
chapter one

General Introduction

This chapter is part of Braad, E. (2024). *Designing Game-Based Learning for Training Metacognition* [Doctoral dissertation, Eindhoven University of Technology].

1. Introduction

1.1 A Case of Metacognition

Below this paragraph, I have listed 16 words. I would like to ask you to set a timer to countdown 1 minute and to use this time to try and memorize all the words listed. When the timer has run out, cover the words with a piece of paper.

ANYTHING	REMEMBER	EVIDENCE	ORGANIZE
CONSIDER	INVOLVED	BUILDING	FOLLOWED
HAPPENED	DECISION	SOUTHERN	SUDDENLY
TOGETHER	POSITION	QUESTION	GROWLING

Let us consider this learning task. Given 1 minute of time, how many words do you think you would be able to reproduce? How sure are you about the correctness of this estimation? These are two questions that involve *metacognition*. Both questions ask you to inspect your cognition to make inferences about learning. The first question asks you to self-evaluate your expected returns of learning or, in other words, to monitor your expected performance. The second question asks about how accurate you expected your estimation to be or, in other words, to monitor your confidence.

Now let us test ourselves. Take a piece of paper and, again, set a timer to countdown 1 minute. Try to reproduce all of the words within this time. When the timer has run out, you can remove the cover and count how many words you have recalled correctly. How accurate was your prediction of your performance? Were you too confident or too cautious? These two questions could provide useful information for learning, because when answered they allow you to adjust your future predictions to be more accurate. This is relevant metacognitive knowledge about yourself as a word-learner.

How did you try to memorize these words? What was your learning strategy? Perhaps you tried to repeat the words over and over, aloud, or silently in your head. Perhaps you grouped the words in groups of four. Perhaps you found conceptual links between the words or created a small story to connect them in a

meaningful way. The way you approached this learning task is also useful information because, together with the previous estimations, you can decide whether your approach was effective and whether you would use the same approach for a similar task in the future. This is relevant metacognitive knowledge about how you can learn words.

1.2 A Different Case of Metacognition

Beyond secondary education, learners will only seldom be asked to memorize a list of words. Attention progressively shifts to higher-order learning outcomes that involve making connections between concepts and that favor understanding above reproducing. It should come as no surprise that metacognition is included at the top level of most common taxonomies of learning objectives (Anderson & Krathwohl, 2001; Krathwohl, 2002; Marzano & Kendall, 2007). For example, Bloom's Taxonomy for the cognitive domain defines the dimension of knowledge from the simple to the complex and from the concrete to the abstract, as (i) factual (the basic elements of knowledge), (ii) conceptual (interrelationships among elements), (iii) procedural (the methods of inquiry), and (iv) metacognitive (general knowledge and awareness of cognition) (Anderson & Krathwohl, 2001; Krathwohl, 2002). The prominence of the role of metacognition in learning thus only increases with the complexity of the learning objectives.

Consider Alex ¹, a student in higher education who, after three and a half years of studying, was starting out the graduation project to culminate in his bachelor thesis. As his supervisors, we asked for a few paragraphs that summarized his interpretation of a particular part of the relevant theoretical background. For the next meeting, he had compiled a text, indeed, but it consisted mostly of direct quotes from other sources. Subsequent attempts saw the text rearranged, the topic altered, and the form of presentation changed. Unfortunately, however, Alex did not succeed in communicating any of his own theory-informed views.

We inquired about his approach to this part of the graduation. We asked how he had previously approached similar assignments during his study, and we asked

¹ Alex is a pseudonym.

about how he thought about progressing through all the other steps of graduation once we would complete the current step. His answer to all of these questions was as straightforward as it was honest: I don't know. The most prominent problem was not him lacking the conceptual and procedural knowledge to read some of the relevant literature and subsequently summarize and synthesize its contents. The most prominent problem was him lacking the *metacognitive knowledge* and *metacognitive skills* to even detect that there was a problem. He was not so much bothered; studying had taken a few attempts and some effort before, and the current graduation project was no different. The severity of the issue was beyond him.

This account is, by no means, intended to illustrate or emphasize his failure to pick up these competences during his study. Rather, we, as the corps of teachers, had failed him. We had failed to teach him, in the three and a half years prior to graduation, to read and interpret literature in a meaningful way. More importantly, we had failed to confront him at any point with the deficiencies of his approach at a time at which he could have done something about it. But most prominently, we had failed to provide him with the *means to detect* when learning was not producing the expected results, or with the *means to alter* learning in pursuit of those results. In other words, we had failed to encourage and enable Alex to develop the *metacognitive monitoring and regulation* of his learning process.

1.3 A Proposition for Metacognition

In higher education, we want learners to think about their learning, to make judgments about their learning, and to take action when they decide learning could be better. In fact, they must, as higher education cannot be limited to preparing learners for one of the current and specific professions. Instead, we are obliged to help raise critical learners who will continue to question their current competence, seek knowledge and training, and learn long after formal and institutionalized learning has faded from the forefront of their lives (Schön, 1983).

One of the most influential determinants of efficient and effective learning is metacognition: the knowledge a learner has about how they acquire new

knowledge and the skills to use that knowledge to monitor and regulate learning (Brown, 1978; Flavell, 1976; Veenman & Spaans, 2005; Veenman, Van Hout-Wolters, & Afflerbach, 2006; Wang, Haertel, & Walberg, 1990). However, not all learners are equally or sufficiently apt in metacognition and, if not attended to, metacognition does not commonly develop autonomously (Veenman, Elshout, & Busato, 1994; Veenman et al., 2006). Therefore, it seems, that providing learners with *metacognitive training* is a very effective way of improving their current and future learning skills and, in turn, their learning performance.

