol written for a CSCW audience can be found in [13].

Backcountry Skiing, Avalanches & Companion Rescue

Backcountry skiing (and snowboarding) is a popular activity. Skiers travel under their own power (both uphill and down) outside of ski resorts in mountains. Rewards include breath-taking views, vigorous exercise, challenging and rewarding ski lines, and pristine untouched snow. The risk is an *avalanche*, a large volume of loose snow that rapidly slides down a slope [12], which can bury and injure skiers, and that can have fatal consequences. When caught and buried in an avalanche, victims rely on teams of rescuers, often their traveling companions, to save them through a process called *avalanche companion rescue.* Companion rescue is challenging, stressful, complex, and time sensitive as the chance of survival decreases significantly after 15 minutes in a complete burial [16].

Most backcountry skiers carry tools to perform companion avalanche rescue. *Avalanche transceivers* (also called *beacons*) are portable electronic devices that transmit a locatable signal. Each skier wears one turned on as a matter of routine. Rescuers can use the same beacon on receive mode to search for the victim, where rescuers try to locate the snowpack surface directly above or nearby the victim. In addition, *collapsible probes* (long poles several meters in length) are used to physically probe the snowpack area to locate a victim. *Avalanche shovels* – collapsible for transport – are used to dig out the victim. While other safety tools are available on the market, the trio of transceiver-probe-shovel is the most commonly used amongst recreationists. Transceivers are the technological tools used to find the most buried victims (as per the last two decades statistics in the U.S.A. [2]).

Companion rescue with an avalanche transceiver follows a well-defined protocol. Avalanche rescue educators and researchers have developed and improved this protocol since the 1970s. It is taught in rescue literature, avalanche rescue classes, and workshops (e.g. [12,41]). While slight variations in advance techniques exist, the main steps remain the same [18]. It begins with *initial coordination*. Rescuers (the victim's or victims' companions who have witnessed the avalanche) quickly coordinate themselves. They discuss further risks for themselves as rescuers (e.g. potential future avalanches, or dangerous terrain like cliffs), and gather information concerning who saw what. They rapidly discuss what needs to be done, where each assumes an initial role with particular duties (e.g., leader, searcher, prober). While taking a minute or two, initial coordination leads to better overall efficiency, better safety management, and makes sure that no time is wasted [13].

The next step is the *signal search*. Here, searchers travel on skis on the avalanche path and the avalanche debris (generally settled hard chunks of snow and ice) in a pattern that covers the whole area that could contain the buried victim. They use their beacons on search mode to find the signal emitted by the victim's beacon under the snow. Once a signal is found, usually at a range of less than 60 meters, the rescuer starts the *coarse search* and follows the indications on the beacon (a visual distance and direction cue, and an audible cue) to get closer to the victim. When close to the victim, the rescuer removes his skis, kneels and starts the *fine search* of the strongest signal (called *bracketing*) to further narrow down the victim's location. Depending on the depth of the burial and other factors, this location may still not be exactly over the victim. To pinpoint the location of the victim, the searcher calls in the probers who start *probing* – repeatedly pushing the probes through the snow in a regular pattern around that region – where they try to strike (and thus locate) the victim. Next is *shoveling* the snow out of the way, first to bring an airway to the victim, and then to extract the victim from the snow. As shoveling through a settled snow pack is non-trivial and exhausting work, there is even a protocol that dictates efficient methods for team shoveling. When the victim is uncovered, first aid begins. The last step is to transport the victim out of the backcountry as needed.

While this protocol sounds straightforward, much can go wrong. For the search portion, beacon signals can be lost or confused, with searchers backtracking or even going around in circles. Rescuers may fixate on one victim's signal, at the cost of another victim. If a party member had accidentally left their transceiver on 'transmit' mode, that signal could mislead other searchers. Probers and searchers doing the fine search work atop the same small area: probers may miss areas that should be covered, or think they have a 'strike' when they do not, and searchers may miss the strongest signal. All leads to confusion. Shoveling through avalanche debris must be done efficiently (via a well-defined method) as it is otherwise extremely difficult, tiring and time-consuming. These all matter greatly, as even the loss of a few minutes in the process may mean the difference between life and death.

Figure 1. a) Practice beacon in waterproof case on plywood. b) Beacon park control box. c) Beacon park area.

