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Design components of serious game based on flow theories

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Abstract: Serious games, defined as interactive digital systems designed with a primary purpose beyond entertainment, have been extensively applied across diverse sectors, including education, training, military, and healthcare. By transforming conventional pedagogical activities into dynamic, interactive learning experiences, these games shift learners from passive knowledge recipients to active constructors of knowledge. Empirical studies consistently demonstrate that serious games significantly enhance learner motivation, engagement, and educational outcomes. The dual imperative of serious games—simultaneously fulfilling educational objectives (e.g., knowledge acquisition, skill development, and affective improvement) and maintaining intrinsic playability—poses a critical challenge for designers and educators, necessitating a balance between instructional efficacy and motivational appeal. Flow theory, pioneered by Mihaly Csikszentmihalyi, has emerged as a pivotal framework for optimizing engagement in educational contexts. Research indicates that students achieving flow states—characterized by deep immersion and focused interaction—exhibit superior learning performance. This study synthesizes existing flow theory models and their applications in serious game design to propose seven key design elements: (1) learning and game goals, (2) immediate feedback, (3) adaptive challenge, (4) control and autonomy, (5) concentration, (6) reward and punishment, (7) sensory immersion. These elements collectively address the tension between educational rigor and engagement sustainability, offering evidence-based guidelines for designing serious games that optimize cognitive absorption, learner engagement, and pedagogical effectiveness. These key design components underscore the necessity of harmonizing skill-challenge equilibrium and systemic coherence to operationalize flow theory in practice, thereby advancing theoretical and applied dimensions of serious game design and development.

1. Introduction

Serious games combine educational or training objectives with engaging, interactive gameplay, offering learners an immersive way to gain new knowledge and skills. Since Clark Abt introduced the concept of serious games in 1970, research in this field has expanded considerably. It has demonstrated that games with clear instructional goals can significantly improve motivation, knowledge acquisition, and emotional engagement. Despite these proven benefits, the design of effective serious games poses a dual challenge: maintaining entertainment value while ensuring that the game fulfills its educational purposes.

Flow theory—initially proposed by Mihaly Csikszentmihalyi—helps address this challenge by shedding light on the optimal psychological states in which learners become deeply absorbed in an activity. When individuals experience flow, they are more likely to demonstrate focused attention, enjoyment, and a willingness to persevere through complex tasks. Flow theory is especially relevant for serious game design, as educators and developers aim to create learning environments where motivation and engagement remain high.

Over time, researchers have introduced multiple flow models, ranging from Csikszentmihalyi's foundational Three-Channel Flow Model to the more nuanced Eight-Channel Flow Model. The Person–Artifact–Task (PAT) model has further emphasized that flow emerges from the dynamic interaction of user characteristics, system affordances, and task design. In serious games, incorporating flow theory involves striking a deliberate balance between challenge and skill, providing immediate feedback, and allowing players autonomy and control.

This paper aims to synthesize these ideas to propose key components for designing serious games that effectively induce and sustain flow experiences. By examining the evolution of flow theory and its integration into serious game frameworks, this study identifies seven key elements—learning and game goals, immediate feedback, adaptive challenge, control, concentration, rewards and punishments, and sensory immersion—that collectively foster deep engagement. By aligning core educational objectives with the psychological drivers of flow, serious games can elevate both the quality of learning and the overall user experience.

2. Flow theory and models

Csikszentmihalyi first introduced the concept of flow in 1975 to describe a psychological state in which individuals become fully immersed and intensely focused on an activity to the extent that they lose awareness of their surroundings [1]. In his book Flow: The Psychology of Optimal Experience, Csikszentmihalyi defined flow as the effortless and fluid sensation individuals often report when performing at their peak [2].

Csikszentmihalyi identified nine key components commonly associated with the flow experience: clear goals, unambiguous and immediate feedback, challenges match skills, merging of action and awareness, concentration and focus, a sense of potential control, a loss of self-consciousness, an altered sense of time, and an autotelic experience [1], as illustrated in Table 1.