This dissertation concerns a search for instructional interventions that could have made Alex aware of how his learning was proceeding and that could have provided him with the chance to do something about it. This dissertation concerns the design of metacognitive tools that are engaging enough to use, and continue using, while at the same time being effective enough to improve metacognition and, as a result, learning.

2. Context and Challenge

2.1 Context and Problem

The educational context this dissertation is concerned with is *higher education* which, in The Netherlands, is the ensemble of scientific education ("wetenschappelijk onderwijs" or WO) and higher professional education ("hoger beroepsonderwijs" or HBO). Although a gross generalization, the following characterization provides some sense of the present context. WO is primarily focused on academic training (although many study programs focus on a particular professional field, such as law or business), and typically works towards a master's degree (although often after completing an initial phase with a bachelor's degree). HBO is primarily focused on professional training (although many study programs, if not all, involve some form of research training and conducting desk and field research), and typically works towards a bachelor's degree (although often a follow-up master program is available). The curriculum of a study program in higher education is typically divided into three, four, or five years, with the initial years organized as separate courses that are often

accompanied by a group project or capstone course, and the later or final years organized around an internship and/or individual graduation work. Education is supported by staff in different roles; it is not uncommon to encounter different teachers for the courses, as well as one or more coaches or tutors for group work, and an academic counsellor or mentor for topics and issues that are not directly related to the contents of the program.

Naturally, many teachers will offer some form of metacognitive support during learning: providing students with reading comprehension strategies, modeling their own thinking and regulation for students to observe, or promoting self-questioning such as through question stems (Hartman, 2001a; King, 1992). At this task- or course-specific and mostly individual level, providing metacognitive support comes somewhat naturally. From the perspective of the student, however, learning transcends the boundaries of courses, periods or blocks, and even years (cf. Derry & Murphy, 1986). Throughout and beyond formal education, being able to recognize a need to learn, to address this need by setting goals, to monitor and control learning activities and learning strategies towards these goals, and to reflect upon both outcomes and process, is essential to succeed.

Unfortunately, the metacognitive knowledge and skills involved in such self-regulated learning are often implicitly expected of students, but seldom explicitly taught within study programs. Moreover, a teacher will not always be available to provide the necessary support when it is needed the most. The problem addressed in this dissertation thus concerns the provision of training and support that aid students in higher education in developing the metacognitive knowledge and skills necessary to study efficiently and effectively.

2.2 Potential for Game-Based Learning

What would such metacognitive training look like? First, an *active* form of training is needed, as learners need not only gain metacognitive knowledge and skills, but also need to practice using these throughout the learning process (Hattie, Biggs, & Purdie, 1996). Second, the development of metacognition takes time and repeated practice, and thus calls upon the motivation of the student to sustain an

effort in metacognitive development (Kuhn, 2000; Veenman et al., 2006). This effort is exerted in addition to any effort invested in regular studying. Metacognitive training thus needs to *engage learners* over a longer period of time. Third, a form of training is needed that students can make use of regardless of whether a teacher is available to provide it. In other words, a stand-alone and *self-contained* intervention is desired that learners can turn to, regularly, as they see fit.

Digital Game-Based Learning (GBL) could satisfy these practical needs, while at the same time focusing attention on a novel area of research. First, digital games are interactive in nature and require that players actively make sense of what the objective is, how to achieve it, and how to enact their plans through in-game actions, all while receiving feedback on whether the actions, and the plans, were successful. Thus, when used for learning purposes, digital games can offer an *active* form of training. Second, digital games are known for their motivational qualities: the challenge and fantasy that games can offer is able to captivate a broad range of people for substantial amounts of time. Games have been used to make practicing existing knowledge and skills, as well as acquiring new ones, a more appealing experience. Thus, games can offer the initial attraction as well as the sustained interest to make the learning activities *engaging*. Third, digital games can support a large range of instructional activities, such as direct instruction, practice, feedback, and assessment. Furthermore, digital games can be used almost wherever and whenever a learner so chooses. Smartphones with an internet connection are widely available in higher education in The Netherlands, as are laptops. Thus, digital games can be *self-contained* tools for learning.

Altogether, we consider GBL as a potentially interesting type of intervention for developing metacognitive knowledge and skills in learners. Indeed, various researchers have suggested that metacognition in relation to GBL be further investigated (Hacker, 2017; Ke, 2016; Sitzmann, 2011). As such, we see an opportunity to investigate whether and how GBL can be leveraged for metacognitive training.

2.3 Research and Design Challenge

Some suggestions for addressing metacognition within game-based learning environments (GBLEs) have been put forward from a broader perspective of self-regulated learning (Nietfeld & Shores, 2011) and in specific domains such as STEM-education (Mayer, 2016). However, comprehensively applying these and other suggestions in the design of GBLEs is not straightforward. As GBL attempts to satisfy both learning outcomes and motivational outcomes, the design of any GBLE needs to somehow combine elements of play with elements of learning. Furthermore, the design of a GBLE to address metacognition, specifically, may further complicate matters as the learning outcomes are related to learning itself. As such, the design of such GBLEs is inherently complex.

