

"Pro-Amateur"-Driven Technological Innovation: Participation and Challenges in Indie Game Development

GUO FREEMAN, Clemson University, USA

NATHAN MCNEESE, Clemson University, USA

JEFFREY BARDZELL, Indiana University, USA

SHAOWEN BARDZELL, Indiana University, USA

The phenomenon of end-user driven technological practices such as DIY making, hacking, crafting, and open design/manufacturing is shaping debates in HCI and CSCW about participatory innovation dynamics. However, prior research also reveals two limitations, namely, unequal participation in decision-making and the neglect of middle-tier "pro-amateur" end users. In this paper, we use independent [indie] game development as a case to explore the above-mentioned two key issues. Specifically, we highlight the importance of small teams, "crafting," and "democracy" in supporting and facilitating middle-tier end-users' engagement with technology. Our focus on indie game developers, an understudied group of middle-tier end users in HCI and CSCW, offers new empirical evidence of the dynamic process through which pro-amateurs can participate in technological innovation. Understanding their practices and the socio-technological challenges that they face, therefore, informs the design of more participatory technologies that both allow hobbyists' and experts' innovation and support the technological practices performed by users who are at the middle-tier. This not only promotes the democratization of technology and bottom-up innovation but also adds nuance to existing literature on end-user driven technological practices.

CCS Concepts: • **Human-centered computing** → **Empirical studies in collaborative and social computing**.

Additional Key Words and Phrases: participation; technological innovation; pro-amateur end users; indie game development

ACM Reference Format:

Guo Freeman, Nathan McNeese, Jeffrey Bardzell, and Shaowen Bardzell. 2020. "Pro-Amateur"-Driven Technological Innovation: Participation and Challenges in Indie Game Development. *Proc. ACM Hum.-Comput. Interact.* 4, GROUP, Article 4 (January 2020), 22 pages. <https://doi.org/10.1145/3375184>

1 INTRODUCTION

In recent years, bottom-up innovation and end-user design and tinkering have contributed to debates about participatory culture in Human-Computer Interaction (HCI) and Computer-Supported Cooperative Work (CSCW). The creation of innovative software, new interactions, and physical prototypes is no longer restricted to well-funded professional designers and researchers' but accessible to everyday users [53]. These lines of research focus on the examination of crowdsourcing,

Authors' addresses: Guo Freeman, guof@clemson.edu, Clemson University, USA, Clemson, SC, 29643; Nathan McNeese, mneese@clemson.edu, Clemson University, USA, Clemson, SC, 29643; Jeffrey Bardzell, jbardzel@indiana.edu, Indiana University, USA, Bloomington, IN, 47405; Shaowen Bardzell, selu@indiana.edu, Indiana University, USA, Bloomington, IN, 47405.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

© 2020 Association for Computing Machinery.

2573-0142/2020/1-ART4 \$15.00

<https://doi.org/10.1145/3375184>

DIY (Do It Yourself) making, hacking, crafting, open design/manufacturing, and citizen science, among others, as case studies of end-user driven technological innovation (e.g., [10, 25, 32, 33, 53]).

Collectively, these studies present how everyday users can engage with technology in novel and more participative ways. It is novel because traditional technology users are taking up new roles, including that of the "creative appropriator, hacker, tinkerer, artist, and even co-designer or co-engineer" [53]. The participative aspect stems from various kinds of actors, including experts and novices, having the abilities to shape the innovation process and products, which dramatically influences how labor, innovation, and power are fostered, acknowledged, and distributed [20, 21, 62].

However, prior research also reveals two limitations. First, the decision-making and evaluation process in these technological practices is not open to everyday technology users. One example is Amazon's Mechanical Turk (AMT): though Turkers provide micro-input that collectively contribute to the final product, they have no access to the overall decision-making process [27]. Second, existing literature on end-user driven technological practices has mostly focused on two populations: hobbyists' bottom-up innovation (e.g., by children [3], the elderly [52], or migrant populations [38]) and skilled experts' endeavors (e.g., open source software [35, 63] or machine learning development [61]). Yet end users who do not belong to either groups (i.e., the "pro-amateurs") have received relatively little attention.

In this paper, we use independent [indie] game development as a case to explore the above-mentioned two key limitations. Our choice was grounded on two reasons. First, indie game development and indie game developers represent a contemporary type of technological practice and an emerging tech labor in the gaming industry. Indie games are broadly defined as games that are consciously created within alternative production and distribution structures compared to mainstream game companies. Though the power relations between the indie game development community and the mainstream gaming industry are complex [34], indie game developers often advocate indie game development as a more participatory technological practice (e.g., accessibility to everyday users) than the mainstream gaming industry [51]. As the filmmaker of the documentary "Us and the Game Industry" summarizes, indie game development "is an open space; it's a space to feel alive in. That's what excited me about these people making games - there is an emotional timbre to why they're doing it. There is a soul." [51].

Second, based on our extensive interactions with indie game developers and continuous engagement in their community activities since early 2017, many indie game developers do not describe themselves as amateurs or professionals/experts but somewhere in between [17, 19]. On the surface, they do not affiliate with any massive game company or publisher. Many indie developers we know are freelancer developers, artists, or everyday users who have little programming/development experiences. However, since game development is a niche technological practice, many who started as novices told us that they had gradually developed strong technical skills and professional work styles by engaging in the indie community. They seem to be at an awkward middle point - as "pro-amateurs" in the profession of game development.

Specifically, we address the following research questions in hopes of extending our current understanding of end user-driven technological practices and informing the future design of collaborative systems to better support their practices:

RQ1: What mechanisms support and facilitate pro-amateurs' participation in technological practices as demonstrated in indie game development?

RQ2: What challenges do pro-amateurs face in their participation in technology as demonstrated in indie game development?

This study makes several contributions to HCI and CSCW. Middle-tier end-users, who are often experienced self-funded makers, creators, producers, freelancers, and innovators, are actively restructuring the innovation model in today's tech economy [5, 9, 18, 33]. Our focus on indie game

developers, an understudied group of middle-tier end users in HCI and CSCW, therefore, offers new empirical evidence of the dynamic process through which pro-amateurs can participate in technological innovation. Understanding their practices and the socio-technological challenges that they face also informs the design of more participatory technologies that both allow hobbyists' and experts' innovation and support the technological practices performed by users who are at the middle-tier. This not only promotes the democratization of technology and bottom-up innovation [18, 32] but also adds nuance to existing literature on end-user driven technological practices. Specifically, we highlight the importance of small teams, "crafting," and "democracy" in enabling and facilitating middle-tier end-users' engagement with technology. By small teams, end-users form "strike teams" consisting with dedicated and skilled amateurs ("pro-amateurs") with everyone closely collaborating for problem solving and innovation on a daily base. By democracy, such users express aspirations for equal input and fair acknowledgement in their technological practices. By crafting, they foster strong emotional attachment and self-identification with their end products, leading to the enhanced freedom and willingness to create and innovate.

2 BACKGROUND

Two strands of research are shaping this study: user participation in HCI and CSCW as well as indie game development as a pro-amateur driven technological practice.

2.1 User Participation in HCI and CSCW

The notion of user participation has been considered a core research interest in HCI and CSCW for more than three decades [28, 55]. Focusing on the researcher/designer-user relationship, various approaches and techniques (e.g., participatory design and user-centered design) have been proposed to involve those affected by the introduction of new technology in the design process for different reasons – e.g., "to democratize the design process; to better inform the design of new systems; to engage the public in the construction of their own futures; or simply to appease funding commitments" [28]. In these contexts, participation was largely geared towards: 1) destabilizing power structures so as to share control with users; 2) collecting meaningful and useful information from users' expertise; and 3) inspiring new technological, organizational, and community change [55].

