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▶ **To cite this version:**

Jannicke Baalsrud Hauge, Ioana Andreea Stefan, Niina Sallinen, Jakob A. H. Baalsrud Hauge. Accessibility Considerations in the Design of Serious Games for Production and Logistics. IFIP International Conference on Advances in Production Management Systems (APMS), Sep 2021, Nantes, France. pp.510-519, 10.1007/978-3-030-85910-7_54 . hal-03806546

HAL Id: hal-03806546

https://inria.hal.science/hal-03806546v1

Submitted on 7 Oct 2022

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Accessibility Considerations in the Design of Serious Games for Production and Logistics

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Abstract. Digital accessibility has been the focus of initiatives, policies and standards at European and international level in the last decade. However, adoption of accessibility guidelines and the development of accessible resources and applications remain limited and education is a primary example of the multiple challenges that must be addressed. This research has highlighted the main barriers that should be overcome in order to make digital educational games accessible for learners with disabilities and it has brought forward the critical need of personalizing the game contexts and analytics to meet specific profiles of learners with disabilities. Building upon the outcomes of two case studies, the authors propose a game analytics framework for learners with disabilities, in an effort to streamline game design processes that target accessibility.

Keywords: Accessibility, Digital educational games, Design Considerations, Engineering Education

1 Serious Games and Accessibility

Using Digital Educational Games for teaching aspects on logistics and production has a long tradition in engineering education [1,2]. Many of the games have been used for many years with good results [3,4], however hardly any of these are, to our knowledge, designed with a focus on accessibility. With an increased focus on different students'

needs and with an increasing number of students with disabilities enrolling into higher education [5], there is a need to ensure that these students have access to the teaching material in a way that serves their rights of adapted teaching and corresponding materials [6-10], in order to avoid exclusions [11]. This has become more a more a topic as online education has been increasingly growing [12], forcefully accelerated during the COVID pandemics [13].

Much has already happened in the field of online material including the Web Content Accessibility Guidelines (WCAG) and there is a wide range of assistive technologies and alternative methods of interaction that enable people with disabilities to use digital documents, as well as web and mobile applications [14]. Research has revealed the complexity of accessibility [15] and efforts have been made to tackle this multifaced issue [16]. A primary goal of applying web accessibility standards is improving the user experience (UX), by balancing the interplay between accessibility objectives and UX [17, 18], extending the availability of multimedia leaning content [19] or applying filtering option to make information on websites more accessible for visually impaired and blind users [20]. In addition to this, as educational institutions within EU, we need to bear in mind that we as public sector bodies need to implement the Directive (EU) 2016/2102 on the accessibility of the websites and mobile applications of public sector bodies. Therefore we have to follow the regulatory framework for the adoption of the accessibility guidelines [21] also for our teaching materials.

The objective of this article is therefore firstly to investigate the situation of games and accessibility in higher education, using an online survey, and secondly, to analyse a set of existing games (case studies A and B) in relation to their accessibility. In case study A, we assess three educational games. In case study B, we explain how we, following the EU directive, have started to improve the accessibility of a digital twin that we use in a gamified way to teach students. The last part of our work addresses some considerations on how we could use game analytics to identify the accessibility needs of students and to adapt the games to meet the students' needs while playing, and not as currently, in the pre-settings of the game.

2 Methodology

The objective of this paper is related to the knowledge and take-up of accessibility standards in higher education. In order to address these research questions, we have used a blended research method:

- A literature review in order to identify the relevant standards
- A survey with 22 questions administrated to teachers that teach in higher education. This survey was distributed in two existing consortia between January and March 2021. The questionnaire comprised 22 questions and was divided in five sections. The questionnaire was created in English and Romanian. It was completed by a number of 27 respondents from nine countries.
- An analysis of existing games that are used for educational purposes and their fulfilment of the current EU directive

- A design consideration on how accessibility requirements will have to be considered in the re-design of gaming applications that do not fulfil the requirements.

3 Analysis Results

This section describes first the online survey results, then the analysis of existing games and gamified applications on how well these meet the requirement given by the EU directive.

