

Article

Game Jams as Valuable Tools for the Development of 21st-Century Skills

Ruth S. Contreras-Espinosa ^{1,*}  and Jose Luis Eguia-Gomez ²¹ Department of Communication, University of Vic—Central University of Catalonia, 08500 Vic, Spain² Department of Project and Construction Engineering, Polytechnic University of Catalonia, 08028 Barcelona, Spain; eguaia@ege.upc.edu* Correspondence: ruth.contreras@uvic.cat

Abstract: The concept of 21st-century skills refers to the knowledge, skills, and emotions that are critical to successfully navigating today's world. Game jams can act as spaces to develop these skills and thus boost cooperative learning, problem-based learning, or co-creation. Additionally, game jams offer opportunities to improve collaboration and creativity skills, among others. This paper summarizes three years of activities designing and studying game jams to develop 21st-century skills, focused on Mexican students aged 12–16 years old. Data were compiled through direct observation, open-ended questionnaires, and interviews and were subject to thematic analysis in order to construct new knowledge on a previously underexplored topic. The results suggest that game jams are valuable tools to develop 21st-century skills, and, although the outcomes of skill evaluation may vary and may be difficult to verify, the participants reported increased skills, such as creativity or collaboration. Finally, this paper provides recommendations based on the research and practice conducted by the authors on how to use game jams to develop 21st-century skills and different ways to organize game jams, along with the resources needed.

Keywords: game jam; 21st-century skills; critical thinking; creativity; communication; collaboration; students



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1. Introduction

A game jam is an event where knowledge is shared by organizing multidisciplinary teams that create a video game, and its purpose is to explore the conceptualization process, the development, and the skills that students developed thereafter. Game jams offer opportunities to improve the skills necessary to develop video games [1], improve skills in STEAM [2], develop interpersonal and intrapersonal skills, and heighten participant self-efficacy [3] or learning motivation [1]. In addition, through game jam experience, participants become more skilled in video-game design, as creativity is highly promoted [4]. Video-game development also presents some challenges, as it requires critical thinking from the developers, and that they learn to evaluate the results [5]. Some studies also report that video games motivate STEM learning [6], while researchers have been particularly interested in the role of problem resolution in these contexts [7]. From a social perspective, communication and social interaction during game jams are essential in order to successfully develop games, especially when participants share ideas, strive to understand the skills of the rest of the participants and effectively distribute tasks [8], and contribute to overcoming the barriers that may hinder participation in such activities [9]. Thus, game jams seem to offer diverse opportunities to improve skills, such as critical thinking, creativity, communication, and collaboration, and can be valuable tools in formal education contexts [10].

Game jams are typically and exclusively devoted to video-game design through collaborative work, while participants have fun in the meantime [11]. Nevertheless, the main goal

of this research was not to employ game jams to learn how to create video games or develop specific skills related to this task, such as programming or character and background design, but rather to help students improve their critical thinking, communication, collaboration, and creative skills, typically enhanced during game jams [12]. In such a short collaborative event, it is unrealistic to expect that all of them will acquire all the necessary skills and learn to program or design characters and scenes [10].

Nowadays, so-called 21st-century skills are crucial. These skills (learn, communicate, collaborate, and solve problems) were identified by UNESCO or the Organization for Economic Co-operation and Development (OECD) as competencies required for a sustainable future of the knowledge society [13]. The P21 Framework precisely addresses the knowledge of 21st-century key topics through the main academic disciplines and suggests that the best way to achieve learning goals in the 21st century is through interdisciplinary approaches. Additionally, the framework highlights that students would have better opportunities to stand out in the increasingly complex job market and daily life if they manage to improve their communication, cooperation, and creative skills [13,14]. The OECD proposed an approach developed over two initiatives: the Definition and Selection of Competencies Program (DeSeCo) and the Program for International Student Assessment (PISA) [13]. DeSeCo's main objective is to provide a framework that can guide the long-term extension of assessments into new competence domains and uses three groups of key competencies: (1) using tools interactively, (2) interacting in socially heterogeneous groups, and (3) acting autonomously. The individuals' ability to think for themselves and assume responsibility in their own learning processes and activities is at the center of the DeSeCo initiative [15].

The current game-jam literature mainly focuses on case studies in which students develop video games from a recreational perspective (e.g., see References [1,5,11]), but it does not discuss the potential of game jams as valuable tools to develop 21st-century skills. We know very little about the motivation of game-jam organizers or how game jamming can be an appropriate teaching method for soft skills, such as communication and collaboration, except for what we can infer from the overall theme of a jam [16]. Despite Aurava et al. [10] already confirming that teachers think that game jamming can be a teaching method for soft skills, and with game jams already being increasingly popular in the education sector, there is still a lack of qualitative research identifying the specificities of each type of events [16].

