

Learn-to-Learn: Game-Based Learning for Metacognition

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ABSTRACT

If we want game-based learning to make learning enjoyable as well as effective and efficient, we need to increase learner's awareness of and ability in learning itself. At the heart of learning is metacognition: a learner's understanding of how knowledge is constructed through learning, and the repertoire of strategies, tactics, and monitoring processes that enact learning. The goal of this PhD research is to inform designers and researchers who want to support and improve metacognition of learners within game-based learning environments, by identifying, implementing, and evaluating generic design principles for metacognitive interventions.

CCS CONCEPTS

• Applied computing → Interactive learning environments • Human-centered computing → Interaction design process and methods • Applied computing → Computer games

KEYWORDS

interactive learning environments; game-based learning; metacognition; design-based research

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1 Introduction

More than a decade of research and development has found that game-based learning, under the right circumstances, may contribute to motivation as well as learning [4]. However, learning within such rich and complex learning environments places a high demand on the learning skills of the learners [3, 16], and may make it more difficult for them to learn effectively and efficiently [18]. While instructional support, such as scaffolds and prompts, may help learners to direct their efforts and reduce this extra effort in the short term, they also deny learners the opportunity to try out, evaluate, and develop their own learning strategies and skills in the long term. Therefore, if we want learners to be able to learn enjoyably as well as effectively and efficiently within game-based learning environments, we need to

foster their awareness of and train their ability in game-based learning itself [15].

At the heart of learning is metacognition: a learner's understanding of how knowledge is constructed through learning, and the repertoire of strategies, tactics, and monitoring processes that aid learning [8]. More precisely, we can distinguish between three components of metacognition: metacognitive knowledge, metacognitive skills, and metacognitive reflection. Metacognitive knowledge refers to what a learner knows about learning, such as under which conditions to apply specific learning strategies or how one expects to perform in a particular topic. Metacognitive skills refer to using that knowledge to monitor and regulate learning. For example, a learner may make estimates of how well learning is proceeding (judgment-of-learning) or how well the current material is known (feeling-of-knowing), and consequently adjust the strategies used. Metacognitive reflection, then, refers to evaluating the learning process and its outcomes, and updating underlying cognitive assumptions, beliefs, and synthesizing learning [6]. In this way, as learners develop their metacognitive abilities, they can apply their metacognitive knowledge and skills in new learning situations, making them more effective learners beyond a single task or a domain-specific learning goal.

Research in game-based learning has advanced from analyzing which features make computer games intrinsically motivating for learning (e.g. [13]), through characterizing how game loops may be paralleled with learning processes (e.g. [9]), towards the point where, depending on the types learning goals, different design frameworks can aid the design of game-based learning environments. For skill-based learning outcomes, providing drill-and-practice exercises in combination with motivational elements and appropriate feedback seems to work quite well, and some even claim this is a part of game-based learning that is "essentially solved" [10]. For cognitive learning outcomes, the learning mechanics/game mechanics approach, informed by activity theory, aids educational game designers by providing links between verbs, objects and goals associated with learning and games (e.g. [1, 5]). For metacognitive learning outcomes, however, we have no design guidelines to aid the design and research of game-based learning environments.

Various researchers have suggested that metacognition in relation to game-based learning be further investigated [12, 17], distinguishing between the observation that game-based learning requires metacognition and the observation that game-based learning can be used to develop metacognition (cf. [2]). Concrete suggestions for metacognitive interventions, such as self-

explanation, collaboration, and adaptive scaffolding, have been put forward from a broader perspective of self-regulated learning [15] and in specific domains such as STEM-education [14]. The next step in advancing game-based learning towards higher-order learning is to bring together these initial insights, observations, and suggestions, and comprehensively address the design of game-based learning environments to include metacognitive learning goals.

2 Research Objectives

The goal of this PhD research is to inform designers and researchers who want to support and improve metacognition of learners within game-based learning environments. First, we want to identify which types of interventions have been found effective in fostering metacognition within game-based learning environments. Second, we want to analyse how such metacognitive interventions improve metacognitive knowledge, skills, and reflection of learners. Third, and last, we want to identify how such metacognitive interventions can be aligned and integrated with the game design elements of game-based learning environments.

There are two important outcomes to this work: generic design principles and concrete implementations. For the design of metacognitive interventions within game-based learning environments, we aim to identify and describe design principles that can aid designers and researchers. We want these design principles to be described in a formalised and generic way, and to be empirically verified in practice. For the empirical evaluation and verification of design principles, we aim to develop concrete metacognitive game-based learning environments. We want these environments to implement various design principles and study their use in real-world contexts in higher education.

3 Method

As can be seen from the outcomes, we strive for both an academic contribution to advance research in game-based learning, as well as a practical contribution to inform designers of future game-based learning environments. As an overall methodology, design-based research is used [11], as it combines such practical relevance (e.g. requirements from the application domain, field testing of interventions) with academic rigor (e.g. theories, concepts, and methods). Furthermore, while not necessarily followed in a linear fashion, design-based research helps to distinguish between different design and research activities and their outcomes, such as identifying insights from literature, designing and developing artefacts such as game-based learning environments based on insights, evaluating in practice which effects these artefacts achieve, and taking these insights to inform further iterations of the design [7].

First, we will conduct a comprehensive literature review on metacognition, game-based learning, and metacognition in game-based learning. With this review, we want to identify the current state-of-the-art of addressing metacognition within game-based

learning. Additionally, with this review we seek to collect examples of metacognitive interventions in conjunction with the underlying concepts of how they should contribute to improving learners' metacognition and how they are situated with the game design aspects. From this, we hope to identify initial design principles that may underlie metacognitive interventions in game-based learning.

