ENGAGING SOUNDSCAPES AND EDUGAME. EXPLORING THE EDUCATIONAL POTENTIAL OF SIMPLEX DIDACTICS AND MUSIC TO FOSTER PUPILS' ENGAGEMENT IN VIRTUAL LEARNING ENVIRONMENTS

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Abstract

Interactive and highly engaging virtual learning environments (VLEs) are increasingly recognized as vicarious teaching tools that support skill acquisition throughout life. Recent studies, including those by Hookham and Nesbitt [1], highlight the multifaceted nature of engagement in educational settings, focusing on its emotional, cognitive, and behavioral dimensions. This paper examines the role of music and sound within edugames, emphasizing how these auditory elements enhance learning experiences and increase student engagement. Neuroscientific studies suggest that soundtracks, audio effects, and feedback mechanisms activate specific brain areas linked to user involvement, underscoring the potential of sound to foster active participation. Teachers play a crucial role in selecting or designing edugames that align with educational objectives, utilizing music and sound to motivate learners. This paper proposes the use of simplex didactics as a metacognitive framework to guide teachers in making strategic decisions about audio elements, ensuring that chosen sound effects cater to diverse learner needs and promote inclusive teaching. Educators can create engaging, flexible learning environments that foster greater involvement and improve educational outcomes by applying simplexity rules. This paper aims to explore how simplexity can help teachers select or design VLEs with sound components that enhance learner engagement.

Keywords: Engagement, Music, Edugames, Simplexity, Inclusion.

1 INTRODUCTION

In recent decades, interest in edugames and serious games has grown considerably, especially with the advent of the digital age. These games have been promoted for their educational value and their ability to engage and motivate users through interactive and innovative game mechanics [2]. One of the key elements that can make edugames so effective is the role of music. Music plays a fundamental function in accompanying the player on the learning path, as it helps to create a strong emotional bond with the character/avatar while facilitating total immersion in the game [3]. However, despite the numerous evidence [4-5] that emphasize the importance of music in edugames, there is a significant lack of studies that specifically analyze the construct of engagement related to the sound element. In particular, the focus is on *musical engagement* in edugames, to verify how sound is useful for improving engagement. In literature, musical engagement refers to interaction with music, both through passive listening and active practice (such as singing or playing an instrument), influencing socio-emotional development throughout life, influencing aspects such as socialization, personal and cultural identity, and mood regulation. It is also closely linked to numerous cognitive and personality traits [6]. Numerous studies also highlight the positive link between musical exercise and various aspects of well-being, such as quality of life, prosocial behavior, sense of social connection and emotional competence can also be mediated by virtual play, by edugames, media devices that aim to induce the learner to train themselves by playing. Specifically, scientific studies on the subject are still not very deep, but they show that the sound component is useful for improving both at a behavioral, cognitive, and affective level, following the axes underlying the three-dimensional construct of engagement [1]. In addition, the careful choice of the musical mediator and the game containing the sound is functional if it follows precise adaptation rules. This idea finds interesting connections with the theory of simplexity proposed by Alain Berthoz [7], which aims to investigate adaptive ways to overcome complexities. This theory, when transposed into the field of mediality and about the choice of educational games strongly focused on the sound component, presents itself as a possible operational guide useful for improving learning processes in users [8].

This paper is placed precisely in this context, trying to explore the link between simplexity, music, and engagement in edugames. The aim is to investigate how the sound element can contribute to improving engagement and the learning experience, focusing on music as a tool not only for emotional support but also for cognitive facilitation, with a specific declination of the properties and rules of simplexity applied to edugames and the interconnected musical element.

2 THE ENGAGEMENT POTENTIAL IN EDUGAMES

In literature, with the advent of the digital age, a great interest has developed concerning edugames or serious games, as some studies argue that game environments are intrinsically engaging [9-10-11] and therefore would allow a positive impact on learning processes [12] [13] [14]. Particularly in Edugames, music plays a fundamental role because it supports the user in identifying with the character/avatar through emotional involvement while promoting total immersion in the game itself [15]. From this, it is understood that the choice of good sound support, during the construction phase of an edugame, is necessary first to arouse greater interest in the user and support the student during the individualized teaching-learning process [16]. This, therefore, also presupposes a careful prior selection of accompanying melodies and soundtracks [17] and the design of an edugame itself. However, despite such scientific evidence that affirms the fundamental role of music in engagement during the use of an edugame and the subsequent impact on the learning and teaching process, very few studies analyze and measure this construction, often taking it for granted. This is because there are different interpretations and definitions also on the concept of Engagement, motivated by the versatility of the construct and conflicting definitions as well as by inaccurate generalizations [18]. The multidimensional nature of user engagement makes it difficult to measure while you are safer to measure concrete events, such as the number of mistakes a user makes when interacting with a system or how long it takes them to find a solution, you are less confident when it comes to activities for which there are no visible or physical results [19].