The present work thus addresses a large knowledge gap by focusing on game jams directed toward enhancing 21st-century skills and provides unique theoretical and practical perspectives about game jams as a pedagogical method, including recommendations on how to organize such events, reduce their typical duration, and employ them as an extra-curricular activity. This research paper summarizes three years of fieldwork and data collection between 2017 and 2019 during game jams aimed at helping Mexican students develop their 21st-century skills. The objectives of this paper, focused on providing a qualitative analysis of the observations, are as follows:

- (1) To discuss how game jams contribute to the development of 21st-century skills.
- (2) To discuss which game jam format is most useful for the development of 21st-century skills.
- (3) To discuss what are the necessary resources to organize game jams.

2. Background

2.1. Game Jams and Video Game Development

The game jam movement was born with the inception of the Indie Game Jam in 2002 [16,17]. The first authors to define the game jam concept were Musil et al. [18], who consider game jams as events with time-boxing, a general theme, ad hoc group forming, and a communal presentation of all the games. The authors did not restrict their definition to online games, as they consider that game jams can be hardware-and-software agnostic. Kultima [19] analyzed 20 papers related to game jams to produce a single definition: accelerated, constrained, and opportunistic game creation events with public exposure, highlighting the use of game jams in the game industry. Some examples of jams as part of

game industry conferences and exhibitions include Develop [20], Pocket Gamer Connects Helsinki [21], and GamesCom [22], among others.

Game jams are gaining popularity because they facilitate the development of the skills necessary to develop video games, such as creative, participatory, and innovation competencies. Creativity as a skill refers to the ability to generate ideas, concepts, and new associations. During game design, participants receive all the necessary information and details that allow them to develop backgrounds, as the goal is to create spaces that enable a variety of activities for the players to perform. In this way, game developers are faced with material that stimulates their creativity [23] and allows them to generate new ideas and concepts. The activities involved in video game creation inevitably lead to cooperation with other developers and, through constructive processes, a team may jointly develop the characters, which promotes group dynamics and favorable attitudes toward learning [24]. Finally, innovation is also necessary during video game creation, as they require graphics projection systems, 3D elements, sound, and modeling, resulting in a new playful interface [25].

The video game industry has not been the only sector that has realized the potential of game jams. Game jams are becoming increasingly popular, and each year the number of events and locations grow [26], including academic game jams, such as the Schloss Dagstuhl Seminars [27], and game jams for research [28] (that provide opportunities for collaboration and playable research) or educational purposes [29] (as part of the learning content of game-related education programs). Thus, there is a wealth of literature on the study of game jams (e.g., [1–6,8–10,12,18,30]) that provides insight and advice from the participant [31] and the facilitator perspective [30,32]. Pollock et al. [2] suggest using game jams to promote education, as they consider that including game-making into after-school programs, would entice young people to get a better education.

2.2. Game Jams from a Pedagogical Perspective

Learning during game jams occurs through emulation of processes common to industrial environments, such as co-creation, co-production, and co-design. Co-creation is a collaborative practice characterized by the active involvement of the users of a product or service during the different stages of the production process [33]. On the other hand, co-production is also natural and inherent to classroom sessions, as the progression in the program of any subject depends, to a large extent, on the capabilities and progress of the students. They co-produce the content that the teacher will deliver in subsequent sessions [34]. Finally, co-design emerges from the User-Centered Design approach, one of the first participatory design methods established both in scientific research and the industry. Depending on the domain, there might be slight differences in the conceptualization of this term. For example, in technological environments, co-design methodologies try to involve as many participants with different profiles as possible during the design process to achieve the highest feasible degree of consensus regarding the design and functionality of the final product [35]. Nevertheless, these concepts are somehow intertwined. Dudau et al. [34] consider that the concept of co-creation is composed of co-production and co-design, while Sanders and Stappers [36] define the term co-creation as an act of collective creativity, with the particular case of co-design being the act of collective creativity at the time when the design is taking place.

The type of learning that takes place during game jams is not very different from that from typical educational environments and includes (1) cooperative, (2) project-based, (3) problem-based, and (4) collaborative learning. During cooperative learning (1), work gets divided into tasks that the students solve independently, and the outcomes are later combined [37]. In game jams, teams work cooperatively, which is especially enhanced when participants count with different sets of skills. Project-based learning (2) occurs when participants solve their own doubts and challenges, but at the same time count with the help of a tutor that supports the process instead of providing all the information [38]. Problem-solving (3) as a skill has gained ground in different disciplines, for example, in Mathematics

and Technology, as solving problems entails combining creativity and innovation to find more suitable and desirable solutions to a range of challenges [7]. Problem-solving allows for more collaborative interactions and more feasible ideas to emerge [15,24]. Lastly, collaborative learning (4) refers to situations in which two or more students work together to achieve a common goal [37], a frequent process during game jams. Cognitive and metacognitive gains do not consist in solving specific problems, but in creating a particular video game and achieving knowledge as a team, thanks to the skills provided by each individual [29]. When participants work together to promote joint learning, not only their own, the (meta)cognitive performance and the social skills of the students are enhanced, which evidences that collaborative learning is, in fact, effective [39]. However, for any collaborative learning to be successful, the figure of the tutor, and their abilities to promote a beneficial interaction, are crucial [40]. This is the key to differentiating purely industrial co-creation, co-production, and co-design processes from collaborative learning activities. Kaendler et al. [40] highlight as didactic competencies for tutors to promote collaborative learning: planning, monitoring, support to student interaction, learning consolidation, and, finally, reflection. All these phases are present during game jams, as reflection occurs at the end of the event when all the groups present the video games created and discuss their projects.

