Toward a Game Design Engineering Process Centered on Player Experience

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***Abstract*—Central to a game is the player experience, a relation characterized by the indirect nature of how the experience emerges through play. This second-order design problem of games introduces a significant challenge for the game design engineering process. In this paper, we propose a model of the game design engineering process emphasizing the player experience as the primary concern. By facilitating a comparison between a system as-it-is and a system as-it-should-be, this approach has the potential to shape future endeavors for planning, validating, and refining player experience in the context of design engineering.**

***Index Terms*—Game Engineering, Game Design, Design Engineering, Player Experience.**

I. Creating Games & Play

Central to the domain of games is the player's experience. This experience is a subjective and human encounter that arises from interacting with the game—by playing the game. The central role of experience is not unique to games. This is the case for all types of entertainment: books, movies, poems, plays, music, rides [1]. The experience arises from interaction with the medium. Weinberger highlights the essence of this relation: "... every reading of every poem, regardless of language, is an act of translation: translation into the reader's intellectual and emotional life. As no individual reader remains the same, each reading becomes a different—not merely another—reading. The same poem cannot be read twice" [2, p. 43]. The same is true for games. Playing a game is an act of translation: translation into the player's intellectual and emotional life. This subjective and unique experience is the *Player Experience* (PX). PX is about the (socio-)psychological experience of the player shaped by nuanced dimensions, including (game-)flow, immersion, challenge, tension, competence, and emotions [3]. Similar to the perspective adopted by many user experience researchers [4], PX can be understood as being influenced by multiple layers: (i) the system itself, (ii) the perceptual and operational actions of the player, and (iii) the context in which the play activity occurs [5].

When designers and engineers create games, the game artifact itself only plays a secondary role. The primary focus is the experience a player has when interacting with the game. This indirect nature of PX is identified as a *second-order design problem* [6] "...meaning that designers are communicating with players indirectly through their games" [7, p. 165]. The goal of the game creation process is to create an experience that aligns with a planned vision. Designers have a specific idea in mind—the plan—and try to shape reality—the PX emerging from playing the game—to come as close as possible to the plan. This process is known as design or engineering, with the plan as a conceptual model of the system.

Conceptual models are simplified representations of systems and are used by designers and engineers. The challenge is to design the simplification so that the model's behavior corresponds to the system's behavior, and it is possible to perform an analysis of it. The engineering method typically begins with the creation of a model representing the system to build. This model then guides the construction of the system based on the model. The system is then analyzed and validated through verification against the model and predicted outcomes.

Traditionally, *game design* and *game engineering* are treated separately [1], [6], [8], [9]. However, from a PX perspective—where PX is the primary overarching and integrating concern and the game a second-order artifact—this division falls short of capturing the full picture. We propose a perspective from an integrated view: *Game Design Engineering* (GDE). Because the PX cannot be shaped directly, GDE demands novel modeling approaches for this second-order challenge. The core of the challenge lies within the comparison of a PX model with the PX. This involves two key sub-challenges: modeling PX for GDE and accessing PX by measuring it for model-checking.

A. The Problem

Game creation often prioritizes the game artifact, overlooking the role of PX. To enable deliberate and systematic GDE, we must reframe our processes to center PX as the primary design objective, with conceptual models centered on PX. The need for formal methods in game design has been recognized for decades. Already in 1994, Costikyan [10] called for a shared vocabulary to support analysis and communication—a call echoed in more recent works [9], [11]–[13].

B. Our Approach

This paper addresses the need for PX-centered GDE by proposing a GDE process grounded in both literature and professional practice. A preliminary set of sources was selected based on the authors' expertise in game design, engineering,

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human-computer interaction, and PX research. This expert-informed corpus was extended through a literature review covering the domains of GDE, PX models, and measuring PX. For each domain, we incorporate both seminal works and recent systematic literature reviews to ensure a well-rounded representation of current academic discourse. Although we aimed for broad coverage, the scope of this paper necessitated a selective presentation of the most relevant literature.

II. Game Design Engineering

A. Related Work

To structure our discussion of related work, we divide it into three sections: (1) the broader field of GDE, (2) existing PX models, and (3) PX measurement methods. Afterwards, we identify the gap that remains for a PX-centered GDE process.

1) GDE: A vast body of literature [1], [6], [9] provides foundational perspectives on game design, exploring theoretical approaches and practical tools for guiding designers. Incorporating these concepts, game creators draw on a variety of formal languages and artifacts to plan and implement games. Almeida & da Silva [13] survey game design methods and tools. Van Rozen [14] systematically maps how domain-specific languages, notations, and tools enhance productivity and game quality. The use of formal languages and models parallels the modeling of requirements and design in Software Engineering (SE) [13]. SE researchers explore the game domain by applying methods and tools to improve game software development [14]. Ampatzoglou & Stamelos [15] conducted a systematic review of SE for computer games, which Chueca *et al.* [16] expanded, analyzing 98 studies. International standards such as the DIN EN ISO 9241-210 norm [17] on human-centered design for interactive systems can be applied to GDE. An important topic in SE is the use of models. Several authors discuss employing the Unified Modeling Language (UML) in the context of game development [13], [18], [19]. Model-driven engineering (MDE) uses abstract models–often visual–to specify, design, analyze, and implement systems. In GDE, MDE is increasingly used to represent game content and processes [16]. Zhu & Wang [20] review 26 such approaches.