3.1 Online Survey Results

The distributed survey is part of two projects. Thus, it addresses more questions on accessibility than just those related to games, and also other fields than production and logistics as teaching topic. The 26 respondents represent: Universities – 9 (35%), Training centers - 5 (19%), University of Applied Science – 5 (19%), Higher education - 2 (11%), Vocational education - 1 (4%), NGO - 1 (4%) and Other - 3 (11%).
Regarding their area of expertise, the respondents come mostly from Computer Science 8 (31%), followed by Business and economics 7 (27%), to which also the field of logistics is counted. Most respondents are highly experienced in their field, with 48% reporting more than 10 years of experience (2 respondents above 20 years) and 52% between 1 and 10 years.
In the survey section that dealt with games and accessibility, 19 (73%) respondents answer that they hardly use digital games for teaching. Thus, 27 % have more experience in using games at least monthly, as follows: four (15%) use games monthly, one (4%) use games weekly and two (8%) use games daily in their activities.
From 26 respondents only six (23%) use digital games as learning activities for students with special needs, but for the other part of the respondents who gave a negative answer 20 (77%) it is possible that there it may be a high risk that they have students with special needs which they are not aware of, due to the privacy restrictions and lack of access to the students records.

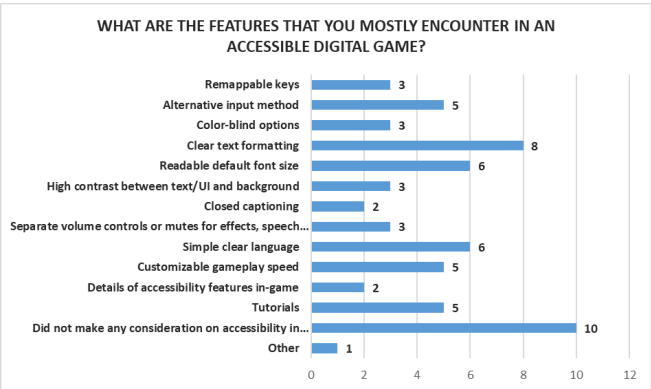

Fig. 1. Features the respondents mostly encounter in an accessible digital game

Regarding the greatest challenges in using digital games, eleven respondents mention insufficient time, followed by nine being unfamiliar with the technology, and eight answering that they lack accessible games that fit their teaching purpose. Only four respondents mention costs as their greatest challenge, and one mentions lack of administrative support.

When asked about the accessibility features that the respondents encounter in a game, 38% of them did not consider these features of a game at all, while 63% chose one or more feature from the list provided to them, as shown in Figure 1.

3.2 Case study A

This section describes the outcome of the assessment of existing games that are used for teaching purposes. Four research assistants not involved in the teaching activities carried out the assessment concerning to what extent these games fulfil the accessibility guidelines given in the EU directives.

RUEU? [22]: This game is used to let students explore different perspectives to a topic. One scenario is related to transport of goods across EU. The design and implementation part of the RUEU? game did not involve any design considerations concerning accessibility. Even though RUEU? is targeted to regular students, this game has potential for re-design to support players with disabilities. Below we present a list of design improvements that we think are relevant:

- *Visual impairment.* RUEU? is a text-based game and involves intensive reading. It is not possible for a visually impaired person to play it. Being able to see the screen and the layout of the buttons involved is crucial to the game-playing actions. This situation can be improved with a text-to-speech functionality with voice command.

- *Auditory impairment:* People with auditory impairment should not have any problem to play the game, given they do not have other difficulties. The music/sound in the game is not a mandatory part for the playability.

- *Silent/Mute:* People who are silent or mute can also play this game if they are able to read.

- *Physical impairment:* People who are physically impaired, in this case the people without fingers and/or hands will have difficulty playing the game. Other than extensive reading, RUEU? game is progressed through clicking the mouse. It could be resolved with implementing a voice command option.

- *ADHD/Autism:* Some of the texts/questions/statements in the game have a time constrain. For people with ADHD and/or Autism or similar impairment, the game could be tweaked to have no or longer time limitation for reading/answering to facilitate better participation.