Furthermore, although ample research on GBL is available, most of this research focuses on training specific knowledge and skills through drill-and-practice. How to leverage the potential of GBL to elicit higher order learning outcomes, such as metacognitive knowledge and skills, is currently unclear. The next step in advancing GBL towards higher-order learning (in general) and metacognition (in specific) is to bring together initial insights, observations, and suggestions, from literature as well as practice, and to comprehensively address the design of GBLEs to include metacognitive learning goals. Investigating how to design GBL for metacognition thus represents both a novel and valuable area of research.

This dissertation discusses the challenge of designing GBLEs to promote metacognition in students in higher education, and the investigations involved in addressing this challenge.

3. Theoretical Background

This dissertation intersects various academic fields and can be considered interdisciplinary in this sense alone. The two key concepts, *metacognition* and *game-based learning*, are both terms with widely varying interpretations and definitions. Considering readership from various backgrounds, we find it necessary and relevant to begin with defining metacognition and GBL in some

depth. Subsequently, we will address a third key concept and describe how *metacognitive training* can proceed through instruction, support, and through GBL, and how to assess its effectiveness.

3.1 Metacognition

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 (Flavell, 1979). Unfortunately, defining metacognition has been the subject of debate within the field of education. The term itself has been named a superfluous epiphenomenon (see Brown, 1977) and the concept it refers to is notoriously diffuse and prone to inconsistent terminology (Brown, Bransford, Ferrara, & Campione, 1983; Kuhn et al., 1995; Moshman, 2018; Schoenfeld, 1987; Schraw & Moshman, 1995; Veenman et al., 2006). Therefore, an integrative but necessarily limited conceptualization of metacognition that is suitable for our purpose must suffice. For a more comprehensive overview of the history, epistemology, and neurological conceptualizations of metacognition, the reader is referred to Dinsmore, Alexander, & Loughlin (2008), Peña-Ayala & Cárdenas (2015), Van Overschelde (2008), Veenman & Spaans (2005), and Veenman et al. (2006).

In the following discussion we build towards a conceptual model of metacognition as depicted in Figure 1.1. This conceptual model combines a declarative view of metacognition and learning (i.e., defining and relating relevant constructs) with a procedural view (i.e., describing interactions and processes). The declarative elements are intended to help to define the relevant concepts and specify their relationships (cf. Efklides, 2006; Kuhn, 2000; Schraw & Moshman, 1995). The procedural elements are intended to help to conceive how metacognition affects learning in practice. (cf. Efklides, 2011; Nelson & Narens, 1990, 1994; Pintrich, 2000; Shimamura, 2008; Veenman, 2011; Winne & Hadwin, 1998; Zimmerman & Campillo, 2003).

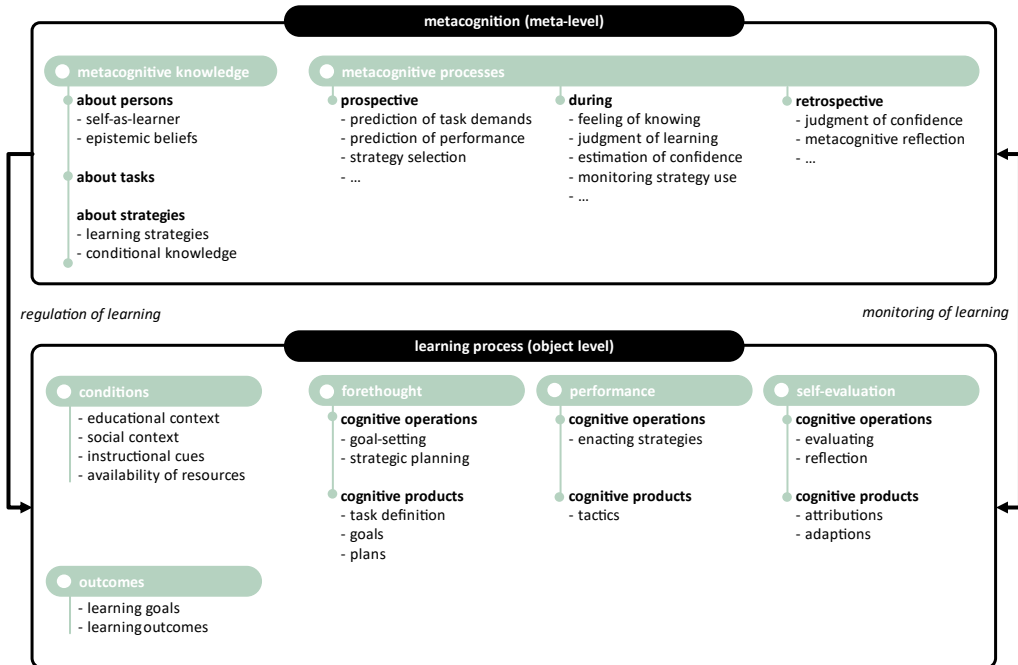


Figure 1.1: A conceptual model of metacognition in learning, based on Nelson and Narens (1990, 1994), Griffin, Wiley, and Salas (2013), Winne & Hadwin (1998, 2013), Zimmerman & Campillo (2003), and Pintrich (2000).

