

A Tale of Creativity and Struggles: Team Practices for Bottom-Up Innovation in Virtual Game Jams

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Game jams are intense and time-sensitive online or face-to-face game creation events where a digital game is developed in a relatively short time frame (typically 48 to 72 hours) exploring given design constraints and end results are shared publicly. They have increasingly become emerging sites where non-professional game developers, amateurs, and hobbyists engage in bottom-up technological innovation by collaboratively designing and developing more creative and novel digital products. Drawing on 28 interviews, in this paper we focus on how game developers collaborate as small teams to innovate game design and development from the bottom up in virtual game jams (i.e., exclusively online) and the unique role of virtual game jams in their technological innovation. We contribute to CSCW by providing new empirical evidence of how team practices for innovation may emerge in a novel technology community that is not widely studied before. We also expand a growing research agenda in CSCW on explicating nuanced social behaviors, processes, and consequences of bottom-up technological innovation.

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

Additional Key Words and Phrases: computer-mediated collaboration, team practices, virtual game jams, game development, indie game development, technological innovation

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1 INTRODUCTION

Game jams refer to intense and time-sensitive game creation events where a digital game is developed in a relatively short time frame (typically 48 to 72 hours) exploring given design constraints and end results are shared publicly [42]. They can be conducted exclusively online through computer-mediated methods (i.e., *virtual/online game jams*) or face-to-face/offline. Increasingly, game jams have become important emerging sites where non-professional game developers (e.g., independent [indie] game developers), amateurs, and hobbyists collaborate as small teams (e.g., 3 to 5 people) to design and develop creative and novel digital products using middleware and free tools (e.g., free game engines such as Unity and Unreal). In this sense, game jams directly reflects and supports the bottom-up innovation model – i.e., end users of products and services are increasingly able to innovate for themselves [63].

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However, while bottom-up technological innovation has become an important research agenda in CSCW [19, 23, 25, 26, 28, 45, 46, 78], previous studies tended to focus on innovative practices such as DIY making [3–5, 45, 54, 54], hackerspaces and fablab [61, 68], hackathons [38, 72, 74], and technology startups and seed accelerators [33]. Other technology communities as potential innovation sites and mechanisms for bottom-up innovation, such as game jams, are understudied. In addition, as creativity-focused teamwork have been considered essential to the traditional top-down manufacturer centric model, (e.g., design, software development, and RD) [7, 41], how these emerging sites and mechanisms for bottom-up innovation support nuanced team practices and dynamics still remain unclear.

Drawing on 28 in-depth interviews, in this study we explore the following research questions to address the above-mentioned concerns:

RQ1: *How do game developers conduct team practices in virtual game jams?*

RQ2: *What is the unique role of virtual game jams in game developers' efforts to innovate game design and development?*

RQ1 explores strategies that game developers use to work as small teams for innovating game design and development in virtual game jams; RQ2 investigates how engaging in virtual game jams may promote or hinder game developers' innovative efforts. We especially focus on *virtual game jams* because they have become popular sites for conducting team efforts to innovate game development from the bottom-up by reducing costs and attract broader participants and audiences [13, 56]. We also focus on virtual game jams that aim at indie game developers or hobbyist because they have been considered an emerging bottom-up workforce to innovate game development outside the mainstream gaming industry [24, 25, 27, 28].

We therefore make a number of contributions to CSCW. Our focus on virtual game jams provides new empirical evidence of how team practices for innovation may emerge and be supported in a novel technology community that is not widely studied before. This not only contributes to existing CSCW literature on virtual teams and computer-mediated collaboration by focusing on a creative and innovative context but also sheds light on how newly emerging innovation sites such as virtual game jams further shift today's innovation model from the bottom up. In addition, we expand a growing research agenda in CSCW on explicating nuanced social behaviors, processes, and consequences of bottom-up technological innovation. We do so in three ways: 1) we highlight the importance of coordinately conducting complex and fast-paced practices among remote team members, learning and sharing high tech skills, creating tangible and deliverable products, and reducing the cost of participating in innovation to promote bottom-up innovation; 2) we point to the rising tensions between play and innovation as well as between team practices and individual intellectual protection in virtual game jams, which reflects the potential risk of exploitation in the name of collaboration in bottom-up innovation; and 3) we propose potential design implications to address emerging barriers that may hinder bottom-up innovation as shown in virtual game jams.

2 RELATED WORKS

Our focus on team practices for bottom-up innovation in the context of virtual game jams is grounded on three interlinked strands of research in CSCW: bottom-up technological innovation; virtual teamwork and creative teams; and game jams as emerging innovation sites. We believe that our focus not only sheds light on novel computer-mediated teamwork in a creative and innovative context but also provides rich empirical data for investigating the diverse forms of bottom-up technological innovation.

2.1 Bottom-up Technological Innovation

Innovation involves the creation, adoption, and spread of new and creative ideas that leads to creations of economic significance [12, 63]. It focuses on the product – to create new and improved material artifacts, as well as intangible services; it also emphasizes the process itself – to explore new or improved ways of producing such artifacts and services [12]. In today's innovation-centric economy, innovation is seamlessly intertwined with technology: innovation turns knowledge and ideas into socioeconomic value and technology supports and advances this process. Therefore, building interactive technologies and infrastructure to enhance innovation has constituted a central research agenda in CSCW and HCI [19, 23, 25, 26, 28, 45, 46, 78].

In particular, there is a growing demand for effective designs, technologies, and practices to further support and enhance the emerging bottom-up innovation model driven by end users. In the traditional top-down manufacturer centric model, innovations were often carried out by large firms, corporations, and enterprises. In contrast, in this new model, end users of products and services are increasingly able to innovate for themselves [63]. It has led to a diversity of new phenomena of end-user driven technological innovation, including crowdsourcing, DIY (Do It Yourself) making, hacking, crafting, open design/manufacturing, and so forth [45, 46, 67]. It has also led to the emergence of "entrepreneurial labor" [4, 5, 26, 46] that is actively restructuring today's tech economy.

Yet existing research on bottom-up technological innovation reveal two main limitations. First, most studies tend to focus on the role of making and DIY by hobbyists (e.g., children [3], the elderly [66], or migrant populations [54]) in the global market [4, 5, 45] or technology startups and seed accelerators as new sites of technological innovation [33]). Other technology communities that endeavor to innovate and other mechanisms/sites for bottom-up innovation are understudied. Second, a body of research have explored the collaborative construction of knowledge [40, 44] and the innovation ecology [25] demonstrated in technological innovation activities from the bottom up. Nevertheless, how bottom-up technological innovation may lead to nuanced team practices, social behaviors, and technological processes still remain unclear. To address these limitations, in this paper we focus on team practices for bottom-up innovation emerging in *virtual game jams* as our research context.

2.2 Virtual Teamwork and Creative Teams

A team is often defined as “a social entity composed of members with high task interdependency and shared valued common goals” [11]. Teamwork is integral to everyday life and commonplace in many different work and play environments. The CSCW community has long been interested in distributed/virtual teams (i.e., teamwork occurring in differing variations of time and space) as collaborative technologies are continually being developed to support distribution and help connect teams in different times and space [8, 29]. Significant attention has been paid to both synchronous distributed teamwork and asynchronous distributed teamwork. In general, synchronous distributed teamwork occurs via audio or video teleconferencing [79] where people are physically separated but interacting in real time. Asynchronous distributed teamwork occurs when a team is physically separated, and communication is not simultaneous or concurrent in time.

In particular, a growing body of literature has focused on creativity-centric teams in distributed settings since such teams are of interest to work environments where creativity and innovation is considered a hallmark of successful work (e.g., design, software development, and RD) [7, 41]. Similar to traditional co-located creative teams, distributed creative teams exhibit an evolving creative process that consists of idea generation, development, finalization/closure, and evaluation

[53]. However, creative virtual teams also face multiple challenges regarding leadership, awareness, trust, and communication.