Table 1: Key components of flow experience.

Key components	Explanations
Clear goals	The individual clearly understands what they are trying to achieve and what success looks like in the task.
Unambiguous and immediate feedback	The person receives direct and timely feedback, helping them adjust their actions and stay engaged in the activity.
Challenges match skills	The task matches the individual's skill level—neither too easy nor too difficult—creating the right conditions for entering a flow state.
Merging of action and awareness	The individual becomes so engaged in the task that their actions feel automatic and effortless, with no distinction between thought and movement.
Concentration and focus	Full attention is directed at the task, with minimal awareness of anything else.
A sense of potential control	The person feels in control of their actions and can handle the situation effectively.
A loss of self-consciousness	The individual is no longer aware of themselves as separate from the activity—they are fully immersed in the moment.
An altered sense of time	Time may seem to speed up or slow down, depending on how absorbed the person is in the activity.
An autotelic experience	The activity feels rewarding, and the individual engages in it for enjoyment and fulfillment rather than for external rewards.

Novak and colleagues further categorized the nine core elements of the flow experience into three distinct groups. "Clear goals," "Unambiguous and immediate feedback," and "challenges match skills" are identified as antecedent conditions, representing the essential prerequisites for initiating a flow state. "Merging of action and awareness," "Concentration and focus," and "A sense of potential control" are classified as characteristics, reflecting the subjective qualities of the flow state as it unfolds. Finally, "A loss of self-consciousness," "An altered sense of time," and "An autotelic experience" are considered consequences of the experience, serving as key criteria for assessing whether flow has occurred. This categorization highlights each element's temporal and functional roles in the development, experience, and evaluation of flow[3] [4].

Flow models are commonly categorized into three primary types: the Three-Channel, Four-Channel, and Eight-Channel Models [5].

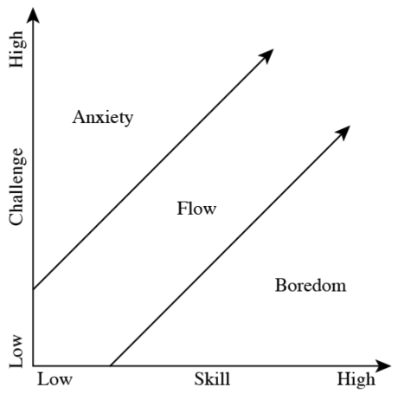

Figure 1: Three-Channel Flow Model.

The Three-Channel Flow Model, initially developed by Csikszentmihalyi based on his flow theory, uses skill as the horizontal axis and challenge as the vertical axis [1], as illustrated in Figure 1. This model classifies experiences into three states: boredom, flow, and anxiety. It emphasizes that the dynamic balance between perceived skill and challenge is a key determinant in the emergence of the flow experience. When an individual's skill level matches the difficulty of the task at hand, flow is most likely to occur.

However, despite its foundational value, the Three-Channel Flow Model has limitations. For instance, research by Carli and colleagues revealed that a balance between low skill and low challenge does not necessarily lead to flow but apathy or disinterest [6]. This finding suggests that the mere balance of skill and challenge is insufficient to induce flow; instead, both dimensions must reach a certain threshold to activate the optimal flow experience. This insight highlights the need for more nuanced models, which led to the development of expanded frameworks such as the Four- and Eight-Channel Flow Models.

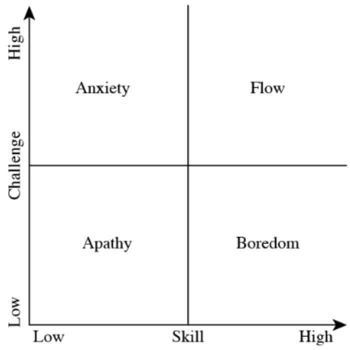

Figure 2: Four-Channel Flow Model.

