
chapter three

Qualitative Review

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1. Introduction

GBL is an active form of learning that may include a variety of learning events (e.g., instruction, practice, feedback, and assessment) and a variety of motivational elements (e.g., challenge, rewards, and fantasy). While various meta-reviews showed that GBL can indeed contribute to both learning and motivation (Boyle et al., 2016; Wouters et al., 2013), it remains unclear how learners learn effectively and efficiently through interactions with GBLEs and which elements in the design of GBLEs promote learning and motivation (Boyle et al., 2016; Ke, 2016). As a result, it is difficult for designers and researchers to make informed design decisions when creating such learning environments.

Metacognition, or cognition about cognition, refers to knowledge about one's own knowledge and the application of that knowledge in the practice of learning. One of the reasons that GBL is not always effective may lie in that complex learning environments place a high demand on the metacognitive abilities of learners (Azevedo, 2005b). Not all learners are equally able to metacognitively monitor and regulate their learning, and it may therefore be necessary that any learning environment should include metacognitive mechanisms to support learners (Lin, 2001). While learners sometimes use metacognitive monitoring and regulation spontaneously while learning with games, it is unclear how to actively encourage metacognition through the design of GBLEs (Ke, 2016). Thus, if we want learners to learn effectively and efficiently through GBL, a crucial next step is to examine which design choices in the design of GBLEs can promote metacognitive knowledge, monitoring, and regulation in learners (Ke, 2016; Nietfeld & Shores, 2011; Sitzmann, 2011).

In this chapter, we present a qualitative review of metacognition within GBL. The goal of this review is to inform educational designers, psychologists, researchers, and other professionals who want to address metacognition in GBL. The focus in this review is on how to design GBLEs to encourage metacognition and hence the review concludes with concrete implications for the design and future research of metacognition in GBLEs.

2. Background

2.1 Metacognition

Metacognition is cognition about cognition: knowing about one's own knowledge and applying that knowledge in practice (Flavell, 1979). In the context of learning, it refers to what learners know about learning and how they use that knowledge to monitor and regulate their learning (Brown, 1978). Metacognition is the most important learner factor that positively impacts academic performance, even outweighing intelligence (Veenman & Spaans, 2005), warranting research into how metacognition can be promoted in learners.

While the concept itself is diffuse and prone to inconsistent terminology (Moshman, 2018), most researchers agree that metacognition consists of metacognitive knowledge and metacognitive skills. Metacognitive knowledge refers to the declarative, procedural, and conditional knowledge a person has about learning (Jacobs & Paris, 1987; Schraw, 1998), such as knowing different learning strategies and knowing when a learning strategy is suitable for a specific learning task. Metacognitive skills comprise the set of cognitive processes through which metacognitive knowledge is applied to learning, most notably through monitoring and regulation. Monitoring refers to inspecting how learning is proceeding, for example by making judgments of learning (e.g., how much have I learned so far) or estimating confidence (e.g., how confident am I that what I know is correct). Regulation refers to using such observations to control learning, for example by applying strategies, selecting and executing learning activities, and other cognitively driven actions (Schraw & Moshman, 1995).

Metacognition is often considered specific to a domain of learning (e.g., reading comprehension, mathematics) or specific to a learning task (e.g., reading a text, solving an equation), although increasing evidence exists for domain-general aspects of metacognition (Veenman et al., 2006). While metacognition may be partially tacit or automatic for some learners, the construct generally refers to a conscious understanding of how to learn, as emphasized in the term metacognitive awareness (Schraw, 1998). For the remainder of this chapter, we will use metacognition to refer

to metacognitive awareness and its components of metacognitive knowledge and skills.

Metacognition may be learnt implicitly but can also be enhanced through direct instruction or indirect metacognitive support (Veenman et al., 2006). Examples of such instructional or supportive mechanisms are metacognitive scaffolding, that provides concrete help to learners (direct instruction), and metacognitive prompting, that cues learners to monitor or regulate their learning (indirect instruction). For this review, we define a metacognitive mechanism as any mechanism through which metacognition is promoted within a learning environment.