For example, similar to leadership in traditional teams, there is a need for leaders in virtual teams to structure group tasks and provide socio-emotional processes [2]. Yet online collaborative leaders face challenges related to design actual projects and manage team members who are artists or innovators [47]. In addition, while awareness is generally considered necessary to overcome time and distance challenges in CSCW teams, researchers identified four awareness breakdowns in virtual creative teams, including the under-considered minority ideas, easily lost novel ideas, lack of critical evaluation of opinions, and weak reflexivity [14]. Building trust is also found to be challenging in distributed software engineering teams but maintaining socially correct behavior, exhibiting technical competency, and demonstrating concern for others as well as informal, non-work related communication could promote trust [1, 73]. Communication is another major challenge for distributed creative teams due to the complexity to share and express creative ideas via computer-mediated communication. For example, Bergström and Törlind found that the creative process was often disrupted during distributed work due to a lack of shared collaborative capabilities (e.g., drawing surfaces) [7].

In summary, existing CSCW research has not only described how technology can facilitate virtual/distributed teamwork but also highlighted various challenges to support team practices in distributed creative teams [18, 55]. We therefore introduce game jams, which are emerging innovation sites for distributed game design and development teams, to further explore how team practices can be facilitated and supported in bottom-up innovation.

2.3 Game Jams as Emerging Innovation Sites

Game jams come in many shapes and sizes from indie, industry, and academic contexts [30, 42]. They also can be held in different modes, including face-to-face offline jams where participants need to be physically co-present in a certain location and virtual/online jams where participants use computer-mediated methods to co-create games without physical co-presence. Typically, all game jams can be described as accelerated opportunistic game creation events where a game is created in a relatively short time frame (usually 48 to 72 hours) exploring given design constraints and end results are shared publicly [42]. Yet the time frame of game jams can also vary, ranging from one-hour jams to online jams lasting for weeks or months.

Prior literature in game studies has highlighted several characteristics of game jams (e.g., [20–22, 76]). These include: 1) *small game prototypes*: the result of participating in a game jam is the creation of a small playable prototype; 2) *time constraint*: game jams often impose a limited time frame ranging from 24 to 72 hours. Some jams may use varied time constraints ranging from one hour to several weeks or months; 3) *theme constraint*: game jams often propose a particular common theme and participants are encouraged to creatively engage with the specific thematic topic; 4) *open participation*: anyone who can contribute to game development (e.g., in terms of design, development, art, and sound) are encouraged to participate; 5) *teamwork*: though participating solo and purely solo game jams exist, most game jams encourage participants to work together as small teams usually ranging from 2–5 participants who may or may not know each other prior to the jam; 6) *tool agnosticism*: unless specified, most game jams encourage any type of game for any platform made with any tools; 7) *public presentation*: games developed in a game jam will be shared with other participants and the general public. These products may also receive feedback, scores, and awards; 8) *innovation-centric*: game jams focus on team efforts for innovating game design and development. As the slogan of the Global Game Jam (the world's largest game jam event taking place around the world at physical locations) shows, "*Innovation - Experimentation – Collaboration*" are the key values of any game jam.

These characteristics have led to an increasing interdisciplinary research interest on game jams. For example, drawing on education science, design research, and game studies, Meriläinen et al. explored the educational aspects of game jams for teaching and learning science, technology, engineering, arts, mathematics (STEAM) skills as well as developing soft skills such as collaboration and communication [52]. Focusing on the social dimensions of game jams, Kultima et al. highlighted the importance of positive social atmosphere for building successful game jam communities, such as the company of others, free food, celebration of the games created, and the smooth social facilitation enabling networking through actual game making [43]. From a design perspective, Goddard et al. defined participation in game jams as a variation of *play*: play is extended from simply playing games to making games – the so-called "ludic craft" where work and play intersect, leading to positive design outcomes [31]. Similarly, Grace suggested that the *play* state is the key factor that distinguishes and enables game jams in ways distinct from other forms of rapid intense development events such as hackathons [32]. And Kennedy offered a critical perspective of game jams [39]. By exploring all-female game jams, she highlighted the diverse forms of labors (e.g., free, hopeful, and affective) involved in such events and how these all-female events can serve as an effective and transformative methodology for feminist intervention [39].

Other studies also focus on how game jams may promote designing and developing more creative and novel digital products. For example, many have focused on game jams as venues for rapid prototyping new and disruptive product ideas [62, 80]. Some have tended to the game making process afforded in game jams, which captures the entire innovation cycle of turning ideas into reality [56, 57]. Some others have especially highlighted the organizational aspect of game jams - many game jams are organized to emphasize openness to making a welcoming, safe, and beginner friendly environment to facilitate developers' innovative practices. As a result, they would attend at a higher rate and are more capable of discovering the creative and innovative nature of game development [42, 58, 59, 62].

However, while bottom-up technological innovation has become an emerging research agenda in CSCW, game jams as potential innovation sites are understudied. Prior CSCW studies have explored related phenomena and technological practices such as makerspaces as sites of entrepreneurship and part of public life and care ethics [35, 69, 71], hackerspaces and fablabs as digital innovation especially for low socioeconomic communities [61, 68], and hackathon as co-production and community building [38, 72, 74]. Yet little to no research has focused on the unique role of game jams (either face-to-face or virtual) in supporting technological innovation from the bottom up. Only a recent study by Faas et al. [13] investigated how virtual game jams support participants' learning process. Nevertheless, this study did not focus on the innovative and teaming aspect of game jams. It was also limited to participants who chose to develop games alone rather than collaborating with others as small teams. Therefore, we consider it important for the CSCW community to further explore how developers conduct team practices in game jams (RQ1) and how such engagement and practices affect their technological innovation (RQ2).

Specifically, in this study, we focus on team practices for innovating game design and development in virtual/online game jams (i.e., game jams that are conducted exclusively online through computer-mediated methods) rather than face-to-face jams. While earlier and traditional game jams often included the location constraint, a growing trend is to move physically co-located jams exclusively online to reduce costs and attract broader participants and audiences [13, 56]. In this sense, we consider it timely and important to investigate virtual game jams from a CSCW perspective.

In addition, we mainly focus on virtual game jams that aim at independent [indie] game developers or hobbyists. Indie developers are also defined 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* [27]. They have been considered an emerging workforce to

innovate game development outside the mainstream gaming industry and frequent participants in many game jams [24, 25, 27, 28]. Studying virtual game jams that focus on indie game developers and hobbyists, therefore, would sheds light on how these events shift the innovation space from the bottom up.

3 METHODOLOGY

Data Collection. This study is part of a broader, multi-year research project on studying indie game development as public engagement in technological innovation. We posted a recruitment message on Reddit and multiple Discord channels for indie game developers to recruit interviewees who had participated in any virtual game jams in the last 12 months. We also directly contacted indie game developers in USA who we already knew to ask their willingness to participate using a snowball sampling. All developers who responded to our requests and agreed to participate were interviewed. As a result, 28 semi-structured in-depth interviews were conducted. Interviews were conducted via voice chat through Discord, Google Hangouts, or Skype based on participants' preferences from October to November in 2019. The average length of interviews was 60 min and participants were given a \$20 gift card after they completed the interviews. Interviews started with basic demographic questions and moved to participants' general experiences of indie game development. Then participants were asked about their engagement in face-to-face (if any) and virtual game jams, such as their general opinions about virtual game jams, how they prepared for a virtual game jam, whom they often worked with in virtual game jams, their experience of the most recent virtual game jam including how they worked as a team and how they communicated with teammates, and how virtual game jams affected their game development/innovation in any way. They were also asked about the impacts of policies or politics on their innovation and the role of game jams in broadening participation in game development. The last set of interview questions were about participants' usage of live streaming in their game development practices, which was not covered in this paper.

Participants. Participants were from various countries including the USA, Canada, India, Malaysia, South Korea, Australia, Nigeria, Brazil, Russia, Japan, UK, Belgium, and Austria. Four self-identified as female, 23 as male, and one as non-binary gender. The average age of the participants was 28.4 years old ($SD=9.6$) and average years of experience in indie game development was 9 years ($SD=7.7$). Nine of them (32%) developed indie games full time while 19 (68%) self identified as hobbyists. Table 1 summarizes participants' demographic information.

