Towards accessibility in educational games: a framework for the design team

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Information design is relevant to game design: especially the design of educational games which must include best practices of game development and the delivery of information to the player. Games and players interact in important ways: the game communicates with the player on how to start and play the game, the player decides what to do in the game, and the player must communicate effectively with the game through different actions. Without attention to accessibility, the game may cause some players informational and interactional barriers. This study discusses accessibility in educational games, including communication channels, users' cognitive processes, and informational inputs. A framework offers a way for developers to think through design which reflects different needs related to accessibility. With this framework, designers can create games that address four key areas of need (vision, hearing, motor control, and cognitive); recognize how game interactions are impacted by those needs; and acknowledge that all players fall somewhere on a spectrum of need within each of those areas.

1 Introduction

Educational games can be defined in many ways. But before any other definition, games are information systems. A system made up of parts that interconnect to make up a complex whole (SALEN; ZIMMERMAN, 2004). This complex system has information at its core. Information tells what players need to know to start and keep playing the game, represents what the game system collects and presents to the player as the game states, and affects the player's action during the entire gameplay experience (JÄRVINEN, 2008). The educational aspect means these games' focus is to promote the learning of specific content, having instructional and educational information as part of its design and experience.

The interaction between the player and the game system happens in a repeated cycle until the game ends. The player first receives information stimuli from the game through language channels, determines responses by cognitively processing the information, then provides input using the game virtual and physical interface (YUAN; FOLMER; HARRIS, 2011). Understanding and designing based on how

players better receive and process the game information is elementary to allow this proper interaction.

Accessibility plays a relevant role in building this interaction cycle, without it barriers may occur in the interaction making it harder or even impossible for players to play the game. From a game design perspective, accessibility represents a set of characteristics that developers design in a game to provide players access, traditionally this includes enabling access to those with barriers related to vision, hearing, motor skills or cognition. In the sense of, can players receive, understand, and take action based on the information received? This study discusses information design in educational games and provides a framework that design teams can use during the design of new games or to analyze already designed games for redesign possibilities. **The goal is to foster accessibility discussion in educational games from the perspective of information design**, highlighting barriers, challenges, and opportunities.

Design teams of educational games might vary depending on the scope of the project. This paper understands the design team as interdisciplinary, encompassing professionals working collaboratively to figure out gameplay, game strategy, and producing the game assets. This team includes developers (e.g., animators, programmers – professionals developing the game assets), instructional and game designers, subject matter experts, and clients.

2 Information design in educational games

Information design helps users effectively acquire information to fulfill their needs and goals, allowing them to build a knowledge base and/or guide their actions in specific tasks. Designed information needs to convey the proper means for action and provide the means for that action. Usually a user-centered design approach is appropriate where: (1) data is compiled; (2) data is changed and organized into information in a specific manner; (3) a graphic product is designed to communicate and transfer this information to the audience (ZWAGA; BOERSEMA; HOONHOUT, 2004).

The graphic product used to communicate and convey the information will vary depending on several aspects: the audience, needs, goals, project demands, and so on. The product can be infographics, animations, printed signs, labels, educational games, etc. This study focuses on educational games as a digital product that conveys information to users/players.

Effective educational digital games give learners meaningful learning experiences in a safe and interactive environment. Most educational games use multimodality to convey information and instruct players, including graphic images, texts, sound effects, oral communication, and tactile stimuli (TOBIAS *et al.*, 2014). The multimedia learning theory suggests that people learn better when

words and images are used together (multimodal) (MAYER, 2009; CLARK; LYONS, 2011). Words encompass verbal representations (e.g., text, narration), and images cover pictorial representations (non-verbal) (e.g., images, illustrations, animations, graphics, videos). This multimedia environment focuses on the player experience (RIEBER *et al*., 1996), the learning occurs through the player interaction with the dynamic elements of the game. These elements are based on information from the interaction between the game system and the player through the game interface.

To allow interaction between players and the game interface information is used to provide: Navigation, Instruction, Interactive Communication (FARIAS; TEIXEIRA, 2014). For each of these interaction functions, the information is designed in a specific manner, allowing players to receive, process, and act based on the information.