From the systematic review published in 2019 by Hookham and Nasbitt, it is clear that the different studies in the literature had different opinions on Engagement: some studies associated involvement only with the behavioral dimension [20-21], others only to the affective dimension [22-23], others only to the cognitive dimension [24]. It has been seen [25] that the theories most used by researchers are the flow theory [26-27], cognitive load theory [28], and multidimensional approach to *engagement* [1]. Flow theory describes the latter as the optimal experience in which there is a state of euphoria and deep enjoyment characterized by: focused concentration, a sense of control, and loss of perception of time. This state often manifests itself when overcoming challenging obstacles, such as those found in video games, and it is a crucial component of deep learning [26]. Cognitive load theory (CLT), on the other hand, offers a framework for understanding the relationship between challenge and skill. CLT postulates that optimal learning occurs when the student's abilities are balanced with the complexity of the task. Research in this area focuses on three types of cognitive load: extraneous, intrinsic, and relevant. The intrinsic load depends on the initial experience and cognitive patterns of the student; the extraneous load is affected by the presentation of the information, while the relevant load refers to a form of intrinsic motivation [29].

However, considering only one dimension of engagement does not allow for a complete measurement of the same, which is why Mills et al. [30], define Engagement as a meta-construct with behavioral, affective, and cognitive components. It is increasingly frequent [31] [32] [14] [33], over the past decade, the three-dimensional view of engagement introduced by Hookham and Nesbitt, 2019, which considers the construct as consisting of: an affective component, which refers to the emotional investment in the task; a cognitive component, which involves attentional resources invested in understanding and mastering the task; and a behavioral component, which concerns participation in a task [33].

At the same time, the lack of an unambiguous theoretical interpretation of Engagement and the multidimensional nature of the construct [34] [35] as well as the nature of the same, which concerns aspects of the mind that are not directly visible, affects the type of measurement method used. Much of the research on Engagement is based on qualitative methods that consist of the use of questionnaires, observations, and interviews [1]. The vision proposed by scholars [1-30] certainly represents a first step towards an approach that integrates the different descriptions of *engagement*. In fact, given the interdisciplinary nature of the term, clarifying its descriptive nature would allow not only to better define the object of investigation but also to identify more precisely the methods of measurement. This aspect is also particularly relevant in educational contexts where edugames or serious games are adopted,

since promoting *engagement* is essential to foster deep learning [14]. According to some research [36-14] students who are highly engaged are more likely to adopt strategies that results in deep learning [14] which involves cognitive processing of stimuli that facilitates understanding and makes information meaningful to the student, producing longer-lasting and stronger memory traces [14]. In fact, it has been found that student engagement improves the deep learning experience, which is why authors such as Bevan et al. [36] recommend incorporating involvement and deep learning into the proposed activities [14].

3 SIMPLESSITY, MUSIC AND ENGAGEMENT IN EDUGAMES: A POSSIBLE *CONTAMINATIO*

In recent decades, the edugames sector has experienced significant growth thanks to the intrinsic potential of combining engagement and learning. This success stems from the ability of edugames to motivate and engage users through attractive game mechanics, interactive experiences, and a tacit pedagogy that fosters the acquisition of skills [37]. The effectiveness of these games, in addition, lies not only in the educational content but also in other key aspects such as sound, capable of enhancing levels of involvement, and promoting processes of motivation to learn implicitly in them. As highlighted by Gustavson et al. [38], sound is a catalytic power, capable of promoting involvement and well-being from different points of view, starting with the cognitive one, increasing levels of psycho-social well-being (Fig. 1).