Because of the above, best practices demand that recreationists learn and regularly practice with their equipment, understand the protocol for finding a victim, and know the procedures for working as a companion rescue team [1]. They must also be ready to work with strangers. They must be ready to improvise and readjust the protocol depending on who is doing the rescue, how many people are available, and to accommodate everyone's skill levels. Recreationists are highly encouraged to take professional avalanche courses, where an instructor offers the basics of avalanche safety, and additionally encouraged to practice their skills on their own (individually or as a team), at least once every ski season [13]. Another option is to train in an *avalanche beacon training park* (or beacon park for short). Unfortunately, there are no data available that can inform us on the number of recreationists that take classes, how they practice, how many use beacon parks, etc. What is known is that there is a huge diversity of training. While many recreationists take training very seriously, there are many backcountry users with little training. Concerted efforts have been made to improve this situation by providing more avalanche training such as avalanche awareness courses to high-risk groups (e.g. high school and university students who have recently taken up backcountry boarding or skiing, and snow-mobilers who have traditionally eschewed avalanche courses). However, avalanche awareness courses are insufficient by themselves: their goal is to have its attendees recognize the risk of avalanches, and to persuade them to take proper avalanche courses (e.g. see www.avalanche.ca/training#overview). The second effort to increase avalanche training is through the provision of avalanche beacon training parks

Avalanche Beacon Training Parks

An avalanche beacon training park is a practice field containing pre-installed avalanche beacons [10]. They are usually located at ski hills or at road heads in backcountry areas, and their locations are advertised and signed (Fig 1c). A beacon park typically comprises 8 to 16 *practice beacons* that emit the same radio signal (457 Hz) as normal avalanche beacons. Beacons are protected in a waterproof case, and screwed to a 50 cm^2 plywood sheet (Fig 1a) that simulates the victim's surface area when probing. Beacons are buried under the snow at the beginning of the season, with their depth varying over time with the snowpack. A beacon park can also be installed temporarily, such as for an event. Beacon parks include a *control box* (Fig 1b) controlling the operation of the practice beacons.

To use the beacon park, recreationists arrive on site with their own beacons. They turn on one or more practice beacons through the control box. They use their personal beacons to do the coarse and fine search towards one signal at a time and then use their probes to detect the plywood holding the practice beacon through the snow. The practice stops there. Unfortunately, while an important skill to practice, digging is generally not done within the beacon park for different reasons: the heavily-trodden snow is often frozen into place and makes digging unrealistic; it keeps the terrain as smooth as possible to eliminate hints for others; it keeps the snow depth deep which simulates deep burials.

Research Questions

We focus specifically on avalanche beacon training parks as an illustrative case study of a technological training ground. We ask:

- How do recreationists use beacon parks for both skill development and team coordination?
- How can we design beacon parks to better fit the needs of the recreational community of backcountry skiers?

The domain of avalanche rescue is largely one of practitioners and practitioner expertise. While there are conferences on all aspects of avalanche (e.g. International Snow Science Workshop), the topic of companion rescue and its associated risks does not lend itself to the kinds of academic treatment that we could expect in typical academic CSCW research. Thus our methodology is not purely objective. We add a subjective component, where we provide our own insights into issues of transceiver use and avalanche risks, and in interpreting what participants do in beacon parks. We stress that our views are not unusual, but they echo views commonly held by avalanche professionals and recreationists. Finally, as we will describe shortly, our methodology is observational by default, but moves to interventionist both to be helpful to the participants (who are using the beacon park for a real purpose) and to see how that intervention helps.

Part I: Observational study and interviews

Part I of the study focused on our first research question. Observational data was gathered with the goal of constructing a detailed portrait of how recreationists used the Mount Baker beacon park somewhat ‘in the wild’: they were allowed to pursue their own activities, but had the option of using an on-site expert as a resource.

Participants. We recruited participants by advertising the opportunity to practice avalanche companion rescue in a beacon park, with the option of participating in a study. We advertised on online sports-related forums, through sports equipment shops’ social media, with print ads in the local community, and on the Mount Baker ski area’s website. We had 22 participants (5 female, 17 male). 12 were related to the Mount Baker ski area and 10 from the general public. We had 10 participants that came individually, 3 teams of 2, and 2 teams of 3. 10 had never used a beacon park, while the rest had used them at other ski resorts. There was a broad range of backcountry ski experience, from no experience to 16 years of experience. All had at least several years of resort skiing experience. We note that downhill skiing expertise did not necessarily correlate with backcountry experience or companion rescue expertise. For example, several volunteer ski patrollers participating in the study did not routinely go backcountry skiing, and had limited companion rescue training (if at all).

We recognize that our participant sample is broad and varied, and may seem ‘at odds’ with a formal study. The benefit is that this variety is representative of people who actually use beacon parks ‘in the wild’. This was intentional. Rather than select a narrow slice of potential beacon park users, we wanted to have enough diversity to observe a range of the ways people went through scenarios. This in turn provides rich and detailed qualitative data. We should also add that this participant diversity matches our own personal experiences in seeing who uses beacon parks.

Tasks. Participants came to the tent (Fig 1c), where we introduced a particular avalanche rescue scenario. They would then do a scenario, usually returning to the tent afterwards for the next scenario. The facilitator would offer his expertise to participants (perhaps after observing participants or on participants’ request), where he would offer tips, comments and even help them through particular scenarios. Otherwise, we let the participants use the beacon park in the way they wanted to keep the ecological validity of the study. We invited participants to perform as many rescues as they wanted. If participants had come alone, we let them use it by themselves. If they had come as a group, we suggested that they perform practices as a team.