- **Navigation**: information to allow players to navigate in the game virtual environment before or during gameplay. For instance, adjusting game preferences (e.g., difficulty level, sound preferences, loading previous gameplay), customizing and selecting characters, selecting, and moving into the game levels, etc.
- **Instruction**: information to train players regarding the game elements and system. For instance, tutorials, controller's explanation, practicing levels, etc.
- **Interactive communication**: information to allow communication between the players and the game systems, the inputs, and outputs during the game experience. For instance, textual messages, oral feedback from the system, players' gestures, or controllers.

Educational games have an additional layer of information: **the educational content** which serves as the base for learning goals. This content establishes necessary changes intended for the player: how the educational content will be presented, what tasks and activities the player will need to do in the game to learn the content or to allow reflections on it. Elements draw on educational resources and instructional approaches to foster learning through the game activities. In summary, according to Winn (2008) and Chamberlin, Trespalacios, and Gallagher (2012), these elements are **content definitions**, **pedagogy approach**, and **educational objective**. These definitions serve as guidelines for the configuration of all game elements (e.g., mechanics, rules, story, theme, character). The educational objectives and the game pedagogy represent the foundation of educational games.

The quality of educational software relies on its capacity to address users' learning needs and requirements (GOMES; PADOVANI, 2005). The sense of quality is essential to determine levels of usability and accessibility that the system provides to users (GOMES; PADOVANI, 2005). There is an overlap between usability and accessibility,

although they represent different things in a system. For example, in an educational digital game, accessibility makes it possible for a wider range of users to play the game; whereas, usability represents how easy it would be for any given user to interact with the game environment.

Playability is another element connected with usability and accessibility that impacts the software quality in games. A well-developed educational game needs to allow players to reach the game (through accessibility), allow the player to achieve productivity in the game goals (through usability), and promote a playful experience (through playability) (Ibid). While the usability goals focus on specific usability criteria (e.g., efficiency) the user experience goals focus on the quality of the experience (e.g., being fun). In other words, the user experience is more than just enabling users to reach and perform the task, it seeks to develop pleasant, fun, aesthetically appreciable interactive systems, etc. (PREECE; SHARP; ROGERS, 2015).

3 Game interaction cycle and possible barriers

During the play of an educational game, informational and interaction barriers can occur, making it difficult or even impossible for some players to perform the game activities. To identify and address these barriers, the design team needs to provide players with accessibility features to accommodate their needs. Accessibility represents a set of characteristics that are designed into the product, environment, service, facility, or system to enable as many people as possible in the widest range of capabilities and circumstances to interact, access, and use it (PREECE; SHARP; ROGERS, 2015, ENGELEN, 2001, ISO/TS, 2013).

Four main categories of disabilities – **visual**, **hearing**, **motor**, and **cognitive** (GILBERT, 2019; AGUADO-DELGADO *et al*., 2018; YUAN; FOLMER; HARRIS, 2011; BIERRE *et al*., 2004) can facilitate discussion, provide an overview picture of disabilities, and allow the identification of possible barriers players may face in games. However, this study also acknowledges the complexity of disabilities, understanding they are in a spectrum from low to high, can be co-diagnosed and may have specific types within each category – for instance, on visual needs, a legal blind player will have different needs from a player with low vision or with color blindness. Additionally there are three possible situations: permanent disability (e.g., person with one arm), temporary disability (e.g., person with an arm injury), and situational disability (e.g., a new parent holding a baby) (MICROSOFT DESIGN, 2016). Based on Gilbert, (2019), Aguado-Delgado *et al*., (2018), Yuan, Folmer, and Harris (2011) and Bierre *et al*., (2004) each category is described below:

- Visual disability: individuals with a certain degree of vision loss; such as low vision, legal blindness, complete blindness, color blindness.

- Hearing disability: individuals with a certain degree of loss in the ability to hear, either from one or both ears; such as deafness, hearing loss, hard hearing.
- Motor disability: individuals with limitation or a loss in the mobility function and muscle control; such as arthritis, paralysis, repetitive stress injury, neurological disorders, age related issues, lack of mobility, lack of steadiness, cerebral palsy.
- Cognitive disability: individuals with mental or psychological disorder, which causes a deficit in the ability to learn, process or remember information, communicate, make social interaction, and make decisions. This type of disability can be a learning disability, intellectual disability, or a specific cognitive ability (e.g., memory, language processing).

