oRedesigning for Accessibility: Design Decisions and Compromises in Educational Game Design

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Abstract

Accessibility in educational media focuses on removing barriers based on learners' varied needs. In educational games, players' diverse needs can impact a wide variety of design strategies. This study focuses on the process used by one design team to prioritize accessibility in the redesign of their older educational games, while creating a process to inform development of new games. The study provides a framework for thinking about games and accessibility vis-a-vis educational games, and documents an action research study with the development team of the Math Snacks project. Using a participatory and qualitative approach, researchers provide a description of the team redesign process to address accessibility: how the team reviewed accessibility gaps in their games; made specific design choices in redesigning for accessibility; and determined which actions could make the games more accessible. The work yielded a process other design teams can implement in their review of existing games.

Keywords: *Educational Games, Design Process, User Needs, Math Snacks*

1. Introduction

The games industry is making important gains in making games accessible. *The Last of Us Part 2* [1] launched with more than 60 accessibility settings – just one example of the industry's increasing efforts to make games accessible to more players. Recommendations for good practices in game accessibility are available online [2-5]; the issue has gained more attention from conference organizers (e.g., Games for Change[1], IGDA-Gaconf[2]); and on social media, members of the community, accessibility advocates/specialists, and game developers frequently engage in discussion about how developers can design with accessibility in mind.

As the movement to improve games' accessibility gains momentum in the commercial games industry, developers of educational or transformational games have the same needs as well as additional challenges related to educational content and learning approaches. Games which seek to change the player in a meaningful way must balance learning goals and content-specific educational approaches with the needs of users. For example, mathematics is traditionally taught with visual guides such as maps and graphs. Translating these mechanics into gameplay can be challenging when those visuals require accommodations for different users. Developers of educational games must address certain

[1] festival.gamesforchange.org
[2] gaconf.com/conference/

aspects of accessibility recommended for all games, while also addressing additional levels of design considerations specific to the educational content.

Ideally, accessibility should guide game design early in the process, and this should continue throughout development. However, this ideal should not prevent developers from updating their games or redesigning them when given an opportunity.

This applied research article provides an operational lens to developers and researchers in moving the educational games field towards more inclusive and accessible games. It assumes that accessible games provide value in education, and that game developers should strive to reach all audiences with their learning tools, both to address possible legal mandates regarding funding of those games and to be more responsive for all learners. Given that, this research demonstrates that even when developers prioritize accessibility in their design, they must make difficult choices due to budget, time, and conflicts wherein an accommodation for one user can create an obstacle for another user. This research reviews the work of one educational game design studio in translating a suite of previously released and highly successful math games to make them more accessible. This research is participatory in nature: it reflects the engagement and actions of developers revising a game to make it more accessible, to capture realistic design complexity and difficult decisions. In having a "before" and "after" picture of a game that was made more accessible, this research demonstrates specific changes clearly applied and visible. It also presents the framework through which a team reviewed and updated their game and provides practical recommendations to help other developers make their games more accessible. Finally, the nature of participatory research offers a clear process of how one studio made their decisions, offering that as a framework for others in the field.

2. *Accessibility From a Design Perspective*

In general, accessibility determines a set of characteristics which developers design into a product, environment, or system. The goal is to provide access to as many people as possible in the widest range of capabilities and circumstances for use [6-8]. All users, even those without disabilities, need a degree of accessibility to properly use and interact with a product [9]. For example, many individuals who do not use a wheelchair benefit from ramps: they may be unstable walking on steps, may need a more gradual incline, or may use a cart or case which has wheels. Users who are on a spectrum of need may not reflect the greatest or most obvious case, and may be overlooked entirely: for example, when focusing only on the most obvious need, such as a user who is blind, users with low or poor vision, contrast issues, or color blindness may not be considered. The lack of inclusion when designing products creates barriers and prevents many users from using products, systems, environments, etc.

Accessibility in games has been gaining attention and relevance among developers and researchers [9-11]. Besides academic publications, initiatives include orientations on how to approach game accessibility, such as those from the Independent Game Developers Association (IGDA) [2] and the AbleGamers Foundation's practical guide to game accessibility [12]. Additional guidelines include online sets of free resources from AbleGamers' Charity to help game developers with accessibility[3] [3]; the reference list for inclusive game design[4] created collaboratively by a group of studios, specialists, and academics [4]; the CIPT's accessibility reference guides[5] [5]; and the Xbox accessibility guidelines[6] [13].

In addition to these important contributions, some accessibility issues in games still need further investigation [14], such as how accessibility impacts the quality of educational digital games [9]. There is a gap in the literature regarding how to make interactive

[3] Available online in: <https://accessible.games>.
[4] Available online in: <http://gameaccessibilityguidelines.com>
[5] Available online in: <https://caniplaythat.com/accessibility-reference-guides/>
[6] Available online in: <https://docs.microsoft.com/en-us/gaming/accessibility/guidelines>

educational tools more accessible and how development teams can shape their design process to consistently address accessibility in educational media.

