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The Process Behind the Creation of a Framework for Participatory Game Design to Support Bilingual Education of Deaf Children

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Abstract The deaf community needs computational tools that support Bilingual Education, which promotes the teaching of Libras (Brazilian Sign Language) as the first language and Portuguese as the second language from early childhood. Within this approach, the main objectives are to strengthen deaf identity and to foster bilingual competence. Although educational games can contribute to this process, many existing titles lack accessibility and fail to reflect the lived experiences of deaf children or the core principles of Bilingual Education. This issue arises because many games are created by developers unfamiliar with the needs of deaf children, underscoring the need for a tool to bridge this gap and include both teachers and deaf children in the game design process. To address this, we present the process behind the creation of the CAJEDUS-DP framework, aimed at facilitating the participatory specification of games to support Bilingual Education for deaf children. The framework promotes equal participation among game developers, deaf children, and their teachers, coordinated by a game producer. CAJEDUS-DP was designed using a methodology based on action research and participatory design during workshops with deaf children and teachers from the National Institute of Education for the Deaf (INES) and virtual meetings with indie game developers. This process revealed the potential for personal development of the participants, especially their creativity, self-confidence, and empathy. Moreover, it led to a game prototype aligned with the realities of deaf children and the objectives of Bilingual Education, named "Casa dos Bichos" (Animal Home). Last but not least, the CAJEDUS-DP framework provides a set of guidelines to assist in mediating the diverse partners involved in game design.

Keywords: Deaf children, Bilingual education for the deaf, Game design, Participatory design, Child-computer interaction, Action research

1 Introduction

Effectively including deaf children has been one of the main challenges faced by Brazilian Basic Education. Although the Brazilian Ministry of Education ensures the inclusion of deaf individuals in Basic Education [MEC, 2017], barriers still exist to achieving true inclusion in schools, both regular education institutions and those specialized for deaf students.

Among the various challenges faced by deaf children in Basic Education, we find the lack of qualified professionals and adequate resources that consider their needs, which leads to academic failure in terms of quality education for these students [Camargo *et al*., 2022]. Effective inclusion of deaf individuals requires schools to facilitate communication through Libras, to value school content, and to recognize the relationship between content and deaf culture [Felipe, 2006], which, in practice, does not occur to the necessary extent.

An additional challenge was imposed to children worldwide when the period of social isolation due to the COVID-19 pandemic resulted in the closure of educational institutions and the beginning of remote lessons. In the specific context of deaf children, research reports issues ranging from a lack of accessibility in virtual learning environments [Pimenta and Silva, 2021] to the difficulty students faced in simultaneously following the online content, the Libras interpreter signing, and the teacher lecturing while taking notes [Palavissini, 2022].

Even in these challenging scenarios, Information and Communication Technology (ICT) has sought ways to create and enhance approaches and technologies to support teaching and learning processes. Among ICTs, digital games have been used in various contexts, for example, as teaching aids for children [Martins *et al*., 2019] and children with disabities [Stone *et al*., 2019], since they are capable of increasing moti-

vation [Burguillo, 2010], and stimulating motor and cognitive skills [Oliveira *et al*., 2014].

Despite the potential for inclusion, many educational games for deaf children present barriers such as a lack of accessibility and disregard for Bilingual Education and the lived experiences of these children [Galvão, 2020]. This finding becomes even more evident during the literature review conducted by Batista *et al*. [2023], highlighting the scarce representation of games for the deaf and the lack of accessibility and usability features in most of these products. Thus, two major problems emerge in the development of games for deaf children: I) The absence of educators in the game development process, which leads to the non-fulfillment or to the inappropriation of the learning objectives for the target audience; and II) The disregard for the lived experiences of deaf children, which results in the development of games that do not bring about significant changes for their context.

Based on these identified problems, it is clear that involving deaf children and Bilingual Education teachers in the game design process is essential. One effective way to include them is through Participatory Game Design (PGD), where users have an active role and decision-making power in the game design, making it a suitable method for stimulating reflection on culture, morals, and values [Allsop, 2012], as well as for developing skills such as creativity and critical thinking [Kalmpourtzis, 2018].

Considering all the previous aspects, this paper presents the design and the development of a framework for the participatory design of games to support the Bilingual Education of deaf children, entitled CAJEDUS-DP (Creation of Educational Games for Deaf Children - Participatory Design). CAJEDUS-DP was intended for multidisciplinary game development teams composed of game developers, teachers, and deaf children; however, its artifacts can also be utilized as a reference by teams consisting solely of developers or other profiles, such as researchers.

The rest of this paper is organized as follows: Section 2 introduces the theoretical basis of this study; Section 3 describes the related works; Section 4 presents the methodology; Section 5 describes the PGD process performed in the study; Section 6 highlights the reached results; and Section 7 presents the final remarks of this paper.

2 Theoretical Basis

Digital games are complex and require a multidisciplinary approach to build them, demanding hard skills such as programming and design and soft skills such as creativity and problem solving [Kalmpourtzis *et al*., 2016]. Specifically, according to Dodero and Melonio [2016], game design involves three primary tasks: I) Analyzing objectives and forming a high-level concept; II) Conceptualizing; and III) Game prototyping. The whole process must be refined iteratively throughout development, improving key aspects such as mechanics, story, and interface through collaboration [Galvão, 2024].

To assist in the specification and structuring of a game concept, game designers use an artifact called Game Design Document (GDD). The GDD serves as a guide and as a means of communication for the entire development team and for distribution partners, defining the scope of the game and allowing readers to understand the basics of the final product [Rogers, 2012]. Creating and keeping the GDD updated is one of the primary responsibilities of a game development team [Schuytema, 2008].

In the context of educational games, game design plays a crucial role. Such games aim to increase students' chances of learning concepts, content, and skills while having fun [Clua and Bittencourt, 2004]. Building on this idea, Schell [2019] emphasizes that effective educational games must go beyond the mere integration of didactic content. They should also incorporate core game elements — mechanics, dynamics, and aesthetics — to fully engage students and promote meaningful learning experiences. In this regard, Perry *et al*. [2007] stress that achieving this balance requires interdisciplinary teams that bring together technical expertise and pedagogical insight.

Furthermore, when children are involved in the game design process, the potential to create technologies that resonate with their context while fostering their skills increases. This involvement can occur through Participatory Design (PD), in which users actively shape, test and design technologies [Fails *et al*., 2013].

Although the involvement of children in the design process adds complexity, due to their difficulty in understanding abstract concepts inherent to the design, children often exhibit greater cognitive flexibility than adults, contributing with more creative ideas [Fails *et al*., 2013]. Druin [2002] outlined four potential roles for children in the design process. A fifth role was added later by Iversen *et al*. [2017]. The latest version is presented in Figure 1.

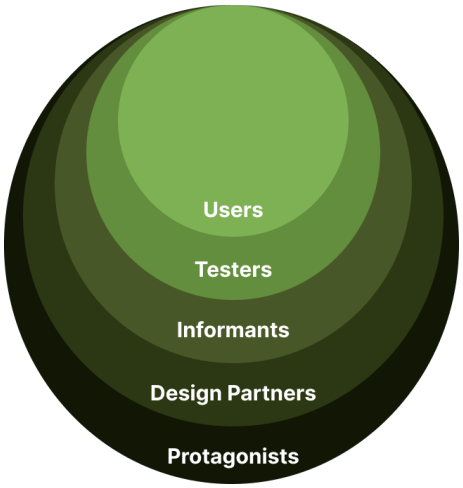

Figure 1. Degree of children's involvement in technology design.

As illustrated in Figure 1, the smaller the circle, the lower the child's level of participation in the technology design process. Each role played by children is presented below:

- Children as users [Druin, 2002]: Children interact with technology only after it is finished and marketed;
- Children as testers [Druin, 2002]: Children test technologies before they are released for general use;
- Children as informants [Druin, 2002]: Children contribute more actively, offering feedback and participating in certain design activities;

- Children as design partners [Druin, 2002]: Children become active participants and equal collaborators throughout the design process;
- Children as protagonists [Iversen *et al*., 2017]: Children lead the design process, reflecting on the technology's role in their lives, focusing on both the process and the final product.

In addition to children's roles in PD, adults also play an essential role in the process, taking on positions such as advisors, facilitators of the design process and co-designers [Korte, 2017]. However, this partnership between children and adults only works if adults respect the ideas and contributions of the children [Fails *et al*., 2013].

Despite the fact that many educational games have been designed for children, few include them in the design process beyond limited roles such as users or testers. By integrating game design with PD, a new method called PGD emerged, in which children can take on the most significant roles. PGD allows children to express their identities, enhance their game design and problem-solving skills, build confidence in their own contributions, and increase their agency in game development [Voulgari *et al*., 2020]. Although PGD offers numerous benefits, it also presents challenges, such as children's lack of technical vocabulary, limited understanding of game design, and their ongoing developing of cognitive and communication skills [Voulgari *et al*., 2020].

3 Related Works

Galvão [2024] presents the conduction of two literature reviews, a Backward Snowballing and a Systematic Mapping Study (SMS), to map studies involving PD with children. Out of the 58 papers identified in both reviews, only 12 reported the active involvement of children in the design process, with 8 of them involving deaf children [Galvão, 2024]. The limited number of such studies may have been influenced by the challenges of researching children with disabilities, such as the need for adapted activities, more intensive supervision by qualified adults, and the cognitive and linguistic delays experienced by some of these children. This result confirms the need for more studies that involve children with disabilities in the design process of technologies. Additionally, there are few studies where adults collaborate with children as equals [Galvão, 2024]. This may have been due to the complexity of mediating such diverse and intricated profiles to create a design that benefits all stakeholders.

Only two methodologies were found in the literature that incorporate both the teacher and the deaf student in the design process: YoungDeafDesign [Korte, 2017] and SPIDeKids [Zabot, 2019]. The YoungDeafDesign framework addresses children's youth, language proficiency, individual deafness, and cultural deafness, enabling adults and designers to create technologies with and for deaf children [Korte, 2017]. It was developed based on the Design Science Research methodology and applied within a design team that included deaf children aged 3 to 5, some of their parents, a sign language interpreter, and the researcher herself. The framework provides recommendations for design methods with deaf children and outlines the goals of each method, as well as considerations to be taken into account before and after design sessions. Its focus is on the overall act of designing and is not specific to game design.

The SPIDeKids methodology, in turn, is an adaptation of the SPIDe (Semio-Participatory Interaction Design) process, an interaction design approach that combines PD techniques with Semiotic Engineering. Zabot [2019] present an experience report on the design of educational games with the participation of deaf children, aged 9 to 14. Responding to an existing school demand, the children developed game prototypes with support from their teacher and two Libras interpreters. After the children identified the prototypes they preferred, the developers built two games based on these designs. The games were then evaluated by the children, who mostly found them enjoyable and engaging [Zabot, 2019].

Although both studies involve deaf children in the design process, neither focuses on multidisciplinary game development teams in which all participants hold equal decision-making power, as proposed in this study. Moreover, Korte *et al*. [2017] investigates a context different from the Brazilian one and from Libras, which has its own particularities, since the study was conducted in Australia. In turn, Zabot [2019] does not aim to present Libras in context, that is, not merely as a set of isolated signs, but as a complete language with its own grammar and structure, which is a central goal of Bilingual Education.

4 Methodology

For this research, an interpretative epistemological paradigm was adopted, with an empirical and qualitative approach. The study was developed based on Action Research methodology, a type of social and empirical investigation aimed at promoting an action or solving a collective problem. In this approach, both the researchers and the participants are involved in a collaborative or participatory manner [Thiollent, 2011].

Data for this study were collected through: I) Characterization questionnaires; II) Video recordings of the meetings; III) Photos of the children's work; IV) Video recordings of the workshops; V) Participant observation of classes at INES; VI) An ethnographic journal; and VII) Semi-structured interviews. Both discourse and content analysis were applied to the responses and research records [Pimentel and Fuks, 2011; Filippo *et al*., 2011].

In addition to Action Research, concepts from Participatory Design (PD) were applied — a design approach that involves interactive experimentation, modeling, testing, practical design, and "learning by doing" [Fails *et al*., 2013]. PD aligns well with Action Research, as it "requires a relational structure between researchers and individuals in the investigated situation that is participatory in nature" [Thiollent, 2011, p. 22]. In this study, all participants acted as design partners, meaning they shared equal decision-making power and collaborated throughout the entire design process.

As with all research involving Action Research, the aim of the process was to understand and mitigate the following identified issues faced by each of the partner profiles involved in the game design process:

- **Game Developers:** Little or no contact with the deaf community and bilingual education, resulting in games that are not suitable for the teaching and learning context of deaf children.
- **Bilingual Education Teachers:** A lack of accessible resources for deaf children, particularly educational games, to support the teaching and learning processes in bilingual education;
- **Deaf Children:** Delays in learning due to late acquisition of Libras and Portuguese in its written form, aggravated by the social isolation period during COVID-19, as well as by the limited availability of educational games that consider their context and experiences.

In this research, deaf children assumed the primary role in content generation, specifically driving the development of the game's narrative, character design, core game mechanics, and paper-based prototyping. Concurrently, Bilingual Education teachers were responsible for pedagogical guidance, providing the specific educational content to be integrated in the game, acting as expert consultants and workshop facilitators, and offering targeted feedback to all research partners. Finally, the game developers were tasked with the technical implementation and design refinement, which included offering peer feedback, drafting the GDD, translating and complementing the children's paper prototypes into digital design.