Data Collection. We conducted a pre-activity questionnaire to gather information about each participant’s motivation for using the beacon park, and their level of expertise in skiing, companion rescue, and beacon parks.

As the participants used the beacon park, we observed them with the shadowing technique. We asked them to describe what they were thinking as they were doing their practice rescues. One researcher followed them and took hand written notes. We also filmed the participants for the length of the search with a GoPro camera. We wrote a report for each participant summarizing our observations on how they performed the rescues, how they used the beacon, how they collaborated with others, and how they modified their strategies of search from one scenario to another.

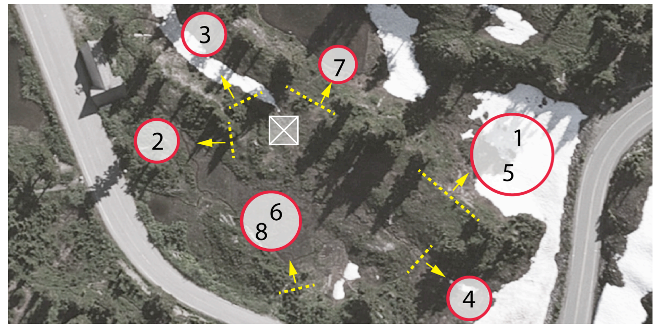

Figure 2. Aerial view of day 3’s beacon park. Red circles show the simulated avalanche debris zones; numbers indicate the buried beacons. Yellow dotted lines and arrows indicate each scenario’s starting gate and direction of the simulated avalanche. (From Google Maps: during the study, snow covered the whole area)

Finally, we conducted post-activity semi-structured interviews with those participants who were willing (9 in total). The interview questions focused on participants’ experience of the beacon park (including positive and challenging aspects of practice, the development of skills, and the practice of coordination) and on beacons and beacon parks could be designed in the future.

Part II: Reflections on maintaining a beacon park

Part II of the study focused on our second research question where we reflected on the design strategies we used to install and maintain the beacon park, and the changes we made to our installation over the course of the study based on our observations in Part I.

Installing and Maintaining the Beacon Park. For each day that we were on site, we created a series of scenarios. For each, we positioned and buried each practice beacon to create a variety of scenarios for participants. Each scenario used bamboo poles to indicate the start and end of the simulated avalanche path. Scenarios ranged in expected difficulty. The simplest were those simulating a single burial. More difficult scenarios simulated two victims located at various distances from one another. Multiple burials make it more difficult to locate a signal (due to multiple beacon signals), coordination complexity, and added stress due to the greater number of victims for the same survivable amount of time. For each day, we used insights gathered from the previous study day to modify the beacon park setup.

Data Collection. The two on-site authors debriefed each other at the end of each study day. Through a written report, they recorded what they had observed in relation to the organization of the beacon park, the way the scenes were installed, the way information was communicated to participants, and impressions for what worked well and what needed adjustment. We took photos of the training scenes and our installation. We also produced an aerial map of the beacon park locating each scenario (as in Fig. 2).

Data analysis

We conducted a thematic analysis [5] with all the data collected from both parts I and II, i.e., we identified and recorded patterns of phenomenon that emerged across the observations, interviews, and reports that comprise our primary data. We identified various themes, discussed next.

RESULTS

Our results are presented in five themes as reflected in our data analysis, each with a variety of sub-themes. Dominant themes include: 1) individual skill development with the technology in context; 2) team coordination training including communication, role distribution, and team rescue strategies; 3) the false sense of confidence; 4) the beacon park as technological training ground, and 5) the role of the facilitator.

Individual skill development in context

The beacon park allowed for participants to practice individual skills with their beacons and advance team strategies for more efficient rescues. We observed a necessary progression starting with an individual's familiarization with the technological tool and its functions, learning how to use that tool in the context of the simulated search, and then to a mastery of particular rescue skills.

From familiarization to a mastery of skills in context

All participants used the beacon park to develop and master particular skills, from beginners learning how to use a beacon to advanced practitioners focusing on sharpening their skills in complex multiple burial scenarios.

For some participants (e.g. P1, P13, P15b)[1], the beacon park was their first experience with a beacon and with the avalanche companion rescue protocol. Their learning largely revolved around the basics of the avalanche transceiver technology: how to turn the beacon on, how to switch between transmit and receive modes, and how to read the signals as one moved over the terrain. Even experienced people practiced with their technology. For example, the beacon park was seen as a good place to get to know new equipment, as functions and modes often differ between beacons. As P10b said, her motivation for coming to the beacon park was to "*get used to my new beacon and practice avalanche rescue*". The beacon park also served as a catalyst for participants to become aware of technical or logistical issues with their equipment such as the lack of recharged batteries for example (P4).