3. *Barriers in Non-Accessible Games*

Developers willing to make their games more accessible can identify possible barriers that players may face. The interaction between players and the game system happens in a repeated cycle until the game ends: the player receives stimuli from the game (visual, auditory, tactile), determines their responses (cognitive decisions), then provides input to communicate their response (players' action through the game's physical and virtual interface) [15]. In the game interaction, accessibility barriers can make it difficult or impossible for some players to perform the game activities.

Players with some disabilities can face three possible barriers when playing a game:

1. **The player is unable to capture stimuli**. For example, in the game Tetris, when a block falls on the screen, the game offers players stimuli through visuals on the screen and sound. Blind players are not able to receive the visual stimuli, and the sound stimuli are not enough to allow proper gameplay.
2. **The player is unable to determine responses.** Players need to think about how to change the blocks' orientation and position to best fit in the playing field. Players with problem solving or visual comprehension issues will face some barriers to determining responses, possibly because of the time limitations offered by gameplay.
3. **The player is unable to properly use the input interface.** Players need to use the arrow keys to move/rotate the block; to drop it faster they use the spacebar. Players with some motor limitation may face some barriers to moving the blocks, particularly if they aren't given the opportunity to change the control mechanism to something they can use.

Multiple disability classifications (Table 1) help categorize types of barriers. Only Gilbert [16] focuses on digital interface in general, while the others focus on digital games. Bierre et al. [4] added a fifth category about technology limitations, which is not within the scope of the work addressed in this paper.

Table 1. *Disability classification. Source: the authors.*

Gilbert (2019) [16]	Aguado-Delgado et al., (2018) [14]	Yuan, Folmer & Harris (2011) [15]	Bierre et al., (2004) [4]
Visual	Sensory disability (Visual and Auditory)	Visual impairment	Visual
Hearing		Hearing impairment	Auditory
Motor	Motor disability	Motor impairment	Mobility
Cognitive	Cognitive disability	Cognitive impairment	Cognitive disabilities
/	/	/	Other issues (technology)

Specific to educational games, four key areas serve as lenses to think about barriers:

- **Visual disability**: The person has a certain degree of vision loss, such as low vision, legal blindness, complete blindness, or color blindness.
- **Hearing disability:** The person has a certain degree of loss in the ability to hear, either from one or both ears, such as deafness, hearing loss, or being hard of hearing.
- **Motor disability:** The person has a limitation or a loss in mobility function and muscle control, such as arthritis, paralysis, repetitive stress injury, neurological disorders, age-related issues, lack of mobility, lack of steadiness, or cerebral palsy.
- **Cognitive disability:** The person has a mental or psychological disorder, which causes a deficit in their ability to learn, process or remember information, communicate, have social interactions, and make decisions. This type of disability can be a learning disability, intellectual disability, or involve a specific cognitive ability (e.g., memory, language processing). It includes developmental disabilities (e.g., dyslexia, dyscalculia), attention deficit hyperactivity disorder (ADHD), Alzheimer's or senility because of aging, the autism spectrum, Down syndrome, and other mental retardation. Some people with cognitive issues need information presented in literal terms for language comprehension. Their thinking is more concrete, rather than abstract [17]. For instance, when playing a game, players with autism may have difficulty understanding ambiguous or metaphorical words or irony/sarcasm. Abstract visuals also can cause some interpretation problems.

Disabilities don't exist in discrete boxes: they are often co-diagnosed, with any given user having needs across several different types of issues. Each area of need exists within a spectrum, from low to high, and there may be specific types within each category. Additionally, the social model of disability defines disability as a mismatch between the design and the person's needs, instead of as a personal health condition [18]. Through the lens of this model, accessibility lives in the product and not in the user: a bad design that does not match users' needs disables people, and a good design that matches users' needs enables people.