2) PX Models: The development of accurate and reliable methods for estimating PX remains a critical challenge within the game research community [3], [21]–[26]. Reliable PX estimation is essential for game developers to assess the quality of their products [1], [26]–[28], to facilitate PX through personalized, adapted, and contextualized PX [29]–[31], and to allow players to reflect on their play and learn [26]. Models from various research fields can help to understand the multidimensional structure of PX. Wiemeyer *et al.* [3] discuss various general and domain-specific models that can provide insights into the essence of PX. Popular models to look at PX include self-determination theory (SDT) [32] and the extension of it to the Player Experience of Need Satisfaction (PENS) model [33], the attention, relevance, confidence, satisfaction (ARCS) model [34], the flow model [35], the GameFlow model [36], presence and immersion, models related to the Game Experience Questionnaire (GEQ) [37], the Core Elements of the Gaming Experience (CEGE) model [38], and the Game Usability Heuristics (PLAY) [39]. Practical PX models explore diverse facets, including psychological and integrative frameworks [3], foundational syntheses serving as a reference for future work [5], computational modeling for personalization [29], contextual influences [31], gameplay pattern analysis [40], PX classification [28], ordinary and extraordinary experiences [41], and onboarding evaluations [42].

3) Measuring PX: Game development often involves extensive playtesting across development phases to identify bugs and gather PX feedback [1], [9], [43], with significant variability in scientific rigor. Understanding and quantifying PX remains a significant challenge for both researchers and game developers [3], [5], [21], [23], [25], [26]. Approaches span three key methods: self-reported data, including self-reports and questionnaires; behavioral data, and physiological data.

a) Self-Reported Data: Self-reported data provides valuable insights into PX [3], [23]. Self-reports can take various forms, such as interviews and questionnaires conducted after play or thinking-aloud methods during play [27]. Standardized questionnaires such as the Player Experience Inventory [44], PENS [33], and GEQ [37] assess specific PX dimensions, with additional tools reviewed by Wiemeyer *et al.* [3]. While allowing the estimation of PX, self-reported data is limited as it is subjective, influenced by environmental factors and formalization, and lacks precise linkage to specific play events when recorded retrospectively. Many questionnaires are not or only partially empirically validated [23], and they are constrained in their capacity to capture holistic experiences [24].

b) Behavioral Data: PX can also be estimated using more objective measurements of what the player is doing. Personal experience often manifests through observable behaviors such as laughing, smiling, or frowning [3], [23], [27]. Several studies have proposed methods for real-time measurement using behavioral data derived from the game [21], [26], [45], [46] and the physical behavior of players [47]. This analysis can include any player-initiated behavior ranging from low-level data, such as button presses and input vectors, to in-game interaction data with regard to the game mechanics and the game state [21], [23]. While these approaches yield valuable insights into player behavior and, indirectly, PX, they often fall short of capturing emotional and affective states [24].

c) Physiological Data: Physiological measurements, including skin conductance, heart rate, blood pressure, eye movement, and brain activity, offer a means to uncover hidden changes in a player's psychological state. Psychophysiology examines the interplay between psychological processes and their physiological correlates. Neuroimaging methods, such as electroencephalography (EEG) and functional magnetic resonance imaging (fMRI), enable real-time estimation of PX by detecting player state changes. [3], [23]–[25], [48]–[50]

These metrics have the potential to reveal emotional responses that might remain undetectable using traditional methods [24], [50], [51]. Observable PX qualities include challenge [52], stress [53], and mental functions, including attention, memory, and decision-making [54], [55]. Application is constrained by hardware limitations, cost, and the reliability of deriving PX quality from physiological measurements [24].

4) The Identified Gap: Despite increasing recognition of PX in GDE, a significant gap remains. Although GDE shares elements with traditional SE, key differences—especially PX and the second order—challenge the direct transfer of established SE methods [12], [15], [43], [56], [57]. Existing GDE approaches often emphasize the game artifact. PX models and measurement methods are researched and applied in isolation. There is no integrated framework that connects PX modeling and measurement within GDE practices to support comparison between intended and actual PX via model-checking. Addressing this gap requires a PX-centered GDE process.