Beyond familiarization with the beacon, participants used the beacon park to master certain skills. For example, couple P11a and P11b pushed each other to get the fastest times on the single burial scenarios. While one was performing the rescue, the other timed the rescue. This additional stress augmented the level of psychological fidelity [3] as well as provided a baseline for comparing results and progress for those participants.

In addition to focusing on the technology (at least initially), participants were also interested in acquiring skills about using that technology within the context of an actual search. As P3c said: "*It's not just about turning the beacon on, but about the way to do the rescue too*". For instance, participants P3b, P5 and P10c all mentioned that they wanted to use the beacon park specifically as a way to become more proficient in the context of multiple burial scenarios. In their case, they used the simpler scenarios (single burials) as a warm up exercise before engaging with the scenarios they wanted to gain more experience with.

The beacon park – more than an individual training tool

It was interesting to note that almost half of our participants came alone to the beacon park. Participants came on their own for a multitude of reasons: they are new to backcountry skiing and are looking for a group to go with (e.g. P1), they had some free time between ski runs by themselves (e.g. P8), or they wanted to focus practice on their device (e.g. P13). Some of them were aware of the potential to practice as a group while others were not. But in any case, all found great value in using the beacon park and in practicing individual skill development with the built in scenarios.

Team coordination training

Our second study theme was how the beacon park supported team coordination training. While we saw that the beacon park can provide a fruitful setting for individual skill development, we also see its immense potential for practicing team coordination. This is important, as coordination is a critical component of a successful companion rescue that also needs practice. In addition, when participants came alone to the beacon park, they missed opportunities to learn from each other and to further deepen their relationships with other members of their community of practice. Some of them also missed opportunities to learn from an expert (if available), such as our own on-site facilitator.

As we described previously, coordination is one of the hardest aspects of avalanche companion rescue, and therefore one of the areas with the most opportunities for improvement. In our discussions with participants, they were enthusiastic at the idea of practicing as part of a team:

"*I think that a group setting is more effective, and more fun than training alone. It is rare, or at least unwise, to travel in the backcountry alone, so training with other people seems to make sense. Also, from personal experience, communication is absolutely crucial in emergency*

[1] Participants who came to the beacon park by themselves are referred to as P#. Participants who came as a group are referred to as P#a, P#b and P#c, with same #.

situations, and it's something that is often overlooked, so working it with other forms of practice, or training is a good idea." (P13)

Although most participants agreed that coordination and communication were highly important for the success of companion rescue, only 6 out of 22 reported to have practiced team coordination in the last year. In addition, as we will show below, practicing coordination did not come intuitively to various participants.

Coordination: beyond the beacon

One of the main challenges we observed in the beacon park was to move beyond understanding the beacon technology, to gain a larger perspective of the situation. When teams arrived on scene, we seldom saw overt discussions about roles or strategies for the rescue they were about to perform. Instead, we saw teams going in a scenario and focusing each on their beacons to look for signals. That is, participants focused on the technology rather than team coordination, and on the details of their search rather than the big picture of what was going on. This lack of communication often continued the rest of the search.

For example, the team of P3a, P3b and P3c began their search by finding the first signal and focusing on it. As the three participants started to do a fine search on the first signal, they were too close together. P3a and P3b were in the way of P3c who was trying to narrow the probing area. Not only was this sub-optimal, but it also meant that no one was searching for the second victim. This could have easily been prevented by simple and short communication between the participants, e.g. 'I'll finish this search, P3b get your probe out, and P3c start the coarse search for the second victim'. Similarly, had a leader been selected, their role would have included identifying and remedying issues such as these.

After observing the above situation, the facilitator debriefed these points with the participants. The participants then moved to the second multiple burial scenario and were encouraged to work more closely as a team and specifically to communicate better. They agreed that communication was important and that they should plan differently for the next scenario. However, in practice, and even with the proper intentions of the participants, communication was lacking and participants still showed signs of working individually instead of as a team. In fact, it seemed that the participants were still very much focused on understanding their own beacons and that most of their attention remained on the technology rather than the teamwork. This finding reveals that coordination and communication may not come easily, and that considerable practice is required to achieve a level of team coordination proficiency. In summary, participants in teams that lacked communication unduly focused their attention on the beacon. They did not maintain a broader perspective of the situation, which resulted in a loss of situational awareness. This is similar to the finding described in [13] and critiqued as a flaw in beacon designs.

As a contrasting example to the previous case, the team of P10a, P10b, and P10c (who had never performed a rescue together) had much better communication and were able to coordinate on the scene. At the entrance of the scenario, P10c proposed to his teammates to split the avalanche path into search paths for each of them. As they walked down the hill, P10c reached the first victim. P10a and P10b got closer to him as well, as their beacons also indicated that direction. While P10b got ready to help P10c by probing, P10a recognized that he was not needed there and walked past them to search and find the second victim. In this case, the team was able to monitor each other's actions and fluidly take the roles that were the best for the team's success (rapidly deciding to be a prober, or to leave the first victim and start the search of the second). This finding illustrates what Faraj and Xiao [17] describe as Plug-and-Play teaming, where team members can take on different roles, as long as the requisite expertise is adequate and situation awareness is maintained. The teams that are flexible enough to subdivide and reconstitute themselves in an ad hoc manner are more successful in emergency situations [17].