2.2 Digital Game-Based Learning

Digital game-based learning refers to learning through interaction with a digital game. A game can be defined as a system in which players engage in artificial conflict, defined by rules, and resulting in a quantifiable outcome (Salen & Zimmerman, 2004). GBL is based on the idea that games can be designed to promote specific learning outcomes through interactive play (Plass et al., 2015). While learning content could be presented separately from game content, both learning and motivation are positively impacted if playing and learning are intrinsically integrated and aligned (Habgood & Ainsworth, 2011). Learners may learn from games by experimenting and practicing in a safe and risk-free environment, by receiving direct and indirect feedback, and by debriefing and reflecting on the playthrough (Garris et al., 2002). Learners may be motivated to begin and continue learning through game design elements such as challenge, control, rewards, curiosity, fantasy, cooperation, and competition (Malone & Lepper, 1987). The instructional and motivational elements of GBL are not necessarily part of the game. Therefore, we will use the broader term game-based learning environment (GBLE) to refer to the environment the learner interacts with.

Learning through playing is promoted through game design elements as part of an interactive game loop of goals or challenges set for the player by the game, actions performed by the player, and feedback and rewards provided by the game in return (Dondlinger, 2007; Garris et al., 2002; Plass et al., 2015). This loop is characterized

by rules that dictate which actions are allowed, core mechanics that determine which responses the game gives to these actions, and is often framed within a narrative setting that provides fantasy and aids understanding and meaning-making for the player (Dickey, 2006; Dondlinger, 2007). Finally, social aspects of gaming can contribute to both learning and motivation, for example through online or offline multiplayer games and by observing others while playing (Gajadhar, De Kort, & IJsselsteijn, 2008).

2.3 Metacognition in Game-Based Learning

Computer-based learning environments in general can be viewed as metacognitive tools for enhancing learning (Azevedo, 2005a, 2005b; Azevedo et al., 2012). GBLEs in particular may be suitable for encouraging metacognition, as learners are involved as active participants in learning (Sitzmann, 2011). Previous research has suggested potentially effective metacognitive mechanisms for GBL, such as adaptive scaffolding, collaboration, and self-explanation (Nietfeld & Shores, 2011). More recently, generic metacognitive design principles for GBL, such as self-explanation, reflection, feedback, and guided practice have been proposed (Mayer, 2016). However, a comprehensive overview that informs the design and research of GBLEs for metacognition is currently lacking.

The challenges in designing GBLEs that encourage metacognition can be summarized as follows. First, it is currently unclear which metacognitive objectives are suitable to address through GBL. Second, given such a metacognitive objective, it is currently unclear which metacognitive mechanisms within the GBLE can address this objective and how to combine such mechanisms with gameplay. Third, and last, it is currently unclear which approaches towards encouraging metacognition in GBL are effective. In summary, insights are needed that relate metacognitive objectives to effective metacognitive mechanisms and ways of aligning and integrating such mechanisms with the gameplay.

3. Approach

The goal of this chapter is to address these challenges by collecting and analyzing studies that attempt to encourage metacognition through mechanisms in GBLEs. We seek to identify implications that can guide designers and researchers of GBLEs. For designers of GBLEs, we want to identify the design choices that have a positive impact on metacognition and learning outcomes. For researchers, we want to identify the gaps that need to be addressed to advance insights on metacognition in relation to GBL.

The challenges in designing GBL for metacognition are addressed by three review questions that guide our search and analysis. The first review question focuses on identifying what the study tried to achieve regarding metacognition of learners, while the second review question focuses on the working mechanisms proposed to achieve this. The third and final review question then focuses on how these mechanisms were evaluated and which effects were found. The review questions are formulated as follows:

- (1) What were the metacognitive objectives of the game-based learning environment?
- (2) Which metacognitive mechanisms were implemented to address these objectives?
- (3) How were these metacognitive mechanisms evaluated and which effects were found?

An initial literature search revealed that no previous meta-analyses of metacognition in GBL have been published to date, warranting a wide literature search. The WorldCat database, including ACM, APA, ERIC and IEEE, was queried using the search terms game(s), gaming, or simulation(s) combined with metacognition, metacognitive, cognition and monitoring, and learning and regulation, and Google Scholar was used to corroborate and augment our results.

The coding and selection process, as shown in Figure 3.2, yielded 24 publications describing 27 studies included in this review (see Appendix A for an overview of the selected publications).