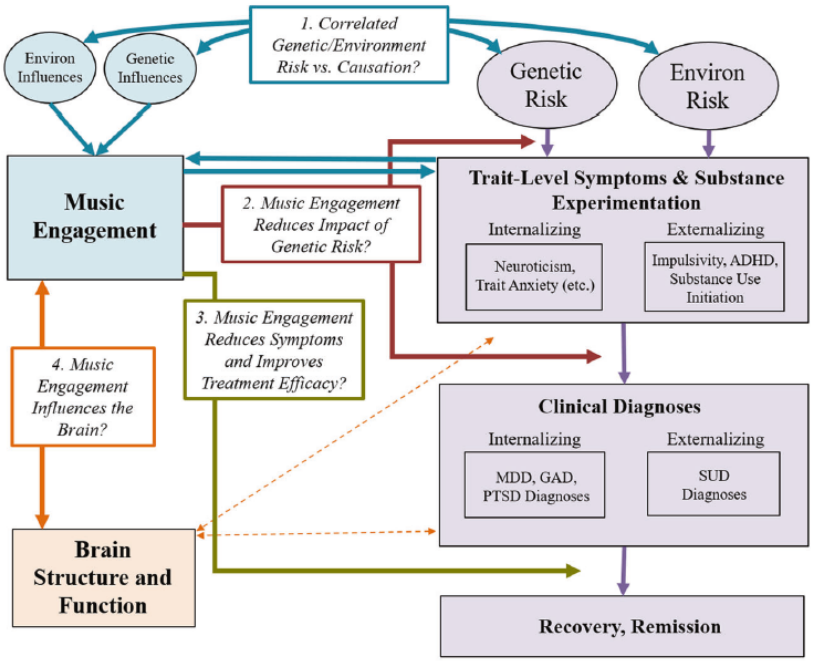

Figure 1. the benefits of musical engagement for Gustavson et al. (2021)

These aspects that are interconnected in edugames are designed to facilitate their simple use, as they are functional to ensure the understanding of the game itself while improving the levels of understanding of the plot, as well as the emotional identification of the user in the subtle narrative facets [39]. In an educational context, where users can often be children or adults who are not familiar with the world of gaming, it becomes crucial to work on the accessibility of interfaces and game mechanics. Simplicity does not necessarily translate into banality, but rather into the ability to convey complex concepts through intuitive and immediate ways, such as using the sound element as a means of support and mediation.

Simple interfaces reduce the "cognitive load" required for the user to understand and interact with the game, facilitating access to the gaming experience and improving the understanding of educational content [40]. For example, a game that requires you to memorize number sequences to solve a puzzle

should have clean graphics and easy controls, so that the player can focus on the didactic challenge rather than on the complexity of the game system and is often associated with sound because through auditory stimulation it is possible to implement memorization, through direct use of the visual sign and auditory stimulus [41].

In this case, the concept of "*less is more*" [42] is more than valid, where the educational message is clear and not diluted by overly elaborate mechanisms or graphics, through a simple and functional interface can promote a more stimulating learning curve, associating this usability with jingles, soundtracks, audio effects that make the game itself captivating and accessible Sound, it can be inferred from this, it does not become an advocate of complexity, but a *vicarious tool* [43], capable of supporting the user in achieving his or her training goal, through direct work on the modulation of emotions in the storage of information. Therefore, sound, in this sense, is characterized as emotional reinforcement, through melodies and sounds that can accompany the player's successes, generating feelings of gratification. Music is also a highly motivational component, often resorting to lively or energetic music that can push the player to continue in the game, increasing levels of resilience and persistence in action [44]. In addition, the aid of sound is useful for reducing stress, as evidenced by a large part of the scientific literature [45-46]. The most relaxing songs can help balance moments of frustration or difficulty, reducing stress and keeping the desire to learn high.

Several studies have shown that music can facilitate the learning and memorization of concepts [47] [48], particularly in edugames, where simple and repetitive melodies can act as "mnemonic anchors", helping players to remember certain information or sequences; For example, an educational game that teaches math might use musical accompaniment to indicate right or wrong operations, making the learning process smoother and more enjoyable. Additionally, music can be used to segment the different stages of the game, helping the player recognize and memorize recurring patterns.

One of the most interesting aspects of music in edugames is its ability to dynamically adapt to the context. The music can change based on the player's actions, creating a responsive and interactive sound environment [49]. This type of dynamism not only makes the gaming experience more immersive but can also have positive effects on the player's concentration and attention, making it easier for them to learn.

