chapter four

Design Framework

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This chapter is based on the following journal paper:

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This chapter incorporates ideas from the following conference paper:

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1. Introduction

The premise of GBL is that the unique aspects of games, such as challenge, fantasy, and interactive storytelling, have a positive impact on both motivation and learning (Garris et al., 2002; Plass et al., 2015). Over two decades of research have demonstrated that GBL can indeed motivate learners and help them to achieve specific learning outcomes (Wouters et al., 2013). Yet, the details of how to effectively combine game features with learning remain unclear (Graesser, 2017; Ke, 2016).

GBL takes place within a GBLE: the digital and interactive environment that contains both game elements and instructional elements (Plass et al., 2015; Vandercruysse & Elen, 2017). An important aspect to consider in the design of effective digital learning environments is metacognition (Azevedo et al., 2012; Lin, 2001): a learner's conscious understanding of how to use declarative, procedural, and conditional metacognitive knowledge about oneself, learning tasks, and strategies, to metacognitively plan, monitor, and evaluate learning (Pintrich, 2002; Schraw, 1998).

Previous research has recommended that the relationship between metacognition and the design of GBLEs should be researched to (1) encourage deep learning over shallow learning and so-called skill drills (Graesser, 2017); (2) encourage self-regulated learning (Nietfeld & Shores, 2011); (3) promote reflection on learning outcomes as well as the learning process (Ke, 2016; Paras & Bizzocchi, 2005; Vlachopoulos & Makri, 2017), and to (4) promote the use and development of metacognitive strategies while learning (Kim, Park, & Baek, 2009; Mayer, 2016). To ensure that metacognition is addressed effectively in GBLEs, it is important to understand how metacognition can successfully be encouraged and improved through the design of GBLEs. However, previous research focusing on metacognition in GBLEs has shown that it is difficult to abstract case-specific findings to more general guidelines for designing such environments (Braad, Degens, & IJsselsteijn, 2020).

The challenge in designing GBLEs is dealing with the degrees of freedom. As stated by Ke, Shute, Clark, and Erlebacher (2019) in their seminal work on the interdisciplinary design of GBLEs: "Game design is characterized by an open-ended or unspecified goal state and an extensive, indeterminate design problem space - in which the transition states (or paths) between the design input and output (or goal) states can be unlimited and their connections are unknown." To deal with this amount of freedom, it is important that a designer, or researcher, can 'navigate' the design problem space, to ensure that the design choices made contribute optimally to the design objectives.

When the expected design objectives include metacognition, however, it is hard to make well-informed design decisions by learning from previous design and research findings. First, previous research has found only a limited number of empirical studies of metacognitive mechanisms in GBLEs, and, moreover, these studies lack sufficient specificity and comparability to collectively inform future GBLE-designs (Braad et al., 2020). Ideally, such studies would have been repeated, connected, and refined to identify design guidelines; in reality however, most of the cases have never been touched again after the initial evaluations. Second, when designing for metacognitive outcomes, it is unclear which general aspects of GBLEs are even relevant to consider. In other words: it is unclear which design choices are likely to positively benefit learners, and hence warrant the effort of researching, testing, and implementing design guidelines to inform these choices.

In this work, a first step is made in dealing with the aforementioned challenge. In short, it is our goal to reduce the complexity of design by bringing structure to the possible design space one has to consider when addressing metacognition in GBLEs. By doing so, the potential impact of the choices made in that design space can be discussed. As a basis for this work, the conceptual model presented in Figure 4.2 was developed. In general, the underlying premise of GBL is that the interactions with the GBLEs lead to an impact on the learner (represented by 'a'). Previous research has focused on the typical GBL-outcomes of learning and motivation. However, additional research is needed into the role of more complex outcomes such as metacognition (represented by 'b'). While acknowledging the importance of motivational effects of GBL, in this chapter the focus is on cognitive and in particular metacognitive effects.

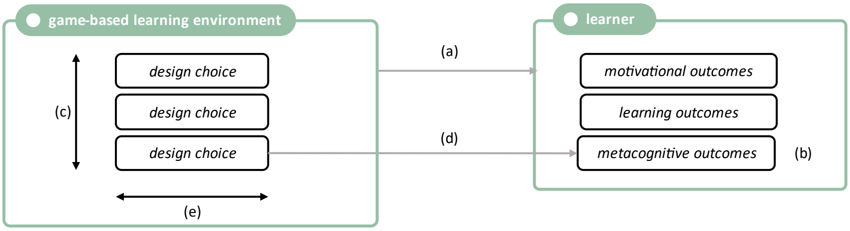

Figure 4.2: A conceptual model of designing game-based learning environments for impact on learners.

A GBLE is a designed artefact that is the result of multiple design decisions (represented by ‘c’), that were made either consciously or unconsciously. A formalized approach to designing GBLEs should thus consider how specific design choices affect specific learner outcomes (represented by ‘d’), and how such design choices are made deliberately and based on existing research. A design choice is also one particular sampling of the design space, and it follows that a design choice is part of some design dimension (represented by ‘e’) that describes a particular area of the design space. It is currently unclear, however, how this design space can be described, what these design dimensions should be, and what is known about the choices to be made.

The key question pursued in this chapter concerns the first two of these issues: how can the relevant design choices in designing GBLEs for metacognition be described? To advance insights in the design of digital GBLEs, the authors propose that a more detailed and structured approach towards the design of GBLEs must be taken. As such, in this chapter, the goal is to reduce the complexity of design by mapping out the design space of GBLEs for metacognition.