Metacognition and the Self-Regulated Learning Process

How well one understands a particular topic, the likelihood of achieving the learning goals, the expected amount of effort and difficulty involved, the habit to regularly check if learning is going as expected, and the ability to change the course of action are all examples of a large group of metacognitive aspects of learning that affect performance (Kuhn, 2000). Learners who consciously plan, monitor, and evaluate how they are learning are more successful in terms of academic performance and find learning more enjoyable. Such active participants in learning can be viewed as a model to strive for, both as a learner and as a teacher (Ertmer & Newby, 1996; Hartman, 1998; Sternberg, 2001). This type of learning with a high amount of learner agency and crucial role for metacognition is known as *self-regulated learning* (Pintrich, 2002; Zimmerman, 1989; Zimmerman & Campillo, 2003).

We conceive of the learning process as the active, intentional, and directed effort of learners exerted towards achievement of a set of *learning goals* (see Figure 1.1, bottom part). Correspondingly, we define the extent to which learning is effective as *learning performance*: how well a learner is able to demonstrate the learning goals in a test or in a practical situation. The direct *outcomes* of learning are thus the (achievement of the) learning goals and the corresponding learning performance.

Following Winne and Hadwin (1998, 2013), we adopt a cognitive information-processing view of learning in which learners attempt to progress towards their goals by performing *cognitive operations* resulting in *cognitive products*. For example, a learner may enact a strategy (cognitive operation) to arrive at a tactic (cognitive product) for learning. Such cognitive processing takes place in a cycle of *forethought* (i.e., setting goals and making strategic plans for learning), *performance* (i.e., conducting learning activities), and *self-evaluation* (i.e., evaluating and reflecting upon learning) (Pintrich, Wolters, & Baxter, 2000; Zimmerman & Campillo, 2003). The cognitive operations produce *cognitive products* that progress through these phases from task definition, to goals and plans, to studying tactics, to adaptations to cognitive and metacognitive knowledge. However, progression is not strictly linear, as learners may step back and forth between phases and products. In this learning process the learner acts given the *conditions* for learning: The *educational context*, *social context*, and any *instructional cues*, along with *availability of resources* such as time, energy, or support shape how learning will unfold and how effective learning will be.

The prefix "meta" indicates that metacognition concerns that which is about cognition, as Nelson and Narens (1990, 1994) have conceptualized in an object-level and a meta-level. The *object-level* refers to the learning process (Figure 1.1, bottom part) while the *meta-level* represents the metacognitive knowledge about that learning process, and the metacognitive processes affecting it (Figure 1.1, top part).

Metacognitive Knowledge

Schraw and Moshman (1995) categorize *metacognitive knowledge* by its type (i.e., declarative, procedural and conditional) and thereby emphasize that metacognitive knowledge is not different from other knowledge in its form, only in its purpose (Flavell, 1979). However, for our conceptual model, a conceptual categorization of metacognitive knowledge is more appropriate. Flavell (1976, 1979) and others (Jacobs & Paris, 1987; Schraw & Dennison, 1994) distinguish between metacognitive knowledge about persons, about tasks, and about strategies.

Metacognitive *knowledge about persons* foremostly concerns knowledge about *oneself-as-a-learner* (Flavell, 1979; Lin, 2001). Additionally, *epistemic beliefs* about the nature of knowledge and knowledge acquisition play an important role in learning, motivation to learn, and learning performance (Ames & Archer, 1988; Dweck, 1986; Schraw, Horn, Thorndike-Christ, & Bruning, 1995). Together, such beliefs relate to intra-individual and inter-individual differences in learning (Flavell, 1979; Sternberg, 2001), such as knowing you are relatively good at mathematics, but not so much at studying lengthy texts.

Metacognitive *knowledge about tasks* concerns previously accumulated knowledge about cognitive tasks and how to perform them. Combined with an assessment of task conditions – such as availability of time and other resources, the educational context and instructional cues, and the social context – metacognitive task knowledge informs judgments about the cognitive task demands and predictions of confidence and success (Brown, 1978; Flavell, 1979; Winne & Hadwin, 1998, 2013).

Metacognitive *knowledge about strategies*, then, concerns knowledge about what strategies are considered to be effective towards what cognitive goals (Derry, 1989; Flavell, 1979). The difference between a cognitive strategy and a metacognitive strategy is in its use: cognitive strategies are used to make cognitive progress while metacognitive strategies are used to monitor and control it (Flavell, 1979; Klauer, 1988). The same strategy can thus be considered either cognitive or

metacognitive depending on its objective. We shall use the term *learning strategy* to refer to such "collections of mental tactics employed to facilitate acquisition of knowledge or skill" (Brown et al., 1983; Derry & Murphy, 1986; Hattie et al., 1996). We consider knowledge of learning strategies, along with the conditional knowledge of when and how to effectively put the strategy to use, as part of metacognitive knowledge (Dansereau, 1978, 1985).

Metacognitive knowledge of persons, tasks, and strategies can, as a whole, be viewed as model of the object-level or, rather, as a *metacognitive theory about learning* held by an individual that informs their conception of learning (Nelson & Narens, 1994; Schraw & Moshman, 1995). Such a theory may be formal or informal, explicit or tacit, based on previous experience or on accumulated beliefs, and may hence be correct or incorrect (Bjork, Dunlosky, & Kornell, 2013; Kuhn et al., 1995; Schoenfeld, 1987; Schraw & Moshman, 1995). Given the conditions for learning, but based on their metacognitive theories, learners set *expectations and standards for learning* and the outcomes thereof. It follows that a particular objective of improving metacognition is to reduce incorrect or unhelpful metacognitive theories and promote correct and supportive ones. Learners can, for example, modify their learning goals and activities based on evaluations of learning (Cnossen, 2009). Metacognitive theories about learning and expectations of learning are two main ways in which metacognition affects the learning process.