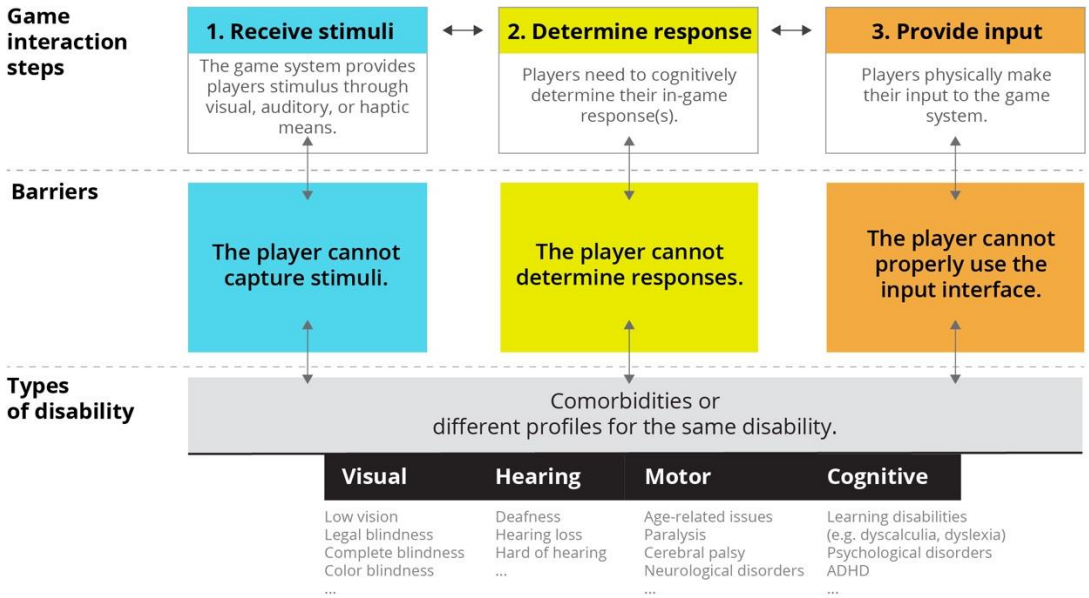

Figure 1. *Graphic synthesis connecting the game interactions, accessibility barriers and types of disabilities. Source: The authors based on [15].*

4. *Case Study: Redesign of Previously Developed Games by a Production Team*

Researchers (faculty members, content experts, instructional designers) and developers (programmers, artists, web developers) from the Learning Games Lab at New Mexico State University have been developing games for 20 years. As a university-based development studio, this team develops educational games, virtual labs, videos, animations, and other interactive tools as part of its outreach and extension mandate. It is not a student studio or academic program, and products are not made by students or as class work. It functions as a non-profit studio with a team of 8 to 12 professional programmers, artists, and developers. The team also includes research faculty who guide development of the products. All products are research informed: user testing and other types of formative research inform the content, approach and usability of final games; and participatory research engages all developers in reviewing the processes they use to develop games, to improve future work. The team conducts post-mortems on completed games, reviewing processes that need revision or improvement. The team also reviews their previously published games that are in use, identifying necessary changes regarding delivery (such as updates to operating systems or browsers), representation and diversity (such as more mature thinking regarding cultural appropriation, stereotypes, or tropes), and accessibility (such as increased capabilities of delivery modes).

With the implementation of the Web in everyday society, the studio has worked to maintain basic accessibility delivery since the early ’90s. Basic accessibility features were added with the use of fonts, text size, colors, closed captioning, limited audio, alt tags on images, tables, forms, and navigational structures, whenever this could be implemented across products using available technology. This approach guided development of the *Math Snacks* suite of games starting in 2009. The team applied what was then known about accessibility in games, and these basic features were implemented in the eight games in the suite, published for web and mobile distribution from 2009 through 2019.

In 2017 in the United States, educational institutions and universities funded by federal agencies were required to bring all digital media products into compliance under Section 508 of the Rehabilitation Act of 1973 – US by January of 2018 [19]. Section 508 aims to enhance accessibility to information and communications technology (ICT) for people with disabilities, updating the requirements to be abreast of constant technological advancements and aligning them with other standards in the US and abroad.

After reviewing their products, the Learning Games Lab team was able to remediate most web-based content to meet the extensive guidelines and strategies documented for images, text, audio, and video. However, few recommendations were provided on making interactive materials such as games accessible. The Learning Games Lab team launched a new research project to identify what best practices were and how others in the industry were designing affordances to meet this mandatory compliance measure in games and interactive media programs. They began investigating the work of other developers, community organizations and accessibility experts to inform their own development practices, and began revisiting previously developed games to improve their accessibility. In doing so, they established a framework for thinking about accessibility in their game design; used previously developed games as a model for thinking through specific changes to mechanics, interface, and visual design; identified barriers and challenges for making necessary changes; and refined processes for revising existing games and developing new games which are more accessible.

5. Methodology

This study documents action research used to carry out practice-led research. The team actively worked to create change and followed a self-reflective spiral cycle of *planning*, *acting*, *observing*, and *reflecting* [20],[21]. Action research is meant to be a continuous, ongoing, and iterative process. This study describes the action research conducted with the first five games developed in *Math Snacks*.