Participants attended virtual game jams at least once in the last 12 months (average: 3 times). Regarding the game jams in which they participated, all participants engaged in typical time limited virtual game jams with similar structures as mentioned in Section 2.3: they lasted 24 to 72 hours, had no limitations on development and communication tools that could be used, had a specific thematic topic, expected developers to create and publicly demo small game prototypes, and often applied an open intellectual property ownership – participants owned the original content but were expected to share the created games, assets, and source code so that other people could download, modify and distribute for non-commercial purposes. Since these jams mainly aimed at indie game developers or hobbyists, they focused on personal outcomes and motivations, creativity, and playfulness rather than commercial outcomes [30]. These jams still allowed solo participation but strongly encouraged teamwork. For our participants, most of them used Unity for development and Discord for communication in these jams; and 27 out of the 28 participants participated in these game jams with team members rather than working alone. They tended to identify potential teammates from existing social networks, Discord channels, or online forums before attending the

Table 1. Demographic information of interviewees

ID	Gender	Age	Country	Occupation	Full/Part time Indie	Experience (Years)
P1	Male	30	USA	Unemployed	Hobbyist	2
P2	Male	26	Austria	Unemployed	Hobbyist	4
P3	Female	24	N/A	Software Engineer	Hobbyist	2.5
P4	Male	35	USA	Wood Worker	Hobbyist	9
P5	Male	28	Malaysia	UX Designer	Hobbyist	4
P6	Non-binary	27	South Korea	Teacher	Hobbyist	N/A
P7	Male	24	UK	Indie Developer	Full Time	10
P8	Male	18	Canada	Student	Hobbyist	4
P9	Male	19	USA	Student	Hobbyist	6
P10	Male	31	USA	Architect	Hobbyist	19
P11	Male	18	USA	Student	Hobbyist	4
P12	Male	50	USA	Indie Developer	Full Time	28
P13	Male	20	USA	Student	Hobbyist	2
P14	Male	18	India	Student	Hobbyist	7
P15	Male	23	Nigeria	Indie Developer	Full Time	4
P16	Male	24	Brazil	Indie Developer	Full Time	7
P17	Male	22	N/A	IT Contractor	Hobbyist	10
P18	Male	40	USA	IT	Hobbyist	2
P19	Female	30	USA	Indie Developer	Full Time	3
P20	Male	25	Belgium	Indie Developer	Full Time	7
P21	Female	18	USA	Artist	Hobbyist	1
P22	Male	51	Russia	Indie Developer	Full Time	15
P23	Male	46	Japan	Indie Developer	Full Time	23
P24	Male	28	Australia	Unemployed	Hobbyist	15
P25	Male	37	UK	Unemployed	Hobbyist	27
P26	Male	22	USA	Student	Hobbyist	2
P27	Male	24	UK	Software Developer	Hobbyist	12
P28	Female	36	USA	Indie Developer	Full Time	9

Note: Country – country of origin; N/A – participants preferred not to answer.

jam because they felt that in contrast to face-to-face jams, there was no effective way to identify team members on site during a virtual game jam.

Data Analysis. We then used an empirical, in-depth qualitative analysis [65] of the collected data. We did not specifically separate full time indie developers' and part time hobbyists' insights to provide a comprehensive image of the data.

Our analytical procedures focused on eventually yielding concepts and themes (recurrent topics or meanings that represent a phenomena) rather than agreement – because even if coders agreed on codes, they may interpret the meaning of those codes differently [51]. Therefore, we did not seek inter-rater reliability in our analysis but endeavored to identify recurring themes of interest, detect relationships among them, and organize them into clusters of more complex and broader themes. Due to the exploratory nature of this work, we also did not use any theoretical lense to analyze the data but applied a grounded theory approach [64]. Our analytical procedures were: 1) both authors closely read through participants' narratives to acquire a sense of the whole picture in regards to virtual game jams and technological innovation; 2) both authors collaboratively identified a preliminary set of narrative themes emerging in participants' accounts toward their teamwork in virtual game jams and how participating in virtual game jams affected their technological innovation; 3) both authors collaborated in an iterative coding process to discuss, combine, and

refine themes emerging in participants' accounts and then synthesized the fundamental aspects of game developers' engagement in virtual game jams.

4 FINDINGS

Using quotes from users' own accounts, in this section we present our findings as two parts. First, we highlight strategies that game developers used to conduct team practices in virtual game jams. Second, we explore how engaging in virtual game jams affected game developers' technological innovation in various ways.

4.1 Strategies for Team Practices in Virtual Game Jams

In our study, some participants (e.g., P8) did mention that they participated in virtual game jams alone, rather than as a team. However, most participants noted that attending a virtual game jam alone might not be productive and they tended to form small teams (e.g., 3 to 5 people) to engage in virtual game jams. They especially highlighted four strategies to conduct team practices for innovating game design and innovation in virtual game jams.

4.1.1 Effectively Assign Roles through Computer-Mediated Methods. All our participants attended time-sensitive virtual game jams. In order to save time and jump start the game development process right away, they tended to identify team members, who were often online strangers, from existing social networks, Discord channels, or social media prior to the jam.

For example, P2 (male, 26, Austria, hobbyist) mentioned his use of Discord channels: "*people usually just have a chat in a Discord channel or server about the jams going on and who wants to participate in which jam. And then we just have a regular chat about this topic and ask if someone is interested in teaming up.*" P1 (male, 30, USA, hobbyist) and P3 (female, 24, N/A, hobbyist) also explained their use of crowdsourcing websites: "*Crowdforge is a website that developers often use to meet people for events, projects, jams and hackathons*" (P1) and "*you can just put a message on itch.io that you're looking for a team; or you can contact people who were looking for a teammate there*" (P2).

As they often teamed up with online strangers, participants regarded effectively assigning roles and responsibility through computer-mediated methods at the very beginning of the jam as the key strategy to facilitate their team practices. For example, when answering the question "*how did you work with your teammates in a virtual jam?*" P27 (male, 24, UK, hobbyist) explained his team's use of Discord to assign roles:

"Basically within half an hour, we came up with a game idea on Discord. Then we immediately started to talk about what needed to be done. Everybody kind of pitched in and said, I can do this and I can do that. After that we wrote down a list of tasks and everybody grabbed them and went to work. I think this process is highly important otherwise no one knows what to do, especially because we only communicate online."

In P27's account, computer-mediated communication methods and tools such as Discord were widely used in fast-paced virtual game jam to identify a shared goal (e.g., a game idea) and a set of tasks and responsibilities within a very short period of brainstorming online. This process then swiftly switched to practices to split the responsibilities and assign roles to each team member via text chat. Only through these communications were individual team members aware of the expected tasks, requirements, and outcomes, which geared their actual game development activities.

In particular, these computer-mediated communications focused on self-reporting one's skills and interests in order to effectively deciding on each one's role and responsibility. Game development requires diverse skill sets (e.g., programming, design, and arts) and team members in virtual

game jams often have little shared history and limited methods/time to interact with each other throughout the jam. Therefore, such a self-reporting mechanism became an efficient strategy for role assignment. P8 and P22 recalled how they worked with others in the most recent virtual game jam:

"We needed to allot tasks to everyone to work on. So we just asked what everyone could do and wanted to do. So it was really based on everyone's skill sets and interests, though we didn't really have any way or any time to verify those information. We were just strangers in an online jam that only lasted 48 to 72 hours." (P8, male, 18, Canada, hobbyist)

"If it was a task about the graphics, it was the artist's job. Really whoever said he/she was an artist would get the task." (P22, male, 51, Russia, full time indie developer)

Though P8 and P22 were from different countries and engaged in game development at various levels (e.g., a hobbyist and a full time indie developer), they had a consensus that self-reporting skills and interests was a useful strategy to quickly assign roles and tasks to team members in a virtual game jam. This seemed to be an effective and straightforward way to jump start their team practices. Yet, they both mentioned a potential challenge: since most participants of virtual game jams were online strangers, there was no established mechanism or tool to verify the claimed skills and interests; there was also no sufficient time to verify such information within the time frame of a virtual game jam.

It should also be noted that assigning tasks and responsibilities via computer-mediated communication at the beginning of a virtual game jam does not mean that team members would only work toward their individual roles and tasks in the actual team practices. For example, P24 (male, 28, Australia, hobbyist) described how he worked with his teammates:

"I usually take on the developer and designer role where I can because that's what I excel at. The others tend to fill various different roles as needed. But really, we all are ready to share hats and do whatever we need to do to make the game good."

In this sense, role assignment in virtual game jams can be shifted and shared throughout the development process. These practices of "*sharing hats*", therefore, make innovative practices in virtual game jams dynamic and collaborative.