Beaconing [23]: Beaconing's target is to break barriers in education through serious games and this project has facilitated a few accessibility options mainly related to sight

and hear impairment as well as dyslexia. The game interface for both teachers and students have possibilities to be disability-friendly. The focus is mostly on visually impaired people in terms of adjustment options, but other disabilities are addressed as well:

• *Visual impairment:* Beaconing has text-to-speech functionality implemented for people who require oral feedback on the screen. The user can use a read-aloud function. .Such a feature helps visually impaired as well as people with dyslexia to play the games. The font size, style and text colour can be changed according to the user needs. This is helpful for people who have lower degree of visual impairment, cognitive disabilities and Dyslexia. There is an option to use a magnification tool, which has adjustable magnification levels like a regular magnifying lens. The lens window can be moved around over the screen as desired. This platform also has the option to use screen tinting which is helpful with Dyslexia and other associated conditions. The access bar of the interface is equipped with different background theme options to facilitate certain eye conditions, acuteness to colour, colour blindness and other visual impairments. The options of having a reading bar that allows tracking of the position on the page with an underlining bar is also available. This feature can be helpful for people who have Dyslexia, ADHD, Down syndrome or other cognitive disabilities. There is another option called an Overlay Bar, which blackens out the content of the page except what the user is focusing on. The colour of the overlay bar can also be tinted when necessary.

• *Auditory impairment:* Beaconing has limited options in this respect. In the settings tab of Access Bar, the users have options to adjust text-to-speech voices, pitch and speed of the narration. This is for people with lower auditory impairment. For complete deaf people, the platform is still usable, as the visual inputs suffice to enable the gameplay and learning experience.

• *Silent/Mute:* People who are silent or mute can also participate in the games, as the interface is friendly enough for them. The games do not mandatorily require voice command to enable any feature.

• *Physical impairment:* Speech recognition has been implemented in the platform to facilitate people with physical impairment. People, who have limited physical abilities, have difficulties in putting information to the platform and in navigating around the page. Voice recognition, however, has over 40 different languages, which is a groundbreaking achievement. Dictated speech is transcribed into text and put into the Beaconing interface. The accuracy of speech to text is fantastic. Physically impaired people who have difficulties in terms of using a keyboard and/or a mouse benefit the most from this feature.

• *ADHD/Autism:* People with cognitive impairment can benefit from this platform as it ensures more inclusiveness for them. Text to speech, different background themes, various options regarding fonts, reading bar and overlay bar are beneficial for them. The lessons designed in different minigames can be changed in terms of time constrains according to user needs. The interface enables the teachers to copy and create another version of the same lesson to facilitate different impaired pupils. This option ensures

that the teachers have options to reuse an existing lesson plan without requiring too much time.

Sumaga Island [24] - a co-operative game used for teaching the bullwhip effect. It is not designed with any accessibility considerations, but has good UI that is clear structured and fulfil the general recommendation for good design.

Visual impairment: People with visual impairment are unable to use the game as the player is required to see the interface and interact with it. Potential improvement that can be relatively easily implemented: voice over everything and prepare for voice-recognition input; this makes the system a little bit like an answering machine. Sumaga Island is a text-based game and it has discrete steps (round based). Conclusion: The game can only be suitable for visual impaired people if voice recognition and corresponding actions on screen might be involved using different sensors etc.

Auditory impairment: As described in the previous section, Sumaga Island is text based, so in this case people who have auditory impairments can play the game. However, depending on the group settings, the students often discuss while playing. This would reduce the suitability for this user group. A work around should be developed in this case.

Physically impaired: The players need to be able interact with the interface and currently this is only possible through a mouse or touchscreens. A possible extension could be to implement eye-tracker options. Again, if the voice recognition and eye sensing is involved in the game, it can be possible for the player to play this game.

Silent/Mute impairment: People who are silent or mute can also play this game if they are able to read.

ADHD/ Autism: Sumaga per-se is not time sensitive; all players have to wait for the slowest one. Time management is not very good in the game because everyone has to wait for the other player to do his task/activity. The infrastructure of the game can be changed from server-client model to standalone entity in which each player performs her duties for a certain period of time and then leaves the game.

In the end, we can conclude by saying that these games have attributes that facilitate different impairments on different levels. There are options to include various features to make the games more inclusive, and thus to improve the accessibility of the games to people with disabilities. As long as these games serve as tools for education, the suggested improvements could be implemented to ensure barrier-free education for all.

3.3 Case Study B

Case study B is about creating a more accessible Digital Twin for logistic operation. The digital twin described in this section is used for problem based and explorative

learning on the topics of technology assessment in logistics [25, 26]. This digital twin environment was originally developed for teaching and research purposes, but due to the pandemic, we needed to shift from laboratory-based teaching to online teaching. Different educational modules were included into the digital twin environment, related to technology usage in production logistics. The environment is adapted to fit the needs of sight impaired students and teachers. The application is used in a gamified way when it is used for teaching purposes and mirrors logistical operations.