Engagement, therefore, is a term that is often used in educational games but is not always fully understood. It refers to the degree of active involvement of the player during the gaming experience. A high level of engagement implies that the player is fully immersed in the game, motivated to continue, and willing to invest time and effort in the experience [50].

In the context of edugames, engagement is not only an indicator of the success of the game but also a critical factor for learning. An engaged player is a player who learns but needs, however, highly juxtaposed engagement factors, which include both game design and external elements such as music and interaction [51].

To maintain engagement, an educational game must properly balance difficulty and gratification. A game that is too simple risks boring, while one that is too difficult can cause frustration and abandonment. The game mechanics, therefore, must be designed in such a way as to offer a constant, but not impossible, challenge and significant rewards for each progress, which is why the sound element needs the same precautions.

Music can act as a powerful tool, therefore, to amplify emotional engagement [52]. During the most intense phases of the game, an appropriate soundtrack can increase levels of immersion and keep tension high, while in moments of calm, it can encourage reflection and absorption of learned concepts. Music can also reinforce the game's storytelling, making the experience more immersive and memorable. A practical example could be an edugame that teaches ancient history: during battles or reconstructions of significant historical events, an epic soundtrack could stimulate strong emotions, helping the player to identify with the historical context and better understand the dynamics of the events, supporting him in the process of adapting to the plots and dynamics of the game, especially when educational.

It is precisely concerning adaptation that it is possible to see interesting connections with the paradigm of simplexity by Alain Berthoz [7], who tried to identify how living beings can adapt to change, deciphering, facing, and overcoming the different forms of complexity present in their path. The paradigm recalls elements referring to the three-dimensional construction of engagement (See par. 2). In particular, the neurophysiologist of perception highlights how the use of rules and properties, i.e. patterns and rules of use, is the non-linear way by which adaptation can be fostered [53]. About the link

between sound and edugames to enhance engagement levels, it is useful to first analyze the properties, precisely by placing them in connection with the theme of sound in edugames.

First, it is useful to analyze the *separation of functions and modularity*, which in musical educational video games, is key to ensuring a diverse and adaptive experience. In a playful context, as in living organisms, these characteristics allow several different functions to be managed in a coordinated manner. Music edugames can separate the various skills required (e.g. rhythm, melody, music theory) and present them in specific time modules, so that the user can focus on one function at a time, without losing the coherence of learning. Each "channel" (e.g., rhythmic practice or musical ear training) operates in a harmonized way, helping students gradually integrate different skills. To this separation, it is useful to add *speed*, which is essential to keep user engagement high [49]. Just as in nature organisms respond quickly to hazards, in edugames it is crucial to have immediate responses to the feedback received. For example, when a player performs a musical exercise, the game must provide immediate feedback (such as scores, corrections, or level changes). This speed of response increases motivation, as the user knows right away if they are progressing or need to improve and allows them to quickly change the digital media or tasks based on the results obtained. Also interesting is the *reliability*, which in musical educational games leads us to reflect on how important it is to maintain consistency between the proposed educational objectives and the actual execution of the gameplay. If the game promises to improve certain musical skills, every action and game mechanic must be calibrated to achieve these goals.

Reliable edugames ensure that each proposed activity contributes to the improvement of musical skills, reducing user error or frustration thanks to solutions such as positive reinforcement, difficulty modulation, and a design that encourages perseverance. In this regard, it is useful to recall *flexibility, vicariance, and adaptation to change*. Adapting to new situations and using different strategies are key elements for success in complex environments [49], such as educational games. Flexibility in music games allows users to take on various levels of difficulty or new musical challenges using different instruments. For example, a user might learn a new melody with one approach but must be able to apply different techniques to tackle a more complex rhythm. This ability to adapt and varied approach keeps the user interested and constantly improving. Understanding the mechanics and acquiring the right skills calls for the need for *memory*, which plays a fundamental role in musical educational games, as users must be able to recall previously learned operating patterns and skills to progress. In a music edugame, users can repurpose music theory notions or technical skills learned in previous levels to tackle more complex challenges. Musical memory (both explicit and implicit) is continuously stimulated, and the game offers the opportunity to put into practice what has been learned in different contexts, favoring the construction of long-term skills. Memory is closely interconnected with *generalization*, which presupposes the ability to apply musical skills learned in a game context to other musical contexts. In musical edugames, this property manifests itself in the possibility of transferring already established concepts, such as the recognition of scales or chords, to new situations. A well-designed game allows users to use previous patterns and skills to solve new musical challenges without having to learn them from scratch. This continuity facilitates learning and makes the game a versatile tool that can also be applied outside the play environment.