Metacognitive Processes

Metacognitive processes mediate between the object-level of learning and meta-level of metacognition through monitoring and controlling cognitive operations involved in learning (Nelson & Narens, 1990; Schraw, 1998). Here, *monitoring of learning* refers to inspecting learning and informing judgments of performance, progress and effectivity while control or *regulation of learning* refers to making informed adjustments in response to such judgments (Flavell, 1979; Griffin, Wiley, & Salas, 2013; Nelson & Narens, 1990, 1994).

Two prominent metacognitive processes that are well-described in literature are *feeling-of-knowing* and *judgment-of-learning* (Brown, 1978). Feeling-of-knowing occurs when a learner becomes aware of having or not having previously encountered and developed some familiarity with the current learning materials (Azevedo, Behnagh, Duffy, Harley, & Trevors, 2012). Judgment-of-learning occurs when a learner becomes aware that they do or do not understand some of the learning materials currently being processed (Azevedo et al., 2012). Both feeling-of-knowing and judgment-of-learning have valence as the outcome can be positive (e.g., feeling that you know the answer) or negative (e.g., judging that you have not learned much). Both are also examples of metacognitive monitoring processes as they involve an inspection of learning. Examples of metacognitive processes of the regulating kind are the selection of a strategy for learning, the allocation of cognitive resources to learning, or the decision to terminate a particular episode of learning.

In reality, metacognitive processes are however more multi-faceted and multi-purposed than the dichotomy of monitoring and regulation processes conveys. Metacognitive processes may often be used *prospectively* (i.e., to predict and plan learning), *during learning* (i.e., to monitor), as well as *retrospectively* (i.e., to evaluate and judge learning) (Brown, 1978; Efklides, 2011; Schraw & Moshman, 1995). Examples that illustrate the diversity of metacognitive processes are the *a priori* assessment of task difficulty and task demands, selection of strategy, and prediction of expected performance, as well as monitoring and regulation of ease of learning, confidence, and strategy use.

Metacognitive processes may occur tacitly in experienced learners, or may occur in response to a cue, or in response to a somewhat spontaneous *metacognitive experience* during the learning process (Flavell, 1979; Griffin et al., 2013). As metacognitive processes can be improved through repeated practice, they are often referred to as metacognitive skills (Baker & Brown, 1984; Brown, 1978; Veenman & Spaans, 2005).

Then, *metacognitive reflection* refers to evaluating the learning process and its outcomes, and updating underlying cognitive assumptions and beliefs, and synthesizing learning (Coulson & Harvey, 2013). 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. We therefore consider metacognitive reflection as the metacognitive process that can be regarded as the quintessence of metacognition (Tarricone, 2011).

3.2 Game-Based Learning

Noticing how captivating digital games can be to a wide range of people, and noticing their potential to foster learning, researchers have a longstanding interest in games as motivational and instructional tools (Abt, 1970; Gee, 2004; Malone, 1980; Prensky, 2003), investigating how to "leverage the appeal of play for the purpose of learning" (Plass, Homer, Mayer, & Kinzer, 2019). More than two decades of research and development have since demonstrated that GBL, under the right circumstances, may contribute to motivation as well as learning (Boyle et al., 2016; Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Ke, 2009, 2016; Nadolny et al., 2020; Sitzmann, 2011; Wouters, Van Nimwegen, Van Oostendorp, & Van der Spek, 2013).

Salen and Zimmerman (2004) define a game as "a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome", and Plass et al. (2019) extend this definition for GBL as "games with specific learning goals". While definitions of GBL are debated, most scholars agree about the characteristics of games as being rule-based (following clearly defined rules of play), responsive (enabling player actions and providing system feedback), challenging (setting an objective that is achievable, but not straightforward to achieve), and inviting (motivating the player to engage) (Mayer, 2014a, 2016; Plass et al., 2019). The player experiences these characteristics through *gameplay*: the way in which the repeated activities, or sets of activities, are performed throughout the game (Plass, Homer, & Kinzer, 2015). As such, interaction,

motivation, and learning should emerge from the system, provided the system is well-designed.

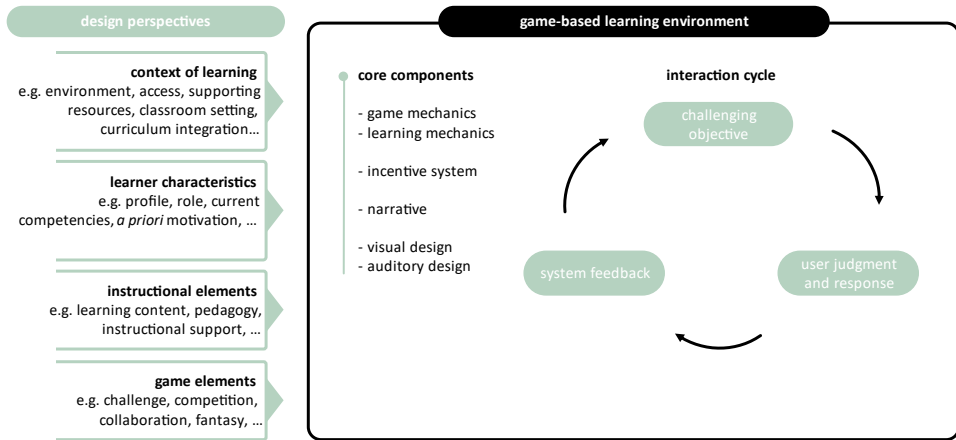


Figure 1.2: A conceptual model of game-based learning, based on Freitas & Jarvis (2009), Garris, Ahlers & Driskell (2002), Plass, Homer, & Kinzer (2015), and Vandercruysse & Elen (2017).