4.1.2 Conduct Fast-paced Practices of Sharing and Management. Once role assignment is established, developers often face the challenge of how to actually carry out the development task within the tight time frame. Participants noted that an important strategy centered on swiftly sharing game development related multimedia materials such as videos, artwork, and code. When answering the interview question "*how did you communicate with your teammates in a virtual game jam?*" P1 (male, 30, USA, hobbyist) and P3 (female, 24, N/A, hobbyist) pointed out,

"We talked a lot about the better ways to share stuff. We talked about recording a clip and then uploading it to YouTube and then sending that to everyone. We talked about streaming materials and everyone following the streaming channel. It was really difficult to figure out how to quickly share materials and assets in a virtual game jam." (P1)

"A lot of our communication focused on the sharing process. We had to decide on how to sharing little gif or video clips depending on what we were trying to show. We also needed to discuss which platform or method that we should use to quickly share those." (P3)

Both quotes highlight that what to share, how to share, and in which format materials should be shared were key to conduct team practices in virtual game jams. As a multimedia art form, developing digital games requires sharing and transmission of varied format of digital materials including video, audio, code, animation, and digital art assets. Failure to effectively sharing these materials in the correct format would slow down the development process (which can be catastrophic in a fast-paced virtual game jam) and lead to compatibility issues.

Participants also revealed the importance of constant project management in their team practices. This focus was largely due to the complexity of developing games in a virtual context. For example, responding to the question *"how did you work with your teammates in a virtual game jam,"* P13 (male, 20, USA, hobbyist) and P21 (female, 18, USA, hobbyist) described that they depended on consistent communication to track and document the team's progress:

"Participating in virtual game jams is about keeping consistent communication to update people. Like 'Hey, I've made this. Test it out. How do you like it?' Most of our communication involves letting people know your progress and being informed of others' progress." (P13)

"We knew that we had very limited time to complete the game. But at least twice a day we paused our work and discussed what we had done, what we would like to do, what we thought of, what we would like to change, and what we discovered while testing the various things we worked on. These gave us a sense of milestones so we could move forward." (P21)

For P13, tracking progress was a key to coordinate team practices in a virtual game jam. Due to the lack of physical presence and real time face-to-face interaction, *"consistent communication to update people"* was needed for informing others of what one had completed to avoid redundancy and increase transparency. P21's account echoed this view. Despite the tight time frames imposed by virtual game jams, P21 still considered it important to pause their work and spend time sharing progresses and expectations. For her, the timely sharing and management of milestones was the driven force for the team to *"move forward."*

In addition, participants mentioned "managing people" as a main theme when conducting team practices in virtual game jams. P11 (male, 18, USA, hobbyist) shared his experience in the most recent virtual game jam:

"I worked with six or seven people in my most recent virtual game jam. So the challenge was how to manage so many people and we spent tons of time talking about tasks, visions, opinions, and directions. There's D, our level designer. There's Y, our concept artist. There's a guy in Israel who did modeling and then another guy in Denmark who wrote the game story. We all had our own passion and lived in different worlds. So managing people was something we really wanted to get right. It's not just about skills but about cultures, styles, etc."

P11's engagement in the most recent virtual game jams involved working in a multicultural team including members from USA, Israel, and Denmark. Consolidating different opinions and quickly bringing team members with diverse cultural backgrounds on board for an intensive 48-72 hour virtual game jam, therefore, became a main theme of their team practices. In this sense, successful team practices in virtual game jams are both project-oriented (e.g., delineating responsibilities based on skills) and people-driven (e.g., better understanding one another's unique background and point of view).

4.1.3 Achieve A Balance between Text Communication and Voice Chat. While conducting fast-paced practices of sharing and management was essential to team practices in virtual game jams,

participants highlighted a balance between text communication and voice chat to conduct these practices as a key strategy. In our study, all participants had access to multimodal communication channels including text, audio, and video that were afforded by diverse communication tools (e.g., Discord and Skype). However, text chat dominated how they communicated and coordinated with teammates while voice/video was often not preferred, as P1 (male, 30, USA, hobbyist) pointed out, *"I would say most teams in virtual game jams use text for maybe 80 to 90% of their communication. We seldom use voice or video."*

Why did this happen? Responding to the question "*how did you communicate with your teammates in a virtual game jam,*" participants shared multiple reasons. For example:

"We mostly used the text chat just because everyone had a keyboard and a mouse but not everyone had a high quality microphone. I did spend several hundreds on a mic but there was no reason to ask others to do so." (P9, male, 19, USA, hobbyist)

"In virtual game jams we tend to only communicate by text. I think when you put an idea by text, you can think more because you're writing this down than just saying something without thinking. So a text description tends to be more constructive than voice description." (P22, male, 51, Russia, full time indie developer)

"Voice communication can be challenging sometimes, especially if you're working with somebody in another time zone. Because when you want to share an idea, you may have to wait like six hours to get an answer, and then vice versa. So voice doesn't really work. What you can do is to send them a very detailed message and then wake up to read their reply." (P19, female, 30, USA, full time indie developer)

These quotes highlighted several advantages of text communication over voice chat when conducting team practices in virtual game jams. First, text chat is more accessible in terms of technological affordance and potential cost. According to P9, having a keyboard and a mouse for typing seemed to be essential for most game developers. In contrast, having a *"high quality microphone"* was not. It was also unreasonable to require every team member to shoulder the financial burden of purchasing such optional devices. These made text chat a natural and default communication method for many virtual game jam participants.

Second, text chat is more informative than voice chat, especially when delivering complicated ideas. As P22 mentioned, crafting a message required more time and thinking, which might be more effective than a quick voice over when communicating complicated ideas and technical issues. In P22's words, this makes text chat *"more constructive"* than voice that.

Lastly, text chat facilitates and supports communication between team members who subject to geographical and time differences. P19 pointed out how the asynchronous text chat worked better for teams who located in different time zones than the synchronous voice chat. In her opinion, coordinating time differences to send *"a very detailed message"* and wake up for replies was a feasible solution to collaborate with team members who might not be able to communicate simultaneously.

However, this does not mean that voice chat is completely discouraged in virtual game jams. Some participants did consider voice chat more efficient, personable, and contextually rich compared to text communication in some ways. When responding to the same interview question, P1 (male, 30, USA, hobbyist) revealed,

"Voice chat is good because you're working on something that's creative and artistic. This sometimes can start an argument. So you want to be able to hear the context of people's voices. With voice, you know when somebody's being mean, and you know if they're really kidding or just trying to be nice."

P1 tended to value the contextual information that was embedded in voice. For him, game development as a "*creative and artistic*" technological practice may lead to potential arguments and conflicts. This made understanding the context of voices especially important for collaboration and coordination.

Participants also noted how both voice chat and virtual game jams were fast-paced, which essentially benefited their team practices for innovation. P14 (18, India, hobbyist) described,

"With voice, you can communicate really fast and come to an agreement faster. At a virtual game jam, you have to get through all possible ideas as soon as possible so voice chat works really well for that. It's also very efficient for planning like you'll be working on an animation and I'll be working on the sound effects."

P14 emphasized his concern about "timing" when working with others in virtual game jams. For him, the faster they could communicate and "*come to an agreement*", the more efficiently they could set up the plan for their game development practices and take actions. Thus, voice chat became a optimal choice because they could go through "*all possible ideas*" as soon as possible.

In summary, the complexity of conducting highly technological practices without face-to-face interaction and the potential geographical and time barriers made text communication the main method to conduct and coordinate developers' team practices in virtual game jams. Yet voice chat naturally fit the creative focus of game development and the fast pace of virtual game jams. As a result, virtual game jam participants often endeavored to achieve a balance – by switching between different communication modes based on the special focus of various development stages (e.g., planning, conceptualization, design, and prototype) in a virtual game jam.

4.1.4 Exchange Diverse Forms of Social and Technological Support. Despite the time-limited nature of virtual game jams, their focus on technological topics, and the fact that most participants were online strangers, participants reported that spending time and effort on exchanging diverse forms of social and technological support in virtual game jams was one of the most important strategies to facilitate their team practices for innovation. Participants especially highlighted three forms of support emerging in virtual game jams that significantly benefited their team practices: technical support, constructive criticism, and emotional support.