Mastering specialized roles

Our results also show another strategy for teams practicing together: mastering specialized roles as part of a team. In some cases, participants, often teams of 2, would each lean towards a role that they would keep from scenario to scenario. For example, P11a acted as the prober while P11b did the fine search and the bracketing:

"*The most challenging parts were probably working out how to best work efficiently as a team. After several tries, we realized that it was best if as soon as one of us got a signal, the other one immediately started getting out their probe. Since it is relatively quick to follow a signal and relatively time-consuming to get out a probe, it almost always still worked out that the person following the signal was bracketing the site by the time the person with the probe was ready to start trying to get strikes*". (P11a)

Their strategy led to very efficient practice rescues. However, the challenge with this strategy is in the lack of flexibility between the roles. In a real accident, one never knows who might be a victim and thus not able to perform their role as rescuer. Similarly, the person with that expertise may be downslope, where it would take considerable time to return uphill to the avalanche site. Hence, it is as important to practice other roles to be more versatile. This strategy can be a stepping stone before practicing a more fluid exchange of roles in the practice. P11a and P11b eventually recognized this as a problem, where they exchanged roles during their last scenario in order to get a feel for each other's role. This example exemplifies one of the types of cross training [42]: *positional rotation*, a strategy where each team member learns about each others' tasks and roles by doing them first hand [8]. In addition, this strategy was reported to lead to inter-positional knowledge which is crucial to "team functioning because it allows team members to anticipate the task needs of fellow team members, thus allowing enhanced coordination with a minimal communication requirement" [42:88]. Moreover, it is central to avalanche companion rescue practice since it is impossible for rescuers to predict what role they will need to take depending on the situation.

Breaking the false sense of confidence

In previous research, it was pointed out that practice that is too simple or too easy can lead to a false sense of confidence for backcountry recreationists [13]. In this study, we found that the way the scenarios were organized in the beacon park and the variety of their expected difficulty could help break that false sense of confidence for participants. This allowed them to realize the complexity and challenges that are part of some avalanche accidents and served as a confirmation that practicing is important for avalanche preparedness.

We often observed the following pattern. Participants who began with a sequence of single burial scenarios became faster and more efficient at finding the single victim. This boosted their sense of confidence about their ability to perform successful rescues. When participants moved to more challenging scenarios, such as a coarse search on a multiple burial scene, difficulty increased significantly, for example because they encountered confusing indications on beacon signals, and because more team coordination was required. In these cases, we saw some participants able to find a first victim but not the second one. In other cases, participants could find both victims but took a much longer time relative to the single burial scenarios. In most cases, the harder scenarios shook the participants' confidence and trust in their beacon.

One issue appears to be that participants – particularly those with less experience – had an incorrect view of the accuracy, precision and robustness of the technology they were using. Beacons have significant problems with the multiple signals received in a multiple burial scenario. They do not always display competing signals in an understandable manner. For example, some beacons alternate distance numbers between the two victims, which some found confusing (e.g. P1), while others fix onto one signal while hiding the other. Beacons sometimes lose the signal due to the rapid movements of a searcher. In other beacons, the screen can even go black. Some beacons try to simplify searching by allowing the search to hide a particular signal (called 'marking'), yet this is considered an advanced feature and introduces further problems. A beacon may even have to be turned off and on again to reacquire a lost signal (e.g. P5). These events are, of course, stressful (as reported by various participants) as this is often the first time they have seen their beacon act like this. Their confidence is shaken, and their mental model of the technology is broken. It is only through practice, repetition and mentoring that participants were able to make sense of the nuances of their beacon and of those signals, where they could eventually perform rescues more successfully.

A sequence of progressively more difficult scenarios helps mitigate this loss of confidence. Although harder scenarios were more challenging, participants appreciated the opportunity to sharpen their skills. For example, P15a suggested: "*Keep the progression of difficulty going. Maybe also add a 3 person burial scenario, something even more complex*". Our decision to seed the beacon park with multiple scenarios representing different levels of difficulty thus proved important. Scenarios of similar difficulty allow people to return and practice their skills; advancing to the next level gives them opportunity to tackle more complex situations, which forced them to acquire a higher skill level (which they appreciated) and increased confidence.

Designing beacon parks as technological training grounds

An important component of how a beacon park is experienced relies on its set up on the terrain and how it is presented to recreationists. In this work, we evolved the beacon park over our study period. Based on our observations and self-reflections about our practices, we now share the varied decisions we made about this technological training ground, and how it influenced participants' ability to practice and develop their skills and team coordination practices.