Figure 2 presents the structure adopted by the research, organized according to the five cyclical steps of Action Research [Susman and Evered, 1978], which are: I) "Diagnose", in which the problem(s) is/are identified or defined; II) "Plan Action", in which alternative action plans are considered to address the problem(s); III) "Intervene", in which a plan of action is selected to take action; IV) "Validate", in which the consequences of the actions taken in the previous steps are studied; and V) "Reflect", in which the main findings are identified. In the following subsections (4.1, 4.2, and 4.3), the three cycles of AR depicted in Figure 2 and their steps will be detailed.

4.1 First cycle: Comprehension

To understand the state of the art and to collect evidence of the research problem, two Literature Reviews (LRs) were developed during the "Diagnose" step. These LRs consisted of a Backward Snowballing approach on Participatory Design methods with children, conducted in January 2021, and a Systematic Mapping Study (SMS) on game design methods with children, conducted in November 2021. The results obtained from the SMS were subsequently published [Galvão *et al*., 2023].

In parallel with the LRs, procedures were initiated in March 2021 for the approval of the research project by the Research Ethics Committees of the involved institutions, the Federal University of Paraná (UFPR) and INES. The project, entitled "Design for the Bilingual Education of the Deaf", aimed to design, develop, and evaluate technological artifacts to support the Bilingual Education of deaf students enrolled in Elementary School. The research project was approved in December 2021 by the Ethics Committees of UFPR and INES (Certificate of Presentation of Ethical Review: 52937321.0.0000.0102).

After the aforementioned steps, the "Plan Action" step started in January 2022. During this step, potential methods, materials, and activities that could be implemented in the game design workshops were selected based on studies previously identified in the LRs, and an initial plan was developed. In addition, the criteria for examining the participation of deaf children during the game design workshops were established, based on Allsop [2012]: I) The acquisition of the curricular content from the teachers who would participate in the research (Mathematics, Science, Libras, and Portuguese); and II) The development of the four skills present in the game design process, namely collaboration, critical thinking, communication, and creativity. Finally, to prepare adult participants for the research, two documents were created covering the main topics needed as a foundation for participating in the PGD process.

During the "Intervene" step, training sessions were conducted and the adult participant profiles were characterized. All participants attended initial online meetings about the project, and those who expressed interest were invited to take part in the training. Interested participants completed a characterization questionnaire.

The developers' questionnaire included questions about their educational background, years of experience in the games field, and prior experience with educational games, accessibility, and Libras. The teachers' questionnaire included questions about their training, years of experience in deaf education, the main challenges they face in the classroom, and whether they used technologies and games during their lessons.

After completing the characterization questionnaire, participants received the training materials. Each participant group then joined online meetings to discuss the content and share related experiences. This step was essential for aligning the knowledge of the adult participants, enabling teachers to become more familiar with game design and developers to deepen their understanding of Bilingual Education for deaf students. In total, four meetings were held during the "Intervene" step, two with each participant profile.

After the training, the "Evaluate" step was carried out, during which the teachers provided feedback for the initial planning of the game design workshops presented by the main author. In this meeting, the teachers expressed their concern about the lack of conceptual foundation among deaf children for participating in certain activities, particularly their difficulty in understanding abstract concepts. As a result, a progressive planning approach (which may be seen as an internal AR process) was adopted, where activities were proposed after each workshop according to children's progress, including what the teachers were already doing in their classes.

Finally, during the "Reflect" step, the teacher's feedback was considered to determine what adaptations would be necessary for teaching game design to deaf children. Additionally, reflections were made on the needs of the adult participants, including what type of information should be available in the upcoming meetings.

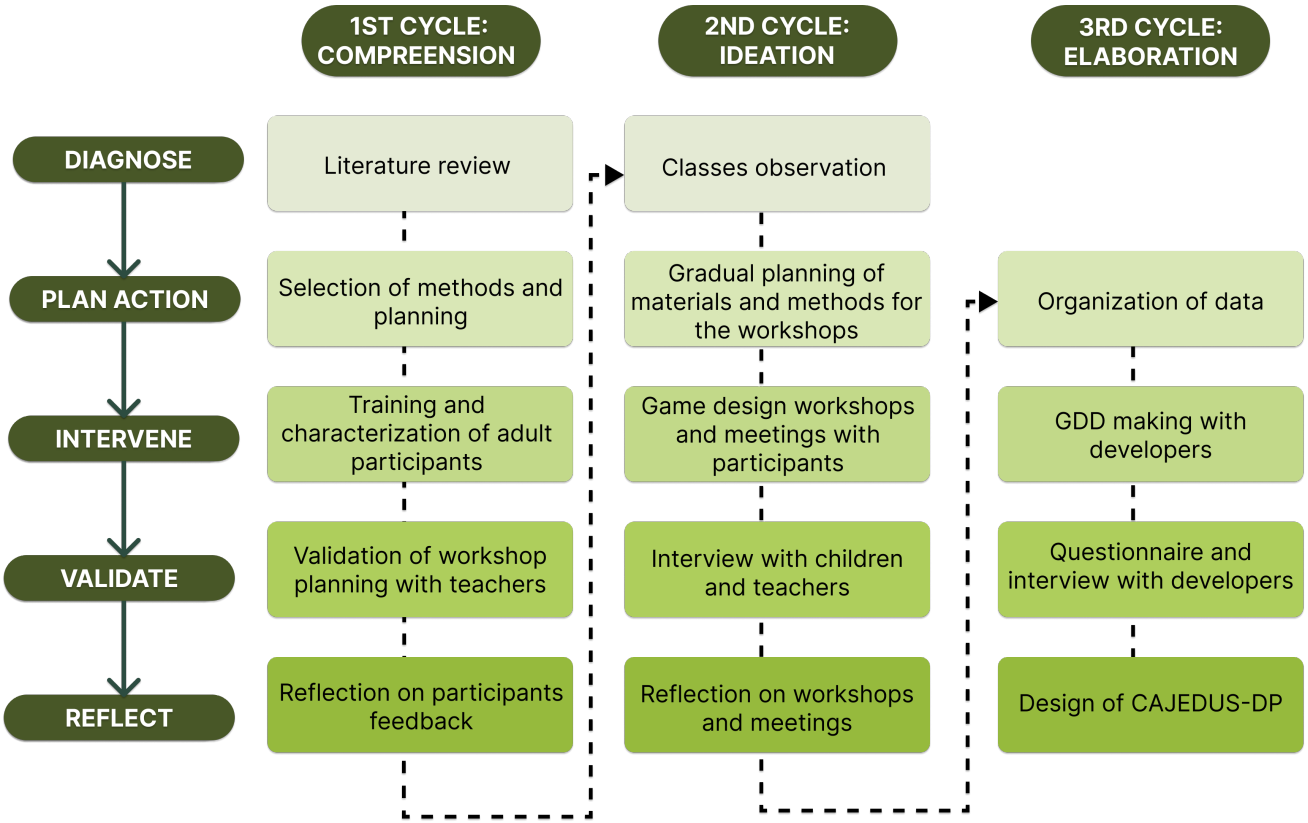

Figure 2. Steps of the Action Research carried out in this study.

4.2 Second cycle: Ideation

The "Diagnose" step of the 2nd cycle of AR (Figure 2) involved observation of two 2nd-grade classes at INES. While the LRs and teachers' feedback offered a general understanding of the problems to be addressed, it was necessary to conduct an initial on-site assessment of the situation, the priority issues, and the potential actions [Thiollent, 2011]. The observation was conducted with the support of the teachers, who translated the children's Libras communication for the main author to understand the context of the conversations. This arrangement was requested by the teachers, who preferred not to have Libras interpreters in the classroom, as they felt that, at their age, the children would not be able to distinguish between the role of the interpreter and that of the teacher. Additionally, the teachers emphasized the importance of experiencing the communication challenges that deaf children face daily.

Through these observations, a diagnosis was made on the following points: I) Classroom dynamics; II) Classroom's materials and infrastructure; III) Educational content and teacher-planned activities; IV) Educational and emotional profiles, as well as the four skills present in game design [Allsop, 2012]; and V) Major difficulties faced by children in their school subjects.

To characterize the children, their guardians completed a questionnaire that gathered information on age, level of deafness, access to electronic devices and the internet, and game preferences. Complementing this, the children's teachers completed a questionnaire to outline their educational profiles, assessing each child's proficiency in the subjects they taught: Libras, Portuguese, Mathematics, and Science.

In parallel with the "Diagnose" step, the "Plan Action" and "Intervene" phases were also carried out. Thus, after analyzing the results of each workshop, the plan for the following workshop was developed and validated by the teachers. Both the teachers and the game developers contributed with ideas for workshop activities, which were discussed and incorporated during the planning process.

Fifteen workshops were conducted over two months, each lasting between two and four hours, depending on the teachers' availability. These workshops were recorded, and their content was later analyzed to understand nuances in the children's behavior, such as gestures and facial expressions, alongside notes kept in an ethnographic diary.

In total, 27 game design activities were planned and carried out with the deaf children. The activities addressed themes the children were studying during the workshops, such as animals and their habitats and diets; identification and writing of first and last names; personal hygiene; numbers and counting; and the concept of time (e.g., days, months, hours, and holidays).

During these activities, many of the deliverables consisted of drawings made by the children, which were collected, stored, and cataloged for use in later stages of the project. The activities conducted, along with the targeted skills and their corresponding sources, are presented in Table 1.

The game design workshops with the children and teachers were conducted alternately with meetings involving the game

Table 1. Summary of design activities, objectives, and sources.

ID	Activities	Objective(s)	Source
A1	Observe children playing educational digital games in Libras and ask them to explain stories from animated video clips	Critical thinking, communication	Main author
A2	Observe children creating a character from a template	Critical thinking, creativity	[Benton *et al*., 2014]
A3	Observe preference between analog or digital games	Critical thinking, communication	[Alves and Hostins, 2019b]
A4	Observe children collaboratively customizing a digital avatar	Collaboration, communication	Participating teachers
A5	Observe children navigating a maze and then ask them to change the maze's rules afterward	Critical thinking	[Valente and Marchetti, 2017; Kalmpourtzis, 2019]
A6	Observe children playing a digital adventure game and discuss its elements	Critical thinking	[Alves and Hostins, 2019b]
A7	Observe children creating and telling stories with picture cards	Creativity, communication	Participating teachers
A8	Observe children and teachers playing tic-tac-toe and discussing its rules	Critical thinking	Main author
A9	Guide children in drawing a game character	Creativity	[Fails *et al*., 2013]
A10	Observe groups creating a game screen from references	Critical thinking, creativity, communication, collaboration	[Zabot *et al*., 2019]
A11	Assist children in assembling a timeline with session photos	Critical thinking	[Alves, 2017]
A12	Group discussion about the animals the children interact with	Critical thinking, communication	Participating developers
A13	Group discussion about zoo video clips	Communication	Participating developers
A14	Discuss with children which zoo animals to include in the game	Communication	[Alves and Hostins, 2019b]
A15	Observe children drawing the animals they selected in A14, including their habitat and food	Creativity, communication, critical thinking	Derived from A2
A16	Observe a role-play activity between teachers and children involving daily zoo routines	Creativity, communication	[Alves *et al*., 2021]
A17	Observe children drawing a uniform design for the game's protagonist	Creativity, collaboration, communication	Main author
A18	Discuss with children the personality traits of the game protagonist	Communication, creativity, collaboration, critical thinking	Main author
A19	Observe group drawing of the protagonist's bedroom	Communication, creativity, collaboration	Main author
A20	Observe group drawing of the zoo map	Communication, creativity, collaboration	Main author
A21	Observe children playing animal-care games in pairs	Collaboration, communication	[Alves and Hostins, 2019b; Zabot *et al*., 2019]
A22	Discuss with children the actions the protagonist would perform in the zoo	Critical thinking, communication	Main author
A23	Observe children in a braindraw activity, designing animal habitats	Collaboration, creativity	Fails *et al*. [2013]
A24	Participate in a role-play with children in order to validate the protagonist's actions in the game	Communication, creativity	[Alves *et al*., 2021]
A25	Present the children with their drawings incorporated into an analog prototype of the game	Communication	[Valente and Marchetti, 2017]
A26	Observe children playing animal-care games and retelling virtual-pet stories	Communication, collaboration, creativity	[Kalmpourtzis, 2019]
A27	Observe children interacting with the analog game prototype (made based on their drawings) to collect requirements for the digital game	Creativity, critical thinking, communication	[Valente and Marchetti, 2017]

developers. In this way, while the deaf children and teachers defined the game elements, the developers provided feedback in four meetings and helped clarify aspects that were difficult to define. Three meetings with the developers took place during this process. After the game design workshops were completed, the "Evaluate" step took place, during which the children and teachers shared their perceptions of the PGD process through semi-structured interviews.

The interviews with the children were conducted individually, in Libras and with the support of the teachers, due to their different schedules. The questions addressed two main aspects: their participation in the workshops and their preferences regarding the game being designed (e.g., what they would like or dislike in the game, whether they enjoyed the activities, what they learned, and their interest in participating in future workshops).

The teachers were also interviewed individually, in Portuguese, with questions focusing on their experiences during the workshops and their perceptions of the children's engagement, difficulties, learning outcomes, and development of skills such as collaboration, creativity, communication, and critical thinking, as well as suggestions for improving the activities. All interviews were recorded, and the data were analyzed using content analysis.

