Gamified Knowledge Encoding: Knowledge Training Using Game Mechanics

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***Abstract*—Game mechanics (GMs) encode a game's rules, underlying principles and overall knowledge. During the gameplay, players practice this knowledge due to repetition and compile mental models for it. Mental models allow for a training transfer from a training context to a different context. Hence, as GMs can encode any knowledge, they can also encode specific learning contents as their rules and be used for an effective transfer-oriented knowledge training. In this article, we propose the *Gamified Knowledge Encoding* model (GKE) that not only describes a direct knowledge encoding of a specific learning content in GMs, but also defines their training effects. Ultimately, the GKE can be used as an underlying guideline to develop well-tailored game-based training environments.**

I. Introduction

A computer game consists of multiple *Game Mechanics (GMs)* that define and structure the gameplay by encoding the game's rules and underlying principles [1]. The *interaction* between the individual GMs not only creates a game's gameplay, but also provides players with feedback about the effects, correctness, and results of their actions. One can distinguish between *Game-Bound* (GBGMs) and *Player-Bound* GMs (PBGMs). GBGMs are related to the game story, game type, and underlying principles which ultimately create the overall game environment [1]. PBGMs, such as movement-control and action-performance GMs, are executed by the players for the purpose of interacting [2] with the GBGMs.

For instance, a computer game might feature moving platforms on which a player is required to jump to proceed with the game. The moving platform element is a GBGM that cannot be controlled by a player. In contrast, the ability to jump is a PBGM that can be executed by a player to achieve an interaction. Based on the outcome of this interaction, a clear feedback is provided as players either hit or miss a platform.

In general, the execution of individual GMs requires and hence trains a specific set of human skills [3]. In particular, a player's periodical execution of PBGMs [4] during the gameplay results in a training of *procedural* and *declarative knowledge* [5] on the *level of rule-based human performance* [6]. As the execution of some PBGMs, such as movement and view-control GMs, results in a sensorimotor direct interaction with the game, computer games also achieve a training of procedural knowledge on the level of *skill-based* performance. The acquisition of procedural knowledges is slow, requires a periodical repetition, and passes through three stages [7]. Although declarative knowledge can be acquired quickly, it requires training and periodical deliberate practice [8] to gain expertise [5] and to shift to a more pattern-driven application.

Training transfer is the application of knowledge trained in one context to a different context [9]. The training transfer takes place on the *knowledge-based* performance which is used in unfamiliar situations to complete self-defined goals. At this level of human performance, the reasoning and problem-solving abilities can be explained with *mental models* [10]. Mental models store specific knowledge in complex mental representations that allow for an internal visualization. They can be compiled with repetitive knowledge training on a rule-based and skill-based level [11]. Gamified Training Environments (GTEs), e.g., serious games, support the compilation of mental models as they audiovisually demonstrate and require the learning content [12].

These theoretically grounded aspects of knowledge, human performance, mental models, and GMs are used to define the *Gamified Knowledge Encoding* model *(GKE)*. The GKE describes how a specific learning content can be encoded in GMs and how the training process in a GTE is structured.

II. Gamified Knowledge Encoding

The GKE utilizes the interaction between at least one GBGM and one PBGM to require the application of the learning content on a rule-based or skill-based level of human performance. As a result, the training process allows learners to compile a mental model for the encoded knowledge which allows for the training transfer to a targeted real world context. The GMs that encode a knowledge's rules and interact with each other create metaphors for the learning content. They are responsible for a player's knowledge gain by acting as *learning affordances* [13]. Learning affordances require the application of the encoded knowledge and inform about the underlying principles thus providing a means of periodic knowledge training. Hence, we define a gamification metaphor as a knowledge's gamified meta-model which can be fully internalized in the form of mental models during the gameplay.