With significant advancements in measuring flow experiences, Csikszentmihalyi et al. extended the Three-Channel Flow Model by applying the Experience Sampling Method (ESM) to real-time data collection and analysis, leading to the development of the Four-Channel Flow Model [6][7][8][9], as illustrated in Figure 2. This model adds nuance by identifying an additional psychological state—apathy—which occurs when both perceived skill and challenge are low. Flow is most likely to occur when skill and challenge are high and balanced.

While the Four-Channel Model provides a more refined categorization of psychological states, it has limitations. First, it lacks clear operational criteria for determining what constitutes “high” or “low” levels of skill and challenge, which can introduce subjectivity in application. Second, the model does not offer practical guidance on how individuals can achieve a high challenge–high skill balance, a process that often requires iterative adjustment and sustained effort.

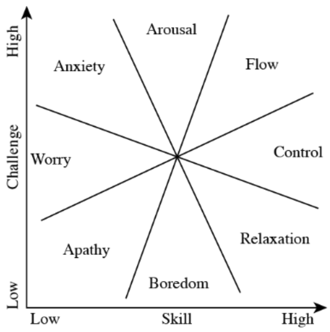

Figure 3: Eight-Channel Flow Model.

With the advancement of flow research, Massimini and Carli conducted a more detailed analysis of the relationship between challenge and skill, leading to the development of the Eight-Channel Flow

Model [10], as illustrated in Figure 3. This model refines the understanding of users' emotional states by categorizing them into eight distinct experiential conditions, based on varying combinations of perceived skill level and challenge intensity. The model offers a more granular framework for analyzing psychological responses by mapping specific emotional states to high, medium, and low dimensions.

As research on flow theory has deepened, scholars have proposed more refined models to capture the complexity of flow experiences better. One such model is the PAT model, developed by Finneran and colleagues, which conceptualizes flow as the result of interactions among three key components: Person, Artifact, and Task [11]. The PAT model underscores that it is not any single element but the dynamic interaction among user characteristics, system affordances, and task design that collectively serves as the critical determinant of whether a flow experience can be achieved.

3. Serious game

Clark Abt first introduced the concept of serious games in his 1970 publication Serious Games [12]. Unlike traditional games designed primarily for entertainment, serious games are structured to deliver educational or informational content through engaging and interactive gameplay. They aim to provide a personalized, immersive, entertaining learning experience that enhances users' creativity and innovative thinking. Later, Marc Prensky referred to serious games as a form of "digital game-based learning," defining them as integrating educational content with computer games [13]. This approach leverages the motivational power of games to support and enhance learning outcomes. Stewart and colleagues argue that serious games operate on three levels of impact: transmitting knowledge, acquiring skills, and improving emotional aspects [14]. These dimensions reflect the multifaceted educational potential of serious games, enabling them to inform, train, and transform users through interactive and engaging experiences.

Since the early 21st century, serious games have entered a period of rapid development and have attracted increasing scholarly attention [15]. Extensive research on serious games and their value has confirmed that serious games can, to a certain extent, promote cognitive development [16], enhance knowledge acquisition, and improve learning outcomes [17]. Moreover, they have increased learners' motivation to learn [18]. Serious games are an important tool for shaping students' emotional experiences [19] and hold significant potential for supporting personalized learning and optimizing educational environments [20].

Design and development are critical stages in the successful implementation of serious games, directly influencing their effectiveness and adoption in practical contexts. The central focus of serious game research has shifted toward "how to design scientifically grounded, effective, and engaging serious games" [21]. This shift reflects a growing emphasis among educational researchers not only on evaluating the outcomes of serious games [22][23] but also on ensuring their alignment with real-world classroom needs and their applicability to solving authentic educational problems [24]. As serious games inherently involve a tension between seriousness and playfulness, designers face the dual challenge of maintaining fun gameplay experiences while ensuring the game fulfills its intended educational or functional purpose. Striking this balance presents both a challenge and an opportunity for innovation in serious game design.