Finally, the "Reflect" step was carried out, involving the analysis of detailed descriptions of all game design workshops and meetings, based on video recordings, notes, and photos. Through this step, reflections were made on: I) The diagnosis of the participant deaf children; II) The children's participation in the game design activities, as well as the importance of accurately mantain the main characteristics of their drawings; III) The benefits and challenges of working with deaf children, as well as the requirements for the game being developed; and IV) The feedback from interviews with the deaf children and teachers.

4.3 Third cycle: Elaboration

Based on the reflections from the second cycle, the data collected during the "Plan Action" step (Figure 2) were analyzed to produce a document that synthesized all the game elements developed up to that point (the Game Elements Document). For this analysis, recordings from the workshops, the children's artifacts, and the teachers' comments were examined. This synthesis was intended to support the subsequent construction of the GDD and the game prototype in collaboration with the game developers. Both the GDD and the prototype were created following an updated version of the CAJEDUS methodology.

In the next step, "Intervene," the CAJEDUS methodology (*CriAção de Jogos EDUcativos para crianças Surdas* - Creation of Educational Games for Deaf Children) was employed. Originally developed to guide game developers in creating educational games for Deaf children aged 4 and 5 years [Galvão, 2020], the methodology was adapted to fit the context of this research. It is structured around five artifacts, as follows:

- **Instruction Manual**: Requested by game developers who reviewed the preliminary methodology version, this manual outlines the steps to be followed in creating a game using CAJEDUS;
- **General Guidelines:** These guidelines provide direction to developers regarding learning, ethical, and accessibility aspects for deaf children;
- **Educational Direction:** This document presents subjects, learning objectives, content, and the capabilities of deaf children, helping shape the educational content for the game;
- **Specific Guidelines:** This document offers ideas and examples of how the educational content could be applied;
- **GDD and Prototyping:** This artifact assists in the specification of game elements and includes a prototype of the main screens of the proposed game.

The GDD and game prototype were developed during the "Intervene" phase. This process followed the CAJEDUS artifacts, as shown in Figure 3. Initially, CAJEDUS was designed in a waterfall format, but its representation was changed to a cycle to accommodate the iterative nature of building a GDD. This approach encouraged the game developers to revisit previous steps to refine their ideas and stress essential concepts for games designed for deaf children. A total of 17 meetings with the developers were held during this process, alongside asynchronous work carried out between meetings.

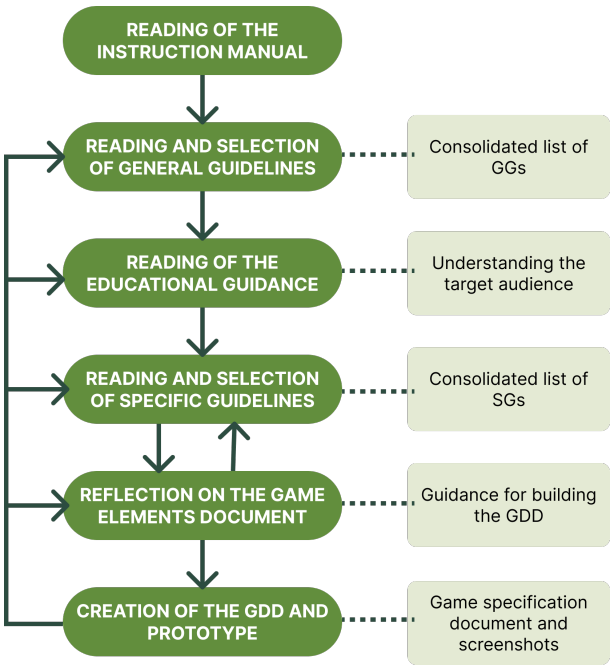

Figure 3. Path adopted for using the CAJEDUS methodology.

The GDD and game prototype development began with each participant reading the instruction manual and General Guidelines. After this reading, the team discussed and selected the highest-priority GGs for the game, consolidating them into a list. Next, the Educational Direction artifact was reviewed to clarify the questions developers had about the game's target audience. Then, each developer read the Specific Guidelines individually, and, after this, the most suitable ones for the project were chosen and consolidated into a list. This list was created with the support of the educational content provided by the teachers, available in the Game elements document, which was read together during the consolidation

meeting.

With the defined game elements, the GDD production began. The following tools were used to create the GDD: I) Google Docs[1], for writing and documenting the GDD; II) Miro[2], for brainstorming and creating moodboards[3]; and III) Figma[4], for prototyping the game screens.

The game developers held regular meetings to work on the GDD, consulting other CAJEDUS artifacts, especially the Game elements document artifact and the list of selected General and Specific Guidelines. The meetings proceeded as follows: I) The main author read the section to be completed along with guiding questions to answer on the GDD; II) We discussed the section's topic as a group, consulting other CAJEDUS artifacts as needed; III) One or more team members documented the decisions in the GDD, with the text then reviewed by other developers. Alongside CAJEDUS artifacts, other documents supported the GDD construction, particularly for the game's educational content, the Common National Curriculum Base [MEC, 2017] and the Libras Annual Early Childhood Education Course Plan by [Cruz *et al*., 2015].

The prototype development occurred alongside the GDD development. Once the game's main elements had been outlined, the team met to decide which screens to design using Figma. In these meetings, which lasted approximately two hours, the team divided tasks such as illustrating the game scenario and designing interface elements like buttons. After completing their tasks, each member presented their work to the group, and the elements were then integrated into the prototype.

In total, 15 meetings focused primarily on GDD development and 2 meetings focused primarily on prototyping. All meetings were recorded and later analyzed. During the GDD meetings, the team typically completed one or more sections of the document and, at the end, revisited the entire GDD to identify inconsistencies. The document was developed with support from the outputs of the second cycle, the selected guidelines, and the collection of visual references from similar games. Prototyping occurred mostly asynchronously, with meetings dedicated to integrating individual contributions. In summary:

- 4 meetings for CAJEDUS guidelines presentation and consolidation;
- 1 meeting for the selection of visual references and writing of the game's high concept;
- 1 meeting for the specification of the GDD section "Context in which the game will be developed";
- 1 meeting for the specification of the GDD section "Content and concepts";
- 1 meeting for the specification of the GDD section "Game story';
- 1 meeting for the specification of the GDD sections "Playable character" and "Non-playable character";
- 1 meeting for the specification of the GDD section "Game world";
- 1 meeting for constructing the flow between game scenarios;
- 1 meeting for the specification of the GDD section "Items";
- 1 meeting for the specification of the GDD section "HUD";
- 1 meeting for the specification of the GDD sections "Technology requirements," "Controls" "Mechanics," and "Rewards";
- 1 meeting for the specification of the sections "Game flow," "Tutorial," "Scoring," and "Feedback";
- 2 meetings focused on prototyping.

In the "Validate" step, feedback on participation in the study was collected from two game developers. They completed a post-study questionnaire, based on the Technology Acceptance Model (TAM) [Davis, 1985], assessing the usefulness, ease of use, and intention to use the CAJEDUS artifacts.

The questionnaire was created using Google Forms and organized into four sections and comprised 19 mandatory multiple-choice questions, 2 mandatory open-ended questions, and 3 optional open-ended questions. The first section characterized the developers' prior experience with GDD production. The second examined the perceived usefulness of CAJEDUS artifacts for specifying an educational game for deaf children. The third investigated the ease of using these artifacts in the context of bilingual education for deaf children. Finally, the fourth section focused on the intention to use CAJEDUS artifacts in future game specification projects. The results of the multiple-choice questions were interpreted with the aid of the charts generated by Google Forms, while the open-ended responses were analyzed using content analysis, in which the data were examined and grouped into categories.

In addition to the questionnaire, the developers participated as a group in a semi-structured group interview to reflect on their experience in the project, including their involvement in meetings interleaved with workshops at INES, the collaborative specification of the game with children and teachers, the strategies adopted for developing the GDD, perceived alignment with bilingual education goals, challenges encountered, learning outcomes regarding the deaf community, and suggestions for improving the methodology. The interview was conducted in a single session, recorded, and the data were analyzed using content analysis.

Finally, in the "Reflect" stage, an analysis was conducted regarding the complexity and suitability of the GDD with respect to Bilingual Education for deaf students and game design principles. This reflection drew on experiences accumulated throughout the project, recordings from the workshops and GDD development meetings, and the developers' post-study feedback. Additionally, the participatory game specification framework involving deaf children, teachers, and developers — entitled CAJEDUS-DP — was created. This framework was derived from the lessons learned during the Action Research cycles, the data collected across the GDD and prototype development process, and the experience of managing a project that brought together such diverse participant profiles. CAJEDUS-DP will be presented in details in

[1]https://docs.google.com/

[2]https://miro.com/

[3]A design instrument used as a visualization panel for characteristics of a specific context, allowing the grouping of images, textures, colors, and other elements [Oliveira, 2016]. It is commonly used in game development to gather inspirations for characters, environments, and similar components.

[4]https://www.figma.com/

Subsection 6.4.

4.4 Participants and Classroom Settings

Sixteen people participated in the PGD, including 5 teachers, 7 deaf children, and 4 game developers. All participants collaborated as design partners in the game design process.

From the 5 teachers involved in the study, 4 were hearing, and one was an oralized deaf individual[5]. They taught Libras, Portuguese, Mathematics, Science, History, and Geography to elementary school students in the 2nd to 4th grades. They identified the main challenges as frequent student absences and failure to complete homework, which hindered content retention. Additionally, they mentioned the lack of accessible materials for deaf students and the difficulty of addressing each student's specific needs, as some classes included children with further other disabilities. Lastly, the teachers used technology in the classroom, such as computers and televisions, and often incorporated games into their lessons, primarily analog ones. Regarding their participation in the action-research cycles, one teacher took part only in the first cycle, another only in the second cycle, and three participated in both cycles.

The seven deaf children were part of two 2nd-grade classes. Their guardians reported that four had profound deafness, three had severe deafness, and one had moderate deafness. Among these seven children, one had a motor disability that limited motor coordination, and another had an intellectual disability. All of the children participated in the second cycle of the research; however, only two took part in the final interview.

All the children had internet access at home, mainly using smartphones and tablets under the supervision of their guardians. Moreover, most children preferred digital games over analog ones and played regularly, favoring playing with others rather than alone. Most of them were proficient in Libras and familiar with finger spelling. They knew the Portuguese alphabet and could write their names, although some needed assistance. In Mathematics, all could count to 10, but most struggled with understanding quantities and temporal concepts. In Science, they were learning about animals. Socially, most of the children were sociable but had difficulties to engage in collaborative activities. The teachers noted that many tended to "guess" answers, showing a lack of reflection on the learned content. Lastly, all the children were interested in creative activities, such as storytelling, acting, and drawing.

The 4 game developers worked independently, with experience ranging from 1 to 3 years. One developer identified as being on the autism spectrum. Most had worked as game designers and had taken on other roles, such as scriptwriting, programming, and sound design. Many expressed concerns about accessibility in games and had prior experience creating educational games. However, they had little knowledge of the deaf community, which they gained only after the research training. None of the developers knew Libras or had previously worked with deaf children. During the second cycle, one developer withdrew from participation, and by the end of the third cycle other developer was unable to take part in the data collection, despite having contributed to the research. The remaining two developers participated in all three research cycles.

Beyond these participants, three researchers contributed to the development of this study. They all share an interest in Bilingual Education for the deaf and interconnect their respective research fields. The first and the second authors have conducted research in the fields of Digital Games, Educational Informatics and Interaction for Social Inclusion, while the third author focuses on research in Bilingual Education for the deaf, and Computational Linguistics of Libras.

Regarding the classrooms where the in-person research was conducted at INES, both were small rooms capable of accommodating up to ten students simultaneously. The resources available for use during the study included basic stationery items, such as colored pencils and blank sheets of paper, as well as a television. Digital activities were carried out using either the notebook or the mobile phone of the main author. When necessary, she also purchased additional stationery materials to support the activities, such as kraft paper and EVA foam.

5 Participatory Game Design Process

The goal of the PGD process was to develop a GDD and a game prototype, with the participation of child developers and teachers. The first stage of the PGD was conducted from March 2022 to July 2022, involving all research partners. The objective of that stage was to collaboratively develop elements for an educational game for deaf children, working closely with deaf children and their teachers. These elements were then reviewed by the game developers, who provided feedback and additional input to enhance the work. The second stage of the PGD took place from June to December 2023, involving only the participation of the game developers. During this period, we met virtually to develop a GDD and a game prototype based on the elements previously specified by the other research partners.

To illustrate the first stage, Figure 4 shows photos of some of the activities conducted during the game design workshops. In photo A, the children participate in a role-playing activity, acting out as animals from a zoo to gather game ideas. In photo B, the children are drawing one of the game's scenarios, the animal caretaker's room. In photo C, they are playing an animal-care game in teams to explore their interest in this genre. Finally, in photo D, one of the participating children interacts with an analog game prototype based on their drawings and ideas, to gather requirements for the digital game version.

To illustrate the second stage, Figure 5 presents an example of an activity that the game developers participated in, the moodboard creation. In this example, they gathered visual references from games that served as inspiration for creating the game's screens and developing educational activities for deaf children.

In general, through the first stage of the PGD, it was possible to partially develop the four intended skills in deaf chil-

[5]Oralized deaf individuals are those who can communicate orally through the Portuguese language, similar to hearing people [Meirelles and Spinillo, 2004].

Figure 4. Photos from the game design workshops.

Figure 5. Moodboard created by game developers.

dren: collaboration, critical thinking, creativity, and communication. The workshops provided a good environment for presenting, solidifying, and continuing the learning of content covered in the classroom, as indicated by two participating teachers.