Given the nature of game jams, the diversity of practices they include (co-creation, co-production, co-design), and the pedagogical processes that take place among participants (cooperative, project-based, problem-based, and collaborative learning), these events can effectively contribute to the development of crucial skills, such as critical thinking, creativity, communication, and collaboration.

2.3. *Twenty-First-Century Skills*

The term “21st-century skills” refers to a group of skills or competencies seen as basics in the actual world, where an individual and society will benefit more from constant learning, adaptation, and innovation than from a fixed set of concepts and information [41].

The 21st-century skills differ from traditional academic skills in that they are not content-based, can be considered multifunctional, cross-cutting, and context-independent. UNESCO argues that they are essential for achieving a sustainable development, noting that not all types of education contribute to it [14]. These skills are often divided into three main areas [42]: (1) learning and innovation skills, (2) digital literacy skills, and (3) skills related to helping in daily life and professional career. The 4Cs of 21st-century skills included in the scope of learning and innovation are particularly relevant for this study: communication, collaboration, critical thinking, and creativity.

Organizations that support the development of 21st-century skills count with broad frameworks about what study plans should include and emphasize different areas within the general skill set. For instance, the association Battelle for Kids, through its P21 Network, proposes workgroups focused on technical skills or that promote digital literacy, highlighting the importance of the use of technology [42]. The key to 21st-century skills is to promote student-centered pedagogical methodologies [14] that involve, for example, co-design or project collaboration. The Skills Outlook Report by the OECD [43] highlights these skills as necessary, together with other basic subjects in a study plan and 21st-century topics [13]. From the moment the student is involved through the co-design activities proposed by the teacher, these become the springboard for the construction of a personalized learning itinerary [44]. Notions that are strongly associated with collective creativity actions and knowledge creation, such as co-creation, co-production, or co-design converge [45], in addition to lifelong autonomous learning, that can be improved through various flexible learning itineraries and become very significant [46].

Game jams require, employ and develop several of these crucial skills, such as communication and collaboration, as Meriläinen et al. mention [12]. Furthermore, the overall inclusion of games in more traditional learning has been used as motivation to get students interested in learning 21st-century skills [47].

3. Materials and Methods

Based on Aurava et al. [10], data were collected between 2017 and 2019 from three on-site game jam events organized by the authors and aimed at creating video game concepts and prototypes. Event participation was voluntary, and participants had previous experience using video game development software. Jammers were part of a program of the National System for Integral Family Development (Sistema Nacional para el Desarrollo Integral de la Familia) of Mexico City, aimed at high school students, that offers workshops and courses to help them develop their skills and acquire the necessary psycho-emotional tools to boost personality development. A total amount of 90 students aged 12–16 joined the events, together with 6 teachers, 6 game designers, and 3 researchers that acted as tutors. The figure of the tutor was represented by experts in various disciplines, such as video games, programming, art, or sustainability, that supported the teams with their advice or helped them with problem-solving during the sessions.

The events were organized following the recommendations of Juergen et al. [18] regarding the common elements in game jams: (1) game jams should aim for experimental video game design in a few hours; (2) the video games developed should follow the same theme, which should be made known to all participants before the event; (3) the event should be open to all interested participants that are willing and able to contribute to the development of the video game; (4) working groups should be comprised of a maximum of 5 or 6 persons; and (5) video game conceptualization can be first performed on paper models regardless of the final format or device in which they will be played. At the end of the game jam, participants present the developed games to the audience, and each project is discussed in order to reach the conclusions of the event, offer remarks and announce the winners of the event. Tenório et al. [48] suggest that in activities such as hackathons (similar to game jams) active working times should be reduced by proposing short challenges. This prevents negative emotions such as fatigue, discouragement, or fear, from arising. Therefore, they recommend events no longer than 48 h. Though some events can last as little as 2 h [9,10,48,49], the authors of this work opted for an intermediate duration of 6 h (as in [10]), during which students developed different video game concepts and playable prototypes in groups. During the game jams, participants would work in teams together with other students that they already knew since, due to time constraints, it seemed to be a suitable solution that could render optimal results. Teams consisted of 6 persons and were balanced according to participant skills: each team counted with participants that could design, program, create animations, create stories, and coordinate. The survey conducted before the game jam (pre-event survey) allowed identifying participant skills. Each of the organized events was slightly different due to slim modifications, such as the title of the event and the proposed theme for participants to develop. Table 1 summarizes the characteristics of each event.

Table 1. Organized game jams.