De Freitas and Oliver have pointed out that the lack of dedicated design frameworks for serious games remains a significant barrier to their practical implementation and broader adoption [25]. While Hunicke et al. introduced the MDA framework—comprising Mechanics, Dynamics, and Aesthetics—as a means to bridge the gap between game design, player experience, and system architecture through alternating perspectives across different levels of abstraction, this framework does not explicitly incorporate educational considerations. Arnab et al. proposed the Learning–Game Mechanics (LGM) model, which attempts to align learning objectives with gameplay mechanisms [26]. However, this model lacks a clear strategy for integrating educational elements with game design components, thus limiting its utility in designing pedagogically effective serious games.

At the core of serious game design frameworks lies the integration of educational principles with game mechanics, and achieving an effective fusion between the two has become a central focus of current research. The first essential step in this integration process is distinguishing commonalities and unique characteristics of educational and game elements. By systematically aligning and combining these aspects, researchers and designers can establish robust design principles that are practical guidelines for developing effective and pedagogically meaningful, serious games [27].

Instructional activities grounded in flow theory have enhanced student motivation, engagement, and, ultimately, learning outcomes. Therefore, developing a serious game design framework based on flow theory can significantly improve the effectiveness of serious games as educational tools, ensuring that learners experience optimal engagement and sustained attention throughout the learning process.

4. Serious game frameworks based on flow theories

Flow is recognized as a key source of engagement in serious games. Serious games that effectively facilitate flow experiences are generally more appealing to learners and are associated with improved learning outcomes. Extensive research has been conducted on the design of educational games based on flow theory.

Sweetser identified flow-related elements relevant to the gaming experience and proposed the GameFlow model for evaluating game enjoyment [28]. This model comprises eight core criteria: concentration, challenge, player skills, control, clear goals, feedback, immersion, and social interaction. These elements align closely with the key components of the flow experience. Researchers like Fu and Khanana have applied the GameFlow model in developing and evaluating educational games, demonstrating its effectiveness in assessing game engagement and entertainment value [29][30].

Drawing on flow theory and experiential learning theory, Kiili proposed the Experiential Gaming Model [31][32]. This model emphasizes the importance of clear goals, feedback, and appropriately balanced difficulty within educational games, as these elements are critical for inducing flow experiences and enhancing the instructional effectiveness of such games. While the model successfully integrates principles from educational game design and flow theory, it lacks specific methodological guidance for the practical implementation of educational game design.

Song et al. proposed the EFM educational game design model by examining the interrelationships among flow experience, learning environment, and motivation [33]. In this model, core elements such as goals, challenges, and feedback are mapped to the key conditions of flow theory, reflecting their integral role in supporting an engaging and practical learning experience.

Kirriemuir and McFarlane identified several barriers to the practical implementation of educational games. They argued that such games should eliminate content unrelated to the curriculum and provide learners with tasks and materials explicitly aligned with educational objectives and curricular requirements [34].

Shang et al. emphasized that the key lies in integrating the intrinsic motivational elements that make digital games engaging into educational software. They argued that effective educational games should incorporate core features of mainstream games—such as challenge, curiosity, and competition—while ensuring that the content and tasks are closely aligned with the curriculum [35].

5. Design elements in serious games for fostering flow

This study thoroughly examines flow theory, related models, and serious game design frameworks based on this theory. It identifies seven essential elements that help induce flow experiences within serious games. These elements are learning and game goals, immediate feedback, control and autonomy, adaptive challenge, concentration, reward and punishment, and sensory immersion. These elements are proposed to enhance learner engagement, motivation, and overall learning outcomes.

5.1. Learning and game goals

Designing clear and specific goals for learners can effectively stimulate their expectations and foster a goal-oriented learning mindset, positively influencing their intrinsic motivation. According to motivation theories, learners' motivation arises from their cognitive appraisal of goals, while motivation theory emphasizes that goals constitute the core of learning motivation. Therefore, incorporating explicit learning objectives at the initial stage of educational game design can activate learners' intrinsic motivation, establish a positive psychological state, and create favorable conditions for entering a flow state.

