

# Summary

One of the most influential determinants of efficient and effective learning is metacognition: the knowledge a learner has about how they learn, and the skills to use that knowledge to monitor and regulate learning. As not all learners within higher education are equally or sufficiently apt in metacognition, providing metacognitive training is a very effective way of improving current and future learning skills and, in turn, learning performance.

Metacognitive training must be active (for learners to understand and be able to apply metacognition to learning) as well as engaging (for learners to put in the additional effort over a longer period of time). In this dissertation, we examine how *game-based learning* (GBL), as a technique to harness learning and motivation in a self-contained *game-based learning environment* (GBLE), can be leveraged for metacognitive training. The educational context for this dissertation is higher education in The Netherlands, where metacognitive knowledge and skills involved in self-regulated learning are often implicitly expected of students, but seldomly explicitly taught within study programs.

The main research question for this dissertation is: How can we design effective game-based learning environments to improve metacognition of learners in higher education? With our research we seek to achieve two objectives:

- (i) *to gather and synthesize design knowledge*, across different disciplines and from existent and new research, to further the understanding of the design of game-based learning environments for metacognition; and
- (ii) *to apply and evaluate design knowledge* in real-world educational settings, through the conceptualization and construction of prototypes, and by collecting insights about and from students using them.

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The overarching research methodology used throughout this dissertation is design research: the systematic and iterative study *of* and *through* designed interventions to inform the design of an effective solution. Design research provides synergy between knowledge contributions and practical contributions, accommodates an interdisciplinary integration of concepts and methods, and provides ways of generalizing findings beyond a specific instantiation. Through analysis of existent work, through design and construction of prototypes, and through design experiments within real-world educational settings, mixed methods are used to gather insights on the design of GBLEs for metacognitive training.

The first part of this dissertation concerns the *Analysis and Exploration* phase, with the objective of gathering and synthesizing current insights on training metacognition, designing GBLEs, and their combination in the design of GBLEs for metacognition.

We conducted a qualitative review of current literature on the design of GBLEs that promote metacognition in learners. Our analysis of the GBLE-designs from the selected studies identified key mechanisms for promoting metacognition within GBLEs, three types of integration of metacognitive content with gameplay, and a number of preliminary design implications. However, we also found that research in this area is predominantly reported as case-by-case findings. The limited ways in which GBLE-designs can be compared across such different studies stands in the way of advancing insights across this field and, correspondingly, there is a lack of design-informing work based on a combination of empirical and theoretical insights.

To improve the way in which the designs of GBLEs for training metacognition can be communicated, we developed a design framework. The *Design Framework for Metacognition in GBL* is derived from existing literature and cases as identified in the literature review, and further elaborated through a formative expert evaluation. For metacognitive instruction, for gameplay, and for the integration of both, the resulting framework defines specific design dimensions that indicate the relevant areas in which informed design-decisions are likely to affect learners' metacognition. As such, this framework aids specification of designs, structured comparisons

between different designs, and a more focused research effort in identifying specific design guidelines for metacognition in GBL.

The second part of this dissertation concerns the phases of *Design and Construction* and *Evaluation and Reflection*, with the objective of applying and elaborating design knowledge through the design, construction, and evaluation of GBLEs for training metacognition.

We first focused on the instructional dimensions of the framework and designed a digital tool to support metacognition through self-explication of learners' otherwise implicit conceptions of learning. Through a pre-test/post-test quasi-experiment with a comparison group we examined a detached approach to metacognitive training, where digital metacognitive support is offered via a digital tool in parallel to ongoing domain-specific training. We compared effects between domain-specific and domain-general metacognitive support, and evaluated how learners use and perceive the use of such a tool. We found that self-explication is an effective mechanism to support and improve metacognition and confirmed the effectiveness of detached metacognitive support. While only domain-specific metacognitive support was found to be effective, quantitative and qualitative analysis warrant further research into domain-general and detached metacognitive support. However, we also found that learners with low *a priori* metacognition were particularly likely to not make use of the available support: the group that can benefit most from metacognitive training does not see the added value of it.

To address this issue by making metacognitive training easier and more appealing to use, we then focused on the gameplay dimensions of the framework and the integration of metacognitive training with gameplay. We formalized and formulated known design principles within the dimensions of the design framework. As such, the descriptive design framework is augmented with increasingly prescriptive design knowledge. We conducted a series of design experiments within real-world educational settings to articulate, apply, and evaluate the design knowledge as applied to the design of concrete GBLEs. Each design experiment addresses a particular configuration of the design dimensions of the framework. From these

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design experiments we were able to synthesize findings into further recommendations for the design of GBLEs for training metacognition.

GBLEs to train metacognition must be carefully designed to effectively promote metacognition and learning, while at the same time inciting and sustaining engagement in learners so they keep making use of it. We found that the design of such GBLEs is a complex endeavor, where many design decisions must be made while little guidance is available. Our work has identified and synthesized relevant design knowledge to provide such guidance. Together, the design framework dimensions and the accompanying design principles, as well as the different integration types and metacognitive mechanisms provide the basis for more informed and more deliberate designs of GBLEs. Furthermore, we provide an initial design process that incorporates these different types of design knowledge.

However, further theoretical and empirical work is needed to advance insights into game-based metacognitive training. For this purpose, the dimensions of the framework can serve as a research agenda by indicating where design knowledge is lacking or needs empirical verification. We also put forward a possible theoretical model that could help to improve understanding of the design of game-based metacognitive training. The ideas, design knowledge, prototypes, and general thoughts put forward in this work form a solid foundation for such relevant future work.