Physical constraints in the beacon park

The beacon park is a technology-augmented context for training, where it should be designed to mimic real-life threat situations. This implies a combination of two things: real life elements as reflected in the terrain; and the technology itself.

Ideally, we wanted terrain that was on a steep slope resembling an avalanche slope. However, this desire had to be balanced against how accessible the beacon park would be for participants, and the constraints imposed by the terrain the ski resort management provided for us to use. The somewhat flat terrain we used (which is true of most beacon parks) did not match a typical avalanche slope. As well, the snow quality differed from the varied snow that could result from an avalanche, as P3c critiqued:

"*The beacon park is generally in a flat area, on snow that is easy to access and walk on. In a real avalanche, the terrain would be much steeper and walking in avalanche debris is more like walking on boulders. So this is not exactly realistic*." (P3c)

In addition, the trampled ground of a beacon park does not visually resemble a real avalanche, which rescuers would normally scan for visual cues to determine the avalanche path and the debris zone.

The technological factors are the number of practice beacons and how they were located and buried across the area at various depths. This greatly influences scenario difficulty. Deeper burials are more difficult to pinpoint, and particular combinations and distances of activated beacons alters how searchers see signals. Yet the terrain constrains the burial depth (e.g., due to the current snow depth) and how far apart one can place the beacons (due to site size). Thus our terrain choice and where to position each beacon had an important impact on the range and degree of a scenario's simulated avalanche accident fidelity.

Scenarios require explicit communication of their details

Because there is no real avalanche, details of scenarios have to be explicitly communicated to the participants. This includes where the scenarios are located and the number of victims. In our study, the facilitator verbally explained each scenario to the participants, and bamboo poles marking the top and bottom of the imagined avalanche zone served as visual cues. Although participants were generally able to imagine the avalanche path and the debris zone, others found that more challenging. For example, P10a mentioned: "*The run out zone (or where the debris would be) requires a lot of imagination on my part, maybe this could be improved.*" (P10a). Factors that require explicit communication affect learning because psychological fidelity is undermined.

Beacon park flexibility

While we had to adjust to the physical constraints of the terrain, the beacon park system is very simple—a set of buried beacon signals that can individually be turned on or off—which makes it highly configurable and flexible in terms of constructing scenarios for different learning situations, e.g., how people navigated through the park, how they configured it for single or multiple burials, how different skills could be practiced, and how more structured teaching can be layered atop of it.

Through our observations, we saw how the beacon park was sometimes seen as this flexible platform supporting a variety of learning activities. We observed various teaching strategies both between the facilitator and participants, and between participants. More experienced participants in a group would teach the less experienced participant basic skills. For example, P16a (who had companion rescue experience) used the beacon park as a place to show his girlfriend (P16b) the basic search movements during the coarse and fine search, including how one should respond to the signal seen in the beacon. In the example of P11a and P11b timing each other, we see how certain exercises could be created ad hoc in the technological setting of the beacon park without the need of external facilitation or suggestion.

The role of the facilitator

A good facilitator is someone recognized as an 'old timer' [24] in the practice of backcountry skiing and avalanche companion rescue, and one who is able to pass on their skills and knowledge to others. However, most beacon parks do not operate with a facilitator. Thus if a team uses the beacon park, its members often rely on a more experienced team member to mentor them (although that person may not necessarily have appropriate training).

In our study, many of our participants were novices and needed some orientation for how to use the beacon park. The first role of our facilitator was to introduce the park and how to best use it, including what scenarios to do, in what order, and where scenarios are physically located. As participants pursued scenarios, the facilitator answered many questions, ranging from specific questions about advanced functions on beacons to deeper understanding of rescue strategies. Finally, we found that participants appreciated debrief sessions or feedback from the facilitator. Once a scenario was completed, the facilitator summarized his observations and asked participants to describe what they saw, how they felt and how they think things could have been better. Through this discussion, the facilitator encouraged the participants to realize what they could do differently. Those conversations often led to improvement in the next scenario performed. For example, with the couple P11a and P11b, the facilitator explained a specific strategy for probing that is particularly efficient with two rescuers; a strategy they tried and found successful in the next scenario. Participants recognized the value of the facilitator: "*Having [the beacon park] staffed also really helped, because when you have someone teach you, this makes a large difference*." (P10c)

In our view, the presence of an 'old timer' was very significant for an effective use of the park. However, staffed beacon parks are not the norm. Without the facilitator, people could easily develop poor practices that could jeopardize how they performed companion rescue during a real avalanche.