Group	Game Jam	Participants	Date Game Jam	Theme	Data Collected
1	Teen innovators	30 students (13 males, 17 females) 5 teachers (2 males, 3 females) 4 designers (3 males, 1 female) 3 researchers (1 male, 2 females)	26 November 2017	Sustainability	
2	Teen Game Jam MX	30 students (15 males, 15 females) 6 teachers (2 males, 4 females) 6 designers (4 males, 2 females) 3 researchers (1 male, 2 females)	25 November 2018	Creativity	Observation; pre- and post-event survey; student prototypes; interviews
3	Innovation Game Jam	30 students (17 males, 13 females) 6 teachers (2 males, 4 females) 6 designers (4 males, 2 females) 3 researchers (1 male, 2 females)	30 November 2019	Innovation	

During each event, qualitative data was collected thanks to pre-event and post-event surveys conducted on the students. The former was based on the questionnaire models implemented in other game jam events [50], while the post-event survey was specifically designed for this study. A total amount of 90 surveys were conducted, 30 per event. Open-ended questions collected personal information (name, age), participant interest in video game creation, what interested them most while playing video games, their purpose to participate in the game jam, and their knowledgeable skills. The post-event survey included close-ended questions and focused on the participant's experience. Questions focused on the practices developed during the game jam activities, which represent common cases encountered during the development of videogames: (1) learning skills; (2) critical thinking displayed during activities such as programming, group organization, time management, bug detection, individual expression, collaboration, integration, or generation of ideas; (3) creativity, the source of inspiration for the concept of the game to be designed (other video games, life experience, history, movies, biology, books, board games, art, music); (4) communication; (5) collaboration during game creation and testing, character design, and programming; (6) individual and collective challenges during the development of the game.

Right after the event, students were interviewed, and this data was complemented with the direct observation of the three game jams, which enabled documenting the use of design tools and, especially, the teamwork process and the development of the 4C skills among jammers. Collins et al. [51] suggest using several sources of data to obtain a clearer picture, including the analysis of the products created by the participants. A total amount of 40 interviews were conducted during the events.

The information collected through the surveys and the interviews was subject to thematic analysis, in which data is iteratively coded and re-coded to identify and construct thematic wholes [10]. The analysis was carried out using the software Atlas.ti and adopting a hermeneutic approach [52]. Two discussion key points emerged: researchers' reflection on the development of jammers' 4Cs and jammers' own experience of the game jam for the development of these skills. The role of the researchers was multiple in this educational project, including that of designers and mentors for teachers [53].

4. Findings and Discussion

This section provides a combination of the results of the qualitative analysis of the three events and their corresponding discussion, organized by topic.

4.1. Game Jams and the Development of 21st-Century Skills

Due to the constructivist nature of the learning that takes place during game jams, it is not possible to use tangible evidence to prove the change occurred in participant skills. Self-evaluation does not always prove that learning took place [10], as situations in which participants inform picking up a new skill may not be clear. The more abstract experiences are, the more difficult it becomes to evaluate the achievements. Nevertheless, learning experiences are relevant, as they may give impulse during future learning and stimulate self-efficacy [1,3].

4.1.1. Learning Skills for the 21st Century

Taking into account the skills and knowledge of each individual is an increasingly important approach in educational contexts to contribute to achieving personalized learning, despite this approach being not widely accepted [54]. Nowadays, adolescents and children are becoming experienced and frequent users of technology and game-development software [55]. Before the game jams, a pre-event survey was conducted in order to detect and classify the skills of the jammers. Participants highlighted their most developed skill and previous experience relevant to video-game development, which enabled creating the teams in a way that ensured a diverse distribution of skills, working social dynamics, and agreeable sharing of tasks [3] before the event. Once the teams were created, participants

received information about the game jam theme and instructions (e.g., existing games could be combined and modified to create new video games). Participants worked for 6 h on video-game development with the help of game designers, teachers, and the researchers as tutors.

The researchers identified five distinctive phases of activities performed by the participants: (1) brainstorming, (2) video-game conceptualization and description, (3) prototype creation, (4) testing, and (5) pitch. These stages are common to all game jams and video-game development in industrial contexts. Through these phases, teams turned their ideas into tangible and playable artifacts with the help of paper models and software. Participants had access to computers and devices to search for information and instructions regarding prototype creation. As Van Mechelen et al. [56] mention, participation in these phases not only enhances the development of 4C skills among attendees but also increases their self-confidence. Table 2 summarizes these phases and their goals and activities in connection to the 4C skills they enhance.

Table 2. Summary of the phases and activities linked to the development of 4C skills.