Technical Support. Game jams for indie developers and hobbyists are technology driven; but many participants are non-professional game developers. Therefore, most participants reported that they exchanged technical support when engaging in teamwork in virtual game jams. For them, attending virtual game jams provided them with valuable opportunities to practice, sharpen skills, and learn from others. For example, when responding to the interview question "*how did you support each other in your team work in a virtual game jam*," P2 (male, 26, Austria, hobbyist) and P6 (non-binary, 27, South Korea, hobbyist) described,

"In my team, if someone has trouble with one feature, they would ask others for suggestions and help. Others are always happy to help and can even take it over if we have time. I think this is really positive and helps us complete our project." (P2)

"One of my teammates was like 14 and the others were adults, at least as far as I know. We were all happy to help the 14-year old learn, such as helping with addressing issues in art assets or telling him about good resources. Everyone was just genuinely friendly people. We were all really supportive of each other even though we were only in a jam for 48 hours." (P6)

According to P2 and P6, offering and receiving technical support works at two levels to facilitate virtual game jam participants' team practices for innovation. The first is at the "product" level

- to help complete the project and build the end product. As P2 mentioned, helping each other address technical issues led to positive development outcomes. The second is at the "people" level
- to help team members learn. In P6's case, virtual game jam team members often demonstrated different skill and even maturity levels (e.g., including both minors and adults). Therefore, it was also important to provide team members who were in a learning process with technical support. This helps them further build and improve necessary skills to create and innovate, which would facilitate the entire team's innovative practices in return.

Constructive Criticism. Constructive Criticism is another form of support that support virtual game jam participants' team practices. Different from technical support that focuses on collaborative problem solving, constructive criticism emphasizes providing feedback and guidelines for future improvement. When answering the question about the advantages of conducting teamwork in virtual game jams, P12 (male, 50, USA, full time indie developer) considered this aspect the main reason why he engaged in game development and virtual game jams:

"I love the feedback and criticism aspect of virtual game jams. Everyone really appreciate any kind of feedback that they receive. That's why I participate in virtual game jams so much. Because it's just really socially rewarding. That's also why I write code for games and not bank software. It's way more interactive both in the game development stage and the gameplay stage."

According to P12, giving and receiving support such as feedback and criticism from team members was what made virtual game jams "*rewarding*" and appealing. For him, what differentiated game development from other software development was its focus on interactivity – not only the game itself is an interactive media form but also developing games involves interactive team practices.

P1 (male, 30, USA, hobbyist) also echoed this perspective:

"I really enjoy the constructive feedback and criticism that I receive from my teammates. I think they help use work better as a team. For example, I will show them what I have done and they will say, that's great and maybe we could move the object a little more to the right. This is good because then I know what the expectations and the bigger picture may look like from others' perspectives. I think this is the best way to game jams, or game development in general."

P1's account especially highlighted how sharing constructive criticism supported his team practices. For many developers, developing games in a virtual game jam is not a sole effort but a process of collaboration and coordination for a common goal (e.g., completing the project). In this process, understanding expectations and "*the bigger picture [...] from others' perspectives*" is essential to move forward as a team, and providing constructive criticism is one of the most effective strategies to support this dynamic.

Others also noted that sharing feedback and constructive criticism did not only limited within a team. P17 (male, 22, N/A, hobbyist) shared:

"Usually at the end of the jam, organizers of the jam would do a stream where we would get to see our games played live by the judges and see the chat react to it. That's the best part because it's fun to know that broader audiences are going to leave a comment on the thing that you made and tell you what they thought of it."

P17 highlighted the importance of receive feedback and criticism from the broader community involved in a virtual game jam – organizers, other participants outside the team, and the general audience. In his opinion, such diverse audiences helped their team keep improving the quality of

their product through multiple channels – e.g., streaming and online comments. They also brought in fresh perspectives that might be neglected by the team before.

Emotional Support. Participants also reported that they received tremendous emotional support from both their teammates and the broader game development community. For them, such emotional support was essential for them to continue developing and innovating games. P17 (male, 22, N/A, hobbyist) and P22 (male, 51, Russia, full time indie developer) explained when answering the question about how they supported each other in their teamwork in virtual game jams:

"Now you're in the meat and bones of the game. You're gonna feel some disappointment and burnt out. So it's very nice to have a Discord server and some kind of group chat with your team. Because everyone is working on the same thing and is with you. You will chat and share jokes and encouraging comments there. It helps you get out of your own head. That's very motivating and helps you keep going." (P17)

"Usually close to the end of the jam, there may be some tensions inside the team due to stress and tiredness. So emotional support is really important. We chat about pets, movies, and family to have some relief. So we can recharge and focus again." (P22)

According to these quotes, in a virtual game jam, developers often worked under excessive stress due to the tight time frame and high demand for technological achievement. It was very likely for them to stress out once they engaged in the solid development phase or had spent long hours working on the project. Therefore, it was critical for them to have a channel to relieve stress and *"recharge and focus again."* Small talks with other team members and exchanging jokes and encouraging comments thus became a crucial strategy for them to distract themselves from the intensive technological matter and calm down, at least for a while.

Responding to the same interview question, P28 (female, 36, USA, full time indie developer) even compared the emotional support that she experienced in her team practices to that in a romantic relationship:

"I feel the way our team treated each other was sort of similar to what people did in a romantic relationship. In our case, we were just really good at working together and we all respected and trusted each other. There was definitely tons of emotional support. We wanted things to happen for everyone and rooted for each other and took care of each other."

For P28, team practices in virtual game jams could be as supportive and emotionally satisfying as in any other close interpersonal relationships. The key was to focus on respecting and trusting each other, which made the team *"really good at working together."* For her, teamwork in virtual game jams was not merely about developing and innovating games but also about building relationships – such relationships helped developers' career goals and let them support and take care of each other as a team.

In summary, many developers considered virtual game jams *"inspiring"* because of the emotional support emerging in their team practices at these venues. For these developers, their team practices in virtual game jams were not only facilitated by varied technological processes but also depended on meaningful and valuable emotional support as a team and as a community. This is how they all came together and dedicated to innovating game design and development.

4.2 A Double-Edged Sword for Technological Innovation

In our study, 26 out of the 28 participants regarded their engagement in virtual game jams as generally positive and beneficial. However, they also raised several concerns, considering virtual game jams a double-edged sword for their technological innovation.

4.2.1 Broadening Participation to Support and Facilitate Innovation. Many participants noted that virtual game jams significantly facilitated their technological innovation because these jams broadened participation in game development in various ways, including providing a broad entrance to game development; enhancing public visibility and diversity of indie game development; and fostering a sense of networked innovative community.

Entry to Game Development at A Low Cost. Game development is often considered a highly sophisticated and technical area with high demand for a variety of skills such as programming, scripting, designing, writing, and animation. When responding to the interview question about how virtual game jams helped their game development/innovation in any way, many participants found virtual game jams as a promising alternative for many newcomers or hobbyists to enter and experiment game development at a low cost. In their opinions, projects in game jams tended to be small-scale and less complicated (thus low time investment); virtual game jams also did not require travel to physical sites (thus low financial cost) and could potentially attract participants from different geographical areas and timezone. For example,

"I think that game jams, especially virtual game jams, are a way for people who don't really participate in game development to get into game development. You just spend a weekend making a game at home. It really is great for bringing in new people." (P16, male, 24, Brazil, full time indie developer)

"I think it's a good introduction to game development because it opens an entry point. Even if you end up with something that isn't really presentable, you only spent like a couple of days on it but you get the valuable experience." (P20, male, 25, Belgium, full time indie developer)

According to P16 and P20, one of the most important benefits of virtual game jams was to introduce newcomers, new ideas, and new perspectives to innovating game development by opening an entry point – even people who were not familiar with game development could participate and experience at very limited costs.

Such a benefit is also not only limited to newcomers. P28 (female, 36, USA, full time indie developer) added that even more experienced game developer could use virtual game jams to seek new opportunities:

"Everyone can benefit from virtual game jams regardless of your skill levels. You can try something that you normally wouldn't have about, or work the people you wouldn't have worked with. Or you can be more efficient because you'll make quick decisions so you can get it done in time. I think that most importantly, it helps people become innovative. Seeing what everybody else is doing is really encouraging." (P28)

As a full time indie game developer who had been engaging in game development for 9 years, P28 still felt that participating in virtual game jams continued to open up new opportunities for her – by encouraging her to try new features or directions, collaborate with new people, and work more efficiently. In this sense, virtual game jams plays an important role in innovating game development by not only opening an entrance for newcomers but also facilitating experienced developers' technological practice – it acts as both great showcase of developers' achievements and a main attraction to new talents.