5.1. Reviewing Games in the Math Snacks Suite: Identifying Necessary Changes

The *Math Snacks* project[7] included the development of animations, games, and apps to help learners in grades 5 through 8 (aged 10 to 14) to better understand math concepts. Children using the suite showed significant improvements in their understanding of mathematics concepts [22]. The first set of five games from the project were completed in 2015 in Adobe Flash and were still very popular leading up to the web plug-in being discontinued in 2020. As the team reviewed all five games (*Ratio Rumble, Gate, Pearl Diver, Game Over Gopher, and Monster School Bus*) in anticipation of reprogramming each for redistribution, accessibility became a major focus. This was a result both of the new 508 compliance regulations and increased awareness of needs by developers. The team applied the same review process to all five games. Researchers elected to review the game *Monster School Bus* as the best example of the process for this case study, with the clearest examples of changes made which are extensible to other developers.

Monster School Bus allows students to visualize the grouping of numbers using ten-frame, allowing users to see in groups of ten with whole numbers, then expanding that thinking to include simple fractions and decimals. Players need to fill up the school bus with [fictional] monster kids from different neighborhoods and to deliver them to the school. Players must drop off full busloads of ten kids to achieve a perfect score, pairing seven kids from one stop with three from another stop, for example. Each neighborhood has differently sized monster kids. In one level, they may have to add four half-sized monsters to eight full-sized to take all ten seats on the bus, where another level asks them to pick up monster slime in digital equivalents. When players deliver a full load to school, flasks of green potion appear on the road. If players smash a green flask, a building in the neighborhood transforms into its "Rocked-Out" version, adding in a bit of fun and visual stimulation.

The redesign process of *Math Snacks* engaged the entire team, which brought in different perspectives, provided immersion and education in accessible design, and was intended to capture the expertise of each team member. Research members of the team elaborated a literature review of current scholarship and recommendations about accessibility, and provided the framework offered in this paper as a lens to think through barriers the game would offer. The team also sought guidance from other developers, studios, and accessibility advocates/specialists. This knowledge was not centralized in one individual; rather the entire team shared current knowledge on accessibility and how it could help the team in its design decisions. This is a key aspect of the ongoing process in the Learning Games Lab: the responsibility for accessibility (both implementation and continued learning) is distributed among all team members, not in one leader. The team also engaged in interviews with others who had expertise in accessibility, including Matt Kaplowitz from Bridge Multimedia and Mark Barlet from AbleGamers. The team discussed what they knew about available resources and the current state of accessibility in educational games. Kaplowitz then shared specific feedback from his team on the *Math Snacks* games in general, and more specifically on *Monster School Bus.* This feedback

[7] mathsnacks.org – The games and animations are available in English and Spanish.

established the first basis of the team's larger review of the game, and many of their recommendations are reflected in the findings listed below.

The team set goals for the redesign process that acknowledged their budget, deadline, and technological constraints. Together, the team outlined goals for the accessibility project: to redesign existing games slated for updating from the *Math Snacks* suite, by revising them and incorporating identified design changes to make them more accessible; to improve the team design process by addressing accessibility needs and demands from more clearly defined categories of users; and to share accessibility learning outcomes of the design process with other studios and researchers.

The team carried out several meetings for each game with an intended focus on redesign for accessibility. These meetings allowed the team to conduct **in-depth product review and analysis,** which considered the knowledge learned from the consultant and the perspective and expertise of each team member. For *Monster School Bus*, for example, two members of the design team (one programmer, one designer) provided an initial analysis to foster discussion by the larger team. The team used the four disabilities areas (visual, hearing, motor, cognitive) as lenses, to ensure each different set of needs was addressed. The two-person team shared their findings with the larger team, which added items as necessary, and discussed the list in terms of doability, benefits of the change, and costs for the implementation. Additional follow-up meetings checked the process of implementation of each game. The team used a similar process for the other games of the *Math Snacks* suite.

The main difficulty Learning Games Lab developers have regarding testing the accessibility of their games is in finding the wide range of users required to test all the accommodations for different needs. On occasion, we are able to benefit from the insights of users who have specific needs, such as an intern who was both an avid gamer and had cerebral palsy, and a series of users with low vision who tested games. The team was careful to remember that although these users can address their own experiences well, one should not assume they represent all users. Some users may address their visual issues using one type of browser, where others may use a different type of tool; a user with specific motor needs may use a completely different setup than another user. The studio recognizes this as a need, and recognizes the challenge of allocating resources to internal quality assurance testing for all issues regarding accessibility. They have developed a guide for doing a limited degree of QA testing based on their findings so far. In addition to quality assurance, the team would appreciate doing some initial user testing with individual users, but don't have access to a wider range of users due to location. Until they can have access to these users or find a partner able to facilitate this testing, they address this limitation by replacing observation with the **consultation of those who have observed other users**. The studio has interacted with Bridge Multimedia[8] and AbleGamers[9] as accessibility specialists. Based on their expertise and knowledge of the user's needs, specialists could identify issues and improvements in the game.