More recently, the prevalence of collaborative technologies and participatory culture has led to HCI and CSCW's growing research agenda on end-user driven technological practices. Prior studies have focused on two forms of end user participation:

1) *Hobbyists' bottom-up innovation* including crowdsourcing, citizen science, DIY making, and hacking. For instance, Kittur et al. [30] studied Amazon's Mechanical Turk (AMT) as a micro-task market where online users can select and complete small tasks for monetary or non-monetary (e.g., reputation) reward. Though highly critical of its implications for labor, Irani and Silberman further characterized AMT as "a source of human computation resources," which turns crowds of digital workers into both an infrastructure and a service of computation [26, 27]. In addition, DIY making and hacking adopt the strategy of community formation to broaden participation by empowering everyone – rich and poor, men and women, young and old, native and migrant [2, 3, 20, 21, 38, 52]. Examples include elderly Chinese electronic hackers' use of making as a hobby to recreate their past and express the sense of belongingness [52] and Vietnamese migrant makers' struggles between the (re)configuration of their Vietnamese ethnicity and the Western trend of techno-entrepreneurs [38].

2) *Skilled experts' engagement in high tech areas* such as open source software development and machine learning. These fields often require advanced technical skills and extensive experience to enter. For example, professional developers join online open source communities where they

can write and share code and collectively contribute to developing and upgrading sophisticated software such as operating systems [36, 49]. They may also build "communities of practice" (i.e., groups of people who share a concern or a passion for a domain they do and do it better in a process of collaborative learning and regular interaction [58]) for social learning, information-rich interactions with colleagues, and professional identity building as shown in the machine learning community [61].

Taken together, however, these studies raise two issues. First, many participative technological practices remain open only to a privileged few. For example, Turkopticon makes AMT digital workers more visible but not necessarily with more agency (e.g., can review employers but not participate in employers' decision making [27]). Second, existing literature largely focuses on either hobbyists [3, 38, 52] or veteran professional technology users [35, 61], which does not explain how people who do not belong to either group (e.g., who are in the transition from hobbyists to experts) participate in innovation.

Only a few studies consider the ramifications of understanding middle-tier end-users' ("pro-amateurs") technological practices. Two typical examples are remix in the online video sharing and editing communities [12, 14] and machinima in online gaming communities [7, 40]. Both emerged in online communities of amateurs (e.g., movie fans or gamers) but required a complicated process of creatively reusing, combining, and modifying existing digital media content as well as developing creativity support technologies. This, therefore, motivated the amateurs to collectively learn and develop sophisticated technical skills, gradually growing into pro-amateurs [40]. Focusing on pro-amateur DIY makers (in contrast to hobbyist makers), Freeman et al. have demonstrated how technological practices of pro-amateur maker groups (e.g., whose members are often veteran engineers, factory owners, open source evangelists, IT managers, and entrepreneurs) are situated in distinctive local sociocultural histories and geographies and tightly coupled with regional and national policies and politics [18]. Kuznetsov and Paulos have highlighted pro-amateur DIY communities' focus on open sharing, learning, and creativity over profit and social capital [31]. These pro-makers have also been regarded as part of the emerging "entrepreneurial labor" [5, 9, 33], who is shifting the innovation model in today's tech economy [18].

This small body of prior work has shed light on the unique sets of values and aspirations embedded in pro-amateurs' technological practices and how they provide opportunities to study the intertwining relationships between technology and politics/policies. Yet they do not focus on the actual mechanisms that enable and facilitate pro-amateurs' participation in innovation, the specific challenges that they face in the process of participation, and how technology design can better support and help them address these challenges. Along with these lines of research, we introduce indie game development, our research site, in hopes of exploring these issues.

2.2 Indie Game Development as A Pro-amateur Driven Technological Practice

Indie games have been broadly defined as games that are consciously created within alternative production and distribution structures outside of the mainstream game companies [34]. Yet indie in the context of indie game development is not necessarily related to hobbyists, amateurs, or unprofessionalism but a complex multidimensional concept: it is about "a social movement, an art movement, a cultural scene, a fad, an ethics, a value orientation, a social identity, an assertion of authority, a cultural politics, an accident, a new form of capitalism" [47]. Drawn upon these understandings, in this paper we define indie game developers as *people who do not affiliate with large game companies or publishers but make and publish games in alternative ways such as self-funding/publishing, small teams/studios, and free labor*.

Grounded on our engagement in the indie game development community since early 2017, we also realize that a significant feature of indie game development community is that it attracts and

fosters diverse technology users who are neither amateurs or professional/experts [17, 19]. Some indie developers were professional game developers who worked in the so-called "AAA" game studios (or Triple-A, which refers to games with the highest development budgets and levels of promotion) but went "indie" for various reasons. Nevertheless, many indie game developers whom we know had no prior experience of programming and game development before but decided to engage in indie game development due to their passion about creativity, innovation, and gaming or the desire to express personal feelings/experiences by using games as an interactive media. A typical example that indie game developers often mention is the successful indie game *That Dragon, Cancer*. The leading developers (who were a couple) had little game development experience but made this game based on the experience of raising their son, who was diagnosed with terminal cancer at twelve months old.

In addition, we identify three features that distinguish indie game development from other pro-amateur driven technological practices such as remix and machinima. First, comparing to the "click and watch" mode of remix and machinima development, the goal of indie game development is to turn "readers" and "viewers" into "active participants," who not only experientially engage in the created content but also directly decide how to unfold the storyline via making conscious choices in the displayed content.

Second, while it may be difficult to reconcile originality and personality with joint or collaborative authorship in remix and machinima [14], there is often a clear association between the indie game developer and the created game, which allows for authorship of the game development process and playable outcome [59].

Third, developing remix, machinima, and indie games all require both artistic skills such as imagination, storytelling and aesthetics and technical skills such as using tools and software to produce videos or digital content. While remix and machinima that mainly require video editing, we understand that indie game development involves a broader spectrum of skills that is considered similar to DIY making but focuses on creativity and experiential qualities even more [60]: reflection (values, attitudes, and perspectives), imagination (game ideas), composing and storytelling (expressing values, attitudes, and perspectives in a story), visualization (visualizing this story in an interactive game), implementation (using game engine, programming, and scripting), sociability (interacting with players and peers; engaging in online/offline communities), test and debug, and publishing and distribution (using developer-to-consumer digital distribution platforms such as Apple Store, Google Play, and Steam).

Due to these requirements for understanding and engaging audience, claiming authorship, and developing various skills, in some sense indie game development can be considered more demanding than other pro-amateur driven technological practices. This observation leads to the research questions that we proposed at the beginning of this paper: what mechanisms actually enable and support end users' participation in such a demanding technological practice and what are the specific challenges that they encounter in this process?

3 METHODOLOGY

Using the definition of indie game developers that we proposed in Section 2.2, we collected three types of data, including threads on online forums, interviews, and offline observations of indie game developers' socio-technological practices.

First, we collected developers' self-reports of their own understandings of indie game development that were posted to active public English language forums. These online forums include Q&A sites such as Unity forum, indie gamer forum, Reddit (game dev), and Reddit (Indie Dev). We used a series of keywords including "indie games," "indie game development," and "indie game developer" to search threads and posts on these forums and filtered out those not directly related to indie game

development (e.g., a thread regarding how to play an indie game) or indie developers' experience of engaging in this field (e.g., a question about how to solve a technical issue when developing an indie game). As a result, 1,653 posts and comments with a time span from 2010 to 2017 were collected.

Second, we requested to join Facebook Groups for indie game developers using keywords "indie game development" and "indie game developer." We then posted a recruitment message on those groups who accepted our requests to join and post (N=6) in order to recruit indie game developers who were willing to be interviewed as voluntary participants. We also directly contacted indie game developers in USA who we already knew to ask their willingness to participate using a snowball sampling. All respondents who self-identified as indie game developers based on our definition and agreed to participate were interviewed.

As a result, 12 semi-structured in-depth interviews were conducted in order to investigate indie game developers' attitudes and experiences that were not included in the self-reported forum data – for example, the implicit psychological and social reasons why they participated in indie game development. Interviews were conducted via text/audio Skype chat based on participants' preferences from December 2017 to February 2018. In each interview, 15 predefined open-ended questions were asked (e.g., *"How serious are you with indie game development? Do you feel indie game development is a participatory or democratized form of technological practice?"*). The average length of interviews was 80 minutes. All 12 participants located in USA. Six were self-identified as female and six as male. Nine were self-identified as Caucasian; two were African American; and one was Asian. The average age of the participants was 31 years old and average years of experience in indie game development was 8.5 years. Participants' extensive experiences show that our sample was composed largely of serious, veteran indie developers. Five of them (42%) developed indie games full time as freelancers or working in small studios (up to five people) while seven (58%) as a part time commitment. Table 1 summarizes the demographic information of interviewees.