Enhance Public Visibility and Diversity of Indie Game Development. Another way through which virtual game jams broadens participation in innovating games is to enhance public visibility of indie game development as a form of bottom-up innovation and to promote diversity in game development.

Many participants expressed their concern that compared to the mainstream gaming industry, the indie aspect of game development was still largely unknown to the general public. As most participants in virtual game jams were indie game developers or hobbyists, they considered these venues crucial to introduce and advocate their technological innovation to the public. For example, P3 (female, 24, N/A, hobbyist) and P28 (female, 36, USA, full time indie developer) explained,

"I think that virtual game jams are extremely important for widening the audience of indie game development. People who don't know much about indies could participate in a jam or watch live streams of these jams. Then maybe they will get a better understanding of what we are doing." (P3)

"Virtual game jams often include other important parts such as publishing online articles or live streaming a bunch of games from a jam. That's the type of great exposure that you would not have. Indie developers aren't necessarily great at marketing or talking to journalists yet and all these things could be kind of a foot in the door for them." (P28)

P3, a hobbyist, and P28, a full time indie developer, both highlighted the importance of virtual game jams to increase the public visibility of indie developers' technological innovation. According to them, participating in virtual game jams often efficiently exposed developers to the public through multiple channels that they would not have access before. For these developers, a better understanding and public acknowledgment of their technological practices was not only *"rewarding"* but also encouraging, which further motivated their innovation.

In addition, virtual game jams were effective to promote diversity in game development, a traditionally white male dominated technological area. All four female participants in our study described their experiences of virtual game jams as supportive, collaborative, and friendly. P19 (female, 30, USA, full time indie developer) and P21 (female, 18, USA, hobbyist) noted when answering the interview question about the advantages of participating in virtual game jams:

"I think virtual game jams are great for diversity. People who are in the underrepresented groups may feel safer because everything is virtual and they can just develop games at home. Also lots of game jams focus on involving particular groups of people such as minorities or women or people under a certain age. I also know a bunch of events and game jams for refugees. I think that most game jams try very hard to be more friendly and inclusive to bring those people into the community. Innovating games definitely needs diversity." (P19)

"I have not had a bad experience working with people in virtual game jams. People know I'm a woman but this doesn't lead to anything negative. They respect me and appreciate my work. I think this is very different from the mainstream gaming industry as sometimes women do get harassed or mistreated." (P21)

P19's and P21's accounts highlighted virtual game jams as valuable venues to both engage and retain traditionally marginalized populations such as women, minorities, and elderly in innovating games. As P19 mentioned, organizers of virtual game jams often made excessive efforts to *"bring those people into the community"* by either ensuring their involvement or hosting jams especially for a certain group (e.g., refugees). P21 also emphasized the generally positive and respectful social atmosphere fostered in many virtual game jams, which encouraged her participation. There seemed to be a consensus that technological innovation in the gaming area *"definitely needs diversity."*

Sense of A Networked Innovative Community. Participants also expressed their appreciation of the sense of a networked innovative community afforded in many virtual game jams,

which connected developers at different locations all together. For them, this sense was significant for supporting and encouraging their technological innovation. P6 (non-binary, 27, South Korea, hobbyist) described this feeling when answering the question about how virtual game jams helped game development/innovation:

"I think virtual game jams do a wonderful job in making people feel like a community. You truly feel that other people care about helping you learn and care about what you're trying to make. This gives you extra motivation to finish whatever you're trying to do."

Similarly, many participants commented that the feeling of warmth, care, and connectedness in a networked community motivated developers who were reluctant to participate in face-to-face jams for being shy to engage in innovation. It also made game development a genuinely interactive and collaborative practice. For example, when responding to the same question, P5 (male, 28, Malaysia, hobbyist) and P12 (male, 50, USA, full time indie developer) noted:

"I think virtual game jams help connect people, especially those who don't like to participate in face to face jams for being shy. Virtual jams allow them to group with people, collaborate, and be part of the community." (P5)

"Virtual game jams do a wonderful job in making participants feel like they are not just making a nebulous game but something that people will play and enjoy. They get a larger community together because people don't need to be physically there. These jams also introduce them to create their own new game development teams. I think that that's one of the key ways that people start to find partners and form teams." (P12)

According to P5 and P12, virtual game jams seemed to afford community participation and interaction both technologically and socially. Technologically, since participating in virtual game jams is completely computer-mediated and does not require physical presence, they become especially useful for involving developers who are introverts and shy in the community and facilitate their innovative practices. In this sense, virtual game jams help innovating game development by inviting and accommodating developers of different needs and personalities. Socially, virtual game jams promote technological innovation as an interactive social experience. P12 pointed out that the social aspect of developing and innovating games emerged as a key emphasis of virtual game jams. In particular, many developers would take advantage of virtual game jams to seek and form their future teams, leading to potentially long term and sustainable innovative practices.

4.2.2 Issues that May Hinder Innovation. As we have shown, virtual game jams certainly support and facilitate developers' technological innovation in varied ways. However, our participants also pointed out that virtual game jams may hinder their innovation, especially with regard to the difficulty to complete a scaleable prototype and emerging legal and copyright concerns.

Difficulty to Complete A Scaleable Prototype. For many developers, creating and completing a prototype that can be turned into a more sophisticated product in the future is what directly benefits and sustains their innovative practices. Yet attending virtual game jams, in fact, did not efficiently help them produce a scaleable prototype. When answering the question about disadvantages of virtual game jams for their innovation, some participants mentioned the time frame as a significant barrier:

"Virtual game jams are a little bit of a double edged sword because it's a lot of work to do in a really short time. It's very challenging to finish everything you want to so you often end up with a half-baked product. (P1, (male, 30, USA, hobbyist))

"Many virtual game jams are only 48 hours or 72 hours. So the biggest challenge is just managing your time effectively. The way I like to approach it is trying to get the game done as quick as possible and then use as much remaining time to polish and add on. The quality is not as good as I want but we will never get it done if we only want quality." (P19, female, 30, USA, full time indie developer)

Both P1 and P19 expressed their struggles between completing their virtual game jam project and ensuring the quality of the product. There seems to be a dilemma: the expectation to produce a complete product in 48 or 72 hours hinders the quality of the end product to a certain degree; whereas the demand to produce a high-quality product will likely not lead to a complete end product. Obviously, neither scenario would benefit these developers' innovative practices.

As a result, many virtual game jam participants had to comprise between quality and completion by limiting their games to a very small scale. P12 (male, 50, USA, full time indie developer) and P24 (male, 28, Australia, hobbyist) noted when explaining their negative experiences of virtual game jams:

"It's very difficult to have a balance between something big that you really want to make and the time you have to finish it. The time frame is much smaller so your idea needs to be much smaller as well. It's a really good way to practice but you cannot always just practice making small things." (P12)

"Most games that are made in virtual game jams are extremely small and slower than almost anything else you have played. Because if the game is too big, it's not going to get finished in time. I think many of them are unmarketable and almost unplayable sometimes. But some may have potential, if the developers keep working on them after the jam." (P24)

In P12's and P24's accounts, a concern was that engaging in virtual game jams may only lead to small-scale, somehow lower quality, and "unmarketable" end products. In this sense, virtual game jams themselves may not facilitate these developers' innovative practices because only making small-scale products is not considered sustainable – in P12's words, they "*cannot always just practice making small things.*" As P24 summarized, a more feasible way was to continue the efforts to keep improving the games after the jam, which may eventually lead to successful innovation.