The Learning Games Lab **documented all the steps, meetings, and decisions during the accessibility redesign.** This documentation provided the team resources to reflect on its own practice and record learning outcomes for future projects. Besides the team's self-designed reflection process, the team provided a set of recommendations which has the potential to benefit other studios and the game community.

6. *Findings: Accessibility Lessons from Monster School Bus*

This section shares some of the most relevant recommendations and details how they improve gameplay and provide access to more players.

While developers reviewed each of the games, considering each of the four areas of disability, they began thinking about how to implement required changes from a

[8] bridgemultimedia.com
[9] ablegamers.org

development perspective. After reviewing all the recommendations across the entire suite of games, trends emerged regarding where changes needed to be made, such as interface issues specific to graphics or characters. These categories began as a natural grouping mechanism for reviewing changes and checking the proposed changes against changes that were made. Throughout the process, these recommended changes became action statements, where developers could articulate the broad goal for all games in development, refining into more specific changes for each game. This grouping is shared to present both the overall recommendation and the specific changes recommended for *Monster School Bus.*

6.1. Digital Interface

Recommendation: Make interface buttons visible, consistent, and logical with standard interface conventions. The team identified the visibility of the UI elements as a visual accessibility limitation in the game. Some of the buttons in the Heads-Up Display (HUD), used for controlling basic settings and audio features, were designed to be small enough to reduce distractions but were so small that it was hard or even impossible for players with low vision to interact with them. The function of some of these buttons could be unclear for users with specific deficits in cognition. For example, the "X" button was previously used to allow players to leave the game (Figure 2), but this could be interpreted more literally by some users as simply an "X". The team discussed using a rollover zoom feature, allowing players a better visualization of the icons without necessarily using large icons in the interface all the time. However, this solution had the potential to bring barriers for players with motor disabilities, who are often unable to use rollovers. This is a good example of how some accessibility recommendations can conflict with other recommendations: the corner UI buttons required improvements for size, contrast, understandability, and motor function, but did not present a single, clear solution for all of them. Ultimately, the team increased the size of these game buttons, increased the space between each element, intensified the contrast between the icon and the background, and added a non-essential rollover feature with labels to offer context. The rollovers are now triggerable with a keyboard, and readable even without the rollovers. The "X" button was replaced by a home button – a house icon (Figure 2), which is a common convention.

Figure 2. Previous and revised version of the game's Heads-Up Display buttons. The button "Q" used to choose the game image quality (in Flash) was removed. This function is not necessary for the Unity version.

Recommendation: Use good letter spacing and prioritize readability when choosing the font. Use a clear, direct, and simple font. The team identified the game typography in menus and narrative dialogues as an accessibility limitation for visuals in the game. The 'grunge-style' of typography used in the menus omits some parts of individual letters, and uses a tight spacing of letters (Figure 3 – left). These typography issues could

make it hard for players with low vision or dyslexia. The team replaced all the game fonts, choosing clear and simple fonts, providing good letter spacing and readability (Figure 3 – right). The team also shortened the lines of narrative dialogue and increased the contrast between the text and the background in the menus, making it easier to read [23]. The original typography was retained in the title of the game to support the visual narrative, but it was changed in text that provided essential information for navigation. This supports players' visualization and processing needs for the game's text-based information.

Figure 3. (Left) Previous version of the game title screen; (Right) Revised version of the game title screen.

Recommendation: Use direct and encouraging language. Avoid ambiguity, abstract words, and harsh language. In trying to offer humor through the narrative of a grumpy school bus driver, the game instructions and narrative lacked clarity about players' actions. It also offered language that was too harsh. The team rewrote the game narrative to make it more explicit regarding game actions that players need to take. The team added a back arrow, giving players full control over the narrative presentation (Figure 4 – right). They also reviewed text for unintentionally harsh language, replacing it with more positive phrasing, and avoiding ambiguous words. These changes may benefit all players, but certainly improve processing of the game by those with cognitive disability.

Figure 4. (Left) Previous version of the game narrative text; (Right) Revised version of the game narrative text, with a backward arrow added, clearer font, and more specific and positively motivating language.

6.2. Physical Interface

Recommendation: Enable players' choice in control of the game, allowing them to remap game commands to alternative game controllers. While the previous version of the game allowed players to use a mouse or arrow keys to move the bus in the game, it did not provide keyboard control support to close windows or navigate through other aspects of the game, which could limit users with motor disability. The team added keyboard control for every window and scene of the game. With keyboard control, players can use the keyboard arrows to move within the interface and press enter to select something. To

progress in the narrative screen dialogue, players can click anywhere on the screen, rather than on a specific button. It is also possible to use the keyboard arrow to control the narrative back and forward and use the spacebar to skip. This change has the potential to make game controls better and easier for all players, mainly for those with motor needs. Finally, all keyboard controls are remappable to other keys.