The formulation of learning goals requires that designers and educators clearly define specific and measurable goals prior to the development of serious games. On the one hand, it is essential to recognize that the target audience of an educational game is not all learners but rather those at a particular educational stage. Therefore, a thorough analysis of learners' characteristics—such as personality, age, and cognitive development—is necessary. Theories such as Piaget's theory of cognitive development, which delineates children's cognitive and thinking patterns at different developmental stages, can serve as valuable references for segmenting the target audience[36].

On the other hand, serious games inherently possess substantial educational value, and the achievement of educational goals is reflected in measurable learner progress across three domains: Cognitive skills, psychomotor skills, and affective development.

Cognitive skills refer to the development of thinking ability in the players, which they can use to solve problems of varying degrees, i.e., from easy to difficult, either as part of learning activities or the evaluations following learning of contents through a game. The categories of cognitive skills have been drawn from the revised Bloom's taxonomy, which includes remembering, understanding, applying, analyzing, evaluating, and creating [37].

Affective skills are concerned with issues relating to the emotional component of learning and range from a fundamental willingness to receive information to the integration of beliefs, ideas, and attitudes. While the cognitive domain is the most widely used of Bloom's Taxonomy, Bloom and his co-workers also researched the affective domain [38]. Bloom and his colleagues developed five significant categories to describe how we deal emotionally: receiving, responding, valuing, organization, and characterization.

Bloom and his colleagues have not categorized the psychomotor skills. However, other researchers have categorized the skills and created their psychomotor taxonomies. These include Simpson's psychomotor domains [39], Harrow's psychomotor domains [40], and Dave's psychomotor domain [41]. Simpson's categorizations help develop these skills from children to adults, including perception, set, guided response, mechanism, complex overt responses, adaptation, and origination.

Game goals should be derived from the underlying learning goals, requiring the decomposition of educational goals into a sequence of in-game tasks presented to the player. Ideally, these game objectives should be specific and clearly defined to ensure players understand expected actions. Vague directives such as "defeat the enemy" are generally avoided in favor of more explicit instructions, such as "defeat ten enemies" or "defeat a specific character." This level of clarity enhances players' understanding of the game's purpose and helps maintain alignment between gameplay and learning outcomes [42]. Clear game objectives enable players to better navigate and monitor their progress within the game and lay a critical foundation for providing immediate feedback.

5.2. Immediate feedback

Feedback is a crucial component in enhancing learners' educational outcomes. Providing learners with specific and immediate feedback can significantly improve their self-awareness and support regulating their learning behaviors. Feedback often elicits positive emotional responses in authentic learning contexts, fostering a more engaged and motivated learning experience. Immediate feedback on learning performance can reinforce positive emotions, encourage sustained effort toward current learning objectives, and create optimal conditions for learners to enter a flow state.

In serious game design, the effectiveness of immediate feedback relies heavily on the functionality of the game system itself. A well-designed feedback system evaluates learners' task performance and delivers corresponding feedback based on their outcomes. For instance, upon completing a task or challenge, the system may assess the level of learning and provide explanations of target knowledge, corrections of misconceptions, and reinforcement of key concepts.

Such feedback mechanisms support learner reflection and enable self-assessment of learning progress. Moreover, when a learner fails to meet the desired learning outcomes, the system should go beyond simple right-or-wrong responses by offering detailed analyses of errors and delivering appropriate scaffolding or learning support. This targeted feedback helps guide learners toward more effectively achieving their educational goals.