Lastly, the first author is an active member of two local indie game development meetup groups. She had attended several events and workshops hosted by the meetup groups and conducted participant observations [48] of developers' interactions, discussions, and activities since 2017 and maintained frequent communication with these groups. She also attended the 2018 Global Game Jam in a mid-sized city in the United States to observe indie developers' socio-technological practices. These observations were valuable for understanding the indie culture and better interpreting developers' self-reports and interviews.

These data were collected as part of a broader, multi-year research project on studying indie game development as public engagement in technological innovation. This project has yield two publications, showing that 1) collaborative information, community support, and awareness of national or regional policy and politics are fundamental to the emergence of bottom-up collective innovation [17]; and 2) how distributed creative teams such as indie game development teams are formed, functioned, and experienced as a mix of online comradery and weak social ties as well as a mix of self-confidence and self-confliction [19]. However, these publications do not explain how indie game development can be a participatory technological practice as what indie developers have claimed, as well as how the specific status of being "pro-amateurs" affects indie developers' participation and the challenges that they may encounter.

For this paper, we re-coded these data around themes pertaining to participation and challenges in indie game development. Using the same search and filter criteria, we also collected a new set of online data from Quora and blogs such as Medium.com (N=403), which was not used in previous publications. In total, 2,056 posts and threads with a time span from 2010 to 2018 were analyzed in this work.

Table 1. Demographic information of interviewees

ID	Gender	Age	Race	Years of Experience	Full/Part Time Indie
P1	Female	33	White	8	Part Time
P2	Female	27	White	5	Full Time
P3	Female	28	White	2	Full Time
P4	Female	33	African American	12	Part Time
P5	Male	27	White	5	Part Time
P6	Female	29	Asian	2	Full Time
P7	Male	25	White	17	Part Time
P8	Male	30	White	6	Full Time
P9	Male	51	White	14	Part Time
P10	Male	27	African American	5	Part Time
P11	Male	32	White	6	Full Time
P12	Female	35	White	6	Part Time

We used an empirical, in-depth qualitative analysis [50] of the collected data to explore indie game developers' participation and challenges in technological practices. Our coding and analytical procedures were: 1) we closely read through the collected data to acquire a sense of the whole picture as regards developers' perceptions and interpretations of their socio-technological practices and collectively identified thematic topics and common features in the data for further analysis; 2) we carefully examined and reviewed the thematic topics and developed sub-themes; 3) we collaborated in an iterative coding process to discuss, combine, and refine themes and features to generate a rich description synthesizing mechanisms that support indie developers' participation and the resulting challenges; 4) three months later, the first author repeated step 1 and step 2 to increase the intra-rater reliability and revisited the coded themes and sub-themes; all authors also collaborated to discuss and refine these themes and sub-themes; and 5) the first author, who maintained close connections with the indie game development community, shared previous publications and preliminary findings of this work with interviewees and other indie developers by posting on Facebook groups to conduct member checking [13]. In general, feedback received from the Facebook groups was positive and pointed to future research directions such as the role of live streaming in broadening participation in indie game development.

4 FINDINGS

In this section, we present our findings regarding mechanisms that enable and facilitate developers' participation in indie game development and challenges associated with such participation.

4.1 Mechanisms for Participation in Indie Game Development

From our data, we identified three mechanisms that enable and facilitate developers' participation in indie game development despite their small sizes, limited resources, and financial instability: small teams, a democratic form of end-user participation, and an identifiable and approachable means for engaging with technology.

4.1.1 Small Teams. Indie game developers often prefer to form teams consisting of a small number of distributed or co-located individuals (e.g., three to five). Compared to large teams with tremendous institutional support, a small team often deals with "small money," less resources, limited manpower, and a higher risk of failure. However, many indie developers considered being in a

small team a significant benefit, rather than hinderance to their participation in game development. They especially highlighted two ways through which working in small teams facilitated their participation.

The first is that *a small indie team is a strike team*. The term strike team refers to teams that perform tasks in highly risky and time sensitive contexts (e.g., SWAT teams, rescue teams, and firefighters). In traditional game development, it is often used to describe an ad-hoc small team formed within a large team to solve a certain complex task. A game developer who worked on both indie and AAA projects explained in a Quora post, *"these teams are small, and thanks to their interdisciplinary structure and a fluid information flow they can quickly deal with an issue."*

Many indie game developers tended to borrow this metaphor to describe the nature of their everyday technological practices: the whole team was a strike team consisting with dedicated and skilled amateurs ("pro-amateurs") with everyone closely collaborating for problem solving on a daily base:

Everyday meetings (e.g., video-conferencing) and a small scope of the project allow us to work together to solve all types of problems and know everything there is to know about all of its layers. Frequent, small team discussions help to promote a unified vision of the game, while appropriate people focus on the coherence of its elements. (an online blog by an indie developer)

The fact that you can see and feel the progress of a smaller project on a daily basis is an advantage of any indie team. In a big team where you are just like a screw. But in a small team, you can see how the game gradually comes together and this helps you identify with the project and your work, and is a powerful motivator to push yourself even harder, to grow as a creator. (a Medium article by an indie developer)

According to these quotes, the small team size and small scope of projects somewhat forced indie developers to collaboratively and professionally tackle various development tasks and issues everyday (*"allow us to work together to solve all types of problems"*). This not only enhanced their skills over time (*"know everything there is to know about all of its layers"*) but also fostered a professional attitude towards game development (*"promote a unified vision of the game"* and *"focus on the coherence of its elements"*). In addition, this dynamic forced indie developers to be more intimate to their products – they were no longer nameless components in a massive production team (e.g., *"a screw"*) but deeply embedded in every step to design and develop their product (e.g., *"you can see how the game gradually comes together"*). This gradually motivated them to be more willing to participate – to establish attachment with the product (e.g., *"helps you identify with the project and your work"*), seek self-identification (e.g., *"grow as a creator"*), and engage more in technological innovation (e.g., *"a powerful motivator to push yourself even hard"*).

The second dynamic is that *a small team affords participation in innovation*. In a Quora thread discussing the differences between indies and AAA, one noted, *"AAA companies cannot afford to be creative in the same way that indie game developers are and indie game developers cannot afford to be predictable and efficient like AAA companies are."* Many comments agreed and described how working with their small teams supported the emergence and growth of the so-called "crazy ideas," which became the driving force for their participation in indie game development. For example:

The larger the number of people on a project, the more it tends towards a common mean: what everybody wants. A large team naturally means that the craziest ideas cancel each other out. Indie development has fewer people and more likelihood that weird ideas will survive – especially if there is no marketing department. Marketers tends to prefer safe bets.

Indies are authors themselves. Crazy ideas can arise in the mind of an author, while a team with 350 people without a well defined director will only move in generic and recognizable directions. As individuals they are not devoid of imagination but as a crowd the project will always move in a generic direction.

Our interviewees shared similar ideas:

When you add more people, though, you add their prejudices and ideas and tastes and disagreements, and eventually you wind up with this bland amalgamation of opinions that's so safe and literally committee-designed that it doesn't strike anyone. an entertaining idea is one that hits a point, hits it precisely and with the right amount of impact. this is why people refer to part of the creative process as "streamlining." (P3, female, 28, white)

These quotes collectively depict how participation is supported and fostered in small indie teams in various ways. Indie teams often adopt simpler and more direct information sharing and communication dynamics than large teams, through which diverse ideas are less likely to get lost in the process of brainstorming, discussion, and negotiation (e.g., *"as a crowd the project will always move in a generic direction"*). In addition, as the second quote shows, indie developers identified themselves as "authors" rather than "employees" working on a corporate project. This self-driven nature made them more willing to experiment, engage, and shoulder risks (e.g., *"crazy ideas can arise in the mind of an author"*). Furthermore, small teams tend to focus on fostering the most unique and creative idea and making it shine (*"streamlining"*). In contrast, larger teams may be caught by the high demands for coordinating different departments, harmonizing various opinions, and identifying *"generic and recognizable directions"* – all of which may hinder the participative process of innovation and the outcomes.