The children's development of critical thinking became more evident when analyzing the progressive shift during the workshops from "guessing" answers to greater reflection before responding. Although the children were unable to develop game rules, they could articulate various actions that players might take within the game. They reflected on their work, commented on their peers' contributions, and demonstrated a certain level of organization in deciding whose turn it was to play. In some cases, the children improved their work based on the feedback from the adults present during the workshops.

Communication among the children occurred in various ways: through Libras, oral communication, and gestures/pointing/drawing. Communication was sometimes negative, such as when children argued with each other or became frustrated when things did not go as they wished. Nonetheless, children negotiated, presented arguments for discussions, calmed one anothers, shared their opinions on raised topics, and told real and fictional stories. One of the greatest challenges faced regarding communication was ensuring that children had understood the questions and could explain the reasons behind their responses. To address this, strategies were implemented, such as providing examples of possible answers and using visual support resources.

According to the teachers' reports, the skills in which the children showed the most difficulty were collaboration and creativity. Exercising collaboration proved to be a challenge, as activities involving collective drawing or stories by the children were not successful. In almost every activity where involving collaboration, children found ways to complete tasks individually. Nevertheless, there were moments when children collaborated, especially while playing games or offering help to peers. With less frequency and only when they felt the need, the children were able to ask for help and make suggestions regarding their classmates' work.

Creativity, on the other hand, involves world knowledge, vocabulary, and abstraction. These aspects were particularly hindered due to several aspects, such as the delayed acquisition of Libras by the hearing parents' children, the lack of accessible media, and the social isolation determined by COVID-19 pandemic, information gathered from reports provided by the teachers. One of the teachers mentioned that most children, even the older ones, were at the preoperational stage (ages 2 to 7) [Piaget and Duckworth, 1970], meaning they were just beginning to master language and communication symbols at that moment. Despite the difficulties, the children demonstrated great aptitude for creative activities. Even if some children disliked drawing, for instance, they found other means of expression, such as through enactment or storytelling. As the workshops progressed, with increasingly targeted questions and a growing number of visual references, they were able to refine their ideas and develop the physical and behavioral traits of their characters. Their stories, initially simple in the first workshops, became increasingly complex to the point of containing a moral or a lesson at the end. In some cases, the children even created new paths that we adults did not anticipate.

Beyond game design skills, the workshops also supported the learning of INES' programmatic content. The teachers noted that the proposed activities contributed to learning, reinforcing, and extending classroom instruction, particularly regarding topics such as animals, new signs in Libras, numbers, and concepts of quantity and time. There were also moments in which children learned content that went beyond what had been taught in class—for example, when we explained that monkeys eat fruits other than bananas. Table 2 presents a set of benefits observed among the children who participated in the workshops, along with the activities in which these benefits emerged and a comparison with related studies identified in the literature reviews previously conducted [Galvão, 2024].

The game design workshops led to changes in classroom dynamics and in the ways how children express themselves and learn. Three months after the workshops, one of the teachers mentioned the progress that the workshops had fostered in the children, both in language acquisition and in creativity in drawing. She noted that children had matured and made great strides in communication; they had developed a greater interest in children's literature and were now drawing with a clear line of reasoning.

Beyond children's involvement in the workshops, the teachers and the game developers also played fundamental roles in the game design process, as they deepened their contri-

Table 2. Benefits identified, corresponding activities, and studies found in the literature reviews reporting similar benefits.

Benefit	Activities	Studies found in the literature reviews reporting similar benefits
Development of critical thinking	A1, A2, A5, A6, A11, A12, A18, A22, A26, A27	[Druin, 2002; Melo *et al*., 2008; Tan *et al*., 2011; Allsop, 2012; Akcaoglu, 2014; Costa *et al*., 2017; Kalmpourtzis, 2019; Alves and Hostins, 2019b]
Development of creativity	A2, A5, A7, A15, A16, A17, A19, A20, A23, A26, A27	[Jones *et al*., 2003; Tan *et al*., 2011; Allsop, 2012; Fails *et al*., 2013; Akcaoglu, 2014; Costa *et al*., 2017; Kalmpourtzis, 2018; Alves and Hostins, 2019b]
Development of communication	A1, A4, A11, A12, A13, A14, A16, A17, A18, A22, A24, A25, A26, A27	[Druin, 2002; Melo *et al*., 2008; Tan *et al*., 2011; Allsop, 2012; Akcaoglu, 2014; Costa *et al*., 2017; Korte *et al*., 2017; Kalmpourtzis, 2018; Alves and Hostins, 2019b]
Development of collaboration	A4, A10, A21, A23, A26	[Druin, 2002; Tan *et al*., 2011; Allsop, 2012; Akcaoglu, 2014; Costa *et al*., 2017; Kalmpourtzis, 2018; Alves and Hostins, 2019b]
Digital literacy and interest in technology	A1, A3, A6, A21, A25, A26, A27	[Baytak *et al*., 2011; Akcaoglu, 2014; Costa *et al*., 2017; Iversen *et al*., 2017; Korte *et al*., 2017; Sjöberg and Brooks, 2020]
Curriculum-related knowledge development	A2, A7, A10, A11, A12, A13, A15, A22	[Baytak and Land, 2010; **?**; Marengo *et al*., 2016; Kalmpourtzis, 2018; Jérôme *et al*., 2019]
Expansion of Libras and Portuguese vocabulary	A1, A2, A11, A13, A18, A22, A26	None
Reframing of game elements from Deaf children's perspective	A2, A5, A6, A7, A10, A15, A17, A19, A20, A22, A23, A24, A26, A27	[Zabot *et al*., 2019]
Immersion and engagement	A1, A6, A13, A16, A21, A25, A26, A27	[Jones *et al*., 2003; Guha *et al*., 2008; Baytak and Land, 2010; Dodero *et al*., 2014; Dele-Ajayi *et al*., 2018]
Free expression and reflection on daily life	A1, A10, A11, A12, A16, A18, A24, A27	[Baytak and Land, 2010]
Positive feelings (belonging, representation, accomplishment, self-confidence)	A4, A11, A25, A27	[Druin *et al*., 1997; Druin, 2002; Jones *et al*., 2003; Brondino *et al*., 2015; Iversen *et al*., 2017; Korte *et al*., 2017; Gennari *et al*., 2017]
Recognition and appreciation of peers' work	A9, A17, A25, A26	[Baytak and Land, 2010; Baytak *et al*., 2011; Valente and Marchetti, 2017; Mansilla *et al*., 2019]

butions throughout the study. The teachers participated in the planning of the workshops by suggesting game design activities and materials we could use with the children. Over time, they developed strategies for teaching game concepts and for encouraging children's reflection during activities. They also successfully defined the educational content for the game, worked as facilitators during the workshops, and offered feedback to other participants.

Initially, the developers' role was limited to providing feedback on game artifacts created during the workshops. However, they became essential in planning the workshops, suggesting materials and activities that could be introduced to the children. They also helped to define game elements that the children found challenging to articulate and guided in the defition of the following steps. In creating the GDD and prototype, they worked hard to incorporate contributions from the children and teachers. They also offered feedback on how to improve the CAJEDUS methodology and on what CAJEDUS-DP framework should offer to future development teams. Through the game design workshops and meetings, it became evident that all participants — deaf children, teachers, and game developers — played vital and complementary roles in the game design process.

Moreover, each partner group included individuals with disabilities, an empowering factor for this community, which is often viewed as "incapable or unfit to carry out tasks like working or making their own decisions as autonomous and independent individuals" [Ferreira, 2023, p. 147]. Additionally, having perspectives beyond those of non-disabled individuals meant that the game's design addressed accessibility considerations beyond those specific to deaf individuals, making the game more inclusive overall.

Concerning the challenges in conducting the PGD process, it was difficult to find accessible materials for the game design workshops, whether games, videos, or stories. Many games and videos related to the topic we wanted to address were in Portuguese. The teachers even mentioned this as a factor that made their lesson preparation and execution more difficult. In this context, searching for media that could be understood through visuals alone was necessary. Even some materials designed for deaf children presented barriers to understanding, as certain parts of the stories were hard for them to grasp due to their limited repertoire of signs in Libras.

Another challenge was the language barrier, as the main author conducted the game design workshops at INES with a limited domain of Libras. However, this experience was fruitful to minimally understand how deaf people feel in their daily lives with hearing people, and the inicial level knowledge of Libras to truly connect with the people involved. Both children and teachers were proactive in teaching various signs in Libras and aspects of deaf culture, breaking down the hierarchical role of the researcher as the sole knowledge holder.

In addition, it was a challenge to mediate such different and complex participants and understand their opinions/interests. This required a deep understanding of each participant to adapt the content and activities according to their needs. This process was long and carried out through trial and error until an adequate solution for everyone was reached. Despite these challenges, creating an environment where all participants had equally important voices proved to be possible.

There were also challenges throughout the development of the prototype and the GDD. Two of the four participating game developers left the project mid-project for personal reasons, which hindered progress, causing delays and adding strain on the remaining developers. This resulted in the main author taking a more active role in drafting the GDD and developing the prototype. Furthermore, towards the end of the project, it became increasingly difficult to find times when the remaining developers could participate synchronously in meetings. Despite these challenges, the intended goal was achieved: building a GDD based on the elements defined during the game design workshops at INES.

6 Results

This section presents the main results of this research in the following subsections: "Casa dos Bichos" GDD (6.2) and prototype (6.3), the CAJEDUS-DP framework (6.4) and the set of guidelines to support the producer during PGD (6.5).

6.1 Participants' perceptions of their involvement in the project

Each participant profile was interviewed separately to better understand their perceptions of the project. The children were interviewed in Libras with the support of their teachers, while teachers and developers were interviewed in Portuguese.

The children reported that they enjoyed the analog prototype created from their drawings—especially the caretaker character and the animals—and showed interest in playing a game centered on caring for animals. They also emphasized that they would like to play the game with friends and at home. Regarding their participation in the workshops, both children reported enjoying the activities and highlighted that their favorite part was playing on the computer. Neither child mentioned any negative aspects. They appreciated working with their classmates, expressed interest in attending future workshops, and showed enthusiasm for continuing to create games. Overall, the children responded positively to the workshops, the activities, and the collaborative environment.

In the interview, the teachers expressed that they enjoyed participating in the workshops and felt engaged in the activities despite the difficulties encountered. They noted that the most challenging aspect was explaining game-related concepts, naturally abstract, especially because some signs used to represent these concepts were highly specific and not widely known. They also highlighted that facilitating collaborative activities was complex due to occasional disagreements among the children. Both teachers mentioned that participating in the project supported their own teaching, as the workshops helped stress content from Science, Mathematics, and Portuguese classes, and introduced strategies and tools specifically designed for deaf students that they could use in the future.

The developers felt involved in the research and agreed that the participation of teachers and children facilitated the game's specification. Although they had previously made games for children, this was their first direct contact with the target audience, which expanded their understanding of deaf culture and Bilingual Education. They emphasized learning about accessibility and felt motivated to learn Libras.

The main challenges faced by the developers included the need to align the game with an educational curriculum they were not previously familiar with, the requirement for individual meetings and the difficulty of balancing them with personal demands. In addition, the lack of direct contact with the children and teachers posed an obstacle, as did the effort to translate ideas and decisions into the GDD.

In addition to the interview, the developers answered a TAM questionnaire. Overall, the responses were very positive, particularly concerning the perceived usefulness and intention to use the CAJEDUS artifacts. However, the methodology still presents some challenges in terms of ease of use. The developers agreed that the artifacts required a considerable amount of mental effort to use. Although specifying a game is inherently complex, the CAJEDUS artifacts should be redesigned to be more intuitive and flexible—changes that were addressed in CAJEDUS-DP (Subsection 6.4).

6.2 "Casa dos Bichos" GDD

The specified game was entitled "Casa dos Bichos", an adventure and simulation mobile game, in which the players assume the role of a child who volunteers at a zoo. Having experienced a wildfire in the Atlantic Forest in the past, the child developed a strong desire to protect the environment. The child character faces various challenges at the zoo, including caring for animals, properly collecting and disposing of litter left by visitors, and managing the zoo's resources. The players are supported by teacher Ana and manager José, as well as their dog, Pingo, to overcome these challenges. At the end of the game, the players are rewarded with a medal recognizing their efforts to learn more about animals and to help preserve the environment.

The game incorporates knowledge related to Libras, Portuguese, Mathematics, and Science, as suggested by the teachers. It primarily focuses on activities related to numbers, animals, time, and other themes such as environmental preservation and good hygiene habits. One of the game's strengths is presenting content using a "semantic trio" format: its graphical representation, its sign in Libras, and its written form in Portuguese [Canteri, 2014]. Another feature introduced in this game, addressing a research gap [Galvão, 2020], is integrating Libras and Portuguese within a meaningful context [Felipe, 2007] and connected to the game's storyline, rather than merely as isolated vocabulary.