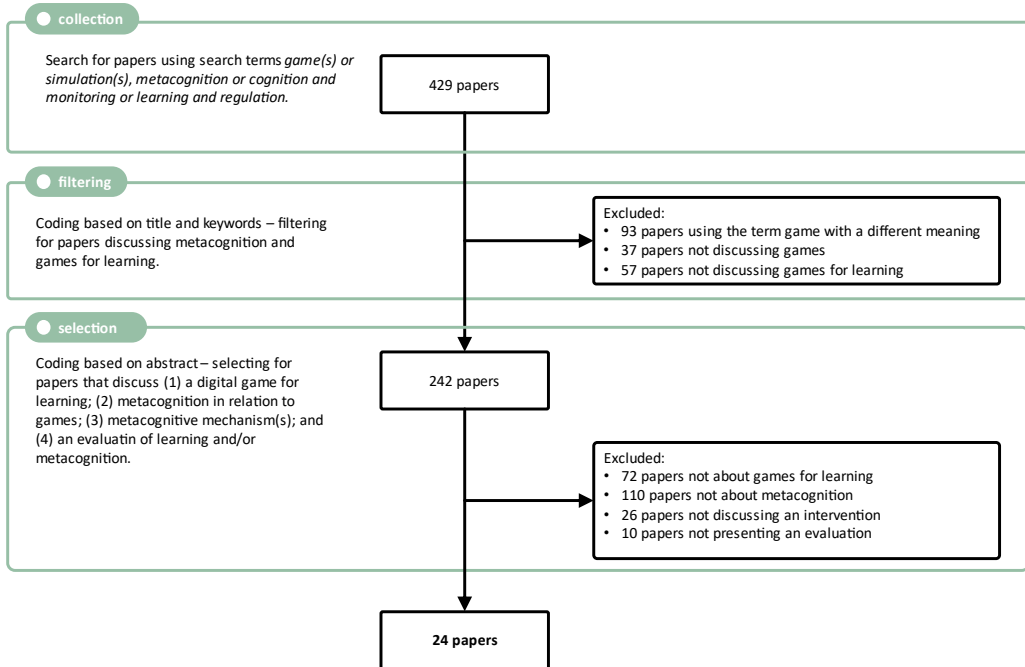


Figure 3.2: Search procedure, selection criteria, and number of included and excluded papers in each step.

Table 3.1: Description of the selected studies in terms of the audience and objectives, metacognitive mechanisms, design of the study, measurements taken, and results found from the evaluation.

#	Audience and Objectives	Mechanisms	Study Design	Measurements	Evaluation Results
1	college students (domain general): improve cognitive bias knowledge and mitigation	· direct/hybrid instruction · self-evaluation (quiz) · performance-based adaptive instruction	between-subjects experiment (N=703) 1x or 2x 30 min. over 2 wks. with post-test after 8 wks.	metacognitive knowledge and skills (questionnaires)	metacognitive knowledge increased and remained higher at delayed post-test under both intervention and repeated play (vs. control group)
2	college students (domain general): improve cognitive bias knowledge and mitigation	as in exp. 1, plus immediate (vs. delayed) metacognitive feedback	between-subjects experiment (N=620) 1x or 2x 30 min. over 2 wks. with post-test after 8 wks.	metacognitive knowledge and skills (questionnaires)	feedback did not make a discernible difference
3	college students (domain general): improve cognitive bias knowledge and mitigation	as in exp. 2, plus single- (vs. multi-)player modes	between-subjects experiment (N=626) 1x or 2x 30 min. over 2 wks. with post-test after 8 wks.	metacognitive knowledge and skills (questionnaires)	social structure did not make a discernible difference
4	college students in engineering: metacognitive monitoring to enhance learning	metacognitive prompt to self-explain	between-subjects quasi-experiment (N=65) +/- 3 days	metacognition (questionnaire)	positive impact of metacognitive prompting on learning
5	college students in game development: improve metacognitive knowledge	in-game metaphors to real-life learning	user study/preliminary evaluation 5-week period	user feedback (log data, questionnaires)	positive user feedback but no metacognitive evaluation
6	4th-grade students in language learning: planning and monitoring to enhance learning	scaffolding by visualization of learning status	between-subjects pre-test/post-test quasi-experiment (N=30) 2x 35 min. over 2 wks.	domain learning performance (knowledge test), metacognitive skills (questionnaire)	· learning performance increased significantly and similarly in both conditions · interventions significantly enhanced metacognitive skills (planning and monitoring)
7	adults in health care: reflection	metacognitive prompt to reflect	user study/preliminary evaluation single session; length not reported	user feedback (questionnaires, interviews)	reflection questions were regarded as positive and relevant