Phase	Goal	Activities	Skills
Brainstorming	Develop ideas Express ideas so that the rest of the team can understand them	Ideation Communicate ideas verbally Visually materialize ideas	Creativity Communication
Video-game conceptualization and description	Documentation Decision making Task sharing	Prototyping Clustering Design challenges Identification of mechanics and connection to the proposed theme	Collaboration Critical thinking
Prototype creation	Unify all the bits created by the team (code, animations, etc.)	Prototyping	Collaboration Critical thinking
Testing	Express encountered bugs Propose solutions	Post-testing communication Reflecting on the testing phase Play	Communication Critical thinking
Pitch	Presentation of the final product (game created) to the audience	Post-jam communication Acting (as professionals) during pitch	Communication Creativity

4.1.2. Critical Thinking

The brainstorming phase requires connecting the game to the theme according to the possibilities and skills of each group. During this phase, jammers were encouraged to generate ideas in relation to the theme provided by the event organizers, and they took their time to discuss the topics in groups. Brainstorming enabled participants to discover how their peers think and understand ideas from different perspectives. At this stage, creativity is necessary to generate ideas, but being systematic is crucial to organize them, prioritize them, and choose the best ones; being critical enables the individual to discard all the unsuitable ones.

Systematic and critical thinking processes also arose during the video game testing phase. During this phase, group members need to review their design proposal, strategically adjust what does not work (bugs and glitches), and add necessary features (music and characters). The multidisciplinary environment contributes to the jammers' compromise toward task completion, while the diversity of participants stimulates new ways of thinking regarding certain topics, the management of programming activities and the video-game-development timeline, and bug handling, which are components of critical thinking.

Through the post-event survey, participants reported having positive experiences during each phase [1] and, apart from learning new concepts, they mentioned that the game jam motivated them to develop skills, such as critical thinking: “testing allowed me to try different ways to test the game and avoid bugs” (participant, Event 2), as reported in Aurava et al. [10].

According to Bezanilla et al. [57], learning how to think critically can be an individual experience, and six categories of skills support the general development of critical thinking skills. These include (1) analyzing/organizing, (2) reasoning/arguing, (3) questioning/asking oneself, (4) evaluating, (5) taking a position/taking decisions, and (6) acting/compromising. Almerich et al. [58] mention that technology use and the subsequently developed skills effectively favor the development of critical thinking. Co-designing is a collective and transformative action aimed at generating new forms of activity with meaningful objectives to participants [59] and leads to thinking critically, for instance, when testing video games to find bugs. Lastly, Papert [60] states that, from a constructivist perspective, game design promotes critical thinking through the design of physical objects.

4.1.3. Creativity Skills

The first step while creating a video game is to develop a rough concept of what kind of game will be created. The output of this initiation process is the game concept and a simple game description, which will later progress to a prototype. Prototypes act as the foundations and structure of the game, which will be refined as players test it. The game jam theme is normally the starting point of the design process and gives rise to discovering the creative ideas of each participant. During the game conceptualization and description phase, the groups generated and shared ideas and explored different manners to incorporate the theme. Once they identified possible solutions, jammers started producing the prototypes.

The video games that participants created during the events were ambitious and imaginative. Some games had mechanics based on Snakes & Ladders, Snake, Frogger, Monopoly, Candy Crush, or UNO. A majority of the games were created with GameMaker Studio, Adobe Photoshop, and Scratch (Event 1). Nevertheless, the use of software does not necessarily shorten the development process, especially when the designer is not proficient in the program. Therefore, one of the workgroups developed some concepts and dynamics through paper models (Figure 1).

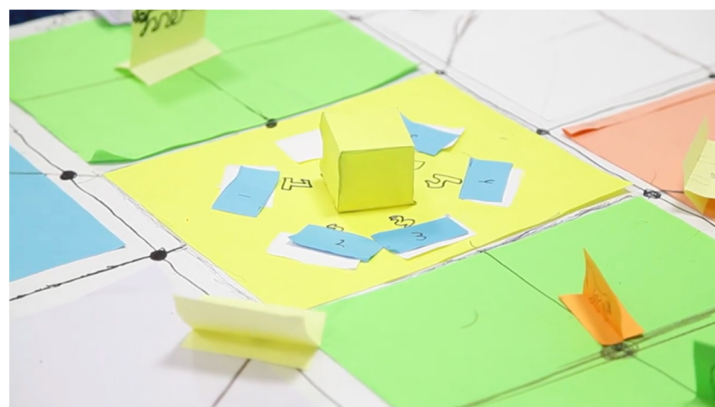


Figure 1. Playable prototype developed as a paper model.

Creativity and imagination enabled bringing ideas to life in tangible prototypes from a selection of materials. Jammers iterated their design ideas through creativity and communication with their team and eliminated design inconsistencies. The tutors aimed at awakening imagination by providing materials, such as dice or paper, and advice. Regarding creativity skills, jammers mentioned the following: “it was useful to follow the advice of tutors to use our life experiences to build our game” (participant, Event 2). To motivate

creativity during the brainstorming, the teams discussed several sources of inspiration (video games, experiences, history, movies, biology, books, board games, art, or music), as well as in which way the ideas would be integrated. Participants also reported that the good results in the prototyping phase were a consequence of the co-design process, which allowed their original idea to improve with the input of the rest of the participants, as is consistent with the findings of Conneely et al. [61]. Working in a group on a team challenge offers productivity and creativity, even more than one would expect from an individual working alone [62].