Overall, we produced a comprehensive GDD, with detailed descriptions in each section. All developers offered unique contributions, such as future improvements for CAJEDUS guidelines, ideas for activities in the game design workshops, discussions regarding game industry's expectations for specific sections, and tool recommendations for the game design process. Additionally, we partially met the selected guidelines and requirements, as detailed below:

- **R1:** *The game should be digital and for mobile devices* - During the workshops, children preferred playing digital games over analog ones, especially mobile games, as they were more familiar with this platform.;
- **R2:** *The game should be short* - Children had difficulty maintaining focus on long activities;
- **R3:** *The game should present Libras signs slowly and progressively, as well as the corresponding words in written Portuguese* - Children had limited vocabulary in Libras and Portuguese;
- **R4:** *The game's story should be understandable through animations or images* - Children found it easier to focus on stories that did not involve Libras or Portuguese;
- **R5:** *The game should incorporate comedic elements* - Children more engaged more in topics when humor was involved;
- **R6:** *The players' avatar should be customizable, representing an animal caretaker* - Children enjoyed making

choices and felt represented when the character resembled themselves;

- **R7:** *The game should cover topics related to Libras, Portuguese, Mathematics, and Science* - These subjects were relevant to the participating teachers' context.
- **R8:** *The game should include activities related to animals, numbers, and time* - These were the subjects the children were studying and found challenging;
- **R9:** *The game's main scenario must be a zoo* - Children were learning about animals and had an interest in this topic;
- **R10:** *The game should feature the following animals: dog, hippopotamus, giraffe, lion, macaw, monkey, alligator, and rhinoceros* - These were the animals chosen and drawn by the children;
- **R11:** *The game should include the following settings: the animal caretaker's room and the zoo (with a map and habitats for each animal)* - These were the settings drawn by the children;
- **R12:** *The game should incorporate drawings made by the children* - Children felt proud when their drawings were respected and valued;
- **R13:** *The game should allow the players to perform caregiving actions with all the animals* - These actions predominated in children's interactions with the analog prototype of the game;
- **R14:** *The game should use accessible yet not rudimentary language for deaf children* - Teachers wanted the game to treat deaf children as capable of thinking and reflecting.

6.3 "Casa dos Bichos" prototype

The game prototype was created using Figma, mostly asynchronously, due to difficulties in scheduling meetings with the game developers. During the meetings we held, we defined which screens to prototype and what each would contain. We then divided tasks according to our strengths and if we had any questions or wanted to brainstorm, we did so through message exchanges.

Fidelity to children's drawings was prioritized in the prototype, especially considering we were working with a marginalized audience, such as deaf children. According to Bettocchi *et al*. [2020], the current process and the imaginary employed in creating and consuming games are Eurocentric, creating an environment lacking minority representation. To incorporate the children's contributions, with their intrinsic characteristics ("drawing perspective" [6]), we decided to use the children's original drawings in the game, which were digitized and digitally colored. Figure 6 shows the versions of the giraffe and the hippopotamus created by the children, along with their digitized versions used in the game.

Figure 7 shows screenshots from "Casa dos Bichos". The original game is in Portuguese, but the screens presented here

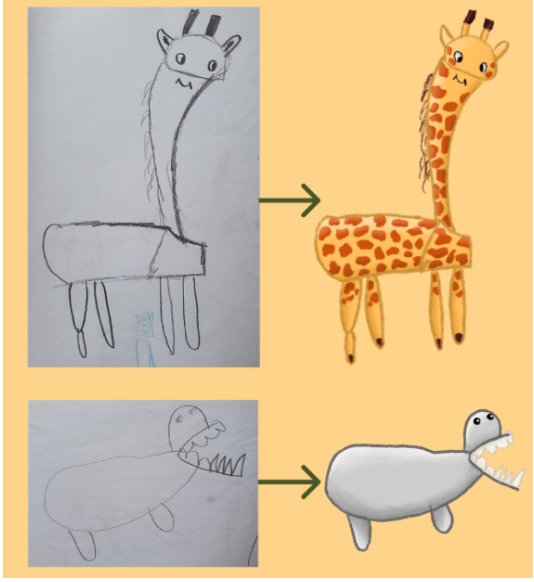

Figure 6. Original children drawings and their digitized versions.

were translated into English to enhance readability. In designing the context screens, we followed the CAJEDUS guidelines, using bold and vibrant colors such as green, yellow, and orange. Since the game centered around a zoo theme, we used various nature-related elements, such as leaves and vines. The settings for the zoo map (main screen) were based on the children's drawings and their interaction with the game's analog prototype.

Figure 7. Translated screenshots of the game prototype "Casa dos Bichos".

The initial screen (Figure 7) was designed to be as simple as possible, containing three interactive elements: a play button, a settings button, and a credits button. We applied this same principle of simplicity to the settings screen, especially considering the reading difficulties some deaf children have.

[6] We use the term "drawing perspective" - in Portuguese, "local de desenho" - in analogy to the term "speaking perspective" - in Portuguese, "local de fala" [Ribeiro, 2019] - which refers to the right to voice by feminist, black, or LGBTQIA+ movements in a society organized on principles of whiteness, masculinity, and heterosexuality. In this sense, "drawing perspective" goes beyond, as society also displays prejudice toward people with disabilities.

Upon clicking "play", the players are redirected to the avatar customization screen, a feature requested by the deaf children. On this screen, players can name their avatar and change its hair and skin color. After completing their avatar, the players are redirected to the main game screen, which presents an interactive map of the zoo, a calendar and a clock at the top of the screen, and a menu at the bottom containing the camera, the map, the diary, and the mission buttons.

By clicking the diary button, the players are redirected to the diary screen, where they can view the photos they took, along with interesting facts about the zoo animals. Clicking on the zoo fountain redirects the players to a minigame (Figure 7) where they must correctly collect and sort the litter found in the fountain. By clicking on one of the habitats, such as the giraffe habitat, the players are redirected to the animal care screen (Figure 7), where they perform actions like feeding the giraffe. Lastly, the game will feature cutscenes that activate at key moments to tell the game's story.

While developing the GDD and the prototype, we prioritized creating a game as accessible as possible for deaf children, following CAJEDUS guidelines. On all screens where text was necessary, we also included a graphic representation and a field for a video in Libras (semantic trio), as seen in the recycling minigame screen in Figure 7. Additionally, each word currently being signed was highlighted in red to facilitate the correlation between the Libras sign and the word in Portuguese. This decision was inspired by the color-coding system used to differentiate words for deaf children, as found in Heleno *et al*. [2019]. In the cutscene screens, we focused on creating storyboards in which the story was told solely through images. We primarily used icons to represent buttons, as seen on the main screen in Figure 7.

Regarding accessibility, we included general features, such as separate volume controls and subtitle customization. We had a neurodivergent developer in the team, who suggested including accessibility features for this audience, such as using a sans-serif font designed for people with dyslexia, *OpenDyslexic*. We paid careful attention to the positioning and the spacing between interactive elements so that children with motor limitations would not accidentally click on an element positioned too close to another, as happened during the game design workshops. The links to access the GDD for "Casa dos Bichos" and its interactive prototype are available at the end of this paper.

6.4 CAJEDUS-DP

Based on the results and reflections developed throughout the research described in this paper, the framework to support the participatory game design was developed, called CAJEDUS-DP. The creation of this framework was planned in the "Reflect" step of the third cycle of AR (Section 4). The CAJEDUS-DP framework builds on and extends the CAJEDUS methodology [Galvão, 2020] to incorporate PD, drawing from lessons learned in this latest research. Therefore, the primary goal of CAJEDUS-DP is to support the participatory game design by multidisciplinary development teams, facilitating engagement with the deaf community and creating games aligned with the context of bilingual education. The CAJEDUS-DP framework also aims to:

- Develop game design skills in deaf children, such as creativity, communication, collaboration, and critical thinking [Allsop, 2012];
- Empower both teachers and deaf children digitally;
- Provide teachers and deaf children with an environment that supports both the teaching and the learning processes;
- Bring developers closer to the lived context of the target audience for the game being specified;
- Provide artifacts to support an accessible and inclusive game design.

In CAJEDUS-DP, all participants are regarded as design partners [Druin, 2002], meaning that everyone has an active role and decision-making power in game design. One key partner for this process, suggested by the participating developers and represented by the main author in this study's PGD process, is the producer. This partner must be chosen by consensus among the other partners and should be a professional with a multidisciplinary perspective and project management skills. The producer's role is not to be the "boss" but to facilitate interaction among the other partners and keep the project aligned with established goals and timelines.

The second profile partner in CAJEDUS-DP is the game developer. These partners are professionals in the field of game development, including game design, art, or programming. Other professionals from areas that support game development may also be included, such as researchers in game-related fields, psychologists, or doctors, depending on the game's theme and on the specific context requirements.

The third profile partner in CAJEDUS-DP is the bilingual deaf education teacher. These professionals join the project to develop a game that supports knowledge acquisition in the classroom. Other educational professionals, such as education researchers, pedagogues, regular education teachers, specialized educational support staff or sign interpreters may also be included in this role.

The fourth and final profile partner in CAJEDUS-DP is the deaf child, student of the teacher involved in the project. This role includes all children on the deafness spectrum (from mild to severe) as well as deaf children with additional specific educational needs, such as motor or intellectual disabilities. Based on this study's findings, it is recommended that deaf children participating in the project be at least seven years old. Younger deaf children may also participate if necessary adaptations are made with support from the other partners.

Figure 8 provides an overview of the four steps of CAJEDUS-DP:

1. **Preparation:** Where partners meet and organize themselves for the game specification process;
2. **Training:** Where partners receive the necessary knowledge for game specification;
3. **GDD Production:** Where, through game design workshops and meetings using artifacts adapted from CAJEDUS, the partners will specify a GDD;
4. **Prototyping:** Where a game prototype is developed and evaluated by partners based on the outputs from the previous steps. The "GDD Production" and "Prototyping" steps are cyclical, meaning that partners move between them as needed according to the project's progress.

Figure 8. CAJEDUS-DP overview.

In general, during the "Preparation" step, the producer should meet the following objectives:

- **Get to know the adult partners:** Identify the knowledge needed for everyone to participate in the game design process, using strategies such as questionnaires and interviews;
- **Get to know the deaf child partners:** Observe classes for at least one week to understand the infrastructure, the necessary materials, and the way in which the interaction between children and teachers occurs, gathering information for the "Game Target Audience Profile";
- **Create the "Game Target Audience Profile":** Together with the teachers, develop a document that characterizes the child partners and identifies challenges and skills to be addressed;
- **Develop training materials:** Prepare materials to teach basic game design concepts and accessibility to the adult partners, considering their needs;
- **Plan the "Training" step:** Schedule the training sessions and workshops, adjusting dates with adult partners to ensure availability.

The expected objectives in the "Training" step are:

- **Train adult partners:** Present the training documents and discuss the document "Game Target Audience Profile", encouraging the exchange of information between the adult partners;
- **Conduct basic game design workshops:** Led by the producer and facilitated by the teachers (with possible participation from developers), children participate in workshops to provide initial exposure to games and design activities. These workshops may involve activities related to mechanics, interface, or narrative;
- **Conduct capability analysis workshops:** The producer examines whether the children understand and can create game design concepts;
- **Gather requirements for the game:** Based on the experiences from both the basic workshops and the capability assessment workshops, the producer should gather potential requirements for the game;
- **Plan the next phases:** Organize the schedule for activities related to "GDD Creation" and "Prototyping", adjusting dates with adult partners to ensure their availability.

The expected objectives of the "GDD Creation" step are:

- **Conduct game design workshops on the game theme:** The producer should ask the partner teachers to choose a main theme for the game and the primary content to be covered. Based on this theme, game design activities should be proposed to define the game elements together with the deaf children;
- **Structure and approve game requirements:** The game requirements, developed in previous steps, should be approved by the other adult partners, who may suggest modifications or the addition of further requirements;
- **Select General Guidelines and Specific Guidelines to be used in the game design:** The developers, guided by the producer, should read and select relevant General Guidelines for the project. Once a list of GGs is consolidated, developers should also read and select Specific Guidelines related to the theme and content to be addressed within the game;
- **Develop the GDD:** With the mediation of the producer, developers should create a GDD based on the approved requirements and the contributions of the deaf children and teachers. Teachers may also participate in this process, helping to define the game's educational content.

The "Prototyping" steps begins while the GDD is still being developed, as soon as the producer and the partner developers agree that enough elements have been defined to start creating a prototype. Therefore, the expected objectives of the "Prototyping" step are:

- **Conduct game design workshops on the game theme:** Based on the theme, game design activities should be proposed to define elements for the prototype, such as characters and scenarios;
- **Create a game prototype:** The producer and partner developers may use the CAJEDUS-DP framework artifact to create the prototype, shown in Figure 9. The producer and the developers need to decide which screens will be prototyped to facilitate task assignments;
- **Evaluate the game prototype:** The producer should lead an evaluation of the prototype, based on the partner(s) who will assess it. From the evaluation, the producer should gather feedback and present it to the developers to make the necessary adjustments for the following prototype version.

Figure 9 presents the support artifacts for using CAJEDUS-DP in its version on Miro, a collaborative editing software suggested during the interviews with the game developers involved in the PGD process. A version of the artifacts was also developed for Google Drive, which can be used in parallel with the Miro version. The link to the artifacts is provided at the end of this paper.

The first board in Miro (Figure 9), entitled "1. Perfil do público-alvo" (target audience profile), should contain information about the context of deaf children, including age range and educational challenges. In "2. Requisitos e produções" (requirements and productions), the game requirements should be listed, along with ongoing decisions and productions, and a space to store children's contributions, such as drawings and texts. The "3. Diretrizes CAJEDUS" (CAJEDUS guidelines) board should contain consolidated lists of selected General Guidelines and Specific Guidelines chosen by the developers.