#	Audience and Objectives	Mechanisms	Study Design	Measurements	Evaluation Results
8	college students in physics: attention direction and reflection to enhance learning	· worksheet to focus on specific elements · worksheet linking game features to learning goals	between-subjects experiment (N=50) 1x 30 min. single session	domain learning performance (embedded knowledge test, questionnaires)	· learning performance higher and perceived difficulty lower at direct post-test (vs. control group) · no increase in self-reported effort (vs. control group) · increased self-reported satisfaction (vs. control group)
9	college students in physics: attention direction and reflection to enhance learning	· worksheet to focus on specific elements · worksheet linking game features to learning goals	between-subjects experiment (N=114) 1x 30 min. single session	domain learning performance (embedded knowledge test, questionnaires)	· learning performance not different between groups · learning performance of high-performing students increased (vs. low-performing students in experimental group)
10	computer science students: reflection	one-on-one in-game competition	user study/preliminary evaluation 2 hours, 2-3 times/week	metacognition, learning performance (observation and field notes)	some indications of inspiring metacognition in learners
11	adults (domain-general): improve cognitive adaptability	· shifting rules and environments · open-ended gameplay	between-subjects experiment (N=39) 12 hrs. over 2 days.	metacognition (questionnaire)	no significant effect found
12	5th- and 6th grade students in physics: metacognitive skills to enhance learning	· process scaffold (checklist) · metacognitive prompts to cue behavior	within-subjects pre-test/post-test experiment (N=20) 30 min. single session	domain learning performance (knowledge test), metacognitive skills (questionnaire)	· significant increase in domain learning performance · non-significant increase in metacognitive skills
13	4th- and 5th-grade students in mathematics: metacognitive awareness to enhance learning	iterative application, testing, and revision of skills in game	within-subjects pre-test/post-test experiment (N=15) 10x 2 hrs. over 5 wks.	metacognition, learning, motivation (questionnaires)	· no significant effect of computer games on learning or metacognitive knowledge · significant increase in learning attitude
14	5th-grade students in mathematics: metacognitive awareness to enhance learning	· games (vs. paper-and-pencil drills) · collaboration (vs. individual or competitive setting)	between-subjects quasi-experiment (N=487) 2x 45 min. p/wk. over 4 wks.	metacognition, learning, motivation (observation, think aloud, questionnaires)	· games were more motivating (vs. paper/pencil drills) but did not improve performance or metacognitive awareness · collaborative setting enhanced the effect of games on motivation but did not affect performance or metacognitive awareness

#	Audience and Objectives	Mechanisms	Study Design	Measurements	Evaluation Results
15	9th-grade students in finance: metacognitive strategies to enhance learning	direct instruction	within-subjects pre-test/post-test experiment (N=132) 2x 45 min. per wk. for 10 wks.	learning (questionnaires, knowledge test)	learning performance increased
16	6th-grade students in mathematics: improve metacognitive awareness	· game challenge · scaffolding (worked examples comparison)	between-subjects quasi-experiment (N=86) 285 min. over 4 wks.	metacognition (questionnaire), domain learning performance (test)	significant higher performance for game challenge with scaffolding (vs. either game challenge or scaffolding alone)
17	high school students (reading comprehension): reflection to enhance learning	· performance-based adaptive transfer · self-explanation	between-subjects experiment (N=234) 5 sessions over 3 days	metacognition (log data), domain learning performance (transfer test)	no significant results for adaptive transfer or self-explanation on comprehension or transfer
18	secondary school students in physics: metacognitive strategies to enhance learning	direct instruction (vs. scaffolding)	between-subjects experiment (N=99) 90 min. of which 20 min. of interaction; single session	metacognition, motivation (questionnaire), domain learning performance (knowledge test)	· no main effects for training and prompting, and no interaction effect · for 20 participants who used prompting appropriately, learning performance increased significantly
19	adults (intercultural competence): improve metacognitive agility	reflective observation role	user study/preliminary evaluation 0-5 hours over 3-month period	user feedback (questionnaires, focus groups)	no evaluation of effects on learning or metacognition
20	college students (incident commanders): improve metacognitive reflection	rewind-and-redo from point-of-error mechanic	exploratory study (N=15) single session; length not reported	metacognition, learning (observations, interviews, questionnaires)	qualitative analysis suggests increase in metacognitive awareness
21	college students in reading comprehension: improve metacognitive awareness	· performance-based metacognitive feedback · performance-based adaptive transfer	within-subjects pre-test/post-test experiment (N=28) 1 hr. single session	metacognition (log data)	automatically computed self-explanation quality increased
22	5th-grade students in philosophy: improve metacognitive strategies	direct instruction	between-subjects experiment (N=49) 90 min.	metacognition, domain learning performance, motivation (questionnaires)	enhanced learning as well as increased (deep) strategy use
23	vocational students in physics: metacognitive monitoring and regulation to enhance learning	metacognitive tools supporting task structure, problem-solving and social interaction	between-subjects pre-test/post-test experiment (N=39) time not reported	learning, motivation (questionnaires, focus groups)	· self-reported proficiency significantly higher when using metacognitive tools · qualitative feedback: tool purpose and use needs to be cued or explained