Of course, a good application of patterns requires precise rules of use, traceable in the rules, which can orient the user in an agentive sense, enhancing the levels of involvement, attention, and interactivity. The first rule is given *by inhibition and rejection*, which involves carefully selecting which actions to take and which to discard to optimize the user's progress. The discarded actions, of course, will be functional to work with a different user [54]. For example, in a game that teaches music theory or instrumental practice, it may be helpful to temporarily exclude certain functions or levels (such as advanced or complex exercises) to focus attention on more fundamental actions that are appropriate to the user's current level. This approach avoids cognitive overload and allows you to advance gradually and progressively, keeping the user motivated without frustration. Another interesting principle is that of *specialization and selection – Umwelt*. Specialization and selection are rules that allow edugames to adapt to the specific needs of users, creating a personalized environment (Umwelt). In music edugames, the gaming experience can be shaped according to the user's context and preferences, automatically selecting relevant information or specific activities [16]. For example, a player might be guided to practice specific scales or chords based on their previous progress, while other activities are temporarily set aside. This allows edugames to respond to the unique needs of each player, adapting the training path and improving involvement. Knowing how to play implies, in addition, knowing how to operate and prevent even in advance, just as highlighted in *probabilistic anticipation*. Probabilistic anticipation is applied in musical edugames using strategies that allow you to predict the user's actions to facilitate the achievement of goals. In a game that teaches music composition, for example, the system might suggest

chord progressions or melodies based on the player's past mistakes or successes, anticipating their moves and guiding them to correct solutions. This mechanism allows you to speed up learning, keeping the user engaged through a smoother and more seamless experience. In addition, the role played by the rule of *detour* is important. The rule of detour encourages the exploration of new avenues and approaches in music edugames, allowing users to experiment with alternative ways of learning. An example would be a game that offers multiple paths to solving a musical problem, such as learning a melody with different instruments or alternative listening techniques. This encourages the user to explore new and innovative solutions, keeping the gaming experience fresh and interesting, thus increasing engagement. Working with sound also implies that in an edugame it is possible to trace a correlation between different channels and factors, in an original way. Linked to this is the rule of *cooperation and redundancy*, which are important for maximizing learning in musical edugames. In this context, a game could combine different means of communication, such as sound, text, images, and videos, to facilitate acquiring new musical skills. For example, while the user is learning a new rhythm, the game could simultaneously provide a demo video, music notation, and audio feedback. This synergistic approach increases the likelihood of success, reducing errors and improving understanding of the material through the overlapping of multiple sensory channels.

Finally, the *sense*, which encompasses all the other rules and properties, leads to the planning and design of an experience that not only keeps the user involved but also guides him towards learning through a structured and adaptable interaction that is also enriched from an ethical and educational point of view. The choice of the musical medium, therefore, must always be calibrated based on the purpose to be achieved in terms of training and cultural and personal growth. These regulatory rules, interconnected with patterns, if implemented effectively, can improve the interaction and impact of edugames, transforming them into powerful educational tools that facilitate immersive, effective, and engaging learning.

4 CONCLUSIONS

In conclusion, it can be said that the integration of sound into edugames proves to be a crucial element in enhancing engagement and learning, creating immersive and motivating experiences. As discussed, sound not only strengthens the understanding of educational content but also acts as an emotional and cognitive catalyst, capable of improving the psycho-social well-being of the user [55]. The importance of simplicity in the interfaces and the modulation of challenges, balanced by rewarding mechanisms, guarantees an accessible and stimulating gaming experience for every type of player. Through a calibrated use of sound dynamics, edugames can facilitate deep learning and memorization, offering an effective and personalized educational path. Finally, the use of the properties and rules identified by Berthoz highlights how adaptation, modularity, and flexibility are keys to successful learning in games, making sound and design patterns essential tools for the cultural and personal growth of the user, thus placing the designer as well as those who use these educational games to implement educational and learning experiences in the condition of carefully selecting the elements sound on which to focus the training action, which is able at the same time to stimulate the user to listen, to active involvement, for a better understanding of the game plots and a more effective form of immersion in the dynamics of the events themselves.

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