Another phase that boosted creativity was the pitch, as teams had to present their prototypes to the audience at the end of the event. This phase created an opportunity for individual and collective creativity to flourish in each team. Pitching a video game not only requires knowing how to speak in public but also how to capture the audience. To this end, some participants included acting during their presentation.

Participants acknowledged that it was clever to consider the skills and knowledge of each of the participants to create the teams before the event. Thus, this allows participants to experience productive learning, which is crucial for the development of creativity [61]. As Vyas et al. [63] observed, they reflect on how to solve problems and find solutions through a collaborative process in which they creatively explore each challenge. Their reflection on this matter was quite precise, as skills should not be exclusively defined by thematic knowledge, but for their contribution to an effort toward problem-solving [64], as required when creating video games during game jams.

4.1.4. Communication Skills

The social aspect of game jams has a positive effect on teamwork and internal group dynamics. During the different phases, participants communicated with each other regarding their ideas and design problems, and this enabled them to discover shared interests. Google Drive was a valuable communication tool to share notes, sketches, and links while at work, and this ensured that all team members were up to date during the design process. Jammers played the role of designers, programmers, etc., and carried out corresponding actions that allowed them to define their communication styles and use specific language and terminology. In this context, it is crucial to contribute to effective communication within the group, especially when communicating creative ideas: “the event helped me learn to communicate my ideas, as I had to explain what I wanted to do with the character in a very clear and brief manner” (participant, Event 2).

The presence of game designers acting as tutors also helped the teams perfect their dialogue when explaining their activities, during the brainstorming, or while communicating problems regarding prototype creation. This helped the groups perfect their language when interacting with game designers, who encouraged them with positive comments. Thanks to it, jammers gained confidence in their creative skills, both individually and as a group, and that motivated them to continue working and improving their design solutions.

Critical thinking, communication, and collaboration skills are linked. Participants expressed this connection as “clear and effective communication” or “cooperating to carry out the agreed tasks”, reflecting two of the skills mentioned by Blomqvist and Levy [65]: communication and compromise. Collaborating in groups during a jam can develop critical-thinking skills as the process advances thanks to the discussion, clarifying of ideas, and the evaluation of the ideas set forth by others [66]. Nevertheless, communication goes beyond verbal skills. Expressing concepts can be difficult when only verbal communication is employed, and, as small groups experience stressful periods, the level of explicit communication may decrease [61]. Several communication channels allow participants to explore how to express ideas [57] and expand communication methods during jams, for instance, by including physical materials; and enable participants to communicate by using whatever channels they feel most comfortable with [9].

4.1.5. Collaboration Skills

Collaboration is mainly based on receiving support, having clear goals and tasks, interaction processes, and individual participation [67]. Team collaboration is crucial for task completion [10,59,60]; otherwise, group creativity could be negatively affected [68]. Collaboration is paramount during the first phases of the development process to improve trust and empathy within the group. Teamwork management was an essential step, as evidenced by good organization, especially during the last phases of the design process and the materialization of ideas into prototypes and the final design proposal. During the prototype creation phase, group members have assigned tasks, and this shared responsibility has the potential to nurture the sense of collaboration thanks to its experiential and social nature. On the contrary, lack of project goals' definition is a barrier to collaboration [67].

These spaces promote collaboration and must be comfortable, well-illuminated, and provide a variety of services, such as Internet access. Some techniques (brainstorming, brain-writing, and mind maps) and tools (StoryCubes, Imagine, and The Design Deck) are useful to motivate participants to collaborate. These contribute to the generation of ideas and help jammers get to know their fellows, with whom they work toward finding solutions to the same challenge. The use of these accessories also allows participants to break psychological barriers and ease conversations that could otherwise hinder collaboration. Google Drive tools were used to facilitate the whole collaborative process, mainly during the brainstorming phase.

Regarding collaboration skills, participants mentioned that their knowledge about video-game creation increased, as reported in Aurava et al. [10]. Some of their responses illustrate a very concrete type of learning: "I did not have a lot of experience with Scratch to create jumping mechanics, but during the jam, I used a tutorial to improve the frog's jump; one of my teammates helped me, and I learned how to create the jump much faster" (participant, Event 1). On the other hand, other comments were not so specific: "we carried out teamwork during the whole jam. I had never worked in this manner, dividing tasks to merge the results later; this is useful to develop ideas jointly" (participant, Event 3). In the post-event surveys, participants also mentioned collaboratively deciding to combine or modify mechanics from existing games (frequent in the video game development industry) [12].

4.1.6. Individual and Collective Challenges

Several shared individual and teamwork challenges present in the three events were identified. These challenges require attention, as they may affect the development of a game jam and the individual and collective learning processes. Table 3 displays the identified challenges in relation to the 4C skills affected and how the experience is materialized.