#	Audience and Objectives	Mechanisms	Study Design	Measurements	Evaluation Results
24	vocational students in engineering: metacognitive awareness to enhance learning	metacognitive tools supporting task structure, problem-solving and social interaction	user study/preliminary evaluation (N=15) time not reported	user feedback (questionnaire)	· students did not always understand how to access or use the metacognitive tools · some of the comments do indicate reflection on learning
25	adults in chemistry: metacognitive level to enhance learning	games conceptualized as the intervention itself	between-subjects experiment (N=176) with post hoc within-subjects analysis 8-week period	metacognition, learning performance, motivation (questionnaires)	· no significant difference between groups · non-significant raise in metacognition within-subject between pre- and post-test)
26	adults in finance: confidence estimation to enhance learning	· metacognitive prompts to explicate confidence · collaborative (vs. individual) discussion of confidence	between-subjects quasi-experiment (N=16) 25 min. single session	metacognition (questionnaires, log data, observation), learning (test, log data)	no significant results for performance or feeling-of-knowing evolution
27	college students in physics: improve accuracy of confidence estimation	· give confidence ratings for answers · feedback on confidence rating accuracy	within-subjects pre-test/post-test experiment (N=28) 20 min. single session	metacognition (questionnaire), learning (embedded test, questionnaires)	· increase in confidence accuracy · mixed results on learning performance

4. Results and Discussion

4.1 Results

The included studies are summarized in Table 3.1. The results are further discussed in the subsequent sections, as organized by the three review questions.

Objectives

There is ongoing debate about what is and what is not metacognition, which is reflected in the widely differing terms and definitions of metacognition used. While most studies referred to metacognitive awareness or its components of metacognitive knowledge, monitoring, or regulation, some studies introduced new constructs such as 'metacognitive agility', 'cognitive adaptability', or 'metacognitive level'. We agree with Moshman (2018) that a shared and specific way of defining and describing metacognitive objectives is necessary, which must also be practically applicable for designers and researchers. Such an objective would be described in terms of the expected effects on learners' metacognition, in a testable way, and in relation to the mechanisms within the learning environment that promote these effects.

- **Research Implication:** More formalized ways of specifying and comparing metacognitive objectives need to be developed.
- **Design Implication:** Metacognitive objectives must be formulated in terms of the expected effects on learning and learners in a testable way.

We further found two distinctions that can improve clarity of the metacognitive objectives. First, the role of promoting metacognition can be either to enhance current learning, or to enhance future learning. If the objective is to enhance current learning, then metacognitive mechanisms must be designed to enable learners to increase the effectiveness and efficiency with which they can achieve the domain learning goals – for example, by scaffolding the problem-solving process or prompting for self-explanation of current understanding. If, on the other hand, the objective is to enhance future learning, then metacognitive mechanisms must be designed such that learners are able to improve their metacognitive knowledge and skills – for example, by prompting for self-explication of the current learning

strategy. Additionally, learners must be enabled to transfer these metacognitive gains to future learning situations. Second, generality of metacognition can be either domain-specific or domain-general. If the objective is to encourage domain-specific metacognition, then the GBLE needs to be designed in a way that emphasizes the domain-specific learning content and supports learners in metacognitively processing that content. If, on the other hand, the objective is to encourage domain-general metacognition, then the GBLE needs to be designed in a way that helps learners to apply domain-general metacognition to concrete domain-specific learning – for example by detaching metacognitive training from domain-specific training but providing heuristics for when and where to use the metacognitive aspects being trained.