The "4. GDD" board, located at the top center of Figure 9, supports the construction of the GDD. Each section of the GDD includes a brief explanation of the information expected in that section, along with suggestions to aid its development. It comprises the following sections:

1. **General Information:** Name, version of the game and team members;
2. **High-concept:** A sentence or paragraph describing the game's main idea [Novak, 2012];
3. **Technology Requirements:** How the game will be implemented and where it will be distributed;
4. **Educational Content:** Educational information about the game's target audience;
5. **Game Story:** Description of the narrative around which the game revolves;
6. **Game World:** Where the game takes place;
7. **Playable and Non-playable Characters:** Physical and personality characteristics of these characters, along with their abilities and motivations;
8. **Opponents:** Physical and personality characteristics of opponents, as well as interactions with playable characters;
9. **Rules, Mechanics, and Obstacles:** Description of these elements and where the players will encounter them;
10. **Controls:** How the players will interact with the game;
11. **HUD (Heads-Up Display) and Buttons:** Information provided to the players, as well as interactive elements;
12. **Items:** Items with which the players can interact and acquire;
13. **Tutorial and Tips:** What the players need to know to play, along with tips if available;
14. **Scoring and Level Progression:** When points are awarded to the players and their purpose;
15. **Feedback:** How, when, and where feedback is provided for the players' actions;
16. **Accessibility Features:** Accessibility resources implemented, specifying which types of disabilities they target.

The "5. Protótipo" (prototype) board provides space to list screens to be prototyped and store images of completed screens. Partner profiles can use the "Recursos adicionais" (additional resources) board to support the construction of the GDD and the prototype, located on the right side of Figure 9. These include:

- **Moodboards/References:** A section for developers to group visual references for game elements like environments, items, and buttons;
- **Brainstorming:** A space to group sticky notes used by partners during brainstorming sessions, keeping contributions organized;
- **Feedback Tracking:** A section to track what feedback from the game has or has not yet been implemented, such as particles and sound effects;
- **Game Flow:** A section to track what will be implemented at each game level.

Finally, the producer can use the "Gerenciamento de projeto" (project management) board to assist in managing the project schedule and activities, located at the bottom of Figure 9. In this way, the producer can keep the team updated on the progress of activities, their roles, and deadlines, with the option to adjust deadlines if necessary. Implementing a project management tool was suggested by one of the PGD developers, who noted that a timeline was needed to avoid project delays. The project management board includes two methods for tracking activities and the schedule:

- **Kanban Board**: Used in the agile Kanban method, divided into columns representing software development steps and the status of each feature [Pressman and Maxim, 2021];
- **Personnel Allocation Chart**: Used by project managers to allocate resources to tasks [Sommerville, 2018].

6.5 DAP: Guidelines to support the producer during PGD

Based on the experiences gained during the PGD, a set of guidelines was developed for individuals in the role of producer who will use the CAJEDUS-DP framework. These guidelines can also be used independently of CAJEDUS-DP by individuals managing PGD projects involving one or more of the listed partner profiles.

The DAP (*Diretrizes de Apoio ao Produtor* - Guidelines to Support the Producer) aims to guide the producer in managing a project with three very different and complex profiles: game developers, teachers, and deaf children. While the guidelines are specific to deaf children, they can also be adapted for hearing children if adjustments are made to suit their context. In the following subsections, specific guidelines for designing games with deaf children (subsection 6.5.1), teachers (subsection 6.5.2), and game developers (subsection 6.5.3) are presented.

6.5.1 Guidelines for working with deaf children as design partners

DAP1. Review previous activities at the beginning of each workshop. As noted by Melonio [2018], it is important to revisit events from previous workshops so that children can recall the context and content they had been working on. In

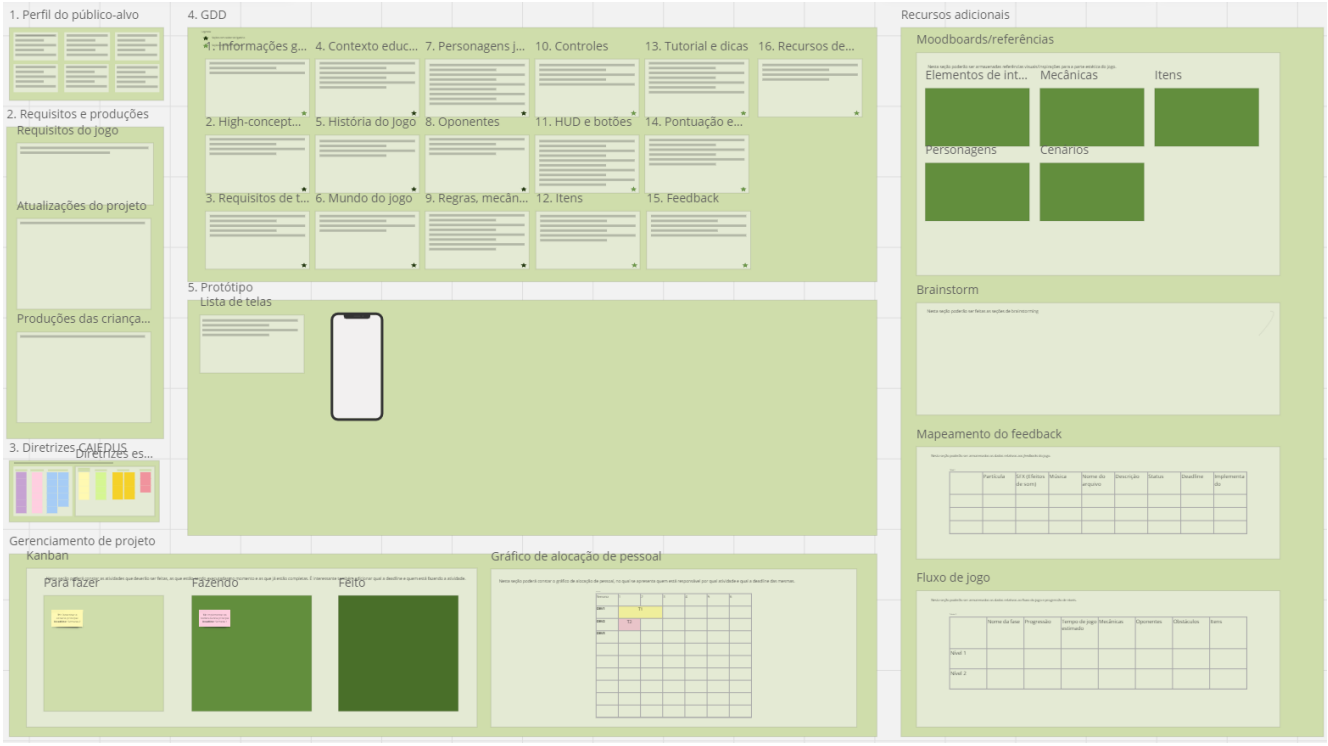

Figure 9. Overview of CAJEDUS-DP artifacts in Miro.

the game design workshops conducted in this research, for example, a timeline activity (A11), inspired by Alves and Hostins [2019a], was used at the beginning of every session to help children remember past activities and productions.

DAP2. Use accessible media for deaf children during the workshops. In many game design activities, it is necessary to use some form of media for support, such as images, videos, or games. Based on the experiences gathered during the workshops, these media resources should be tailored for deaf children or, at the very least, should not rely on sound, written Portuguese, or highly complex instructions or mechanics. For example, in Activity A1, a video was used that, although it contained audio, had a storyline that could be fully understood through its animation alone.

DAP3. Offer a wide range of visual references for the workshops. During the game design workshops, the deaf children demonstrated strong visual tendencies and faced difficulties with creative tasks. Therefore, in any activity involving creation, it is necessary to provide visual examples (such as images, videos, or games) to help them understand what is expected and how the task should be carried out. However, there is a risk that children may simply reproduce the examples provided, which makes it necessary to offer a large variety of visual references to mitigate this tendency. Additionally, using references that evoke feelings of diversity and representativeness can foster engagement, as in A27.

DAP4. Introduce familiar elements to deaf children during the workshops. Children feel more comfortable participating in activities that feature elements they are already familiar with, such as famous cartoon characters or facts about their daily lives. Incorporating these elements is an effective way to introduce more complex concepts without causing too much resistance.

DAP5. Create direct and specific questions for deaf children..Due to the challenges in acquiring Libras demonstrated by the children in this study, long, compound, or complex questions were often not understood. Therefore, when formulating questions, abstract elements should be avoided, and a direct and highly specific approach should be adopted. Providing answer options and visual cues can support children in formulating their responses. For example, during Activity A12, a sheet with drawings of animals was shown to help them indicate which zoo animal they liked the most.

DAP6. Promote short activities. As previously noted by [Korte, 2017], deaf children tend to have short attention spans. As a result, lengthy or multi-step activities often became tiring, leading some children to disengage over time. For instance, during Activity A24, several children chose not to participate because they were already fatigued by earlier tasks. In this context, it is essential to design game-design activities that are brief and self-contained. These activities should be introduced with visually engaging materials, such as images or videos, and ideally should not exceed one hour in duration.

DAP7. Optimize the focus of deaf children. It is important to plan activities in a way that optimizes the children's short attention spans. Ideally, activities involving gameplay should be scheduled at the end of the workshops, as children tend to become distracted afterward. Meanwhile, activities requiring greater focus and effort should take place at the beginning of the workshop, after reviewing past activities, as this is when the children have the most energy. It's also essential to consider breaks between classes, as children often return from breaks feeling distracted.

DAP8. Adapt activities according to the children's needs. When working with a deaf children, it is essential to design activities that take their needs into consideration. However, during the workshops, several activities had to be adapted in real time based on the children's emerging needs

and interests. One example was replacing activities in which children were asked to develop game rules, an approach that proved overly complex, with tasks focused instead on identifying possible player actions. Considering children's limitations in this way respects their capabilities and provides an environment in which they can express themselves to their fullest potential.

DAP9. Offer options for children to complete the game design activities. During the game design workshops, it became evident that each child had a preferred mode of expression. For instance, some children performed particularly well in role-playing activities, whereas others excelled in drawing tasks. Allowing children to engage in game design activities using the modes of expression they are most comfortable with helps ensure that they feel at ease and enables the extraction of their full potential. Useful options include drawing, role-playing, and explanations in Libras, among others.

DAP10. Be patient and allow time for each task. Some activities required more time and effort, even when designed to be as simple as possible—especially those involving abstract concepts or higher levels of collaboration among the children. For example, in A22, the children needed additional time to reflect on the actions that the animal caretaker would perform in the game. In such cases, it is advisable to respect the classroom's pace and, when necessary, offer a break or discontinue the activity and move on to an easier one. This approach provides time to replan the activity with the adjustments required.

DAP11. Encourage the participation of parents or legal guardians. In studies such as [Korte, 2017], parents of deaf children actively participated in the workshops, which did not occur in this research. Many caregivers were unable to participate due to limited knowledge of Libras or work commitments. Yet, their involvement could have increased children's engagement and helped families better understand their needs [Mansilla *et al*., 2019]. Thus, it is advisable to encourage parental participation whenever possible, or provide alternatives such as optional at-home game design tasks for children to complete with their caregivers.

6.5.2 Guidelines for working with teachers as design partners

DAP12. Plan and conduct game design activities related to the content being taught. It is essential to propose game design activities that support partner teachers and assist in teaching and learning processes. For A7, for example, cards were created with images related to the content being taught—animals, hygiene items, and weather. Designing activities that connect to classroom content makes them more meaningful for both teachers and children, helping stress, consolidate, and extend the material being taught.

DAP13. Develop the game design workshops based on activities and materials already used by teachers. A variety of activities and materials already used by teachers in the classroom can be adapted for game-related contexts. During the research, for example, one teacher suggested using a material she regularly employed in class: picture cards that children had to connect to create a story. This resource was incorporated into A7 and proved useful for stimulating creativity and narrative construction—skills that are essential in game design.

DAP14. Provide a list of specific terms to be used in the workshops in advance. Teachers serve as a bridge for communication with deaf children, especially in cases where other partners do not know Libras or are not familiar with the children. However, some topics introduced during the activities may require signs that are not commonly used and may be unfamiliar to both teachers and children. Terms such as "design" and "gameplay" are not widely used, and their signs are generally known only by Libras interpreters who work in game-related contexts. An example occurred during A8, when the children did not understand the sign for "rules," and the teacher had to use an adapted expression—"can or cannot"—a set of signs used in the classroom to communicate social norms. By presenting a list of these specific terms prior to the sessions in which they will be used, teachers can better prepare for their introduction, researching the appropriate signs or identifying similar signs already familiar to the children.

DAP15. Give teachers the freedom to present game concepts in their way. The planning of game design workshops should be flexible, allowing teachers to reinterpret the concepts that will be introduced to the children. This often leads to certain game-related concepts being presented in ways that are more accessible to deaf children. During A9, for example, one of the teachers explained that the children would need to draw themselves not through signing, but by standing each child next to the board and creating drawings of them.

DAP16. Make it clear that teachers should act as facilitators, not as authority figures, during the workshops. It is important that teachers understand their role in the workshops as supporting deaf children in completing the activities, rather than directing them or doing the tasks on their behalf. Viewing the teacher as an authority figure may lead to negative reactions, as observed in one of the interview results in which a child stated they did not want the teacher to appear in the game. Therefore, it is essential to clarify during training meetings that all participants are partners in the game design process, sharing equal opportunities for expression and decision-making.

6.5.3 Guidelines for working with developers as design partners

DAP17. Encourage developers to participate in person during game design workshops. Encourage the in-person participation of at least one developer in the workshops, as this interaction allows for real contact with the game's target audience. This direct contact can lead developers to gain insights closer to the reality of deaf children than those obtained solely through documentation or presentations.