6.3. Gameplay

Recommendation: Make all the visual game elements literal and easy to understand. Some users may struggle to understand icons, so it is important to make visual elements easy to follow for users with cognitive needs who have difficulty processing information. For example, as the player selected monsters to ride on the bus, monsters could move on and off the bus without a door opening or closing. That doesn't make sense to a literally minded player who expects to see a door opening. Some players with cognitive disabilities need literal reinforcement. They know that without an actual door opening, monster kids would not be able to exit the bus. As a solution, the team changed how the bus was represented, showing the bus door open and close. Players can open and close the door using a visual handle on the interface (Figure 5). This simple accessibility action improved gameplay by giving all users the ability to intentionally choose which kids to pick up and which to drive past, to pick up on a later trip. Previously, players would automatically pick up whatever monster kids they drove past, which did not encourage them to be mindful in using the 10-frame guide to fill a bus. This change improves the gameplay and allows players to have better functionality when picking up and delivering the kids as part of their intentional math decisions.

Figure 5. (Left) System showing players the closed bus door; (Right) System showing players the open bus door, explaining how monsters get on and off a bus.

Recommendation: Check the level progressions, providing scaffolded learning. The team identified the need for more levels in the worlds where the math content tends to be more difficult for learners, especially those with learning disabilities, such as dyscalculia [24]. The game starts with whole numbers, moving into simple fractions and then decimal numbers. Some players needed a more gradual transition, as simply seeing the additional place values can be overwhelming (moving from a whole integer of "2" to "2.5", which adds a new place value setting and makes the number different). The team added two new levels, one in each world, to help players move more gradually into decimals, adding tenths and hundreds (Figure 6). For example, instead of moving "2" to "2.5", it is easier for learners to move from "2.0" to "2.5" because the number of places is the same. Similarly, players can more easily interpret "0.50" compared to ".5", without feeling the stress of the additional place value. These levels use easy numbers to pair, allowing players to practice and understand the new content. This change has the potential to make the game better

cognitively for all players, especially for players with learning disabilities who need more time practicing to master an activity.

Figure 6. (left) Level preparing players to play using decimals; (right) Level preparing players to play with the whole unit equal to 1.0.

Recommendation: Make the representation consistent. The team standardized number representation in all levels. The decimal number representation used in some levels was difficult for players to understand, mainly for players with learning disabilities. To solve that, the team added "ones" or "tenths" to make the representation consistent (Figure 7 – right). For instance, the way decimals were written was changed from ".6" to "0.6" and ".2" to "0.2", depending on the level. In levels that have numbers that go to hundredths, the game now uses "0.20" instead of just ".2" to keep the consistency.

Figure 7. (left) Previous game number presentation; (right) Revised game number representation.

Recommendation: Time pressure is often used to increase challenge, but usually offers unfair challenges to those with a wide range of needs. Time pressure was previously used to have a player race the clock to deliver a full load to school. Players needed to be fast because the green potions (which transformed the buildings) disappeared quickly. This pressure can be frustrating to some players with limited motor skill, those using special key commands, or those who need a little more time to work through the puzzle. The team kept the same dynamic for a bonus item to create the magic effect but removed the time pressure. The flasks of potions will stay on screen till the player gets them (Figure 8). Although some players enjoyed the time challenge in the original version, this change encourages all players to be more mindful in solving the math aspect of the game, without rushing to meet a time mechanic. This change may benefit all players, especially those who need more time to move the bus or identify the best route to do so. Importantly, it improves math learning by encouraging more thoughtful reflection on problem solving by all players: the challenge is in the puzzle, not the timing.

Figure 8. The green flasks on screen.

Recommendation: Allow players to select the level of difficulty of the game. Previously the game required learners to play in sequence and unlock levels one at a time. This limitation could frustrate players who want to learn about a specific number set, instead of playing the whole game, as well as those who feel that the initial levels are not challenging enough for their skills. Players will face different challenges based on their skills. For instance, some players may need more practice with certain math concepts, and others may find specific layouts to be a greater challenge in moving through the motor skills required. An open level system helps support various levels of learning and cognitive issues. By removing the requirement that levels be unlocked, players can progress at their own pace across different devices. For example, players who would play at school could then play at home without having to unlock levels – an important benefit. The team moved to a completely open level screen, which allows players to move to whatever level they prefer, while still suggesting a recommended order, and noting which level was completed successfully. This change allows players to choose any level to play and have access to the tutorials, while also receiving visual reinforcement of what they have accomplished. Visual information about the levels informs players about the content of each site (such as what types of numbers or decimals are used) (Figure 9), so that players can choose the math and difficulty level which is most appropriate. This change may improve the sense of control for all players and may benefit teachers who are looking to teach with a specific set of numbers, for example, asking players to move directly to the levels which use decimals.