In summary, the description of metacognitive objectives should not only include a proper definition of metacognition (e.g., knowledge, skills, awareness), but also the role of metacognition (i.e., enhancing current or future learning) and the domain-generality of metacognition (i.e., domain-specific or domain-general).

- **Design Implication:** Metacognitive objectives must be formulated in terms of the definition, the role, and the domain-generality of metacognition.

Mechanisms

The terminology used to describe the different metacognitive mechanisms in the selected studies varies widely. This makes it hard to transfer knowledge gained from individual case studies to inform future designs, as it is hard to compare similar mechanisms that are named and described differently. In other words, without a shared way of specifying and comparing metacognitive mechanisms and the underlying design guidelines, it remains hard to extract generalized knowledge from case-by-case research findings and apply it to other GBLEs.

CHAPTER THREE. QUALITATIVE LITERATURE REVIEW

Table 3.2: Overview of metacognitive mechanism types for game-based learning.

Mechanism Type	Description	Studies
direct instruction	Definition: instructing learners directly about metacognition. Example: metacognitive strategy training before learning activities.	1, 15, 22
adaptive instruction	Definition: altering the instruction, support or feedback based on learner behavior. Example: transferring underperforming learners to remedial activities.	1, 17
metacognitive cues	Definition: reminding students to perform metacognitive activities while learning. Example: asking learners to reflect on their current learning strategy.	7, 18
metacognitive scaffolds	Definition: providing learners with supports that make it easier to apply metacognition Example: providing (partial) worked examples for comparison.	6, 8, 9, 12, 16, 18, 23, 24
self-explanation	Definition: making current learning progress explicit by expressing it Example: asking learners to describe their current understanding of the domain learning content.	1, 4, 8, 17
self-explication	Definition: making metacognitive processes explicit by expressing them. Example: entering a degree of confidence in answer correctness when giving that answer.	9, 26, 27
metacognitive feedback	Definition: providing learners with feedback on their metacognitive activities. Example: displaying how accurate confidence explications are.	2, 27
social interaction	Definition: using the interaction with others to support metacognitive activities. Example: comparing and discussing confidence explications before giving an answer.	3, 14, 19, 23, 24, 26
game design features	Definition: employing specific game design features to encourage metacognition in learners. Example: using cooperative or competitive multiplayer modes between players.	3, 5, 10, 11, 13, 14, 16, 20, 25, 27

Further analysis on the purpose of the mechanisms allowed us to group the collected studies into nine types of metacognitive mechanism for GBL. This notably excludes

prompting as a single mechanism type, since prompts can be used for different purposes such as cueing, scaffolding, or self-explication. An initial overview of metacognitive mechanisms for GBL, with their definitions, examples, and studies that discuss them, are shown in Table 3.2. However, further research is needed to identify which type of mechanism is (most) suitable for which type of metacognitive objective.

- **Research Implication:** More formalized ways of specifying and comparing metacognitive mechanisms need to be developed.

The term game is used to refer to a wide range of GBLEs: from basic multiple-choice quiz games to immersive 3D-environments with a wide range of goals, mechanics, narrative elements, and social interactions. Various game design elements are suggested for encouraging metacognition, such as competition, challenge, use of metaphors, the dynamic changing of rules and environments, and multiplayer interactions.

We identified two design implications that aid the design of GBLEs for metacognition. First, almost all the games in the selected studies adopt a step-by-step, deliberate style of gameplay, as opposed to time-based, action-packed, reactive gameplay. This allows players to consciously consider, select and evaluate actions and outcomes at their own pace; an important prerequisite for metacognitive monitoring and reflection. Second, the GBLEs differ in how much freedom a player has to choose actions. A few games even try to adapt the game activities to the individual needs of the player, by suggesting or presenting different game activities. Striking the right balance between enough freedom to practice and enough guidance to apply metacognition effectively to learning is a key design goal for metacognitive mechanisms in GBL. Apart from these two initial design implications, further research is needed to identify applicable design guidelines for designing gameplay that encourages metacognition in learners.