Second, we want to specify these design principles in a more formalised and generic way, such that they can be used in the design of different game-based learning environments, instead of applying to very specific cases only. For this, we will need structured ways of identifying and describing design principles at different levels of instantiation, spanning from theoretic concepts to concrete design choices. We are considering the development of a (visual) notation system that can represent different aspects in the design of game-based learning and their function.

Third, we want to verify the design principles in practice, by implementing them in concrete real-world game-based learning environments. We will adopt an iterative approach and elaborate the design in steps. For example, we will first construct a non-digital card-based game that is easy to adjust quickly, and evaluate it with small groups of students. Such a card game will then serve as a paper prototype for more elaborate and digital systems, once we have an initial impression of how different aspects in the design of such game-based learning environments should be configured.

Fourth, we will employ various methods to gather insights on how different versions of metacognitive interventions within game-based learning environments affect the effectiveness, efficiency, and enjoyment with which students learn. While previous work in metacognitive development often focuses on children and reading or teenagers and science subjects, our focus will be on students in higher education. As our research group is closely connected to and physically co-located with undergraduate programs in Computing Science and in Communication & Multimedia Design, these will be our primary evaluation groups.

While measuring metacognitive processes and improvements thereof is complicated, we strive to use a mixed-methods approach that combines learning performance outcomes with self-reports, trace data from the learning environment, and retrospective think-aloud protocols. The outcomes from these evaluations will be used to update the initial design principles, such that we can construct a model consisting of generic design principles, that links metacognitive processes of learners to the features and interventions in the design of game-based learning environments.

4 Results

As a first step, we have collected and reviewed the relevant literature, focusing on empirical evaluations of metacognitive interventions within game-based learning environments. In this paper (submitted), we present a structured way for discussing metacognitive learning goals, interventions, and their integration within game-based learning environments.

A first finding from this review is that insights are currently only reported on a case-by-case basis: for designers and researchers seeking to address metacognitive learning goals within game-based learning, it is hard to readily apply these insights to their own designs. Therefore, we have explicitly formulated concrete implications for improving design and research. For example, in contrast with most current work, future designs should specifically define the metacognitive learning goals addressed and to what extent they are expected to improve through interaction with the game-based learning environment. As another example, future research should investigate and identify ways of integrating metacognitive interventions with game design elements and develop more formalised ways of specifying and comparing metacognitive interventions.

A second outcome from this review is that we have collected a set of initial design principles that underlie the metacognitive interventions included in the review. These initial design principles form the starting point for elaboration by exploring the design dimensions of metacognitive interventions through paper-based and digital prototypes. For example, one initial design principle we found is that students will need different amounts of freedom and guidance when developing their metacognition: too much guidance may foster an overreliance on the presence of these scaffolds, whereas too much freedom may lead to (meta)cognitive overload and learners abandoning learning.

We are currently exploring the dimension of freedom and guidance using a paper-based card deck with questions, instructions, and cues. We have created various versions that are either domain-specific (i.e. they apply to learning how to program) or domain-generic (i.e. they make no reference to the topic at hand), or are task-specific (i.e. they help to complete a programming assignment) or course-specific (i.e. they help to successfully complete a course). An initial qualitative evaluation with a panel of students yielded positive impressions of the usability and usefulness of the deck, as well as critical feedback on the phrasing, design, and use of the deck. Our next step is to evaluate this card deck in practice by providing the different versions to different classes as part of an undergraduate programming course.

5 Future Work

Having established an overview of literature and initial design principles, the next steps are to create concrete designs, non-digital prototypes, and digital games, and empirically evaluate their effects on learners' metacognition. There are, however, a number of challenges in the areas of design and methodology that we will need to address.

In the area of designing game-based learning environments, we see two important challenges. First, as metacognition by definition refers to the learner itself – i.e. the person he or she is outside of the game – it must almost by necessity break the fourth wall. This seems to sit at odds with theories of flow and narrative engagement, that advocate a full immersion in the gameplay. Second, as developing metacognition is more about trying out

learning strategies and skills, and then reflecting upon how a learner is learning, there is no immediate wrong or right. This seems to sit at odds with the goal-directed and feedback-dependent mechanics common to games for learning. As game-based learning is becoming more common within higher education, it is becoming more urgent to start discussing these design challenges.

In the area of methodology, we see two different challenges. First, as metacognition consists of processes taking place inside the learner, it is complicated to find reliable measurements of what is going on. Currently, most studies are limited to measuring increases in academic performance over time. However, for game-based learning addressing higher cognitive and metacognitive processes, we need to start looking for more accurate measurements. Second, we will need to be able to more formally describe the design of game-based learning environments: the elements within it and their function, be it game-like elements to foster motivation, learning content elements to foster domain learning, or metacognitive interventions to improve metacognition. Only when we find common ways of describing such designs can we effectively compare them and transfer knowledge from one case to another. We think that starting to discuss measurements and more formalised design approaches can help to further mature the field of game-based learning.

In summary, if we want learners to learn effectively through game-based learning, we need to design effective game-based learning environments that supports their learning. We advocate that it is becoming increasingly important to include support for metacognitive knowledge and skills within such game-based learning environments. However, in order to do so, we also need advances in measurements and formal design methods. This PhD research can be viewed as an attempt to set this stage for metacognition in game-based learning.

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