Seeking a definition that emphasizes both the intentional design of such a system and the interaction involved in learning, we define GBL as an approach to learning where gameplay is designed to help learners achieve specific objectives through interaction with the GBLE. The GBLE is the digital and interactive environment facilitating GBL and that may contain game elements and instructional elements (Plass et al., 2015, 2019; Vandercruysse & Elen, 2017). As such, we view a GBLE as a specific type of serious game aimed at learning and as an equivalent to the term educational game. We specifically limit our discussion to digital GBL and digital GBLEs.

In the following discussion we build towards a conceptual model of GBL as depicted in Figure 1.2.

Design Perspectives for Game-Based Learning

Multiple perspectives on playing and learning need to be integrated in the design of GBLEs. For example, the *context of learning* (e.g., environment, supporting resources, classroom structure, curriculum integration) and the *learner*

characteristics (e.g., profile, role, competencies, performance, *a priori* motivation) need to be considered (Braad, Žavcer, & Sandovar, 2016; Degens, Bril, & Braad, 2015; Van Staalduinen & De Freitas, 2011; Vandercruysse & Elen, 2017). Most prominently, however, *instructional elements* must be combined with *game elements* (Garris, Ahlers, & Driskell, 2002; Ke, 2016; Slussareff, Braad, Wilkinson, & Strååt, 2016; Vandercruysse & Elen, 2017). One of the key challenges for designers of GBLEs is thus to balance learning and play (Ke, Shute, Clark, & Erlebacher, 2019; Plass et al., 2019). If the emphasis is too much on learning, the elements of play will feel superfluous and chore-like, instead of achieving the intended motivational effect. If, on the other hand, the emphasis is too much on playing, the learning content may not come across and no learning effect will be achieved.

One way to combine playing with learning is by alternating playing activities and learning activities, however, such exogenous game design is often not sufficiently engaging to motivate players to continue to play or learn (Rieber, 1996; Squire, 2006). A more integrated way of embedding learning content in gameplay is to employ the narrative qualities of games to foster motivation as well as the construction of a cognitive framework, by designing the setting, characters, and events to foster challenge, fantasy, and curiosity (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005; Dickey, 2006; Malone, 1981; Rieber, 1996; Van Oostendorp & Wouters, 2017). Another way of combining learning and playing is to align game activities and goals with learning activities and goals, such that engaging with the gameplay becomes equivalent with engaging in learning (Amory, 2007; Arnab et al., 2012, 2015; Bedwell, Pavlas, Heyne, Lazzara, & Salas, 2012; Carvalho et al., 2015; Hung & Van Eck, 2010; Lim et al., 2013). Such an intrinsic integration of learning with gameplay fosters motivation to learn as well as learning, as learning and playing largely coincide (Habgood, 2007; Habgood & Ainsworth, 2011; Ke, 2016).

Core Components of Game-Based Learning

GBL is perhaps best known for its potential quality to combine learning with motivation to learn. Malone (1980, 1981) questioned how the features that make

computer games so captivating could be used for learning, striving for games offering "intrinsically motivating instruction". Typical game elements that can foster motivation as well as learning are challenge, fantasy, curiosity, and control from an individual perspective, and competition, collaboration, and recognition from an interpersonal perspective (Amory, 2007; Malone, 1980, 1981; Malone & Lepper, 1987; Sanchez, 2017; Ter Vrugte et al., 2015). For example, the narrative setting and plot in a game may foster curiosity as to what has happened or will happen next, while at the same time using metaphor and analogy to support learning (Barab et al., 2005). Likewise, competition and collaboration may offer social incentives to engage with the gameplay as well as the learning content (Barab, Dodge, Tuzun, Job-Sluder, et al., 2007; Steinkuehler & Tsaasan, 2019; Ter Vrugte et al., 2015). While game designers strive to make the game narrative and mechanics themselves interesting enough to foster motivation (Kenny & Gunter, 2007), games often also employ explicit incentive structures, such as scores, levels, leaderboards, and achievements (Nebel, Schneider, Beege, & Rey, 2017; Plass et al., 2015).

The design of a GBLE typically comprises a number of core components: game mechanics, an incentive system, a narrative, and the visual and auditory design (Plass et al., 2015, 2019). The *game mechanics* define the essential interactions within the GBLE. In view of the goal the player is set to achieve, a game mechanic consists of the actions the game allows a player to take and the corresponding responses the system would provide. The *incentive system* guides the player's behavior in an enjoyable way. Using intrinsic (i.e., that contribute directly to gameplay; e.g., special abilities) and extrinsic rewards (i.e., that do not contribute directly to gameplay; e.g., scores, badges, and trophies). The *narrative* consists of the general setting of the game, and the characters and events contributing to a story. The role of narrative can be strictly motivational, but often also provides a cognitive framework for interpreting and situating the learning content (Asgari & Kaufman, 2004; Malone & Lepper, 1987). The *visual* and *auditory design*, together the aesthetics, determine what the game looks and sounds like. Note that this is a different interpretation of aesthetics than used by Hunicke, LeBlanc, and

Zubek (2004), who use aesthetics to refer to the desired emotional responses as evoked in the player when interacting with the game. Confusingly, as the visual design determines not only how gameplay but also how cues and feedback are displayed, its function is both aesthetic and cognitive (Plass et al., 2015). While there is a lack of research on the role of music and sound in GBL, it is generally agreed that audio can have a substantial effect on a player's emotional state, as well as improve learning through auditory feedback (Pawar, Tam, Plass, & Pawar, 2019).