Design team can identify possible barriers players may face in the game interaction due to their needs. The interaction between players and the game happens in a cycle, which is repeated until the game ends: **Receive stimuli** from the game (visual, auditory, tactile), **Determine Responses** (players cognitive decisions), **Provide Input** (players action through the game physical and virtual interface) (YUAN; FOLMER; HARRIS, 2011). Based on the established types of disability and this interactive cycle, this research proposes a framework to identify barriers in the game, following three questions (Figure 1). The framework has the potential to help game design teams think through games and accessibility in educational games. Design teams may use this framework to review their old games and inform the development of new games.

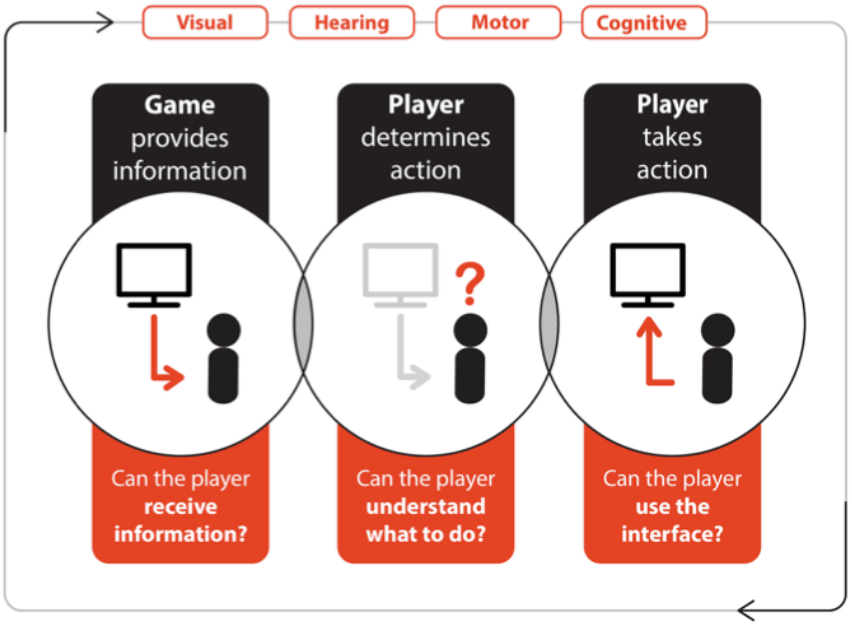

Figure 1 Framework to discuss accessibility in games. Source: the authors based on Yuan, Folmer, and Harris (2011) interaction model.

3.1 Can the player receive information?

The game information (navigation, instruction, interactive communication, content) needs to be communicated in a way that players can receive it. Several game elements will influence the players' ability to receive the information, and the main determinant is the communication channel used (visual, auditory, tactile). For instance, if the game uses the solely visual channel to convey information; such as giving information to players only through graphics, players with some visual impairment (e.g., blind, low vision) will be unable to capture the stimuli, preventing them from determining appropriate action for the stimuli.

The communication process happens through the language channels and modes of representation. Twyman (1985) proposed a model describing the graphic language in two channels: **auditory (verbal and nonverbal)** and **visual (verbal, pictoric, schematic)** (Figure 2). The **auditory information** in games can be **verbal** – narrated information (e.g., instruction about how to play, narrative presentation, gameplay information, and general verbal feedback) or **nonverbal** – sound effects, music, feedback such as clicking sounds to communicate how much time a player has left to make a decision. The **visual** graphic information in games can be **verbal** – written text menus, score numbers, dialog boxes, written tasks; **pictoric** – the virtual game environment with illustrations, characters, objects, which can be realistic or abstract; **schematic** – graphic marks used in the game that are not numbers, words or pictures, such as arrows to drag players attention to objects, glowing areas, or diagrams showing character skills.