DISCUSSION

Our results provide insights into particular changes that can make beacon parks more efficient, more inviting and more tailored to the training of backcountry recreationists. In addition, our work also has particular ramifications for CSCW. Specifically, the advent of mobile computing means that non-expert collaborators are now using sophisticated technology while on the move and within specific contexts. Unlike desktop computers that people can learn while at home or in the office, training in the field becomes increasingly important. For this reason, in this discussion, we focus on high-level strategies that can be applied to technological training grounds beyond avalanche companion rescue. These include training and simulation systems for non-experts in many fields, including but not limited to extreme sports.

The value of progressive scales of difficulty

We saw significant value in using progressive scales of difficulty in beacon park scenarios. As previously described, the facilitator encouraged participants to follow a progression, where he suggested to do simple single burial scenarios first until they mastered their basic skills, and only then to make their way to the complex multiple burials. While solidifying basic skills increased self-assurance, the complexity progression of the scenarios also helped break the false sense of confidence. We saw how more complex scenarios provided a space to ask questions, reflect on more difficult situations, understand device and personal limitations, and overall provide a sense for how hard companion rescue could be. Learning is influenced by the progression of scenarios, by practicing in context even if simulated, and (sometimes) by team mentoring. This follows the theory of situated learning [24] where the physical and social situation constructs a context for participants to make sense of some functions or errors of their beacons as they pursue their practice.

The idea of progressive learning and learning by mastering is, of course, not new. Indeed, many formal learning environments are structured so that students must achieve proficiency at a given difficulty level before they are allowed to continue to the next level (for an example in computational games, see [26]). In spite of this, technological training grounds are not structured in this manner; instead, they are offered as environments where people attempt to learn on their own and in an ad-hoc manner. We believe these training grounds can be improved dramatically by offering scenarios of increasing difficulty (as we did), by explicitly describing skills that should be mastered at that level, and by offering a way for learners to 'grade' themselves in terms of mastering a scenario level. Based on our findings, we also suggest that this information should be communicated to recreationists in ways that are appropriate to the activity and the physical context. For example, in outdoor training grounds, using weather resistant posters to describe scenarios, potentially augmented by digital material (accessible via a mobile device) to describe best practices and learning goals. Beyond extreme sports training, this strategy can also be applied to train volunteers and citizens who are helping in disaster relief and emergency situations. In the cases of volunteer work and citizen-to-citizen communication [34], short training sessions can also include a progressive scale of difficulty to help build assurance but not over-confidence.

A variety of levels of fidelity

The beacon park is a technological training ground that includes a variety of levels of fidelity along the three aspects of environment, equipment and psychological [3] (as described in our related works section). Throughout our results we have articulated how certain aspects could reach a higher level of fidelity while others could not. For beacon parks, the level of environmental fidelity is difficult to manage, for it is heavily constrained by the terrain available. If varied terrain is available, areas should be chosen to match the scenario conditions (e.g. steepness of the slope, the presence of terrain traps, etc.). However, the level of fidelity for equipment is under our control. As we saw, signals from buried beacons are indistinguishable from real beacons, and we expect learners to bring in their own personal equipment including their personal beacons. This situation might be similar to how other researchers are aiming at training with new wearable technologies where the environmental aspect cannot be adapted, but where the technology is "real" and not simulated (e.g. [9,22]).

The low level of environmental fidelity can be partially remedied by manipulating the psychological level of fidelity, i.e., the ways participants construct believable stories for themselves about the rescue situation. This is especially important for practicing team collaboration [3]. In our study, this was done by constructing scenarios that included a story of how the avalanche happened, using buried beacons to represent victims, and by visually marking areas in the environment to simulate environmental conditions (e.g., bamboo poles indicating avalanche boundaries). We saw that participants were largely able to construct the story in their minds and reach a higher level of psychological fidelity. This strategy echoes what Klann describes in his work with fire fighters [22], where he argues that it is through 'playing out' a scene that firemen best expressed their skills and experiences. The novelty of each scenario added to their believability since others created the scenarios. In addition, we could manipulate people's stress (e.g., by observing, timing and critiquing people's rescue performance), which proved effective in increasing the level of psychological fidelity.

More generally, technological training grounds should follow similar practices. When environmental high fidelity is rarely possible, which is often the case with natural disasters and emergency situations, they should offer a story behind each scenario (again, through on-site posters and visual markers, and/or through digital media). At its best, the technological training ground should offer a 'full mission' context for practice (in the words of Beaubien and Baker [3]) while still operating within the constraints of multiple ranges of fidelity.

Balancing skill development and coordination training

We saw a large number of participants focus on learning individual skills at the cost of communication and coordination training. This likely occurs because, at the surface level, the beacon park emphasizes the technology itself (beacon search), whereas the need for communication and coordination learning is tacit and thus easily overlooked. This very likely happens with other technological training grounds, particularly in activities that require a personal digital device while in a group setting (e.g. with wearable devices [9,22]). More specifically, there is relatively little research that looks at how non-experts familiarize themselves with a new mobile device before focusing on communication and coordination.