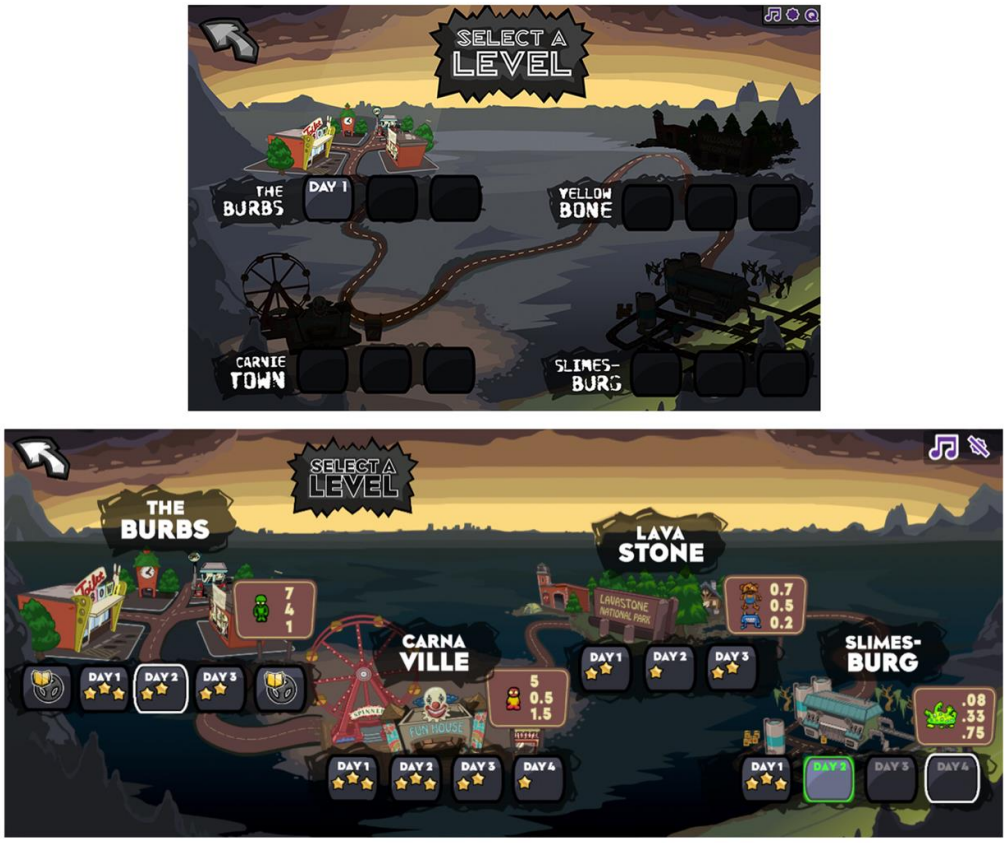

Figure 9. (top) Previous version of the game level select menu; (bottom) Revised version of the game level select menu, where players can side scroll.

6.4. Graphics/Visuals

Recommendation: Provide solid contrast between backgrounds and game elements the player will use to interact, such as menus and characters. The team identified some contrast issues in the game character select screen. They also identified a lack of character diversity. The lack of contrast between the character and the background made it difficult for players with low vision or contrast to properly navigate the screen (Figure 10 – left). As a solution, the team removed the transparency and added a black outline around the character. When players select the character, it increases its size and gets brighter (Figure 10 – right). The team tested all the game graphic elements for color blindness and contrast ratio.

Figure 10. (left) Previous game character select screen; (right) Revised game character select screen.

Recommendation: Make all paths visual, literal, and easy to follow. The team revised the game paths to avoid visual blockage that could confuse learners with cognitive disabilities, who need literal paths. In the game levels, parts of the road moved "behind" lava pools or waterfalls (Figure 11 – left). This limitation could confuse players visually and cognitively about the bus driving path, as they would see the lava as a visual block on the road. The team redesigned the roads, keeping the same style and removing graphic elements (lava/water) that go over the road (Figure 11 – right). They also made the road consistent in each level, so that even when the bus travels over a bridge, it is clear where the path is.

Figure 11. (left) Previous gameplay screen with parts of the road blocked; (right) Revised gameplay screen without blockages at the road.

6.5. Voice Narration

Recommendation: Implement voice narration description for the game instructions. Adding voice narration may provide players more than one modality by which to access critical gameplay information. This was not implemented in *Monster School Bus* for two reasons: adding this feature was viewed as time-consuming at a time when so many other changes were necessary; and file size was an issue. Because the game is available in English and Spanish, it would require twice as much audio. In addition, Unity (the engine used in the game) does not have screen reader support or text-to-speech capabilities, so any voice audio would have to be recorded by a hired voice actor and programmed into the game. The voice-over narration would benefit players with visual needs, but having text-to-speech capabilities within the authoring environment would be an ideal solution. This feature will be kept on the team's list to be improved in the next project and game update.