Complementing Twyman work, Spinillo (2001) adds to his model the **tactile channel**, bringing more communication possibilities (Figure 2). The **tactile graphic information** can be verbal, pictoric, schematic – such as braille text or tactile floor, which does not currently apply to most games. However, the tactile channel is highly

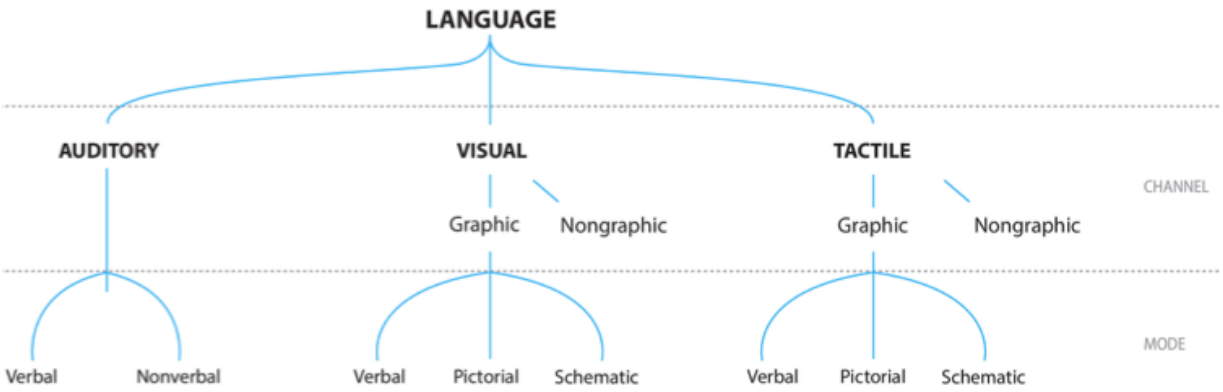

Figure 2 Model of language approaches. Source: Adaptation of Spinillo (2003) previous work – Revision of the language channels proposed by Twyman (1985), revised by Spinillo (2003).

used in games as a **nongraphic form** – communicating players using haptic information through touch sensation, such as vibration.

By understanding the language channels and their communication possibilities, design teams can design strategies to convey the game information, in a way to enable all players to receive information, regardless of where they are on a spectrum of accessibility.

3.2 Can the player understand what to do?

The game actions and tasks need to be designed in a way that players will have the capacity to understand and think in a strategy to execute. Several informational game elements and factors will determine if players can or not understand the information, such as layout, color, graphics, visual/auditory/tactile messages, time-based and information complexity. Similar to all areas of ability, all players fall somewhere on a spectrum of cognitive function. For example, if the game demands time-based responses for determined action, some players may be overwhelmed by the time pressure, and unable to process the appropriate step, unable to perform the activity and determine appropriate responses. Similarly, visual cues can exacerbate cognitive challenges: players who depend on a screen reader receive information in linear patterns, with the layout determining the order in which onscreen text is read to them.

That means a user may still be receiving information from a screen reader, (or may receive it out of order) while the game has expected that player to act. Pettersson (2010) provides information design guidelines that can facilitate users cognitive process, these guidelines were restated below in a more accessible way to reflect all areas of need.

- **Facilitating and holding attention**: use visual or auditory information to call users' attention; use graphics or pictures relevant to users; provide ways to direct attention to some information; use bold and bright colors to get attention.
- **Facilitating perception**: provide training or tutorials for contents; avoid irrelevant and distracting information; provide enough contrast between graphics and background; avoid too short or too long text lines; pay attention to the space between objects making clear their relationship or not; use color coding to enhance perception but being mindful that many users are color blind.
- **Facilitating mental processing**: provide enough time for users to process information; design text or narration easy to understand; use examples when appropriate; be consistent in the use of graphic elements; avoid inconsistencies in font, graphics, and language.
- **Facilitating memory**: present a limited amount of information at the time; create meaningful messages and content to players;

foster a connection between different communication channels (e.g., text and illustrations, sound and haptic stimulus).

Players need to understand how to act in a game, and this is most frequently processed cognitively. By addressing players' cognitive needs and guiding design decisions based on research on how learners better process content, design teams can increase the game quality experience for all players. This aspect is even more relevant when thinking about educational games, where addressing the content is part of the game experience.