The solution is, in part, to make communication and coordination learning an explicit activity. Toups et al. [40] argued for focusing solely on distributed cognition and team coordination training for firefighters, both for economical and focus reasons. They proposed a 'zero-fidelity' computational simulation that removes the realistic elements found in higher fidelity simulations to keep only the bare essentials for learning team coordination (such as eliminating fire and smoke visualizations but keeping time pressure for example). In outdoor physical training grounds, the simulation takes place in a real world setting and offers the opportunity to focus solely on the coordination practices if desired. The scenarios and learning descriptions mentioned earlier should include these not only as goals to incrementally master, but should describe the steps on how to achieve them. If individuals (rather than teams) appear on site, the usage descriptions of the area should highly encourage them to find other like-minded people to do the exercises together. Perhaps meeting times can be advertised as a way for ad hoc groups to gather opportunistically. This solution, of course, will show better results if participants are familiar with the technology required before and can focus on the coordination training rather than mastering their own device.

Supporting the community of practice

As we have presented earlier, we see backcountry recreationists as a community of practice. However, we also observed that learning from others within beacon parks is not as common as it could be. As with communication and coordination, this is also likely due to the emphasis on the technology, which seemingly favors individual skill development over team learning. This also likely occurs with other technological training grounds.

A partial solution is to recast the technological training ground in a way that encourages mentorship and facilitation within the community of practice. Since the scenarios can be structured and ready to use, members of the community can go straight to the heart of the topic without spending a whole day preparing the site, which was identified as a challenge in previous research on avalanche companion rescue [10]. Importantly, technological training grounds such as beacon parks can be designed as a common space where members of the community can group and build relationships between each other, which create opportunities for more knowledge exchanges.

For example, technological training grounds could be presented and advertised as an area inviting people with more skills to teach novices particular skills. For instance, when a person has mastered a particular scenario difficulty and skill, they could be encouraged to mentor others going through simpler scenarios. The payback is that people often gain even more mastery by teaching. In addition, a training ground can advertise particular times as a 'meet and greet' event for like-minded people to learn, socialize, and meet potential activity partners (for example ski partners in the case of the beacon park). Moreover, a training ground can leverage existing social organizations, such as clubs, schools and groups. Communities of practice often have structured clubs where its members gladly teach others through courses, or act as facilitators to share their expertise and support discussion amongst all participants (similarly to the role our facilitator played on site). Finally, many high-risk communities of practice encourage skill development through competition (e.g., mountain bike racing, competitive rock climbing). The training ground can be offered as a place for holding competitions, where teams 'race' against each other.

Overall, we found that it is important to create opportunities for recreationists to meet with others and to exchange knowledge. The strategies proposed above can be applied in cases where unacquainted people engage in real life exercises to train for a variety of situations. For example, in emergency response, teams of on-site workers or volunteers would benefit from learning from each other as part of a community of practice, even if they are supported by coordinators who are in a remote command center [9]. The ability to work together on site can increase team coordination and situational awareness and hence take away some of the strain on the link between the command center and the disaster scene.

LIMITATIONS OF THE STUDY

The study we presented in this paper has some limitations (which we see as great starting points for future research). The study was conducted on a short period of time (4 observation days) and would benefit from an extended observation period to see if more practice patterns emerge and also to try other strategies in maintaining and designing the practice scenarios. On the positive side, the study results we saw are very much in keeping with our own previous experiences in beacon parks, where what we saw appears to be a representative sample. Of course, further participants could also lead to a more detailed understanding of the experience and nuances of using the beacon park.

Our results are qualitative, where they helped us identify particular learning strategies within the beacon park training ground. A next step is to collect performance data after completing various learning stages to evaluate the efficiency of these learning strategies in making recreationists faster at companion rescue.

CONCLUSION

In this paper, we have looked at the specific case of avalanche beacon training parks as a way to illustrate how technological training grounds can support skill development and team coordination training for recreationists. With regards to the design of technological training grounds beyond avalanche training parks, our findings point to the importance of progressive scales of difficulty; the management of different levels of fidelity; the balance between skill development and team coordination training; and strategies for supporting a community of practice. These findings not only point to the future design of technological training parks for multiple communities of practice, but also build on and expand beyond previous work in CSCW about team training, ad hoc and volunteer teams and emergency coordination.

We reiterate that one of the distinctive aspects of this work is our focus on recreationists ad hoc teams rather than professionals. We also believe our findings can apply to other non-expert teams in non-extreme situations. For example, Dunlap et. al. [15] explored the role of technological training grounds for learning by citizen scientists who may have little background in the area. While the authors initially focused on skill acquisition (which also involved a mobile device), feedback from citizen science experts suggested that they should also consider citizen science as a community of practice, i.e., where citizen scientists should be expected to learn and perform the activity together, including self-coordination. While their context and methodology differs significantly from ours, the fact that their results are similar to our own suggests that these results are likely generalizable to technological training grounds supporting different communities of practice in a variety of domains.

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