As in other cases found in the literature [9,10], language barriers may constitute a challenge, and despite all the participants being proficient in Spanish, dialectal varieties may have hindered communication. A common language must be used and developed to allow for effective communication [67]. Otherwise, collaboration would be affected [69]. Jammers described two determining factors at the individual level that could affect participation during game jams: personality and competition. Sociable participants report feeling more committed than those that may experience language barriers, are introverted, and are sensitive about competition.

The authors believed that using the pre-event survey based on the work by Zook and Riedl [50] and other recommendations [3,54] to detect and classify the skills of the jammers would be greatly valuable to create better teams before the start of the event. However, a more detailed screening of participant skills would be necessary. Not all jammers were equally proficient in software usage, and they reported that a more thorough selection strategy regarding participant skills could have been very beneficial for the teams. A possible solution would be to use a pre-event survey with open-ended questions that truly delve into participant skills. These questions should not only intend to assess the type of

software participants use but also their level of proficiency. Using collaborative software would have also contributed to overcoming challenges.

Table 3. Individual and teamwork challenges.

Challenge Type	Determining Factor	4C Skills Affected	Experience
Individual	Language barriers	Collaboration Communication	We use different words to refer to the same concept (we are from different cities in Mexico)
Individual	Personality	Creativity Collaboration	Working in teams is not easy
Individual	Competition	Creativity Collaboration	I prefer non-competitive activities
Teamwork	Skills	Creativity Collaboration Communication	Detailing the skills and knowledge of participants would enable creating groups with a diversity of talents
Teamwork	Software	Creativity Collaboration Critical thinking	The event should count with collaborative work software
Teamwork	Duration	Creativity Collaboration Critical thinking	The duration of the jam affects the type of development process and the methodology, but it does not limit it. I could not believe that in 6 h we would be able to develop games

Finally, time constraints can also constitute a challenge, as Torres-Toukoumidis et al. [11] highlight. Despite the fact that participants did not complain about the duration of the game jam, to improve the experience, the jam should be carefully planned, with a focus on practical activities and a process that fosters positive behavior [57].

4.2. Game Jam Format for the Development of 21st-Century Skills

There is not a unique format or specific blueprint for game jam organization, and some are online events. When talking about game jams, what comes to mind are on-site events, such as Global Game Jam, which lasts 48 h, and this format is deemed as the best option and is often reproduced (see Reference [11]). It is noteworthy that, in the literature about game jams and 21st-century skills, the reflections about the common elements in events devoted to promoting these skills are generally scarce and too general and do not focus on the skills or previous experience of jammers with development software. Through this work, it was possible to identify the following key organizational elements: (1) Detect the skills of jammers and classify them through a pre-event survey. This contributes not only to effectively organizing the working groups but also identifying the software that the organization should install on the computers and provide to the participants [9]. In the video game industry, companies count on staff with a diversity of skills and knowledge. When tasks are distributed thoughtlessly, male participants tend to assume coding tasks, while females tend to choose tasks related to arts and storytelling [10,70]. Video-game-development software is diverse and complex, and, despite a great number of tutorials is available, these platforms can be time-consuming for first-time users. Therefore, it is very useful to understand the skills of the participants beforehand. In some cases, open-access software is recommended [10], but these development tools are not always widely extended in the market, and participants may not have experience with them. After studying the experiences described in other research works [9–12,48,49], the authors decided to use pre-event surveys to detect and classify the skills of jammers. It was not deemed suitable to conduct workshops so that participants would learn to use the software before the event, as reported in other studies [10,49], as this implies an additional effort from the organization and does not ensure that a basic knowledge of the software would be attained. Detecting and classifying the skills before the event enabled jammers to focus on content creation instead of on learning the software, which is beneficial to reduce the anxiety that participants might experience during the event [3]. (2) These events should count with tutors familiarized with video-game development. As in game-based pedagogies, it is

necessary to count with pedagogical, technological, collaborative, and creative competencies [35] to participate as a tutor in a game jam devoted to developing the 4C skills. In this way, they are better prepared to help participants improve their skills and support them with the necessary resources, apart from making them feel that they are in a safe and free space [71]. In activities that involve creative design, participants need to feel supported to experiment, fail, and try again as many times as necessary [1]. Participants positively value this additional help, and, thus, the organization also invited game designers. (3) The duration of the event does not necessarily have to be 48 h. Concerning this topic, previous experiences [9,10,48,49] and participant surveys revealed that 48 h are not strictly necessary in these events and that, instead of being helpful, this can hinder problem-based learning [12]. If game jams have a duration of fewer than 6 h, as some authors suggest [48,49], the authors of this work consider that a quality collaborative and creative process cannot take place, as it is necessary for teams to transit through the first four phases of game development so that they can transform the ideas into tangible and playable products. Participants in these events highlighted that the short duration was experienced as part of the challenge and that, while it affects the type of prototype development, it does not limit it, and, as Meriläinen et al. [12] mention, time constraints improve creative thinking. (4) Game jams should be organized as additional activities to a course. Aurava et al. [10] affirm that creating a game jam within a formal course could be a difficult task, as it would depend on the characteristics of each course. In a school environment, the use of game jams with teachers lacking the necessary competencies could be compromised and could lead to the positive learning outcomes being lost due to the mandatory nature of formal learning. For instance, in public schools in Mexico, each subject is taught by a different teacher. Therefore, if a game jam was to be organized for each subject, students would lose motivation because what initially should be a challenge becomes a repetitive activity [9]. Additionally, participation would not be voluntary, and this could negatively affect motivation [10]. The idea of introducing game jams in formal school contexts should be taken into account as a new pedagogical approach destined to promote new skills and practices; however, it should be seen as an addition, instead of a core component.