3.3 Can the player use the interface?

The player interacts with the game system through the virtual and physical interface. The interface needs to be able to capture the player inputs. For example, if the interface demands a specific combination of motor action for the input, some players with motor disabilities will be unable to perform that action. The reference list for inclusive game design[1] created collaboratively by a group of studios, specialists, and academics (Game Accessibility Guidelines) share a set of guidelines for improving control and mobility in games interface:

1 Available online in: http://gameaccessibilityguidelines.com

- Provide controls to be remapped or reconfigured.
- Make controls simple or provide a simpler alternative.
- Allow players to adjust the sensitivity of controls.
- Provide toggle/slider for any haptics.
- Make sure interactive elements (virtual) are large and with appropriate spaced.
- Make sure that all areas of the user interface can be accessed using the same input method as the gameplay.

By ensuring players with permanent or temporary motor limitations alternatives in the game controllers, the game system allows them to communicate their inputs to the game interface. Some games are compatible with assistive technology, which extend the range of users for the game. While motor function can be one of the greatest barriers to interacting with the interface, other needs can also impede players' use. For example, visual and audio cues are often used to help the player focus on important parts of the screen, helping predict action. Time pressure can also impede this action if users need additional time to navigate text or audio with assistance, and then are unable to respond in time.

Some of the three guiding questions may feel more relevant to each of the four areas of need. For example, in asking, "Can the player understand what to do?", this is particularly important in considering users with cognitive challenges. However, all players must be able to receive information, understand what to do, and use the interface,

and design should consider and accommodate for all four areas of accessibility needs (visual, hearing, motor, and cognitive).

While using the framework, the design team also needs to consider that several players use assistive technology (e.g., text-to-speech, specific controllers) to play games. The game needs to be able to recognize and communicate with these technologies, allowing players interaction. For example, to enable a proper text-to-speech feature that benefits players with vision loss or those with reading challenges, the game text and elements need to be programmed to be interpreted by assistive software that provides this feature.

When using the framework to identify possible players' needs and barriers with games, design teams may face several contradictions, which can impact design decisions. The accessibility needs of some players might make the situation less accessible for other players with other needs. 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 games narration. A rollover feature in a given graphic can help players with cognitive challenges better understand the meaning or nature of that graphic; but is inaccessible for players with motor needs. 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.

4 Final considerations

Accessibility design impacts the entire design and development process of an educational game. Acknowledging and addressing these needs represents one way a team can prevent possible interaction and informational barriers and enhance players' experience. This paper's contributions result from articulating several sources on how theoretical and practical knowledge from information design can support the game design process towards accessibility. The study used as a starting point the interaction model proposed by Yuan, Folmer & Harris (2011), expanding its ideas creating a more approachable framework, with guiding questions for game designers. A development team can use this framework, taking an established game and reviewing it for accessibility, using the guiding question to reflect along with the four areas of accessibility, identifying the need to develop skills before creating their games.

Designing a game to be used by all people is almost an impossible task, considering the existence of a large range of human abilities and disabilities (NICOLLE; ABASCAL, 2001). Trying to make games usable by all players bring some intrinsic conflicts, since providing

access to users with a type of disability may turn this product notably more difficult or even impossible to be use by other groups of users, either for people without disabilities or with a different type of disability (NEWEL *et al*., 2011, NEWELL; GREGOR, 2000). Taking that in consideration, design for accessibility can be seen as a process that aims to design a product excluding as few as possible people from using it, which through flexibility and adaptability try to provide accommodations to a wide range of users needs and preferences, acknowledging that sometimes it is impossible to accommodate all users in a single version of the product (KEATES *et al*., 2000; VANDERHEIDEN; TOBIAS, 1998). This is what design as a process is about, dealing with conflicts to make a product useful and meaningful for users.

Information design brings theoretical and practical knowledge on how players can receive, process, and respond to the game information. This knowledge may benefit design teams' during design decisions. The framework proposed here is simple and does not intend to solve all accessibility issues in games. The goal is to provide design teams an easy way to start thinking and discussing how barriers can be identified and addressed in the game interaction cycle of educational games.

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