While most games, if not all, will contain game mechanics and incentives as core components, a narrative is not always present, nor will all games put a strong emphasis on aesthetics. Whichever core components are used, they together allow gameplay to occur and, in turn, foster learning and motivation.

Motivation and Learning from Game-Based Learning

The process of learning through interacting with a GBLE is often described as cycle of user and system actions (Garris et al., 2002; Plass et al., 2015), where (1) the system presents a *challenging objective*; (2) the user makes an interpretation and *judgment* of what is presented and makes a selection of available actions as a *response*; (3) the system provides *feedback* in response to these actions. Note that this loop can be traversed at different speeds: fast-paced (e.g., the game shows a target, the player aims and shoots, and the game awards a score based on accuracy) or slow-paced (e.g., the game presents an incomplete electrical circuit, the player manipulates the circuit to make it work, and the game provides feedback on the solution). Further, note that this loop is a generalization; for example, the system will often provide feedback or change the challenge even when no action is selected.

The challenge provided by the system affects learning directly, as well as through increased engagement, but needs to be in balance with the current skill level of the player (Hamari et al., 2016). Some games employ dynamic difficulty adjustment (Hunicke, 2005) to attempt to achieve and maintain this balance, whereas other games have a built-in difficulty curve that usually increases as the

player progresses through the game (Schell, 2019). The feedback provided by the system also affects learning, and needs to take into account the content (e.g., explanatory or corrective, on process or outcome), modality (e.g., auditory, visually, textually), and timing (e.g., immediate, delayed) for the provided feedback to be effective (Johnson, Bailey, & Van Buskirk, 2017). Instructional support, such as reflection prompts or scaffolding through worked examples, can be implemented to further improve learning effectiveness (Wouters & Van Oostendorp, 2013, 2017).

Altogether, the challenges and objectives, actions and responses, and feedback can pertain to gaming, to learning, or when both are designed to fall together, to *intrinsic instruction* (Arnab et al., 2015; Carvalho et al., 2015). Together, the purpose of these elements is to help learners arrive at the *learning outcomes* by fostering motivation as well as learning.

3.3 Training Metacognition

Metacognitive Instruction and Support

Of course, one could teach learners directly about metacognition. For example, one can explain that spaced repetition works more effectively and more efficiently than cramming for a test (Bjork et al., 2013), or one could provide instruction on the declarative and procedural components of planning, monitoring, and evaluation (Zepeda, Richey, Ronevich, & Nokes-Malach, 2015). Such a direct form of *metacognitive instruction* implies that learners must transfer metacognitive learnings to future learning situations, as instruction is separated from application by time (Brown et al., 1983; Osman & Hannafin, 1992). Although early criticism asserted that metacognition must develop over time and cannot be regularly taught or transferred (Gagné, 1980; Klauer, 1988), there is now ample evidence that this transfer can indeed occur and that direct instruction of metacognition is effective and contributes to an altogether awareness of learning (Brown et al., 1983; Hattie et al., 1996; Paris & Winograd, 1990).

However, there is more to metacognitive training. Consider a hypothetical learner who has gained knowledge about all relevant metacognitive strategies and knows

when and how to apply them. This learner has successfully reduced a *knowledge deficit* to near zero. It is known from field studies that even a learner with sufficient metacognitive knowledge may still exhibit a *production deficit* and may not produce the behaviors that are expected to align with this knowledge (Veenman, Kerseboom, & Imthorn, 2000; Veenman et al., 2006). In other words, knowing and being aware of metacognition needs to be connected to applying metacognition to ongoing learning in practice. This involves activities such as, but not limited to, getting to know oneself as a learner, knowing how and when to apply which learning strategies, how to monitor learning for effectiveness and efficiency, finding ways to keep track of goals, plans, tactics, evaluations, organizing constructive feedback on both performance (as is common) and approach (not as common), modeling others' behaviors, trying out strategies and evaluating them for effectiveness (Hacker, 2017; Lin, 2001).

It is clear that these metacognitive activities are closely related to and embedded in the learning process itself. In addition to metacognitive instruction, training should thus also involve supportive elements that connect knowledge of learning to applying this knowledge to learning (Bannert & Mengelkamp, 2013; Veenman & Spaans, 2005; Veenman et al., 2006). When learners have access to help while learning, any transfer is reduced as such *metacognitive support* is available during the learning activity. Examples of metacognitive support are processing scaffolds (e.g., providing the steps to be taken), question prompts (e.g., asking about why an answer is thought to be correct), and cueing prompts (e.g., reminding to check on learning progress).

We collectively refer to instructional and supportive mechanisms to promote metacognition in learners as *metacognitive training*.

Metacognitive Training through Game-Based Learning

As we have already mentioned, we find that potentially GBL offers an appropriate method for developing metacognition in learners (cf. White & Frederiksen, 2005, 1998). GBLEs present an active form of learning with a high degree of agency for learners, while at the same time offering the engagement for learners to use and

keep using the environment. As such, they might constitute an effective way of training metacognition over the longer period of time that is required (Hacker, 2017; Mayer, 2016). The core question is how we can design a GBLE such that learners are motivated to invest some of their learning effort into metacognition and such that metacognition and ultimately learning are improved.