B. A PX-Centered Game Design Engineering Process

We advocate for a GDE process integrating PX as the primary focus. This process is illustrated in Figure 1. Our process addresses the second-order design problem—how a game's design shapes PX—by distinguishing between the PX and the game artifact. This split in the GDE process is necessary because the evaluation of the technology (the game) is fundamentally different from evaluating the higher-level PX [3], [31]. This differentiation enables systematic evaluation through a dual-system model: the *as-it-should-be* system, representing the designer's vision, PX plan, and game plan, and the *as-it-is* system, representing the actual game, player, and emerging PX. The *as-it-should-be* system begins with a designer's vision of the desired PX. This vision is crystallized into a PX plan, a conceptual model that guides the creation of the game plan. The game plan is subsequently transformed into the actual game artifact by implementing the game. This game artifact is then played by the player—from which the PX emerges. The as-it-is system can be evaluated by measuring and observing the player-game system and estimating the PX as described in the related work II-A3. These measurements are then processed into a format that can be compared with the PX plan for model-checking. Simultaneously, the game and the game plan can be compared using established SE principles. The proposed GDE process connects the concepts from PX models and PX measurements in the context of GDE approaches as presented in the related work II-A.

With this process, our aim is to contribute a step towards shifting the GDE efforts to the central role of the PX. The process we propose is a first step to be discussed and used as a basis for future publications that focus on a guiding question: *How can we plan PX so that we can later create a game that implements this planned PX?* In the context of GDE, this question leads to two sub-questions that follow the two core challenges identified earlier: *(q-i) How can we plan PX?* and *(q-ii) How can we measure PX for model-checking?* Here, (q-i) refers to the quality of being able to model the behavior of the system, and (q-ii) means being able to perform analysis on it. These central questions should guide the development of future solutions.

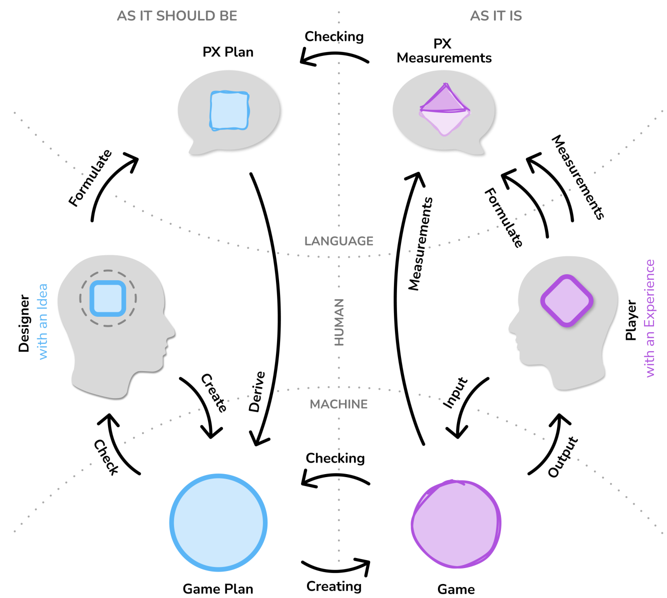

Fig. 1: A model of the GDE process with an as-it-should-be system and an as-it-is system, differentiating between the PX and the game.

III. The Process in Perspective

Our process builds on a broad foundation of existing research in GDE, PX models, and measuring PX, integrating and interrelating their principles. This PX-centered GDE vision can be applied in the context of established approaches, including game design [1], [6], [9], [13], [14], SE [15]–[19], MDE [16], [20], and standardized human-centered design activities [17].

A. Discussion

1) Challenges & Limitations: Our approach views games as formal systems, which contrasts with the inherent imprecision of their connection to human experience. While games are precise as isolated artifacts, their design process—rooted in creativity and human interaction—often operates within the realms of intuition and imprecision. Formalism demands precision, but design thrives on flexibility and the freedom to be imprecise. The GDE process must accommodate both the formal, precise nature of games and the intuitive, imprecise aspects of creativity and PX. This has to be respected when creating solutions in the context of the proposed model.

Tooling is essential for the benefits of models, especially in the context of MDE [58], [59]. The success of the presented approach will depend on the tools created.

Ethical concerns regarding the collection and use of sensitive personal data in the context of PX must be addressed.

2) Opportunities & Implications: A PX-focused GDE process introduces the potential for a shared planning language that bridges the diverse disciplines involved in game development [1], [7], [8]. Visual, model-centered PX representations can enhance communication [6] and support collaboration across roles [16]. Conceptual models centered on PX offer the potential for more standardized game design documents [60], supporting clearer communication and laying the foundation for a comprehensive PX-driven design methodology [12], [13].

B. Conclusion & Future Work

The proposed process strengthens GDE by emphasizing the PX as the primary concern, with the game and its plan serving as derived artifacts. By facilitating a comparison between a system as-it-is and a system as-it-should-be, this approach provides a robust framework for planning, validating, and refining PX. In the future, we will present concrete models and processes following our GDE approach. This paper is a step towards GDE with a focus on PX. We invite all researchers to contribute to this vision of a PX-centered GDE process.

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