It should also be noted that some indie developers expressed concerns about the small team tradition in indie game development, considering that it may hurt the quality of their technological practices and products. For example, a Quora post expressed,

Yes the most important thing in indie game development is creativity. That's the reason why our teams are much smaller. But it also means that our games may have errors, bugs, bad spelling, unfinished parts, bad programming, and memory leaks.

In this sense, "pro-amateur" indie developers subject to many more disadvantages and challenges than their expert, professional counterparts, which we will discuss more in section 4.2.

4.1.2 A "Democratic" Form of End-user Participation. Many developers regarded indie game development as a democratic form of participating in technological practices. For example, an indie developer wrote in his blog, *"game development isn't like filmmaking, in which the director is God and everyone else just does as they're told (and gets paid handsomely for it). We all expect to have some creative input."* Another blog shared similar thoughts:

AAA teams are less likely to respond to a gameplay idea from an artist or programmer. Everyone has a specialization and they mostly stick to it. Indie teams are far more flexible and varied in how they handle creative input. Some teams are rather democratic, taking ideas and feedback from everyone.

According to them, in the context of indie game development, being *democratic* is described as "taking ideas and feedback from everyone," which indicates equally engaging everyone in decision making. The indie culture seems to be more open and acceptable to this decision making model, especially comparing to some other collaborative creative/technological practices (e.g., film making) or even its counterparts with more resources (e.g., AAA studios).

Others also discussed about how the indie game scene made more people participate in game development. One indie developer wrote in a blog:

Game development seems to have gone from something even more inaccessible than film production to an artform that anyone with a few evenings available and some willingness to learn can participate in. [...] Art should be democratized. Everyone should be able to tell their story or make their experience. It looks like game dev might - for well-chosen projects, at least - be the third art-form after writing and music to become truly democratic in the digital age.

Our interviewees also echoed this stance:

I enjoy being able to work with a smaller team, which gives me more say in the overall development of the project. Because our team is so small, I have been forced to learn many new skills that I may not have learned at a larger studio since many tasks are divided up among larger groups. (P6, female, 29, Asian)

Basically, a smaller indie project has more freedom to be creative and everyone has more power to decide what they want to make and which direction they want to go. (P4, female, 33, African American)

These quotes further highlight how the indie game development community approaches participation, innovation, and decision-making in technological practices in different ways. For them, engaging with technology and participating in technological practices do not rely on a clear leadership structure, a rigid definition and specification of each member's role and responsibility, or a potential power hierarchy. In particular, they do not consider their production and innovation a strategic business decision to optimize resources for the lowest risk and highest profit. Instead, it is about how to encourage everyone to actively and willingly participate in and make unique contributions to every step of their technological practices. This aspiration for equal participation and freedom to create, as P4 noted, is how the indie game development community can survive, sustain, and thrive.

In summary, what we see from our data is that indie developers consider their technological practices a democratic form of end-user participation due to three arguments: 1) anyone who is interested in gaming and game development can be part of an indie team; 2) every team member is expected to make creative input; 3) every member's ideas and feedback are taken into account for decision-making. For them, indie game development seems to both accessible to the general public (e.g., freelancers, amateurs, and non-professional technology users) and encourage, recognize, and acknowledge each member's input. In this process, indie developers demand a voice, have a voice, and actively participate in designing, using, appropriating, and creating their products.

4.1.3 An Identifiable and Personable Means to Engage with Technology. A third mechanism to facilitate the participation in indie game development is an identifiable and personable means to engage with technology. It refers to both the created content (i.e., the game) and the creator (i.e., indie developers).

Regarding the created content, indie developers often focus on portraying subjective, in-depth, and rich human experiences in their technological products (i.e., indie games). For example, developers pointed out the focus of unique human experience in their technological practices and considered it the most appealing feature of making indie games. In a Quora thread discussing why indie games are creative, two game players noted,

*Indie games often cover unusual and specific narrative content and topics. You can find stories like the heartfelt and intimate teen girl internet romance *Cibele*, or the radical progressive steampunk picaresque *80 Days*, or the bleak, quiet immigrant struggle of *Cart Life*.*

Indies cover a broader range of emotional and tonal expression. Where bigger titles focus mostly on challenge and adventure, in indies you have the quasi-religious transcendence of Journey or the filth and disgust of Binding of Isaac or the entire cycle of love and loss in Passage.

According to these quotes, indie game developers' technological practices were appreciated and highly praised because such practices and products were imbued with affections, values, reflections, and care for the humankind and their lived experiences.

P10 (male, 27, African American) also added,

"Our team wanted to create something to reflect our values and life experiences. I found my team members in an forum for indies. We only had three people but we all were concerned about social issues such as bullying. We all somewhat got bullied in middle school. It's definitely not a good memory and we wanted to raise people's awareness. We built this small game based on our experiences of being bullied and how we dealt with bully. We think this game may really speak to people's hearts, especially those who experienced bully and want to make a change."

For P10, he believed that engaging in indie game development provided him and his fellow developers with freedom to depict individual life experiences and afforded rich emotional expressions rather than merely designing challenges and levels in a game. For them, this experiential/emotional aspect of creating indie games made both the game content and the technological practices close to some of the deepest and most meaningful aspects of human experiences, such as care, love, and empathy.

In addition, regarding the creator, technological practices in indie game development are identifiable and personable because indie developers, as creators, present themselves as real human beings rather than faceless names attached to their products. In a Quora thread regarding why indie games are different from AAA games, a few indie developers described,

For indies, people are not just playing a game from a faceless team - they are playing a game by someone they have interacted with online or possibly even met in person. It adds a completely different dynamic both to how the developers create and how the players perceive and experience indie games.

Making an indie game require a lot of social engagement. The team needs to engage with potential players in ways that make them feel like they have some investment in the game before it comes out: discuss ideas, take suggestions (even if you can't implement them you can certainly kick the ideas around: it's a great way to get fans feeling that you want them to have fun). This lets you benefit from their feedback, gives them good feelings about your project and creates a whole group of people who are happy to spread the word for you.

These accounts collectively point to the differences between the traditional "corporative" approach of game development in creative industries, which indicates structural, institutionalized, and revenue driven, and the emerging self-driven and bottom-up approach of indie game development, which tends to be accessible and flexible. Indie developers are not faceless employees in a large corporate. Rather, they are *identifiable* – players and fans can easily relate to and interact with the developers behind an indie game. They are creators who are attached to their products; and their products function as a vehicle to share and express their experiences and values. They are also *personable* – they often open up their design and development process to players and welcome feedback and suggestions throughout the process. In summary, such an identifiable and personable approach suggests a more open and touching tactic of engaging with technology.

4.2 Socio-technological Challenges for Participative Technological Practices in Indie Game Development

The mechanisms of small teams, democratic end-user participation, and an identifiable and personable means to engage in technology support and facilitate indie developers' participation in a rather demanding technical domain and enhance their independence (e.g., from the commercialized massive game industry). Yet this does not mean that their participative technological practices are free of challenges, risks, and uncertainties. In this section, we tend to these socio-technological challenges that indie developers often encounter.

4.2.1 Identifying Team Members with A Shared Passion. Creating a successful indie game obviously requires various technical skills such as programming and modeling. Yet many indie developers regarded the "shared passion," rather than any technical skill, as the most important need for supporting their technological practices. For example, an online post on the indie gamer forum and P8 explained how a shared passion was central in indie game development:

You need to find people who are passionate about creating a vision together and want to bring their strengths in to make it happen. Over the course of time you then have to accept that this team will have highs and lows, people come and go, but with a strong enough core team who share the same passion, you should still be fine. (a post on the indie gamer forum)

When we are brainstorming on new ideas for the game, I normally have a rule of following the passion. We are on a team together because we want to be, so we have to trust each other. If someone is very passionate about something, you trust that they will follow that idea through to the end. (P8, male, 30, white)

According to this poster, though interest-based online teams may subject to its loose structure ("people come and go"), a shared passion for collaborative creativity ("creating a vision together") and team efforts ("bring their strengths in to make it happen") was fundamental to build a stable and reliable team over time. In particular, P8 highlighted how a shared passion may bridge trust and collaborative technological practices. On the one hand, passion led to participation – team members were willing to optimize their various strengths and fully engage in the technological practices because they shared similar goals and visions. On the other hand, passion made team members trustworthy – as they shared the same passion, it was believed that they would be more likely to collaborate together throughout the whole process to realize such a passion rather than disappearing abruptly. In this sense, identifying team members with a shared passion became one of the most significant requirements to support participation in indie game development.