- **Design Implication:** Adopt deliberate step-by-step gameplay.
- **Design Implication:** Adaptively balance freedom and guidance.

- **Research Implication:** Further research is needed to identify guidelines for designing gameplay to encourage metacognition.

Literature suggests that learning and motivation are positively impacted by designing GBLEs such that learning and playing are intrinsically integrated and aligned. Few studies attempt such intrinsic integration, for example by designing the narrative and mechanics such that they contribute to encouraging metacognition. However, in most studies, metacognitive mechanisms are introduced without relating them to the gameplay itself.

Table 3.3: Three integration approaches for metacognitive mechanisms in GBLEs.

Integration	Description	Studies
exogenous	Definition: metacognitive mechanism is not part of or related to the gameplay or game environment Example: metacognitive strategy instruction before game-based learning activities.	8, 9, 13, 14, 15, 19
extrinsic	Definition: metacognitive mechanism is part of the game environment but not related to the gameplay Example: process-scaffolding tools to keep track of problem-solving steps	4, 6, 12, 16, 17, 18, 21, 23, 24, 26
intrinsic	Definition: metacognitive mechanism is part of the gameplay Example: self-explicating confidence as part of an in-game puzzle.	1, 2, 3, 5, 7, 20, 22, 27

Further analysis allowed us to group the different approaches to integration in three high-level categories of integration: exogenous, extrinsic, and intrinsic integration, as shown in Table 3.3. While intrinsically integrating metacognitive mechanisms with the gameplay is applaudable, it is also more challenging. Metacognitive learning goals require that learners examine their own thoughts, tactics, and strategies in the real world, rather than focusing only on actions and responses within the game environment. Therefore, it seems, a metacognitive mechanism is harder to integrate intrinsically into the game design than for other learning goals. Some examples are adopting metacognition as the topic of the game or disguising metacognitive prompts as part of an in-game puzzle. However, such approaches hinge on very specific game design choices that are hard to generalize to other

games. A next step for intrinsic integration of metacognitive mechanism would be to examine the dimensions of game design that allow alignment of metacognition with gameplay and to identify generic design guidelines that apply across different cases.

- **Research Implication:** Further research is needed to identify guidelines for intrinsically integrating metacognitive mechanisms with gameplay.

Effects

While literature on addressing metacognition through GBL is increasing, we found only 24 studies that include some form of evaluation, of which six studies are only preliminary studies and the remaining 18 studies reporting mixed results. The studies varied widely in sample size, running time, and whether measurements of learning, metacognition, and/or motivation were analyzed. As metacognition develops slowly over a longer period and in individually different ways and at different rates, studies that run over a longer period are preferred over single-session evaluations. Likewise, more insights can be gained from studies that assess metacognition as a dependent or intermediate variable, instead of only measuring effects on learning performance. In other words, we contend with Veenman et al. (2006) that in addition to measures of learning performance, measures of metacognition itself need to be taken. We add that the effects on motivation must be studied – as learners must be sufficiently motivated to exert the additional effort to add metacognitive processing to domain- and task-level cognitive processing.

- **Research Implication:** Evaluations of metacognitive mechanisms in game-based learning must assess domain learning, metacognition, and motivation.

Only nine studies reported clear and significant effects of the intervention on learning or metacognition. Of these studies, three studies found a positive impact on metacognition, all three the result of some form of direct instruction. The remaining six studies found a positive effect of metacognition on domain-learning performance, most prominently through direct instruction or metacognitive prompting. In short, the quantity and quality of the evidence for metacognition in GBL is currently very limited and there is ample room for experiments that evaluate the effects of different

types of metacognitive objectives, different types of metacognitive mechanisms, and different types of integration in games.

- **Research Implication:** Evaluations are needed that assess the impact of metacognitive mechanisms on metacognitive objectives.

While a quantitative meta-analysis is beyond the scope of this review, it appears from the results that more direct mechanisms (e.g., instruction) are more effective than more indirect mechanisms (e.g., feedback). Furthermore, direct instruction, scaffolding, as well as cueing, seem to have a positive impact on enhancing learning as well as on improving metacognition. However, none of the social features were found to have an impact on learning or metacognition. Of the different game design elements suggested for encouraging metacognition, positive effects were found only for game challenge combined with scaffolding, and for embedding of metacognition in the narrative and mechanics of the game. The benefits of integrating mechanisms with gameplay are also not evident from the studies analyzed in this review.