An analysis of the original digital twin showed that it did not conform to the EU accessibility directive. Since the teaching modules for which it was planned to be used was finished after September 2020, the directive was already in force and we needed to fulfil its requirements.

As a first step, we therefore selected one of our regular target groups - a group of people with sight impairment, to test with us the digital twin environment. An analysis of the User Interface showed that the following functionalities could be added: a) Font size b) Subtitles c) Audio Assistance. These functionalities were implemented by March 2021, and even though the first experiments show an increased accessibility for sight impaired users, the current tests have shown that we need to improve the contrast in data visualisation. In addition, the system also has a replay function, which can be used for its original purpose of analysing different logistics operations, but also for a sight impaired person to investigate the operations with reduced speed. This function might also be used at a later stage for supporting students with minor learning difficulties.

The digital twin has the capability to start different physical operations via the user interface. This opens up the possibility for carrying out experiments in risk areas. The mixed-reality digital twin environment is in its prototypical implementation phase and the results are preliminary. We still need more testing with sight impaired people.

4 Design Considerations

The analysis presented in section 3 reveals that there is still much work to do in order to meet the EU directive on accessibility for the games and gamified applications we are currently using in our classes. A main issue is however related to how we can identify what we need to change, both while playing or as in case study B, as pre-selection option before starting. Research on learning analytics has shown that original assessment designs require adaptations [27] and when it comes to accessibility, Gilbert [28] stated that “design is much more likely to be the source of exclusion than inclusion”. Based on our collective experience in game re-design, re-purposing and adaption, we have made a first draft of a ‘Game Analytics Framework for learners with disabilities’ which we will apply for the games in case studies A and B for verification. The framework consists of four steps, illustrated in Figure 2 and the associated text below.

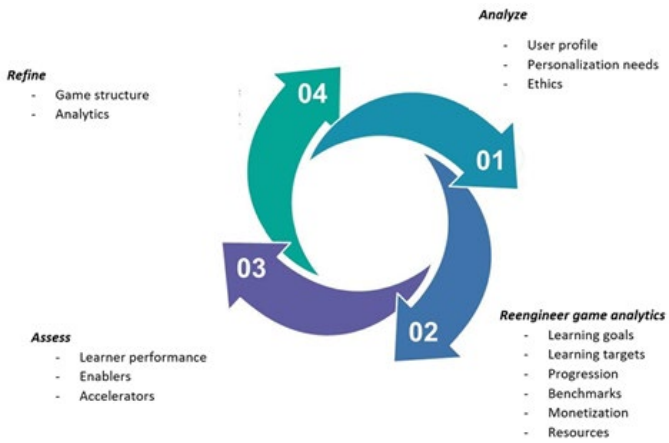

Fig. 2. Game Analytics Framework for learners with disabilities
01) Analyse: User profile: The user data represents the reference point for reengineering game analytics; Personalization needs: Specific user needs are identified; Ethics: User data has to be subject to data protection. **02) Reengineer game analytics**: Learning goals: The standard learning goals are analysed against the personalization needs; Learning targets: Obtainable performance levels are defined; Progression: Game progression is optimized based on specific needs; Benchmarks: Game benchmarks are adapted to match user personalization needs; Resources: Game resources are optimized to stimulate engagement and motivation. **03) Assess:** Learner performance: The player performance is evaluated and a summary of recommendations is made; Facilitators: The assessment identifies components that stimulate the learner and motivate learning processes; Accelerators: the assessment identifies adaptations that were successfully applied. **04) Refine:** The game structure: Further adaptations are implemented to enhance the player experience; Game analytics: Analytics are reviewed to maximize learning outcomes.

5 Conclusion and Next Steps

Just like content or web performance, accessibility represents a core consideration not only for creating websites [29], but for creating any type of educational resource or application [30, 31, 33], including digital games [32].

Efforts towards establishing guidelines for game accessibility [33] have shown that rearrangement in the game design can help make games more accessible for people with disabilities. However, such guidelines have not addressed the challenge of adapting game analytics to learners with disabilities.

Acknowledgment

This work has been partly funded by the EU projects Unilog (CB743), Includeme (No. 621547-EPP-1-2020-1-RO-EPPA3-IPI-SOC-IN), and by the German Federal

Ministry of Education and Research (BMBF) through the project DigiLab4U (No. 16DHB2113) References

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