However, a challenge for indie developers to identify such team members is that the current designs of sociotechnical systems seldom fulfill this need. A post on the indie gamer forum detailed such a challenge,

"it's so easy to find highly technical people online now – you can just post on online forums, tweet, or join a Facebook group. You usually can find people with good skills to join your team quickly. But it's so hard to find people who share the same passion or vision with you. A shared interest does not automatically mean you share the same passion."

This post points to an important question for supporting participative technological practices: how can a shared passion be identified and evaluated? In the context of indie game development, online communities connect remote individuals who share same interests (e.g., game development) together; and various collaborative technologies facilitate the exchange of different ideas, opinions, and information. Therefore, it is possible to quantify and evaluate skills (e.g., number of certificates,

years of experiences, and levels of training) even interests (e.g., years of practices, participating in the same online communities, and previous projects).

However, merely depending on current collaborative technologies and systems, few indie developers can identify potential team members who share similar passion and vision concerning the future direction of the game at the very early stage of forming their small teams. Rather, they tend to resort to game jams and local dev meetups as a trial period, if possible:

"Even if there's not a jam on, if there's someone you're interested in working with I'd start with a jam between you, because that's lower stress / commitment / overhead than a proper project and lets you test the waters of 'getting stuff done' with each other before increasing the commitment." (a post on the indie gamer forum)

How to design collaborative technologies to better reveal social cues of the level of shared passion of potential team members, there, becomes crucial to encourage and support pro-amateurs' technological practices.

4.2.2 Visibility. Promoting visibility has also been recognized as a significant challenge for developers to participate in indie game development. For example, P2 (female, 27, white) described how difficult it was for indie teams to receive public attention and how the lack of visibility severely undermined their technological practices:

"most people think of AAA studios when they think games, which is a shame. Because games are so much more than that. It's hard to keep creating stuff if you know nobody except your team members cares."

An indie developer also posted on Reddit,

"we need audience. We want to see our game being loved and appreciated by others. I remember how happy we were when our game hit 100 downloads. If nobody knows about our game, it's very discouraging and I honestly don't know how long our team can last."

Many other developers expressed similar concerns and shared various strategies to increase the public visibility of their teams and games, including social media platforms, digital distribution channels (e.g., Steam), and live streaming:

A great tactic is to set up social accounts for your game and use them. Reddit, n4g, Facebook, Twitter, Google+ etc.. Social networking for the win. The only thing worse than not having social setup to talk to your base, is having social and not using it. (a post in a Quora thread offering general suggestions to people who want to go "indie")

The public notices, and they're noticing because of platforms like Steam. They can spend \$.99-\$10.00 for a game rather than only spending \$60 on console titles or scouring a gamestop to hopefully get the game for under \$50. (P4, female, 33, African American)

You can contact Twitch streamers. Some streamers are playing any kind of games and at least 20,000-30,000 people watch them in every stream. I don't know if they want money for playing your games but i know that some streamers play the indie games only for fun (but they generally wait for a streamer copy of game). (a post in a Quora thread offering general suggestions to people who want to go "indie")

For them, their presence and interactions on various social media platforms could bring them closer to potential players who were also heavy social media users; indie friendly distribution channels such as App Store and Steam offered opportunities to work around publishers to directly expose their games to players; and live streaming became a cheap and interactive way to advertise their games. Yet even with these efforts, indie game development is still largely unknown to the general public. P1 (female, 33, white) summarized, *"I'm not sure how aware the general public is*

of the indie movement, to be honest. I think indies have very niche audiences and we always talk to the same people." This quote highlights one of the many weaknesses of promoting indie game development mainly through social media: the lack of diverse audiences. Unfortunately, indie developers often struggle with finding existing technological platforms, if any, that can meet their needs for promoting themselves and making indie game development more visible.

4.2.3 Using Various Technologies to Suit Multiple Roles. Indie developers also highlighted the challenge to manage various technologies simultaneously. They attributed this challenge to the fact that every member in an indie development team wears "a lot of hats," as the two posts in a Quora threads on differences between indie and AAA described,

One of the key differences that I personally live (and why I historically worked with indies vs AAA) is that you get to wear a lot of hats. Your input is valuable (and will probably be needed) in almost every area, so you get to do art and code and design and anything else the studio requires.

We all have to be highly flexible and wear multiple hats. We may have a team leader but he/she is also your co-worker. We may all be team leaders because we equally contribute. Today you may be the level designer and tomorrow you may be the AI engineer. Due to the lack of specialized producers, in order to support proper communication we all have to learn things beyond what's our nominal job.

According to these quotes, role assignments in an indie development team were fluid and blended rather than clearly defined and highly specified. Very often, a team member's role was not determined by his/her expertise but by the timely needs of the collaboration. In this process, a team member was expected to switch from role to role frequently and adjust to the assigned new role quickly (e.g., designer to coder or vice versa).

Indie developers considered such a loose leadership and flexible roles essential to their technological practices, for example, P7 (male, 25, white) said, "*it's a good way to work alongside individuals who are tackling challenges in new ways and who are in a position to take risks from both a technical and creative perspective.*" Yet they also mentioned that this team structure raised new and high demands for using various technologies to suit various roles simultaneously. An poster in the indie gamer forum explained how his/her indie team dealt with these demands,

You need to have your software game at max, you need to know good software for making communication super easy. We use Skype and screenshare, or Google Plus Hangout so multiple people can share screen at the same time. Another good site is Reep.io, a really simple P2P system for sending files that are otherwise too big for Email, like Unity Asset Packages. We also use Notepad.pw, which we use for organizing notes and checklists.

P9 (male, 51, white) added,

I have forced myself to learn so many things since I join this team. I was trained as a 3D modeller so my team asked me to do level design. I had to learn Unity and C for that. I also handled music and audio for our game so I had to learn a bunch of audio editing tools. In this process I also learned how to use GitHub – never thought I would be a coder while I was in the art school. I often need to open like 20+ windows on my computer while working on our game and switch back and forth. Sometimes I lost track.

Both quotes explicated the challenge for managing and switching between multiple technologies in indie game development. This skill was essential to support their technological practices by promoting team communication, increasing team effectiveness, and optimizing team member's

various skills all at the same time. However, learning and mastering multiple collaborative technologies not only required excessive time investment but also may lead to unnecessary information overload (e.g., exposing to too much irrelevant information) and waste of resources (e.g., only using one feature of each tool). As P9 highlighted, many collaborative technologies were not specifically designed for small indie teams. Mastering various technologies, while beneficial, may also introduce confusions and exhaustion.

5 DISCUSSION

To answer the two research questions that we proposed at the beginning of this paper, we have used indie game development to show that 1) mechanisms of small teams, a democratic form of end-user participation, and an identifiable and personal means to engage with technology support and facilitate pro-amateurs' participation in technological practices (RQ1); 2) pro-amateurs also face various socio-technological challenges in their participation in innovation, including identifying team members with a shared passion, visibility, and managing various technologies to suit multiple roles (RQ2). We now use our findings to first discuss the implications of this work for existing literature on end-user driven technological practices in HCI and CSCW. We will then shift our focus to use the identified socio-technological challenges to explore potential design implications for collaborative systems that support and enhance participation in pro-amateur driven technological practices.

5.1 A Collaborative Community of Practice for Supporting Pro-Amateurs' Participation in Technology

Similar to communities of expert-driven technological innovation such as open source software and machine learning development [36, 49, 61], the indie game development community can be understood as a community of practice [58] due to its focus on collaboratively learning skills through doing. Yet our work also reveals that a core aspiration in the indie community is to make game development a more participatory technological practice than the mainstream gaming industry and more accessible to everyday users. Therefore, how to supporting and facilitating broader participation through multiple mechanisms as well addressing challenges in the process of participation become important part of their community practices in addition to learning and doing. We further discuss these mechanisms as follows.