5.3. Adaptative challenge

As proposed in the Three-Channel Flow Model, the early flow theory posits that individuals can experience flow when perceived challenges are matched with their skill levels—whether at high or low intensity. That is both high challenge–high skill and low challenge–low skill combinations may elicit a flow state. However, subsequent refinements, including the Four-Channel and Eight-Channel Flow Models, emphasize that flow occurs specifically when high levels of challenge are matched with equally high levels of skill. This perspective narrows the conditions under which flow is optimally achieved, underscoring the importance of maintaining an appropriate balance at elevated levels of difficulty and competence.

Adaptive challenge refers to the dynamic adjustment of difficulty levels based on the player's performance to prevent frustration caused by excessive difficulty or boredom from too-easy tasks.

The early stages of a serious game typically present simpler tasks or challenges to avoid the mismatch between high challenge and low skill. This also allows players to become familiar with the game mechanics and rules more efficiently. The system gradually introduces more complex and demanding challenges as players develop cognitive and behavioral skills. By maintaining a balance between high skill and high challenge, the game fosters sustained flow experiences and deepens player immersion.

However, prolonged exposure to high-challenge environments can lead to sustained cognitive strain, causing players to experience mental fatigue due to continuous attentional demands. Therefore, adaptive challenge mechanisms must align with the player's evolving skill level and dynamically adjust the difficulty to mitigate fatigue. One practical approach is the implementation of a stair-step difficulty curve, in which the challenge within each task gradually increases. In contrast, the initial difficulty of a new task is set slightly lower than the final difficulty of the preceding one [42]. Nevertheless, the overall difficulty at the end of each task continues to increase progressively across the game, as illustrated in Figure 4. This stair-step design allows players to recuperate following periods of high intensity and reinforces a sense of achievement. Players are more likely to perceive the preceding effort as meaningful, thus enhancing their sense of competence and motivating continued engagement.

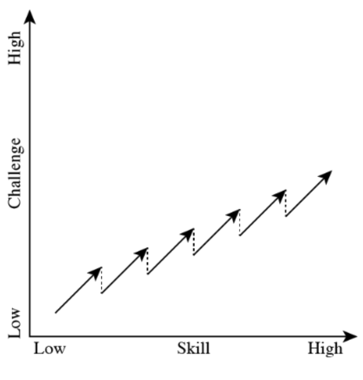

Figure 4: Stair-step difficulty curve.

Furthermore, when players encounter excessively difficult challenges and repeatedly fail to overcome them, the game system can adapt by reducing the difficulty level or by providing appropriate support or scaffolding to facilitate task completion.

In summary, adaptive difficulty mechanisms are essential for real-time monitoring of learners' developmental progress. When a learner's current ability does not align with the demands of a learning task, dynamic difficulty adjustment enables the segmentation of content to balance the relationship between skill and challenge better, thereby sustaining immersion in the learning activity. Previously acquired skills prepare learners to face more complex challenges, while higher levels of challenge necessitate the development of new skills, establishing a new dynamic equilibrium. Through continuous reflection and trial, learners' cognitive structures are progressively expanded and reorganized [14].

5.4. Control and autonomy

Csikszentmihalyi's research revealed that across all demographic groups, the term "sense of control" consistently emerged in descriptions of the flow experience. Specifically, activities that induce flow are characterized by a perceived sense of control, distinguishing them from everyday experiences where individuals may constantly worry about losing control. Entertainment game designers, in particular, emphasize ensuring players feel in control during gameplay to prevent anxiety or confusion resulting from perceived loss of control.

From the learning motivation perspective, providing learners with a sense of control fosters active engagement, enhances intrinsic motivation, and improves learning outcomes. It also supports the development of metacognitive and self-regulatory skills [43].

In the context of serious games, control entails offering players greater autonomy and the ability to customize their learning experiences. Most serious games allow players to select difficulty levels that match their current skill set, thus respecting individual differences.

Players generally prefer to engage with games in ways that align with their preferences, necessitating that developers grant players a certain degree of decision-making power. This autonomy contributes to a stronger sense of control and facilitates entry into the flow state. For instance, in role-playing-based serious games, players often design their avatars, freely explore open environments, and make choices across multiple narrative paths—features that collectively enhance the sense of agency and immersive engagement.