Legal and Copyright Concerns. Some participants highlighted certain legal and political concerns emerging in virtual game jams, which became obstacles for their technological innovation. Above all, they were well aware that their innovation did not occur in a vacuum but was directly affected by various policies and regulations in the broader social context. Since most participants attended virtual game jams that applied an open intellectual property ownership, how to approach and manage copyright became a central concern. When answering questions regarding how policies and politics affected their game development/innovation in virtual game jams, P3 (female, 24, N/A, hobbyist) and P9 (male, 19, USA, hobbyist) explained:

"In a virtual game jam, you can stream your project and your code. So a possibility is that your intellectual property could be stolen. How would you protect yourself?" (P3)

"If I stream my work in a virtual game jam, I don't archive my streams because I don't really want someone to take my programming and idea. I don't mind them learning from it, but if people copy things exactly, that's not the most respected thing and it hurts my own creativity." (P9)

It is obvious that developers would be willing to share and open up their development process to others in virtual game jams so they could help others learn. They also went out their way to make this happen (e.g., through live streaming). However, it is unclear how they could protect themselves and ensure that their creativity and innovation would not be stolen while still helping and sharing with others. This leads to an increasingly important question surrounding game jams: how can virtual game jam participants balance the culture of mutual help, sharing, and openness in the community (especially indie game development community) and the urgent needs to protect innovators' intellectual property rights?

Others added that this concern was not only about developers' individual practices (e.g., learning vs. stealing from others) but also related to issues in broader copyright policies. For example, when responding to the same interview question, P28 (female, 36, USA, full time indie developer) felt confused about whether the jam itself or the developers owned copyright to their products:

'Usually we need to upload the game to the website once the virtual game jam is done. So it does look like you still created the game and own all of it. But the jam can keep a copy that people can download. If you did come up with a really innovative concept and it was going to become something, it would be very confusing. Can I keep going with this and sell it? Should I ask the jam to take it off from the website?'

(P28)

According to P28, how to appropriately manage copyrights of innovative products from virtual game jams seems to be a gray area. On the surface, it is clear that developers are the actual owners of what they create. Yet the game jams have rights to make the developed games available to the general public through free downloads and free play. While participants appreciate this public visibility that the virtual game jams bring to them, they are often confused about to what degree their future development and innovation is restrained by the jams and how the jams can protect their creative ideas and products.

More importantly, participants felt that there was a lack of copyright policies/regulations at the national level to address this gray area. This also seems to be a university issue across different countries. P14 (male, 18, India, hobbyist) shared his experience about policy issues in virtual game jams in India:

'In India, you don't have a 'if you made it, your own the copyright' policy. It is 'you made it, you have registered it, and then you have the copyright.' So the copyright system in India is not friendly to indie game developers or game jam participants. Because for every tiny idea and every tiny thing that you make, you have to file a copyright. Things in the USA may be better but the same issue is still there.'

P14's account highlights that the legal and copyright concerns emerging in virtual game jams is not within one community or one country. Rather, the fact that policies regarding creative industry and economic development at the national level may hinder technological innovation is a growing universal phenomenon. As P14 noted, no matter in India, USA, or other countries, the existing policies of copyright appeared to be insufficient to protect and motivate virtual game jam participants' innovation.

5 DISCUSSION

To answer our research questions, our findings have shown: 1) game developers employed four main strategies to conduct team practices for innovating game design and development in virtual game jams, including effectively assigning roles through computer-mediated methods; conducting fast-paced practices of sharing multimedia materials and project management; achieving a balance between text communication and voice chat; exchanging diverse forms of social and technological

support (RQ1); and 2) virtual game jams serve as a double-edged sword for developers' technological innovation. On the one hand, they broaden participation to support and facilitate innovation. On the other hand, they may hinder innovation due to the difficulty to complete a scaleable prototype and emerging legal and copyright concerns (RQ2).

In this section, we discuss the implications of our findings for extending current CSCW studies on virtual teams and bottom-up technological innovation by focusing on virtual game jams. We also outline potential design recommendations for addressing challenges that innovators may face in these emerging innovation sites and mechanisms.

5.1 Facilitating Virtual Team Practices for Bottom-up Innovation

As noted, there are growing interests in both game jams [13, 48] and bottom-up innovation [19, 23, 25, 26, 28, 45, 46, 78] in CSCW. Typically, these areas have been studied separately without research integration. This disconnect motivated the study presented here. In this study, we endeavor to understand team practices that occur during virtual games jams and how they impact bottom-up technological innovation.

Above all, our findings highlight how virtual team practices can be supported and facilitated in a creative and innovative context that has not been widely studied in CSCW (i.e., virtual game jams). As previous literature has shown, creative virtual teams often face challenges regarding leadership [47], awareness [14], trust [1, 73], and communication [7]. However, game developers in this study applied multiple strategies to overcome these challenges when conducting team practices in virtual game jams. First, while it was difficult to establish leadership among innovators who were online strangers, assigning roles based on self-reports through computer-mediated methods (e.g., text chat via Discord) was proved to be effective for jump starting team practices and laying the ground for everyone's responsibilities. Second, the challenge of awareness for creative virtual teams was mitigated by fast-paced practices of sharing and management. As our findings have shown, game developers consistently tracked and documented each other's progress. In this process, they were well aware that they, as a team, moved forward towards their common goal (e.g., designing and developing a digital game within time limits). Third, virtual game jam participants faced similar communication challenge of sharing and expressing creative ideas via computer-mediated communication as any other creative virtual teams. They even faced additional challenges as virtual game jams were fast-paced and required immediate feedback/reaction. In our study, participants achieved a balance between text communication and voice chat to address these challenges - text for exchanging complicated ideas between team members with geographical/time differences; and voice for contextually rich communication (e.g., addressing arguments and conflicts) and fast actions. Lastly, participants highlighted various forms of social and technological support that they exchanged in virtual game jams, which fostered a sense of trust among team members.

These strategies, therefore, effectively facilitated game developers' efforts to innovate game design and development as small teams. Similar to other well studied innovation sites such as makerspaces, hackerspaces and fablabs, and hackathon [35, 38, 61, 68, 69, 71, 72, 74], virtual game jams also foster values of openness, teamwork, and community support for innovation. Yet, they tend to leverage diverse computer-mediated methods to facilitate remote team members to coordinately conduct complex and fast-paced practices that are both technical and artistic (e.g., game design and development), learn and share high tech skills, create tangible and deliverable products, and significantly reduce the cost of participating in innovation. All these characteristics not only highlight the educational [52], social [43], and design [31] aspects of game jams but also show how virtual game jams can be valuable and unique sites for bottom-up innovation compared to the above-mentioned traditional innovation spaces. Through virtual game jams, indie game developers and hobbyists endeavor to make their technological practices more visible to the general

public; and they strive to offer social support to community members in need – such as women. For them, virtual game jams are valuable innovation space because they are built on a shared belief that everyone in principle can participate in game development with reduced participation cost. This may significantly advance a more inclusive and diverse agenda in game development and encourage underrepresented populations such as women to engage with innovation.

5.2 Rising Tensions for Innovations in Game Jams

Despite the rising opportunities to leverage virtual game jams for innovation, two consistent themes that emerged in our findings was 1) tensions between the "play" nature of virtual game jams for indies and hobbyists and developers' intention to create complete and marketable products; and 2) tensions between team practices for innovation and protecting one's individual work.

Play vs. Innovation. As mentioned earlier in this paper, existing literature on game jams has highlighted "play" as a defining feature of game jams [31, 32]. Yet in our study, some participants considered that such a focus on "play" contradicted their endeavor to innovate. These jams mainly emphasized personal engagement, social experiences, and playfulness, which often led to a half-baked product and a less than desirable prototype. For jam participants who aim at eventually turning an early prototype to a commercial product, this is certainly an issue moving forward, as the goal of virtual game jams is to encourage producing innovative prototype and ideas. In addition, some participants expressed concerns about the highly stressful development environment at many game jams. Virtual game jams often focus on fast-paced game development with online strangers, which could introduce unnecessary stress compared to some less competitive and time sensitive events such as local meetups. For some developers, such stress may hinder rather than promote their innovation. In this sense, while game jams are considered an intersection of work and play [31, 32], how to actually balance work and play to support and promote developers' innovative practices becomes an important question.

Team practices for innovation vs. Individual protection. Another tension emerges in the risk that during game jams individuals can be *exploited in the name of collaboration*. While the potential exploitation of labor such as the issues of "digital sweatshop" and invisibility of workers in crowdsourcing [36, 37] has been and will continue to be an area of interest in CSCW, exploitation in the area of bottom-up technological innovation and in the form of teamwork is often neglected.

When discussing with our participants, it was clear that virtual game jams might often encompass many different types of game developers ranging from professionals to hobbyists. Yet, the overwhelming amount of our participants were either 1) *hobbyists* who were curious about game development and participated in game jams as a hobby or a way to occupy time; or 2) *indie game developers* who had varying levels of experience and skills and sought to learn and/or expand their connections. Inherently, some people in these populations would be vulnerable to exploitation – those who provide novel ideas and knowledge yet do not know how to legally protect themselves and their intellectual property.