5.1.1 How Democracy in Small Teams Supports Pro-Amateur Driven Technological Practices. In our study, indie game developers often noted that their technological practices actively stemmed from a democratic mindset – team members had equal availability to contribute to their project in an open manner. How, if at all, this democratic aspect affects and supports end-user driven technological practices needs further research attention.

Although democracy is a central concept in modern political discourse, it does not consist of a unifying definition. One of the most popular definitions in the political context is closely associated with "regular elections, fairly conducted and honestly counted"[45]. However, with an emphasis upon democracy extending beyond the ballot box [45], many political scientists deemed consensus, participation, and access as essential components of democracy. According to Munck [37], democracy is about deliberation: modern democracy provides citizens with a variety of competitive processes, platforms, and channels (e.g., Habermas' theory of public sphere [23]) to deliberate among themselves and to express interests and values; democracy is about the value of freedom – freedom from political domination or freedom as "obedience to a self-prescribed law"; democracy is also about the value of equality, which means everyone "who lives under a

government has the same claim to freedom and thus should have his or her preference weighted equally."

The notion of democracy has also been introduced to the HCI and CSCW communities. Many have explored its importance in a myriad of contexts such as design [6, 16] and digital democracy/civics [24, 56]. Similarly, democracy is not foreign to teamwork literature. Previous works have suggested that democratic leadership in teams can be viewed as either positive or negative in different contexts and collaboration should be democratic and void of power hierarchies [1]. For example, Flora noted that "without community empowerment and broad participation in agenda setting, the decision-making process of discussion, debate, and compromise is relatively meaningless" [15].

Yet the concept of democracy in participative end-user technological practices is intriguing. In practice, democracy seems to well fit pro-amateur end-users' small teams. It is "democratic" because it embodies a culture of collaborative problem-solving and civic intelligence [46]. Such users appear to possess the necessary skills and the professional attitude to afford "democracy" as well as being open-minded enough to collaborate and accept different opinions. The size of their teams is also often small, which dictates many of the intrinsic abilities of the team, ranging from communication style to coordination abilities. Naturally, when a team becomes too large, the affordance of democracy may become unavailable. In contrast, the affordance outlined in our findings highlights how indie game development is able to foster a democratic form of end-user participation in technological practices. First, a limited number of team members allows for more frequent and often richer communication with the availability to create coordinated awareness. Second, the small size of the team develops an openness regarding their communication with a certain amount of freedom to propose and pursue creative ideas that are not feasible in larger teams. From a team dynamics perspective, such democracy helps ensure that all team members openly listen and consider each other's skills, knowledge, and abilities as well as actively work towards the same shared goal.

Therefore, our findings suggest that middle-tier users' participative technological practices require specific unique sociotechnical components that are founded in their aspirations for a *democratic* form of end-user participation, which may also be applied to hobbyists or tech savvy driven technological innovation. However, it is incorrect to consider that all technological practices should be conducted in a democratic manner without taking team members' diverse sociocultural backgrounds, shared history, and values into account. Rather, people who engage in such practices must inherently understand the value of democracy and willingly work towards it. Yet we do need to heighten the awareness that "pro-amateur" end-users such as indie game developers are able to work in this manner, and it seems to be an effective means for their technological practices.

5.1.2 How "Crafting" Brings Pro-Amateur Innovators and Technology Together. Another highlight of our findings is how indie game developers emphasize and value the significance of "crafting" in their technological practices. Crafting is defined as "to make or produce with care, skill, or ingenuity" [57]. In particular, ingenuity, which is often viewed in the same light as creativity, is highlighted as fundamental to the process of crafting. In our study, indie game developers often described their technological practices as *crafting*. Our data has shown that they forge strong emotional attachment with their end products and assign ownership to their work in a more personal manner – for example, by carefully developing games to express their own stories, understandings, and experiences – "experiential qualities, such as involvement, delight, coming alive, pleasure, and embodiment [...] all of the objective and subjective qualities come together coherently as a whole" [8].

Our data has also shown that this personalized attachment often results in more creative freedom (e.g., the autonomy to create specific characters, narratives, and experiences that are personal

to them) and increased self-identification with their products. In many ways, indie developers considered that this approach made them identifiable and personable, which was fundamentally important for sustaining their participation and engagement in technological practices.

In addition, we found that indie developers often aligned their technological practices with how they attached themselves to their products. The relationship here is specific to the creator and the created, not creator to creator. This brings forth some interesting questions that postulate the need for both technological processes and design to focus on bringing people and technology closer at two distinctly different but related levels: 1) *creator to creator*, and 2) *creator to the created*. Our results indicate that workflows and technology need to support each of these relationships in parallel. Currently, much more attention has been given to developing a myriad of technological tools and systems that support creator to creator relationship and social interaction rather than creator to created. For example, Aragon and Williams [4] highlighted the importance of implementing software interfaces to afford socioemotional communication among distributed team members so as to facilitate collaboration. And as we discussed earlier in this paper, design for user participation often focuses on engaging the public in building their own futures, sharing control with users, or collecting information and opinions from users' expertise [28, 55].

However, would a stronger emotional attachment to the created product lead to higher user participation? For middle-tier end-users such as indie game developers, *crafting* fosters a casual-professional relationship between their products and themselves: as casual and personal as amateurs to encourage the sense of attachment, and as professional and serious as pros to care for quality. More research needs to be conducted to further explore these intertwined relationships between technological practices as crafting and users' willingness to participate in such practices, especially with regard to in which ways aspirational collaborative design can support and foster a socioemotional bond between creator and the created product for all tiers of end-user driven technological innovation.

5.2 Design Implications for Supporting Pro-Amateur Driven Technological Practices

We now highlight potential design implications that aim at addressing challenges of 1) identifying a shared passion; 2) promoting visibility; and 3) accommodating multitasks and multi-roles for supporting participative end-user driven technological practices. We attempt to discuss less established design affordances (i.e., not communication or awareness) to push the conversation in an open and creative manner. We also endeavor to explore both the specificity of these design implications to indie developers' practices and how they may benefit technological innovation driven by various tiers of end-users beyond game development.

5.2.1 A "Dating" App for Identifying and Matching Shared Passion. Developing sharedness is fundamentally linked to both teamwork [11] and effective design [39, 42, 43]. In particular, shared activities and mental models are positively related to developing collaborative practices [44]. However, our participants also specifically noted the challenge to support shared passion for participating in indie game development. Indeed, it is difficult to objectify and define passion on its own but a necessary means for end-users who endeavor to participate in technological practices to better identify collaborations. For indie game development, a potential design is a mobile app exclusively for indie developers to network or identify team members, which allows for a repository of individuals to rate their interests and passion levels. A recommender algorithm can also be implemented to "match" indie developers with similarly rated passionate interests to form teams with a shared passion. In many ways, this is similar to social matching systems [54](e.g., online dating apps) but adapted to indie developers' needs. It may also be customized to support other types of pro-amateurs and their technological practices such as making, hacking, and remixing. In

addition, collaborative filtering techniques can be applied within this app to facilitate user-initiated identification of shared passion (see [22]), such as adding and creating customized search criteria.

5.2.2 Using Local Visibility to Reach Broader Audiences. In the game world where "discoverability" (e.g., to be noticed and to be desired, see [41]) is the key, many indie game developers with little marketing budget/experience struggle to make an impact. Very often, they have to rely on various forms of "cultural intermediary" (organizations that mediate between various stakeholders with different needs and goals) to achieve the production, distribution, reception, and consumption of their games and realize their "indie-ness" and independence [41].

In our study, indie developers also routinely noted the challenge for increasing visibility of their work to better promote and motivate their technological practices. Not being supported by any game companies or publishers, many of them must organically promote their work on their own time using their own resources. Therefore, there seems to be a significant need to have a collaborative system in place that allows for highly productive and high quality developers to be promoted within the larger community. However, the current design of sociotechnical systems is often highly user customized – e.g., offering system recommended/customized content based on a user's specific interests and browsing history. In addition, many such systems tend to order their content by popularity (e.g., number of clicks) and marketing budget (e.g., paid advertisements), indie game development is automatically disadvantaged due to its non-mainstream status and low budget.