DAP18. Encourage the learning of sign language. Encourage developers to learn at least a few basic signs to facilitate communication with deaf children, as there won't always be interpreters available for the classroom, and relying solely on teachers for communication can overburden them. Additionally, since the game will include sign language, developers need to understand how it works to have

a foundation for creating educational activities in the game. Useful signs to learn include greetings, congratulations, agree and disagree.

DAP19. Encourage developers to provide respectful feedback on children's work. Most developers do not have experience working with deaf children; thus, during training, it's necessary to emphasize how to interact with the children. Even though developers are experts in game development, they are partners in the design process with equal decision-making power alongside deaf children and teachers.

DAP20. Present what has been straightforwardly produced by other partners. The more direct the presentation of what has been produced and documented to the developers, the easier it will be for them to integrate it into the GDD and the prototype.

DAP21. Encourage developers to stay up to date. If developers don't try to keep up with project updates and report their progress, the effort made by the producer to keep the team updated will be in vain. The project management tool on Miro (Subsection 6.4) serves this purpose, as developers can report whether they have completed their tasks. Another way to keep the team updated is through regular meetings to check the progress.

7 Final Remarks

The research described in this paper showed the potential of PGD — involving deaf children, teachers, and game developers — to ensure the specification of games aligned with the objectives of Bilingual Education and relevant to the context of deaf children. Through the lessons learned during this research, it was possible to develop a participatory game design framework to support the Bilingual Education of deaf children, titled CAJEDUS-DP. This framework is intended for multidisciplinary teams and involves four partner profiles in game design: the producer, the game developers, the Bilingual Education teachers, and the deaf children. It is expected that through the use of CAJEDUS-DP, games that are relevant to the context of deaf children can be specified.

The entire PGD process provided various insights into the participants, mainly, in how to propose a way to specify games in an accessible and inclusive manner. Through the game design workshops, it was possible to analyse the children's participation in each game design activity and the benefits and challenges of their participation. According to the teachers, the workshops served as a means to reinforce and continue building knowledge about the program content taught, in addition to stimulating creativity, critical thinking, collaboration, and communication among the deaf children. The deaf children showed difficulties in collaborating and understanding abstract concepts, challenges that were also noted in previous studies involving children [Galvão *et al*., 2023].

Instead, as the workshops progressed and some activities were adapted, there were indications of improvement in the children's skills, particularly in communication and critical thinking. Furthermore, the children enjoyed participating in the workshops, bringing their unique perspectives and showing glimpses of all they are capable of when others believe in their potential.

The teachers also benefited from participating in the game design workshops during the PGD. Beyond the support for the teaching and learning processes provided by the workshops, the teachers expressed interest in using the media employed in the workshops. They appreciated the materials presented during the training and were eager to exchange ideas with the developers, even remotely. Additionally, they were pleased to have contributed ideas for the game "Casa dos Bichos" and were excited about the perspective of using the game in the future.

The developers, who were present at all steps of the PGD, were pleased to work with the teachers and the deaf children. They highlighted how the project helped them build self-confidence, as their ideas were listened to and respected, and how they were motivated to learn more about accessibility in games, Bilingual Education, and Libras. They also emphasized the potential of the game "Casa dos Bichos" and how they enjoyed using the CAJEDUS artifacts to support the construction of the GDD and the prototype.

Moreover, within the context of this study, it was possible to question and begin to deconstruct views that portray people with disabilities—whether children or adults—as incapable. Observing "Casa dos Bichos", a declaration expressed in the form of a game, suggests how inclusion and accessibility can play a fundamental role in the evolution of games, technology, and society more broadly.

This study's main contribution is the CAJEDUS-DP framework, a participatory game design model supporting bilingual education for deaf children. It expands on the CAJEDUS methodology by introducing a game producer as the leader. Structured into four steps, CAJEDUS-DP has the potential to support the specification of games that are more closely aligned with deaf children's experiences.

Although CAJEDUS-DP focuses on deaf children, the PGD process that served as its foundation also involved children with other disabilities, including intellectual and motor disabilities. Because it was developed through reflections drawn from such a diverse context—and because it is a framework, a generalizable structure—it can potentially be adapted to other contexts and to other types of disabilities. Furthermore, the framework can be implemented in schools with limited resources, since such constraints characterized the environment in which it was originally developed. As long as the school has basic stationery supplies and at least one mobile phone or computer, it may be possible to carry out activities similar to those conducted during the PGD, depending on the specific context and available support.

Key outcomes include the GDD and prototype of "Casa dos Bichos", a 2D mobile adventure-simulation game where players care for zoo animals while learning about animals, numbers, and temporality in Libras. Additionally, the study presents 21 guidelines called DAP to assist in GDP mediations with deaf children, teachers, and developers. While tied to CAJEDUS-DP, these guidelines can be used independently and adapted for hearing children.

In the context of the seven Grand Research Challenges in HCI in Brazil [Pereira *et al*., 2024], this study aligns particularly with two of them. First, by valuing the representativeness and decision-making power of historically underrepre-

sented minorities, it directly connects with "Grand Challenge 3: Plurality and Decoloniality." Second, by highlighting the positive impacts of including participants' lived experiences and perspectives, as well as by incorporating cultural and expressive elements of deaf children into the game, the study also relates to "Grand Challenge 4: Socio-Cultural Impacts." In this way, the research contributes to current HCI issues while also offering insights for researchers, educators, and developers interested in working in contexts similar to that of this study.

Despite its contributions, this study presents some limitations. Not all partners were able to meet and collaborate simultaneously, which may have limited potential advancements and contributions. In addition, the parents/guardians of the deaf children did not play an active role during the PGD, which might have provided additional motivation for the children during the game design workshops. The small number of participants, as well as their withdrawal or absence during the PGD, also constituted a limitation. Furthermore, the TAM evaluation involved a very small number of developers and should therefore be interpreted with caution.

Considering the voluntary nature of participation, the physical distance between participants, and the time required to complete the PGD, these limitations were expected and were addressed as much as possible. In future opportunities, establishing clearer engagement agreements at the outset, offering flexible participation formats, and scheduling periodic check-ins may help mitigate developer withdrawal and maintain continuity within the team. Finally, it was not possible to delve deeper into, consolidate, implement, and evaluate the CAJEDUS-DP framework as extended in this paper.

For future work, we plan the implementation of the game specified during the PGD, "Casa dos Bichos", and its evaluation with deaf children. In this way, we hope to demonstrate that an educational game created with the participation of the target audience is more aligned with their interests and needs. In addition, we intend to develop another PGD project for an educational game to support Bilingual Education, this time using the CAJEDUS-DP framework.

Declarations

Authors' Contributions

Ludmilla Fernandes Oliveira Galvão is the main contributor and writer of this manuscript. Laura Sánchez García, Tanya Amara Felipe, Elaine Costa Honorato, José Cezar de Souza Filho, Candida Vieira Barbosa and Kael Rhuan Campos de Araújo participated in the conceptualization, validation of the study, review, and final editing. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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Availability of data and materials

1. "Casa dos Bichos" GDD: `https://drive.google.com/file/d/1Ccw5LBK3gyzat5d0FMhq4kyf0wtLt7tl/view?usp=sharing`
2. "Casa dos Bichos" prototype: `https://www.figma.com/proto/iQGyRgAkecAsNRqnUuiHQj/Casa-dos-bichos--Copy-?node-id=410-469&p=f&t=hbm1uFvZXvi2vNBd-1&scaling=min-zoom&content-scaling=fixed&page-id=103%3A23&starting-point-node-id=410%3A516`
3. CAJEDUS-DP artifacts: `https://drive.google.com/drive/folders/1r_pUrPniTKEElS89GNPwhEwuoEkeQthX?usp=drive_link`
4. TAM questionnaire: `https://drive.google.com/file/d/1myF4MJ2YCv0O4oFdFIEdqFZXPW-lXOqI/view?usp=sharing`

References

Akcaoglu, M. (2014). Learning problem-solving through making games at the game design and learning summer program. *Educational Technology Research and Development*, 62(5):583–600. DOI: 10.1007/s11423-014-9347-4.

Allsop, Y. (2012). Exploring the educational value of children's game authoring practices: A primary school case study. In *Proceedings of the European Conference on Games Based Learning*, pages 21–30. Available at: `https://www.researchgate.net/publication/284371934_Exploring_the_Educational_Value_of_Children's_Game_Authoring_Practices_A_Primary_School_Case_Study`.

Alves, A. G. (2017). *Eu fiz meu game: um framework para criação de jogos digitais por crianças*. PhD thesis, Universidade do Vale do Itajaí, Itajaí, Brasil. DOI: 10.12957/redoc.2020.50465.

Alves, A. G. and Hostins, R. C. L. (2019a). Desenvolvimento da imaginação e da criatividade por meio de design de games por crianças na escola inclusiva. *Revista Brasileira de Educação Especial*, 25:17–36. DOI: 10.1590/S1413-65382519000100002.

Alves, A. G. and Hostins, R. C. L. (2019b). Elaboração conceitual por meio da criação colaborativa e coletiva de jogos digitais na perspectiva da educação inclusiva. *Revista Brasileira de Educação Especial*, 25:709–728. DOI: 10.1590/s1413-65382519000400011.

Alves, A. G., Hostins, R. C. L., and Magagnin, N. M. (2021). Autoria de jogos digitais por crianças com e sem deficiências na sala de aula regular. *Revista Brasileira de Educação Especial*, 27. DOI: 10.1590/1980-54702021v27e0079.

Batista, L. d. S., Navarro, A. d. M., and Kumada, K. M. O. (2023). Análise sobre jogos digitais bilíngues para surdos: um caminho para o letramento e a inclusão digital. *Revista Brasileira de Informática na Educação*, 31(1):353–377. DOI: 10.5753/rbie.2023.2933.

Baytak, A. and Land, S. M. (2010). A case study of educational game design by kids and for kids. *Procedia-Social and Behavioral Sciences*, 2(2):5242–5246. DOI: 10.1016/j.sbspro.2010.03.853.

Baytak, A., Land, S. M., and Smith, B. K. (2011). Children as educational computer game designers: An exploratory study. *Turkish Online Journal of Educational Technology-TOJET*, 10(4):84–92. Available at:`https://www.tojet.net/articles/v10i4/1049.pdf`.

Benton, L., Vasalou, A., Gooch, D., and Khaled, R. (2014). Understanding and fostering children's storytelling during game narrative design. In *Proceedings of the 2014 conference on Interaction design and children*, pages 301–304. DOI: 10.1145/2593968.2610477.

Bettocchi, E., Klimick, C., and Perani, L. (2020). Can the subaltern game design? An exploratory study about creating a decolonial ludology framework through ludonarratives. In *Proceedings of DiGRA 2020 Conference: Play Everywhere*, pages 1–18, Tampere, Finland. DOI: 10.26503/dl.v2020i1.1218.

Brondino, M., Dodero, G., Gennari, R., Melonio, A., Pasini, M., Raccanello, D., and Torello, S. (2015). Emotions and inclusion in co-design at school: Let's measure them! In *Methodologies and intelligent systems for technology enhanced learning*, pages 1–8. Springer. DOI: 10.1007/978-3-319-19632-9_1.

Burguillo, J. C. (2010). Using game theory and competition-based learning to stimulate student motivation and performance. *Computers & Education*, 55(2):566–575. DOI: 10.1016/j.compedu.2010.02.018.

Camargo, C. S., Melo, G. C. O., and Araújo, S. M. G. (2022). Inclusão de alunos surdos no ensino regular. *Revista Científica FESA*, 1(20):195–210. DOI: 10.56069/2676-0428.2022.225.

Canteri, R. d. P. (2014). Diretrizes para o design de aplicações de jogos eletrônicos para educação infantil de surdos. Master's thesis, Universidade Federal do Paraná, Curitiba, Brasil. Available at:`https://hdl.handle.net/1884/35755`.

Clua, E. W. G. and Bittencourt, J. R. (2004). Uma nova concepção para a criação de jogos educativos. *Simpósio Brasileiro de Informática na Educação*, 36. Scientific journal.

Costa, C., Tyner, K., Henriques, S., and Sousa, C. (2017). Games for media and information literacy–developing media and information literacy skills in children through digital games creation. *EDULEARN 17 Proceedings*, pages 2997–3004. DOI: 10.21125/edulearn.2017.1627.

Cruz, A. M., Miranda, J., Rossi, H., Maia, M. C., Mojon, Q. H., and Felipe, T. A. (2015). Plano anual para educação infantil bilingue para crianças surdas - 4 e 5 anos. Available at:`https://drive.google.com/file/d/1sd3R_3rBEUX4DT9iT8euveHRVffr_ILG/view?usp=sharing`.

Davis, F. D. (1985). *A technology acceptance model for empirically testing new end-user information systems: Theory and results*. PhD thesis, Massachusetts Institute of Technology, Cambridge, United States of America. Available at:`https://dspace.mit.edu/handle/1721.1/15192`.

Dele-Ajayi, O., Shimwell, J., Emembolu, I., Strachan, R., and Peers, M. (2018). Exploring digital careers, stereotypes and diversity with young people through game design and implementation. In *2018 IEEE Global Engineering Education Conference (EDUCON)*, pages 712–719. IEEE. DOI: 10.1109/EDUCON.2018.8363301.

Dodero, G., Gennari, R., Melonio, A., and Torello, S. (2014). Towards tangible gamified co-design at school: Two studies in primary schools. In *Proceedings of the first ACM SIGCHI annual symposium on Computer-human interaction in play*, pages 77–86. DOI: 10.1145/2658537.2658688.