5.5. Concentration

Novak et al. classified "concentration" as an experiential factor of flow rather than a precondition [4]. However, serious game design can actively regulate this factor to facilitate a state of attentional concentration. Given the limited capacity of the human brain to process information, serious games must strategically allocate users' attention within the interface [44], ensuring that more working memory resources are reserved for the processing of instructional content.

Excessive or disorganized information can impose cognitive overload, hindering the extraction of goal-relevant content and impeding the onset of flow [44]. Therefore, interface design should control the quantity and sequencing of information, prioritize essential content, and clearly distinguish between primary and secondary elements. Visual hierarchy can be established using layout, color, and size differences to efficiently direct learners' attention toward key information.

Compared to reading text, users—especially children—prefer and more easily process graphical representations. Visualizations enhance perceptual salience and compress information into more digestible forms, enabling more efficient knowledge transmission and reducing cognitive load. This, in turn, supports deeper engagement and the emergence of flow.

5.6. Rewards and punishments

In serious games, rewards and punishments function as a dual motivational mechanism to elicit desired behaviors and sustain learner engagement. While the use of rewards to reinforce correct behaviors and punishments to discourage incorrect ones has been widely validated in educational contexts, it is important to recognize that learners do not engage in serious games to experience failure. Therefore, punitive mechanisms in serious games should be implemented with caution.

When a learner fails a task, the system should not impose penalties but assess the causes of failure, provide immediate feedback, and offer possible solutions when necessary. Game designers must seize every failure as an educational opportunity—delivering informative prompts before the player becomes frustrated and disengages. Such interventions can significantly enhance learners' understanding of the game's educational objectives and prevent negative emotional responses.

Positive reinforcement through reward mechanisms is critical in guiding player behavior and fostering flow states, essential for sustained immersion. In current serious game design, rewards typically take several forms, including task completion rewards, login rewards and physical or offline Rewards.

Receiving rewards generates short-term satisfaction and positive emotions, with some rewards carrying instructional value that further supports the learning process. Ultimately, well-designed reward systems motivate players to engage more deeply with the game and persist in their learning journey.

5.7. Sensory immersion

A distinguishing feature of high-quality serious games is the seamless integration of visual and auditory elements. Intuitive audiovisual experiences are among the most effective means of facilitating flow states, as they directly influence the player's initial perception and emotional engagement. Players' most immediate judgment about a serious game is often based on its visual presentation and sound design.

In the early stages of gameplay, visuals and audio serve as the primary channels through which the game's educational value and thematic atmosphere are conveyed. These sensory elements help establish a preliminary sense of recognition and emotional resonance with the player. Empirical data indicate that approximately 50% of users discontinue a game after the first experience, typically due to three main factors: overly complex user interfaces, content misaligned with user expectations, and poor initial impressions. High-quality audiovisual design can significantly mitigate these issues by enhancing clarity, reinforcing thematic coherence, and creating a compelling first impression.

Modern game engines such as Unreal Engine and Unity 3D offer advanced real-time rendering capabilities that enable the development of visually immersive and realistic environments. These technological affordances empower designers to create aesthetically rich and emotionally engaging serious games, supporting educational impact and sustained player engagement.

6. Conclusion

Flow-informed design principles provide a robust theoretical foundation for improving engagement and learning outcomes in serious games. By systematically aligning challenges with learners' skill levels, articulating clear goals, offering immediate feedback, promoting autonomy, and enhancing audiovisual elements while minimizing cognitive overload, developers can create experiences that are both pedagogically rigorous and intrinsically motivating. Ongoing research should refine adaptive algorithms, integrate emerging technologies, and ensure further alignment with curricular standards to optimize flow-driven frameworks. Ultimately, the structured application of flow theory in serious game design can heighten learner immersion, motivation, and educational efficacy.

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