7. Recommendations for Studio Processes

7.1. Recommendations for Development

While this research yielded a specific set of changes to the *Math Snacks* suites of games, it also gave the studio an important process for regular review of accessibility considerations during the design and development of new games. This is particularly important since "checklists" of accessibility items, while valuable, can differ greatly from game to game and studio to studio. In committing to regular review of accessibility as a studio practice, developers can stay current with best practices while also ensuring continued professional development of team members. These specific guidelines have been established by the Learning Games Lab team for development and may also guide other studios who choose to make games more accessible.

Engage the entire team in accessibility design. Provide an environment where the entire team can engage in thinking, discussing, and sharing their thoughts on accessibility in product design/development. Fostering this mindset among the team has benefits over assigning a single individual to be responsible for game accessibility. It brings multiple

perspectives to the design process, based on every team member's expertise. The Learning Games Lab team organizes large meetings with the entire team at the beginning of the design process, revisiting old games, and bringing accessibility specialists' knowledge to the team discussions.

Create an accessibility guideline list for your team. Create a document that the team can easily access and update, and assume guidelines need to be constantly revised based on learning from projects, interaction with other studios or accessibility experts, and technological advancements. As previously mentioned in this paper, there are several game accessibility guidelines and best practices online. However, teams need to create their own lists based on individual studio setup, type of games developed, equipment available, and so on. Visiting accessibility guidelines before every project is a useful approach, which provides the team a point of reflection that considers each project's individuality and gives an accessibility standard quality for every game designed.

Design for as many players as possible. The Learning Games Lab does extensive formative testing during game development but cannot always access players with each of the diverse needs represented here. The team consults with accessibility specialists, which may be a realistic way to assess potential needs and successes given the diversity within the needs of those needing accommodations. These specialists have observed users with different needs and have a deep understanding of user profiles. Specialists' knowledge is valuable and useful, while users with disabilities are still the experts as knowers. Because testing with all users and meeting the wide range of different needs is not always doable, the lab tests with users where they can, and encourages ongoing feedback once a product is released.

Make your games better by improving accessibility. Think of accessibility as part of a player's needs, instead of something related solely to disabilities: How can we make the game experience better? How can we improve players' learning experience with the game? Accessibility is not something extra; it needs to be part of the entire design and development process. Any given user has needs across several different types of access: each area of need exists within a spectrum, from low to high, and includes specific types within each category. Through the extensive review of the *Math Snacks* suite of games, the developers have fostered their own intuition in what needs to be considered earlier in the process.

Your design team may face several accessibility contradictions. Use creative strategies to find solutions that better address different players' needs. There are likely to be several contradictions within any set of accessibility needs, which will impact design decisions. For example, providing full recorded narration of any on-screen text can help those with visual impairments and provide the theming, music and atmosphere often given by graphics; however, when enabling subtitles for hearing impaired, the system may read on-screen captions and overlap with the game's narration. Contradictions are part of the design process, and addressing these conflicts creatively is what makes design impactful to society. Engaging the entire team in the accessibility mindset can help navigate the contradictions, to make the best decision for the game.

Find and reflect on your team's accessibility approach. Identify and discuss with your team what works, taking into consideration your possibilities and constraints. Accessibility for game design is gaining attention; studios and researchers are increasingly sharing approaches and best practices for accessibility in games. However, there is not only one way to do this. It is necessary to reflect with your team on your approach. The Learning Games Lab has used action research to enable this self-reflection and identify implications for the studio design process.

8. Conclusion

Addressing accessibility is an important aspect of meeting the needs of all users. Findings from this work provided a specific set of changes to make the game *Monster School Bus* more accessible, but also yielded a process to be used by developers to consider accessibility in the design of new games. As part of a constant iterative cycle, the lab intends to keep revising and updating process and guidelines after each project outcome. Their experience may guide other studios who choose to make games more accessible or are willing to reflect on their own process.

This article was prompted by the need for specific guidelines on making games, particularly educational games, more accessible. While the research conducted by this team shaped a framework for considering accessibility in the design of games, research should continue to inform this lens. To facilitate accessibility by other designers, additional research and contributions from the community are necessary. User testing and quality assurance is critical in shaping games that are accessible across the diverse range of need. There would be value in a service which coordinates access to users with a variety of needs and using a range of equipment, offers a mechanism for compensating those services, summarizes needs, and publishes coordinated findings and recommendations for developers. Additionally, research should continue to shape user testing methodologies. Finally, the operational nature of this research provides an important link between research and development. Additional case studies which highlight specific processes, design steps, and challenges experienced by developers can inform the field, improving the quality of all games.

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