This challenge is not exclusive to the indie game development community: many other types of pro-amateur driven technological practices (e.g., makers, hackers, and freelancer digital artists) also engage in niche areas with small audience and struggle with reaching a broader audience rather than the traditional target group. Therefore, system designers and developers need to explore methods regarding pagerank [29] and recommender algorithms to better support these end-user driven technological practices.

One potential design would be leveraging local visibility to reach broader audiences. This requires the inclusion of sharing, recommending, and broadcasting resources and information related to indie game development or other technological practices in social network apps for neighborhoods and local communities (e.g., Nextdoor) to promote geographic proximity. The benefit is to increase the visibility of indie game development or other technological practices in local neighborhoods/streets and potentially facilitate community building, which can be more influential than posting in an indie or game-only platform or system.

5.2.3 Simplistic and Customized Design for Switching between Different Modules of Tasks and Roles. Our findings also demonstrate indie developers' constant struggles with adapting to and switching between various collaborative technologies as they frequently switch roles in their technological practices. They were proud of being technology savvy but concerned about distraction, confusion, and sharp learning curves, which would likely undermine their participation in innovation. This issue raises a crucial challenge for indie game development: many existing tools and platforms are not designed for such practices as they often incorporate abundant unused features and require professional knowledge (e.g., Github) or time investment to master.

However, indie game development tends to be small-scale (e.g., small teams) and the demand for complicated system features (e.g., multi-participant video conference calls) is low. Though many indie developers could fall under the umbrella of pro-amateurs, their skills and experiences also vary, which means that the software application interface cannot be complex. In addition, developers' roles in their technological practices are fluid, which means that the system should also support multitasks and frequent shifts of various tasks. All of these seem to point to new requirements for designing new tools and platforms to accommodate indie developers' technological practices:

simplistic interface and selective, customized features, but also with the flexibility to quickly switch between and adapt to different modules of tasks based on the team's specific needs – for example, a simple all-in-one "white board" platform that supports collaborative coding, storyboarding, and concept art sketches. Though the design examples may vary for other types of pro-amateurs, this strategy may still benefit technology communities who face similar challenges of multitasks and multi-roles.

5.3 Limitations

A few limitations of this study should be noted. Our definition and understanding of indie game developers and the indie culture are grounded on our own engagement in the indie game development community in the past several years. These experiences may not represent the ideology and practices of indie game development as a whole. All interview participants were volunteers recruited from Facebook groups and indie game developers' self-reports were collected from online forums. There is a potential bias toward indie developers who were active social media users. In future research, a variety of other data sources (e.g., logs and large-scale surveys) could be used as a way to reach a broader participant population and further validate findings from the interviews and online forum data.

6 CONCLUSIONS

Using indie game development as a case, we have demonstrated three key findings. First, mechanisms of small teams, a "democratic" form of end-user participation, and an identifiable and personal means to engage with technology support and facilitate pro-amateurs' participation in technological innovation. Second, several socio-technological challenges, including identifying team members with a shared passion, visibility, and managing various technologies to suit multiple roles, often emerge in the process of pro-amateurs' participative technological practices. Third, design approaches for addressing such challenges would focus on a "dating" app for identifying and matching shared passion, using local visibility to reach broader audiences, and simplistic and customized design for switching between different modules of tasks and roles.

We believe that our focus on indie game development contributes towards addressing the two limitations in prior literature on bottom-up innovation and end-user driven technologies practices, namely, unequal participation in decision-making and the neglect of middle-tier "pro-amateur" end-users. We hope that these insights point to potential directions for designing collaborative systems that better support the emerging "entrepreneurial labor" [5, 9, 18, 33], who is actively restructuring the innovation model in today's tech economy.

ACKNOWLEDGMENTS

We thank our participants and the anonymous reviewers. This work was supported by the National Science Foundation under award 1849718.

REFERENCES

- [1] Dana Al Rahbi, Khalizani Khalid, and Mehmood Khan. 2017. The effects of leadership styles on team motivation. *Academy of Strategic Management Journal* (2017).
- [2] Morgan G. Ames, Jeffrey Bardzell, Shaowen Bardzell, Silvia Lindtner, David A. Mellis, and Daniela K. Rosner. 2014. Making Cultures: Empowerment, Participation, and Democracy - or Not?. In *Proceedings of the Extended Abstracts of the 32Nd Annual ACM Conference on Human Factors in Computing Systems (CHI EA '14)*. ACM, New York, NY, USA, 1087–1092. <https://doi.org/10.1145/2559206.2579405>
- [3] Cecilia R Aragon and Alison Williams. 2011. Collaborative creativity: a complex systems model with distributed affect. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 1875–1884.

- [4] Cecilia R Aragon and Alison Williams. 2011. Collaborative creativity: a complex systems model with distributed affect. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 1875–1884.
- [5] Seyram Avle and Silvia Lindtner. 2016. Design (ing)‘Here’and‘There’: Tech Entrepreneurs, Global Markets, and Reflexivity in Design Processes. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 2233–2245.
- [6] Liam Bannon, Jeffrey Bardzell, and Susanne Bodker. 2018. Introduction: Reimagining Participatory Design-Emerging Voices. *ACM Trans. Comput.-Hum. Interact.* 25, 1 (2018), 1–1.
- [7] Jeffrey Bardzell. 2007. Creativity in amateur multimedia: Popular culture, critical theory, and HCI. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments* (2007).
- [8] Jeffrey Bardzell and Shaowen Bardzell. 2015. Humanistic Hci. *Synthesis Lectures on Human-Centered Informatics* 8, 4 (2015), 1–185.
- [9] Jeffrey Bardzell, Shaowen Bardzell, Cindy Lin, Silvia Lindtner, Austin Toombs, et al. 2017. HCI’s making agendas. *Foundations and Trends® in Human-Computer Interaction* 11, 3 (2017), 126–200.
- [10] Shaowen Bardzell, Jeffrey Bardzell, and Sarah Ng. 2017. Supporting cultures of making: Technology, policy, visions, and myths. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, 6523–6535.
- [11] Janis A Cannon-Bowers and Eduardo Salas. 2001. Reflections on shared cognition. *Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior* 22, 2 (2001), 195–202.
- [12] Giorgos Cheliotis and Jude Yew. 2009. An analysis of the social structure of remix culture. In *Proceedings of the fourth international conference on Communities and technologies*. ACM, 165–174.
- [13] John W Creswell and Dana L Miller. 2000. Determining validity in qualitative inquiry. *Theory into practice* 39, 3 (2000), 124–130.
- [14] Nicholas Diakopoulos, Kurt Luther, Yevgeniy Eugene Medynskiy, and Irfan Essa. 2007. The evolution of authorship in a remix society. In *Proceedings of the eighteenth conference on Hypertext and hypermedia*. ACM, 133–136.
- [15] Cornelia Butler Flora. 2018. *Rural communities: Legacy+ change*. Routledge.
- [16] Guo Freeman, Jeffrey Bardzell, and Shaowen Bardzell. 2017. Aspirational design and messy democracy: Partisanship, policy, and hope in an Asian city. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing*. ACM, 404–416.
- [17] Guo Freeman, Jeffrey Bardzell, Shaowen Bardzell, and Nathan J McNeese. 2019. The Innovation Ecology: Collaborative Information, Community Support, and Policy in a Creative Technology Community. In *International Conference on Information*. Springer, 614–624.
- [18] Guo Freeman, Shaowen Bardzell, and Jeffrey Bardzell. 2018. Bottom-up imaginaries: The cultural-technical practice of inventing regional advantage through IT R&D. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 325.
- [19] Guo Freeman and Nathan J McNeese. 2019. Exploring Indie Game Development: Team Practices and Social Experiences in A Creativity-Centric Technology Community. *Computer Supported Cooperative Work (CSCW)* (2019), 1–26.
- [20] Verena Fuchsberger, Silvia Lindtner, Martin Murer, and Manfred Tscheligi. 2015. Rethinking Technology Innovation: Factories, Fabrication & Design Research.(2015).
- [21] Verena Fuchsberger, Martin Murer, Manfred Tscheligi, Silvia Lindtner, Andreas Reiter, Shaowen Bardzell, Jeffrey Bardzell, and Pernille Björn. 2015. The future of making: Where industrial and personal fabrication meet. *Aarhus Series on Human Centered Computing* 1, 1 (2015), 4.
- [22] Patrick John Giordani, Carlos A Moreno, and Vaclav Petricek. 2012. Collaborative filtering to match people. US Patent 8,332,418.
- [23] Jürgen Habermas. 2010. The public sphere: an encyclopedia article (1964). *The idea of the public sphere: A reader* (2010), 114–120.
- [24] Kenneth L Hacker and Jan van Dijk. 2000. *Digital democracy: Issues of theory and practice*. Sage.
- [25] Julia Katherine Haines. 2014. Emerging innovation: the global expansion of seed accelerators. In *Proceedings of the companion publication of the 17th ACM conference on Computer supported cooperative work & social computing*. ACM, 57–60.
- [26] Lilly C Irani and M Silberman. 2013. Turkopticon: Interrupting worker invisibility in amazon mechanical turk. In *Proceedings of the SIGCHI conference on human factors in computing systems*. ACM, 611–620.
- [27] Lilly C Irani and M Silberman. 2016. Stories we tell about labor: Turkopticon and the trouble with design. In *Proceedings of the 2016 CHI conference on human factors in computing systems*. ACM, 4573–4586.
- [28] Ole Sejer Iversen, John Vines, Peter Wright, John McCarthy, and Rachel Clarke. 2012. Participation and HCI: Why Involve People in Design? *Proceedings of Chi, 5-10. May, Austin, Tx, Usa* (2012).
- [29] Feng Jiang and Zhijun Wang. 2010. Pagerank-based collaborative filtering recommendation. In *International Conference on Information Computing and Applications*. Springer, 597–604.