5. Conclusions

In this chapter we have presented a review of metacognition in GBL and have identified important implications for future design and research. Additionally, we have presented an initial overview of metacognitive mechanism types and ways of integrating metacognitive mechanisms with the goals, mechanics, narrative and social elements of the game design. We found that the limited ways in which GBLE-designs can be compared stands in the way of advancing insights across this field. To advance GBL from case-by-case findings towards generalized design guidelines for encouraging metacognition in GBLEs, we need to create insight across different fields, terms, and experimental findings. The overview of metacognitive mechanisms for GBL presented in this chapter, in conjunction with the insights regarding how these mechanisms can be integrated in the GBLE, can be regarded as a first step towards these goals. However, we need to develop more formalized ways to communicate about designs in general and the mechanisms implemented in particular. If we want to advance insight in which mechanisms can be used to help

encourage metacognitive knowledge and skills, we must be exact about what it is that we want to promote and how it is promoted.

5.1 Limitations

We have already highlighted the complexities of metacognition as a term: there are many other concepts and constructs that can be viewed as part of metacognition. Therefore, we may have missed studies that address these specific constructs without explicitly referring to the larger construct of metacognition. For example, the broader construct of self-regulated learning encompasses metacognition, but also cognition and motivation, and we refer to a comprehensive review by Nietfeld and Shores (2011) for recommendations regarding self-regulation in GBL. Furthermore, as we have focused on collecting different approaches towards addressing metacognition in GBLEs, we did not conduct a quantitative meta-analysis on which approaches are effective. We also did not distinguish between the different types of learners. However, the limited quality and quantity of current work illustrates the limited potential of such an approach at this point in time. A future review including a meta-analysis of the empirical results from these and other studies may shed further light on which types of mechanisms are particularly effective and for whom. Nonetheless, as the first review to our knowledge that comprehensively addresses both metacognitive objectives and metacognitive mechanisms within GBLEs, we have contributed to advancing design and research in GBL as well as educational psychology and instructional design.

5.2 Future Work

As research on GBL is only in its adolescence, it is no surprise that we find large differences in concepts, definitions, mechanisms, and measurements. We propose three consecutive future directions for GBL: specificity, comparability, and transferability.

Specificity. To advance the efficiency and effectiveness of digital learning environments for learners, we must work towards a clear, shared, and practical view on metacognition as well as GBL. Important questions that can advance the literature base on metacognition in GBL are (i) which aspects of metacognition are specifically

relevant to be addressed within GBLEs; (ii) how these aspects can be defined in terms of testable behavior or change within learners; and (iii) how these aspects could be captured by a combination of online and offline measurements. Important insights for advancing research of GBL are (i) being specific about which elements are included in the design; (ii) for what purpose (e.g., to motivate, to teach, to support practice, etc.); and (iii) how these elements contribute to this purpose. At that point, it is not so much relevant whether something is or is not a game, but to what extent motivation and learning are impacted by interactive elements within the design of the learning environment.

Comparability. In order to develop generic design knowledge on how to improve learning within GBLEs, it is paramount to be able to compare different approaches and systems. We propose that further formalization of the design of digital learning environments could contribute towards this goal. Such a formalization would allow us to define the different components and their functions, describe relationships and interaction between components, and, most importantly, describe how the interaction between learner and system contributes to learning.

Transferability. From the available case-by-case evidence, it is hard to distinguish between specific design choices made in one instance and design guidelines that can be applied in general. This hampers the transfer of knowledge from specific cases towards other, current and future, designs of learning environments. If we find ways of more specifically defining the concepts we address, and can compare different designs systematically, we can work towards transferring the critical design decisions in effective designs to future designs.

To advance GBL, a multidisciplinary effort, involving expertise from educational psychologists, instructional designers, and experts in GBL and game design is required. The lens of metacognition is a particularly important lens, as it addresses the study of learning itself by learners themselves and interrelates with cognition and motivation. This chapter is a first attempt to integrate results and approaches from different fields. Our aim is to further develop formalizations of metacognition and GBL, and use them to specify, implement, and evaluate more effective

metacognitive mechanisms. We believe that the next step for GBL is to move beyond specific designs for specific skills or domains and to identify which generic elements within the design of GBLEs can foster metacognitive knowledge and skills in learners.

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