Dodero, G. and Melonio, A. (2016). Guidelines for participatory design of digital games in primary school. In *Methodologies and Intelligent Systems for Technology Enhanced Learning*, pages 41–49. Springer. DOI: 10.1007/978-3-319-40165-2_5.

Druin, A. (2002). The role of children in the design of new technology. *Behaviour and information technology*, 21(1):1–25. DOI: 10.1080/01449290110108659.

Druin, A., Stewart, J., Proft, D., Bederson, B., and Hollan, J. (1997). Kidpad: A design collaboration between children, technologists, and educators. In *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems*, pages 463–470. DOI: 10.1145/258549.258866.

Fails, J. A., Guha, M. L., and Druin, A. (2013). Methods and techniques for involving children in the design of new technology for children. *Foundations and Trends in Human-Computer Interaction*, 6(2):85–166. DOI: 10.1561/1100000018.

Felipe, T. A. (2006). Políticas públicas para a inserção da libras na educação de surdos. *Revista Espaço*, (25-26):33–47. Available at:`https://seer.ines.gov.br/index.php/revista-espaco/article/view/1056`.

Felipe, T. A. (2007). *Libras em Contexto: Curso Básico: Livro do Estudante*. 8ª edição, Rio de Janeiro : WalPrint Gráfica e Editora. Available at:`http://www.librasgerais.com.br/materiais-inclusivos/downloads/libras-contexto-estudante.pdf`.

Ferreira, E. C. (2023). Refletindo sobre a inclusão escolar: O que é capacitismo? *Revista Científic@ Universitas*, 10(1):146–157. DOI: 10.29327/2276101.10.1-9.

Filippo, D., Pimentel, M., and Wainer, J. (2011). Capítulo 23: Metodologia de pesquisa científica em sistemas colaborativos. In Pimentel and Fuks [2011], pages 379–404. Available at:`https://sistemascolaborativos.uniriotec.br/wp-content/uploads/sites/18/2019/06/SC-cap23-metodologia.pdf`.

Galvão, L., García, L. S., and Felipe, T. A. (2023). A systematic mapping study on participatory game design with children. In *Proceedings of the XXII Brazilian Symposium on Human Factors in Computing Systems*, IHC '23, Maceió, Brazil. Association for Computing Machinery. DOI: 10.1145/3638067.3638078.

Galvão, L. (2020). CAJEDUS: Uma metodologia para concepção de jogos educativos para crianças surdas baseados em objetivos de aprendizagem da educação infantil. Master's thesis, Universidade Federal do Paraná, Curitiba, Brasil. Available at:`https://acervodigital.ufpr.br/handle/1884/67123`.

Galvão, L. (2024). *CAJEDUS-DP: Um framework para a especificação participativa de jogos de apoio à educação bilíngue de crianças surdas*. PhD thesis, Universidade Federal do Paraná, Curitiba, Brasil. Available at:`https://acervodigital.ufpr.br/handle/1884/88606`.

Gennari, R., Melonio, A., Raccanello, D., Brondino, M., Dodero, G., Pasini, M., and Torello, S. (2017). Children's emotions and quality of products in participatory game design. *International journal of human-computer studies*, 101:45–61. DOI: 10.1016/j.ijhcs.2017.01.006.

Guha, M. L., Druin, A., and Fails, J. A. (2008). Designing with and for children with special needs: An inclusionary model. In *Proceedings of the 7th international conference on Interaction design and children*, pages 61–64. DOI: 10.1145/1463689.1463719.

Heleno, L. L., Reque, M., Calomeno, C., and Bueno, J. (2019). "As Sereias da Ilha do Mel": o design centrado no usuário para desenvolvimento de projeto gráfico de livro para apoio ao letramento de crianças surdas. In *Anais do 9° Congresso Internacional de Design da Informação*, volume 6 of *Blucher Design Proceedings*, pages 2622 – 2632. DOI: 10.5151/9cidi-congic-6.0053.

Iversen, O. S., Smith, R. C., and Dindler, C. (2017). Child as protagonist: Expanding the role of children in participatory design. In *Proceedings of the 2017 conference on interaction design and Children*, pages 27–37. DOI: 10.1145/3078072.3079725.

Jérôme, D., Capucine, B., De Nancy, R. D. L., Lara, H., *et al*. (2019). Collaborative game design with children with hemophilia as a tool for influencing opinions about physical activity at school. *Psychology in Russia: State of the art*, 12(4):159–171. DOI: 10.11621/pir.2019.0410.

Jones, C., McIver, L., Gibson, L., and Gregor, P. (2003). Experiences obtained from designing with children. In *Proceedings of the 2003 conference on Interaction design and children*, pages 69–74. DOI: 10.1145/953536.953547.

Kalmpourtzis, G. (2018). Connecting game design with problem posing skills in early childhood. *British journal of educational technology*, 50(2):846–860. DOI: 10.1111/bjet.12607.

Kalmpourtzis, G. (2019). Developing kindergarten students' game design skills by teaching game design through organized game design interventions. *Multimedia Tools and Applications*, 78(14):20485–20510. DOI: 10.1007/s11042-019-7393-y.

Kalmpourtzis, G., Vrysis, L., and Veglis, A. (2016). Teaching game design to students of the early childhood through forest maths. In *2016 11th International Workshop on Semantic and Social Media Adaptation and Personalization (SMAP)*, pages 123–127. IEEE. DOI: 10.1109/SMAP.2016.7753396.

Korte, J. (2017). *YoungDeafDesign: A method for designing with young Deaf children*. PhD thesis, Griffith University, Brisbane, Australia. DOI: 10.25904/1912/3087.

Korte, J., Potter, L. E., and Nielsen, S. (2017). How design involvement impacts deaf children. In *2017 International Conference on Research and Innovation in Information Systems (ICRIIS)*, pages 1–6. IEEE. DOI: 10.1109/ICRIIS.2017.8002527.

Mansilla, J. C., Betancur, L. M., and Lambach, C. Q. (2019). Transmedial worlds with social impact: Exploring intergenerational learning in collaborative video game design. *Journal of Childhood Studies*, pages 103–110. DOI: 10.18357/jcs00019337.

Marengo, A., Pagano, A., and Ladisa, L. (2016). Mobile gaming experience and co-design for kids: Learn german with Mr. Hut. In *Proceeding of the 15th European Conference on e-Learning (2016) ECEL, Valbonne, France, FR*, pages 467–475. Available at:`https://www.academia.edu/41172531/Mobile_Gaming_Experience_and_Co_Design_for_Kids_Learn_German_With_Mr_Hut`.

Martins, R. S., Raulino, F., Burlamaqui, A., and Burlamaqui, A. (2019). SGDDEdu: A model of short game design document for digital educational games. *International Journal for Innovation Education and Research*, 7(2):167–180. DOI: 10.31686/ijier.Vol7.Iss2.1335.

MEC (2017). Base Nacional Comum Curricular: Educação é a base. Available at:`http://basenacionalcomum.mec.gov.br/`.

Meirelles, V. and Spinillo, A. G. (2004). Uma análise da coesão textual e da estrutura narrativa em textos escritos por adolescentes surdos. *Estudos de Psicologia (Natal)*, 9:131–144. DOI: 10.1590/S1413-294X2004000100015.

Melo, A. M., Baranauskas, M. C. C., and de Matos Soares, S. C. (2008). Design com crianças: Da prática a um modelo de processo. *Revista Brasileira de Informática na Educação*, 16(01). DOI: 10.1590/S1413-294X2004000100015.

Melonio, A. (2018). Is participatory game design effective over time? Let's assess its products. In *Digital technology and organizational change*, pages 81–93. Springer. DOI: 10.1007/978-3-319-62051-0_8.

Novak, J. (2012). *Game development essentials: an introduction*. Cengage Learning, 3rd edition. Book.

Oliveira, C. M. M. d. (2016). O Moodboard Como Estímulo à Inovação no Processo de Codesign: Estudo de Caso em uma Startup. In *Anais do 12º Congresso Brasileiro de Pesquisa e Desenvolvimento em Design*, volume 9 of *Blucher Design Proceedings*, pages 876–887. Blucher. DOI: 10.5151/despro-ped2016-0075.

Oliveira, G. A. A. d., de Bettio, R. W., Rodarte, A. P. M., Ferrari, F. B., *et al*. (2014). Grubibots educational: A game for teaching algorithms in basic education. In *Brazilian Symposium on Computers in Education (SBIE)*, volume 25, page 584. DOI: 10.5753/cbie.sbie.2014.584.

Palavissini, C. F. C. (2022). Perspectivas e estratégias realizadas por docentes durante a pandemia de covid-19 no atendimento educacional especializado de estudantes surdos. Master's thesis, Universidade Estadual do Oeste do Paraná, Cascavel, Brasil. Available at:`https://tede.unioeste.br/handle/tede/6094`.

Pereira, R., Darin, T., and Silveira, M. S. (2024). GranDIHC-

BR: Grand Research Challenges in Human-Computer Interaction in Brazil for 2025-2035. In *Proceedings of the XXIII Brazilian Symposium on Human Factors in Computing Systems*, pages 1–24. DOI: 10.1145/3702038.37020.

Perry, G. T., Timm, M. I., Silvestrim, F. G., and Schnaid, F. (2007). Necessidades específicas do design de jogos educacionais. In *Anais do Simpósio Brasileiro de Jogos e Entretenimento Digital (SBGAMES 2007)*, pages 7–9. Available at:https://www.sbgames.org/papers/sbgames07/artanddesign/short/ads2.pdf.

Piaget, J. and Duckworth, E. (1970). Genetic epistemology. *American Behavioral Scientist*, 13(3):459–480. DOI: 10.1177/000276427001300320.

Pimenta, G. D. F. and Silva, A. B. d. (2021). SUAP: uma reflexão sobre acessibilidade digital para surdos e deficientes visuais. *Revista Informação em Cultura (RIC)*, 3(1):05–25. DOI: 10.21708/issn2674-6549.v3i1a8596.2021.

Pimentel, M. and Fuks, H. (2011). *Sistemas Colaborativos*. Elsevier, Rio de Janeiro, 1st edition. Available at:https://sistemascolaborativos.uniriotec.br/.

Pressman, R. S. and Maxim, B. R. (2021). *Engenharia de Software*. Porto Alegre: McGraw Hill do Brasil LTDA, 9th edition. Book.

Ribeiro, D. (2019). *Lugar de Fala*. São Paulo: Pollen Editorial Production LTDA, 1st edition. Book.

Rogers, S. (2012). *Level Up! The Guide to Great Video Game Design*. São Paulo: Blucher, 3rd edition. Book.

Schell, J. (2019). *The Art of Game Design: A book of lenses*. AK Peters/CRC Press, 3rd edition. Available at:https://www.sciencedirect.com/book/monograph/9780123694966/the-art-of-game-design.

Schuytema, P. (2008). *Game Design: A practial Approach*. Cengage Learning, 1st edition. Book.

Sjöberg, J. and Brooks, E. (2020). Problem solving and collaboration when school children develop game designs. In *Interactivity, Game Creation, Design, Learning, and Innovation*, pages 683–698. Springer. DOI: 10.1007/978-3-030-53294-9_52.

Sommerville, I. (2018). *Engenharia de Software*. São Paulo: Pearson Education do Brasil, 10th edition. Available at:https://archive.org/details/sommerville-engenharia-de-software-10e/page/296/mode/2up.

Stone, B. G., Mills, K. A., and Saggers, B. (2019). Online multiplayer games for the social interactions of children with autism spectrum disorder: A resource for inclusive education. *International Journal of Inclusive Education*, 23(2):209–228. DOI: 10.1080/13603116.2018.1426051.

Susman, G. I. and Evered, R. D. (1978). An assessment of the scientific merits of action research. *Administrative science quarterly*, pages 582–603. DOI: 10.3280/SO2022-002006.

Tan, J. L., Goh, D. H.-L., Ang, R. P., and Huan, V. S. (2011). Child-centered interaction in the design of a game for social skills intervention. *Computers in Entertainment (CIE)*, 9(1):1–17. DOI: 10.1145/1953005.1953007.

Thiollent, M. (2011). *Metodologia da Pesquisa-Ação*. São Paulo: Cortez Editora, 18th edition. Available at:https://konektacommerce.nyc3.cdn.digitaloceanspaces.com/TEXT_SAMPLE_CONTENT/metodologia-de-pesquisa-acao-89057-1.pdf.

Valente, A. and Marchetti, E. (2017). From cards to digital games: Closing the loop. In *2017 6th IIAI International Congress on Advanced Applied Informatics (IIAI-AAI)*, pages 507–510. IEEE. DOI: 10.1109/IIAI-AAI.2017.50.

Voulgari, I., Vouvousira, S., and Fakou, A. (2020). A game about our neighbourhood: A case study of participatory game design with pre-school children. In *International Conference on the Foundations of Digital Games*, pages 1–5. DOI: 10.1145/3402942.3409612.

Zabot, D. (2019). SPIDEKIDS: Adapting an interaction codesign process for deaf or hard of hearing children participation. Master's thesis, Universidade Federal da Bahia, Salvador, Brasil. Available at:https://repositorio.ufba.br/handle/ri/37378.

Zabot, D., Andrade, S., and Matos, E. (2019). Game design participativo com crianças surdas e com deficiência auditiva: Uma experiência no ensino fundamental. In *Anais do I Workshop sobre Interação e Pesquisa de Usuários no Desenvolvimento de Jogos*, pages 49–58. SBC. DOI: 10.5753/wiplay.2019.7839.