Previous work on metacognition and GBL has focused on helping learners succeed in learning effectively and efficiently within GBLEs. For example, not all learners may have adequate learning skills to extract the domain-specific knowledge and skills embedded within such complex learning environments, and the high cognitive load required to interact with the game may leave no room for goal-directed behavior in terms of what is relevant for learning (Azevedo et al., 2012; Azevedo & Hadwin, 2005). These obstacles for learning may be alleviated through the implementation of metacognitive support to make the GBL process itself more effective (Azevedo et al., 2012; Wouters & Van Oostendorp, 2017). Potentially, some of the metacognitive outcomes of such an approach could transfer to other learning situations (GBL or non-GBL), however, this is not the primary purpose (Azevedo, 2005a, 2005b).

In our work, the transfer of metacognition from GBL to other learning situations is intentional (Hacker, 2017). In terms of the conceptual model of metacognition (see Figure 1.1) and the conceptual model of GBL (see Figure 1.2), we seek to make inferences about what mechanisms to introduce in the latter that positively affect the former. Or, put in different words, our aim is to improve learning by *improving metacognition*, with GBL as the means to that end, and with a focus on *how to design GBLEs* with that purpose in mind.

Metacognitive Training Effectiveness

Various meta-analyses of instructional interventions provide evidence that training metacognition and self-regulated learning is effective for increasing assessment performance of learners (Dignath & Büttner, 2008; Hattie, 2009; Hattie et al., 1996; Muijs et al., 2014). When we seek to improve metacognition through GBL, we need to determine how to assess the effectiveness of

metacognitive training though GBL. While measurement of metacognition is a complex challenge (Oguz & Sahin, 2011; Veenman et al., 2006), we provide a brief introduction here. Specific measures are discussed in the methods section of the corresponding studies.

Three main areas are usually considered when measuring metacognition: (1) the extent to which learners have participated in training (e.g., how much time did a learner make use of the provided intervention, in what ways was the intervention used, what type of interactions occurred); (2) the extent to which metacognitive knowledge and metacognitive processes are present in and used by learners (e.g., what do learners know about their own learning, which behaviors do they produce, what strategies do they use); and (3) the learning performance delivered by learners (e.g., how many test items were answered correctly, what grades do learners achieve, to what extent where the learning outcomes achieved). Research on interventions regarding metacognition tends to focus only on product measures (i.e., effects on academic performance as per the relationship between (1) and (3)) or only on process measures (i.e., effects on metacognition as per the relationship between (1) and (2)) (Muijs et al., 2014; Veenman et al., 2006; Wang, 2015).

Product measures of metacognition attempt to relate direct measures of metacognition to observed performance of learners. For example, researchers may ask learners to make a prospective judgement of performance like we asked at the start of this chapter regarding the number of words you expected to be able to recall. Likewise, retrospective judgements could be collected in terms of predicting how many words were correctly recalled. Contrasting such judgements with observed performance produces measures of calibration: the accuracy of a learners' perception of their own performance (Hacker & Bol, 2019; Pieschl, 2009). As such, absolute accuracy (i.e., the degree to which judgements correspond to performance) or relative accuracy (i.e., the degree to which judgements discriminate between correct and incorrect answers) can be viewed as a measure of metacognition (Rhodes, 2019; Schraw, 2009). *Process measures* focus on whether and how metacognitive training affects metacognition. For example, researchers may ask learners about which learning strategies they know

about and which ones they used on a particular learning task (Winne & Jamieson-Noel, 2002).

As different types of assessment are appropriate for measuring different aspects of metacognition, it is advisable to combine multiple assessments (Oguz & Sahin, 2011; Wang, 2015; Zepeda et al., 2015). Key distinctions in measuring metacognition are whether metacognition is assessed online or offline (i.e., measurements obtained during or either before or after task performance) (Veenman et al., 2006) and whether observations or self-assessment is used (Gascoine, Higgins, & Wall, 2016).

Examples of observation-based measurements are the use of thinking-aloud protocols (Ohtani & Hisasaka, 2018), systematic observations (Veenman & Spaans, 2005), computer log data (Snow, 2015; Winne & Hadwin, 2013), and eye-tracking (Taub et al., 2016). Examples of using participants own (re)telling include interviews or open-ended questions (Jacobs & Paris, 1987) and self-report questionnaires (Meijer et al., 2013; Pintrich, Smith, Garcia, & McKeachie, 1993; Schraw & Dennison, 1994). Drawbacks of such self-report measures are that participants may rationalize their answers or even answer with socially more acceptable answers, leading to concerns about validity (cf. Veenman, 2011a). Benefits, however, are that larger groups of learners can be studied without intervening strongly in their learning process or learning environment.

The research in this dissertation, focusing on how metacognition can be trained in real world educational settings, is suitable for using mixed methods to assess metacognition. In particular, GBLEs are suitable for collecting trace data of learner behavior and the educational context makes it possible to employ questionnaires and interviews. As such, we can collect insights on how our designs affect and are experienced by learners, and whether they are potentially effective.

The following chapter outlines the research methodology that we will use to address this aim and discusses the research design. The outline for this dissertation is presented at the end of the next chapter.

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