4.3. Necessary Resources to Organize Game Jams

Time is an essential resource to organize such an event. It is also crucial to determine a specific schedule [11]. Therefore, it is important to find specific times in which participants can dedicate a minimum of 6 h to the event. Another thing to consider is the venue where the event will take place. The space should favor working and collaboration. The venue must count with electricity, Internet connection, and tables where the jammers can work. Additionally, the space should include an eating area with food and quiet resting areas. Game jams also require a diversity of materials. Depending on the event organized, the resources provided to the jammers must be non-digital, digital, or of both types [49,72]. Providing a variety of materials, such as pencils, sticky notes, colored paper, dice, cards, cardboard, scissors, and glue, can be useful to develop the first game concept or for the brainstorming phase. For those groups that choose to work on software, it is advisable to provide them with laptops and working tables, with installed software of use for the event, including Scratch, GameMaker Studio, Adobe Photoshop, or Google Drive tools to incentivize collaborative work, and Unity to synchronize projects. In virtual events, tools such as Discord are very useful to facilitate collaborative work and video-game presentation. In general, in on-site jams, participants tend to bring their own laptop, but the authors recommend providing extra devices in case any of the laptops of the jammers fail, or in case they do not own one. Even if participants choose to develop the games on paper, they should have access to computers and the Internet to check information on other game mechanics, use of objects and artifacts in other games, or study in depth the theme of the event. It is also recommended to count with a printer to print out figures, for example.

Game jams should count on tutors and voluntary workers to help during the development of the event. Voluntary workers may help in tasks such as (1) idea-generation

techniques, which include selecting the optimal technique by considering the context and the type of participants; (2) extra materials, which include providing the material participants require, such as boards, markers, modeling clay, glue, etc.; or (3) technical problems, such as software installation, solving Internet connection problems, battery, and file storage. On the other hand, tutors shall create a favorable atmosphere for idea generation, as well as choosing the optimal technique. Baillie [73] highlights that this will help participants feel engaged and part of the larger design jam experience. Tutors must also be neutral and not display any preferences or prejudices to foster a truly creative session. Wrobel et al. [74] remark that they should show both impartiality and equidistance. This will help teams collaborate and communicate openly, which can be achieved through creative facilitation. Game jams can be understood as a creative facilitation tool, linked to activities such as prototype creation, with the help of a variety of materials and idea generation. Thus, it is essential that tutors also help with the material provision and technical problems.

4.4. Limitations of the Study

The main limitation of the present work refers to the multiple roles of the authors and researchers, as they were responsible for organizing the events under study. Despite granting the authors essential insight into both the challenges and possibilities while organizing game jams, and allowing them to epistemically anchor the knowledge, this dual role may have affected data collection and interpretation. Additionally, the students that participated in the game jams were volunteers, and, therefore, they displayed a positive predisposition and attitude prior to the events. Though this may have affected the results, it was also deemed to be very helpful, as their feedback positively contributed to the research process.

5. Conclusions

Game jams are collaborative experiences that facilitate learning as part of a team. As the team advances in the process, the jammers get involved in the different development phases, through which they develop 4C skills, while they work in collaboration to generate a creative solution based on team communication and decision-making.

This study suggests that participating in game jams activates creativity and critical thinking in participants, and they contribute to the development of communication and team collaboration skills. Additionally, this work delves into how game jam activities could be improved to adapt to 4C development, for example, by including jammers with a variety of skills, as these affect their ability to create and collaborate with the rest of the participants. The findings of this work suggest that participants found the creative and collaborative process to be very useful to generate solutions. However, the results are mainly based on the experience gained by the authors.

The analysis of the previous literature focused on game jams was crucial to plan and organize the events studied and helped decide on the duration and the involvement of tutors. Tutors should have knowledge about game development or the theme, and they should have pedagogical, technological, collaborative, and creative competencies.

Participants indicated that a more detailed skill selection in jammers could have benefited the teams. Thus, the authors suggest studying in-depth the different ways in which the skills and knowledge of jammers can be identified in order to create more effective and diverse working groups with different talents and skills.

Finally, new studies should examine the scope and development of the 4C skills, as game jams offer great opportunities through their various activities. Another area of future research includes the exploration of the experiences of game designers and teachers, in addition to that of the students, and how these actors navigate issues such as introducing concepts, methodologies, etc., into game jams.

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