Working with the GKE (see Figure 1), the learning content first is segmented into smaller and coherent knowledge packages. Then, these knowledge packages are transformed into

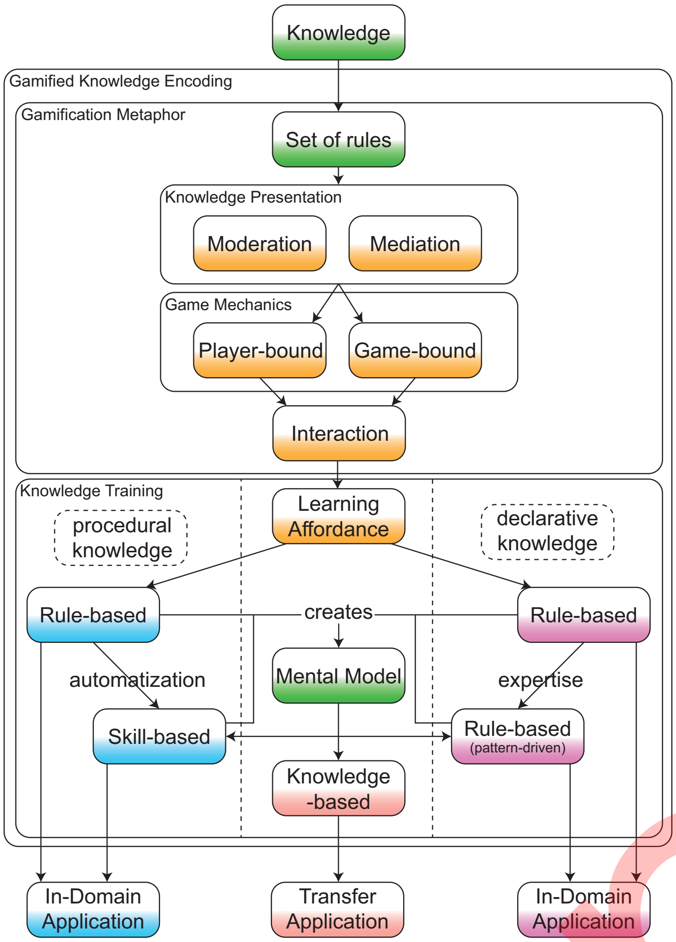

Fig. 1. The GKE describes the process of knowledge encoding and training using GMs. At first, the knowledge gets segmented into coherent sets of rules which can be mapped to GMs. The mapping process is determined by the knowledge presentation allowing for a scaling of the knowledge's level of abstraction by moderating its complexity and/or mediating it using intuitively designed GMs. The GMs used to encode the sets of rules generate a gamification metaphor representing the knowledge inside of the GTE. PBGMs require the application of the knowledge, whereas GBGMs provide learners with feedback or demonstrate the encoded principles. The interaction between individual GMs creates a learning affordance initiating the theoretically grounded knowledge training process.

clear and well-defined rules that are encoded as the game-knowledge rules of interacting GMs. This mapping process includes a *knowledge moderation* and a *knowledge mediation*. The knowledge moderation scales the level of abstraction of the encoded knowledge by adjusting the accuracy and selection of the knowledge rules mapped to the GMs. A moderation can be adjusted over time, e.g., difficulty levels, thus achieving an intuitive knowledge training. The knowledge mediation is the choice and the design of the used GMs which partly depends on the degree of the moderation. A low degree requires GMs that accurately encode the knowledge rules thus simulating the learning content. A high degree reduces the constraints and allows for GMs that represent complex knowledge rules with generalized and intuitive interactions. For instance, a racing simulation can allow for an individual utilization of the clutch or automatically include it in a shifting process.

Utilizing the GKE creates GTEs that fulfill the conditions for optimal learning [8]. By encoding the learning content in interacting GMs, the GTE provides learners with *immediate feedback* about the correctness of their inputs. By adjusting the knowledge moderation, a requirement for *pre-existing knowledge* is achieved. A *periodical knowledge application* is established by the repetitive requirement to execute the gamification metaphor's GMs. Simultaneously, this gameplay results in *highly motivating* flow keeping learners engaged.

III. Conclusion

The GKE is, to our best knowledge, the first approach describing how specific knowledge can be directly encoded and trained in GTEs. The model utilizes the general training effects of interacting GMs to encode and require a specific learning content. For this purpose, the knowledge is segmented into coherent packages that are encoded as a GM's internal rules. The GMs require the knowledge's application during the gameplay and visualize the resulting effects thus demonstrating the underlying principles. Players train the encoded knowledge on a *rule-based* and *skill-based level of human performance*. This leads to the compilation of a *mental model* allowing for a knowledge transfer from the GTE to a target context. The GKE ultimately provides a guideline for the development of transfer-oriented GTEs.

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