- [30] Aniket Kittur, Ed H Chi, and Bongwon Suh. 2008. Crowdsourcing user studies with Mechanical Turk. In *Proceedings of the SIGCHI conference on human factors in computing systems*. ACM, 453–456.
- [31] Stacey Kuznetsov and Eric Paulos. 2010. Rise of the expert amateur: DIY projects, communities, and cultures. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*. ACM, 295–304.
- [32] Silvia Lindtner, Shaowen Bardzell, and Jeffrey Bardzell. 2016. Reconstituting the utopian vision of making: HCI after technosolutionism. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 1390–1402.
- [33] Silvia Lindtner, Garnet D Hertz, and Paul Dourish. 2014. Emerging sites of HCI innovation: hackerspaces, hardware startups & incubators. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 439–448.
- [34] Nadav Lipkin. 2013. Examining Indie's Independence: The meaning of "Indie" Games, the politics of production, and mainstream cooptation. *Loading... 7*, 11 (2013).
- [35] Nora McDonald and Sean Goggins. 2013. Performance and participation in open source software on GitHub. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems*. ACM, 139–144.
- [36] Ines Mergel. 2015. Open collaboration in the public sector: The case of social coding on GitHub. *Government Information Quarterly* 32, 4 (2015), 464–472.
- [37] Gerardo L Munck. 2016. What is democracy? A reconceptualization of the quality of democracy. *Democratization* 23, 1 (2016), 1–26.
- [38] Lilly U Nguyen. 2017. Ethnic platforms and the failure of techno-futurity. *Journal of Asian American Studies* 20, 1 (2017), 51–68.
- [39] Lora Oehlberg, Kyu Simm, Jasmine Jones, Alice Agogino, and Björn Hartmann. 2012. Showing is sharing: building shared understanding in human-centered design teams with Dazzle. In *Proceedings of the Designing Interactive Systems Conference*. ACM, 669–678.
- [40] Tyler Pace, Jeffrey Bardzell, and Shaowen Bardzell. 2011. Collective creativity: the emergence of World of Warcraft machinima. In *Proceedings of the 25th BCS Conference on Human-Computer Interaction*. British Computer Society, 378–384.
- [41] Felan Parker, Jennifer R Whitson, and Bart Simon. 2018. Megabooth: The cultural intermediation of indie games. *new media & society* 20, 5 (2018), 1953–1972.
- [42] Arnaud Prouzeau, Anastasia Bezerianos, and Olivier Chapuis. 2018. Awareness Techniques to Aid Transitions between Personal and Shared Workspaces in Multi-Display Environments. In *Proceedings of the 2018 ACM International Conference on Interactive Surfaces and Spaces*. ACM, 291–304.
- [43] Markus Rittenbruch. 2015. Supporting collaboration on very large-scale interactive wall surfaces. *Computer Supported Cooperative Work (CSCW)* 24, 2-3 (2015), 121–147.
- [44] Catarina Marques Santos, Sjir Uitdewilligen, and Ana Margarida Passos. 2015. Why is your team more creative than mine? The influence of shared mental models on intra-group conflict, team creativity and effectiveness. *Creativity and Innovation Management* 24, 4 (2015), 645–658.
- [45] Philippe C Schmitter and Terry Lynn Karl. 1991. What democracy is... and is not. *Journal of democracy* 2, 3 (1991), 75–88.
- [46] Doug Schuler. 2001. Computer professionals and the next culture of democracy. *Commun. ACM* 44, 1 (2001), 52–57.
- [47] Bart Simon. 2013. Indie Eh? Some Kind of Game Studies. *Loading... 7*, 11 (2013).
- [48] James P Spradley. 2016. *Participant observation*. Waveland Press.
- [49] Igor Steinmacher, Marco Gerosa, Tayana U Conte, and David F Redmiles. 2019. Overcoming Social Barriers When Contributing to Open Source Software Projects. *Computer Supported Cooperative Work (CSCW)* 28, 1-2 (2019), 247–290.
- [50] Anselm L Strauss. 1987. *Qualitative analysis for social scientists*. Cambridge University Press.
- [51] Keith Stuart. 2012. Us and the game industry – How indie games are the new counter-culture. <https://www.theguardian.com/technology/gamesblog/2012/mar/12/us-and-the-game-industry-feature>
- [52] Yuling Sun, Silvia Lindtner, Xianghua Ding, Tun Lu, and Ning Gu. 2015. Reliving the Past & Making a Harmonious Society Today: A Study of Elderly Electronic Hackers in China. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*. ACM, 44–55.
- [53] Joshua G Tanenbaum, Amanda M Williams, Audrey Desjardins, and Karen Tanenbaum. 2013. Democratizing technology: pleasure, utility and expressiveness in DIY and maker practice. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 2603–2612.
- [54] Loren Terveen and David W McDonald. 2005. Social matching: A framework and research agenda. *ACM transactions on computer-human interaction (TOCHI)* 12, 3 (2005), 401–434.
- [55] John Vines, Rachel Clarke, Peter Wright, John McCarthy, and Patrick Olivier. 2013. Configuring participation: on how we involve people in design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 429–438.

- [56] Vasillis Vlachokyriakos, Clara Crivellaro, Christopher A Le Dantec, Eric Gordon, Pete Wright, and Patrick Olivier. 2016. Digital civics: Citizen empowerment with and through technology. In *Proceedings of the 2016 CHI conference extended abstracts on human factors in computing systems*. ACM, 1096–1099.
- [57] Merriam Webster. [n. d.]. Merriam-Webster Online Dictionary. Retrieved February 20, 2019 from <https://www.merriam-webster.com/>
- [58] Etienne Wenger. 1999. *Communities of practice: Learning, meaning, and identity*. Cambridge university press.
- [59] Emma Westecott. 2013. Independent game development as craft. *Loading ... The Journal of the Canadian Game Studies Association* 7, 11 (2013), 78–91.
- [60] Emma Westecott. 2013. Independent game development as craft. *Loading ... The Journal of the Canadian Game Studies Association* 7, 11 (2013), 78–91.
- [61] Christine T Wolf. 2019. Professional Identity and Information Use: On Becoming a Machine Learning Developer. In *International Conference on Information*. Springer, 625–636.
- [62] Anna Xambó, Robin Laney, and Chris Dobbyn. 2011. TOUCHtr4ck: democratic collaborative music. In *Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction*. ACM, 309–312.
- [63] Yutaka Yamauchi, Makoto Yokozawa, Takeshi Shinohara, and Toru Ishida. 2000. Collaboration with Lean Media: how open-source software succeeds. In *Proceedings of the 2000 ACM conference on Computer supported cooperative work*. ACM, 329–338.

Received June 2019; revised October 2019; accepted November 2019