Indeed, legal and copyright concerns were brought up multiple times during our interviews. In general, virtual game jam participants are aware of the potential risks for their intellectual property to be stolen due to the collaborative and open sharing nature of the game jam environment. This poses a major potential problem associated with virtual game jams - the aspects of games jams that make them highly effective and valuable for bottom-up technological innovation, such as open communication, creation of novel concepts and methods, and the ability to support each other, can also become the very same reasons why individual game developers are at risk of having their skills used without proper credit. Therefore, the question becomes: how do individual game developers

who participate in game jams contribute to collaborative innovation while still ensuring that they have the appropriate rights and protections?

Certainly, there is not an easy answer to the above-mentioned question. Yet, prior CSCW literature on labor and technology [24, 36, 37, 75, 77] may inform potential recommendations for preventing exploitation in collaboration. In general, the game development community needs to put forth a more explicit effort to educate people on what game jams are, what they consist of, and how individuals should participate in them both at a team and individual work level. Moving forward, sponsors and/or organizers of games jams need to clearly outline the rights of participants. They should not only inform the participants of such information but also take proactive action to educate them to ensure that all participants have common knowledge.

In addition, game jam participants need to inform themselves on intellectual property and copyright issues. Such issues regarding user-generated content and online creative communities have been well discussed in CSCW [15–17]. The broader game development community needs to take a stance in better educating and providing game developers, especially indie game developers, with knowledge pertaining to team practices for innovation. Yet, this education ultimately falls on the shoulder of the individual game developer. As the CSCW research agenda on bottom-up innovation continues to grow, the issues surrounding how to manage open collaborative environments and individual intellectual property rights will continue to grow in their importance. Game jams, thus, bring forth a rich and promising context to further study such issues.

5.3 Design Implications for Supporting Team Practices for Bottom-up Innovation

As our findings have shown, team practices in virtual game jams supported bottom-up technological innovation in multiple ways ranging from community building to idea generation to actual development. Grounded on game developers' four strategies to conduct teamwork in virtual game jams, in this section we outline design implications to facilitate virtual team practices for bottom-up innovation.

Design Affordances for Role Identification and Shared Goals Development. In our study, participants identified the need for role identification to occur even prior to beginning their team practices. Indeed, role identification is not unique to game jams, as it is one of the most relevant and common place concepts related to general team effectiveness [6, 10, 34, 60]. In regard to potential design implications, therefore, there is a clear need to attempt to ensure that role identification and shared goals are defined before the innovation process begins and are aided by collaborative technologies. Specifically, collaborative technologies used in game jams, or any other mechanisms for bottom-up innovation, should put a priority on allowing team users to assign specific roles and identify a shared goal. This can be as straightforward as providing a simple feature that allows "Team Role" to be assigned or filled in under each users' name. Specific to games jams, potential team roles could be: designer, programmer, visual artist, and sound artist (to name a few). Predefined roles can be included that are specific to most game jams, but there should also be the functionality for a team to create/name additional roles that are specific to their team. In addition, at the landing page of the collaborative software, a "Shared Goal" feature can be filled in that is always clearly available to all users. "Shared Goals" may range from: what genre of games they want to make, multiplayer vs single player, the artistic/aesthetic styles, and storytelling styles. Again, these can be suggestions but the availability for teams to enter their own specific shared goals should be attainable. More advanced options may include a skill survey, which will be shared within the whole team after each team member fills out. This added feature also aids skill identification, which is in concert with role identification. This feature would reduce the overall time that is needed to pre-plan as

well as identify and assign roles, allowing teams to quickly start the process of idea generation and development.

Design Affordances for Fast-paced Communication and Multiple Modalities of Communication. Communication is often identified as at the core of teamwork [49] and one of the more challenging facets of teamwork [9], especially in virtual collaborative environments [50, 70]. In our study, participants often suggested that communication was especially crucial considering the fast-paced nature of the virtual game jams. This consideration holds true to any innovative environments or events that requires rapid prototype or development (e.g., hackathon). In addition, the presence of multiple communication modalities in virtual game jams was identified as being problematic to game developers. For them, the access to multiple affordances introduces additional decision-making, which may add ambiguity or conflict to a team.

To address this issue, our recommendation is to afford fast-paced communication in a simplified manner. We suggest a design affordance where the collaborative system prompts the team to define a communication plan that is relevant to the innovation context. Often, teams fail to plan how to communicate while assuming that they know how. Having the collaborative system prompt this for discussion will help enable that this conversation occurs.

Another recommendation, in response to the overwhelming amount of communication modalities, is to obviously limit these modalities. This recommendation is two-folded and focuses on to separate but related areas. First, it would be useful to limit the pure number of collaborative technologies that are being used to aid teamwork and collaboration. Far too often, and is the case in game jams, teams use too many technologies all of which each have their own affordances (often multiple communication modalities within the technology). This obviously overwhelms the user and requires cognitive bandwidth devoted to managing multiple technologies. Second, the number of communication modalities and mediums present within one single collaborative technology should be limited. For example, our participants highlighted that they did not need more than a simple chat and voice interface. Therefore, these suggestions should be implemented in a simple design that allows for integration of each.

Design Affordances for Prototyping in Game Jams. Issues relating to prototyping were routinely brought up by virtual game jam participants. In general, there are two contrasting ways to view the lack of high-quality prototypes in virtual game jams: 1) prototypes are not the meaningful outcome of game jams but the process and idea/knowledge generation is, or 2) this is a significant challenge and leads to innovative products that is then not usable or marketable. In discussing this with our participants, it was clear that most of them lean towards viewpoint 1, seeking to highlight the benefits of the virtual game jam. Yet, they also clearly acknowledged the value in developing the prototype. Therefore, design implications relating to this issue clearly identify that collaborative technologies should allow consistent methods to create prototypes and help set expectations for what the prototype will consist of.

Our recommendations are less traditionally design related in this section than the previous sections; we recommend using collaborative technology as a mechanism to promote valuable human team behavior. Based on our interviews, there seems to be varying levels of expectations related to the type of prototype that is created during a virtual game jam. Some participants were satisfied with lower quality small prototypes, but others expected to develop high quality robust prototypes. Depending on the time limits of the game jam, the latter prototype is not always feasible. Therefore, in an attempt to better align team members' goals for prototyping, we recommend that the collaborative systems prompts users with a question outlining what expectations for the prototype are and how they will achieve those. This will help the virtual game jam participants to

collaboratively decide the size, quality, and scope of the prototype by 1) setting forth a foundation for what the prototype is, 2) streamlining ways to achieve it, and 3) leveling out expectations. This is in direct concert to our prior suggestions relating to role identification and shared goal delineation. This prototyping question could be separate or directly integrated with the design affordances that we previously suggested.

5.4 Limitations

A few limitations of this study should be noted. First, our findings are representative of the experiences of the participants in the virtual game jams that we interviewed. We acknowledge that our findings may not represent different types of game jams with diverse environmental aspects, such as focus and time limitation. To address this limitation, we attempted to encapsulate a wide sample size of game jams by interviewing virtual game jam participants across different countries. In addition, we acknowledge that our sample leans heavily towards male game developers, with many being hobbyists. With the growing interests in critical analysis of game jams such as [39], we endeavor to further explore the role of game jams and indie game development in promoting gender equality in the traditionally male-dominated gaming industry.

6 CONCLUSIONS

In this paper, we have highlighted the unique role of virtual game jams in promoting bottom-up technological innovation by supporting and facilitating complex and fast-paced practices that are both technical and artistic among remote teammates, creating tangible and deliverable products, and significantly reducing the cost of participating in innovation. We have also shown that though these emerging innovation sites allow for nuanced virtual team practices for bottom-up innovation and foster a supportive environment (both technical and emotional), they also create several barriers for innovation and lead to tensions between play and innovation and the potential risk of exploitation in the nature of collaboration. Therefore, realistically balancing the pros and cons of team practices in emerging innovation sites and mechanisms is an important area of future CSCW research, and one that will help design future collaborative technologies to facilitate bottom-up technological innovation and protect populations that may be more prone to exploitation than others in the innovation process.

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