Ultimately, the objective is to aid both designers and researchers of GBLEs. For designers, the goal is to make it easier to focus on the relevant areas where informed decision-making is likely to affect the metacognitive outcomes the most. For researchers, the goal is to identify areas where more specific design guidelines that inform such design decisions for each dimension should be investigated. These objectives require that insights from existing literature, practical approaches studied in published experiments, and professional vocabulary of experts from different fields be combined. An iterative approach to constructing and evaluating such a framework is therefore adopted.

The chapter is structured as follows. First present, an analysis of the current literature and practical examples is presented, from which an initial set of design dimensions of GBLEs for metacognition is derived. Subsequently, a formative evaluation is discussed, in which experts evaluate these initial dimensions for three real-world cases of metacognition in GBL. The resulting design framework is presented. The implications that follow from both the resulting framework and the approach are discussed.

2. Design Dimensions for Metacognition in Game-Based Learning

As a first step, the aim is to identify and combine the theoretical and practical insights from existing literature that could inform the design of GBLEs for metacognition. In particular, the goal is to identify design dimensions that describe a particular and relevant area of choice-making for designers of such GBLEs. With such design dimensions, it should become easier to identify and describe the similarities and dissimilarities between designs – in turn making it easier to consider such design choices more consciously in future GBLE designs as well as GBLE research.

2.1 Derivation from Literature

This aim was addressed by analyzing literature on the design of metacognitive training. With the goal of formalizing the design space for GBLEs in mind, from existing literature, the dimensions that can be used to describe different approaches to implementing metacognitive instruction in digital tools were distilled. In line with previous literature (Garris et al., 2002; Vandercruysse & Elen, 2017), two perspectives on GBLE-design are employed: an instructional perspective that considers what aspects in the GBLE facilitate learning and a gameplay perspective that considers what aspects facilitate play.

For the instructional perspective, well-established work by Veenman, Van Hout-Wolters, and Afflerbach (2006), Schraw (1998), Pintrich (2002), Osman and Hannafin (1992) and Derry & Murphy (1986) presents ample general advice on the different considerations for designing metacognitive training. Four design dimensions for metacognitive instruction were identified (see Table 4.1).

For the game perspective, in contrast, there is only limited insight in how to address metacognition in the design of GBLEs. Work by Ke (2008a, 2008b, 2016), Greasser (2017), Nietfeld & Shores (2011) and Mayer (2016), however, addresses some of these considerations. For the game perspective, five design dimensions for gameplay were identified (see Table 4.2).

Table 4.1. Design dimensions for metacognitive instruction in GBLEs. For each dimension, its opposite ends, definition, and rationale for each, and references are shown.

(1) To what extent is metacognitive instruction embedded within domain-specific content?		
Opposites	**embedded**	**detached**
Definition	metacognitive instruction is part of the domain-specific learning content	metacognitive instruction is separated from domain-specific learning content
Rationale	makes it easier for learners to connect metacognitive knowledge and skills to concrete and ongoing learning	makes it easier for learners to isolate and transfer aspects of metacognition to different learning situations
References	Derry & Murphy (1986), Osman & Hannafin (1992), Hartman (2001a), Pintrich (2002), Schraw (1998), Veenman et al. (2006).	
(2) To what extent is the metacognitive instruction direct about what a learner needs to do?		
Opposites	**direct**	**indirect**
Definition	metacognitive instruction is explicit about metacognition and aimed at increasing awareness and use of metacognition	metacognitive instruction is implicit about metacognition and aimed at improving use and effectiveness of metacognition
Rationale	helps learners to increase knowledge and awareness of metacognition	helps learners to produce metacognitive behaviors more often and more effectively
	addresses an availability deficiency by increasing knowledge	addresses a production deficiency by improving and practicing application
	may be best suitable for novice and young learners	may be best suitable for older and more advanced learners
References	Bannert & Mengelkamp (2013), Derry & Murphy (1986), Osman & Hannafin (1992), Ke (2016), Lin (2001), Pintrich (2002), Schraw (1998), Veenman et al. (2006).	
(3) To what extent does metacognitive instruction guide students while learning?		
Opposites	**guided**	**unguided**
Definition	metacognitive instruction provides a learner with clear directions on what to do next	metacognitive instruction is available upon request from the learner
Rationale	makes learners perform effective metacognitive activities through guided practice	the ultimate goal is to become independent of external guidance
	may be used in the short term if gradually faded over time	allows learners to practice self-guidance without restriction
References	Azevedo et al. (2012), Bannert & Mengelkamp (2013), Derry & Murphy (1986), Graesser (2017), Osman & Hannafin (1992), Hartman (2001b), Lin (2001), Mayer (2016), Nietfeld & Shores (2011), Roll, Aleven, McLaren, & Koedinger (2007).	
(4) To what extent is metacognitive instruction integrated with the gameplay activities?		
Opposites	**extrinsically integrated**	**intrinsically integrated**
Definition	metacognitive instruction is situated outside of the gameplay activities	metacognitive instruction is situated within the gameplay activities
Rationale	reduces cognitive load and increases relevance of feedback to playing, learning, and metacognition	performance and motivation are positively impacted by meshing learning content with play
	may disrupt flow and be perceived as irrelevant	is unclear if this principle extends to integration of metacognitive instruction with gameplay
	may be unavoidable for complex learning content or content reflective in nature	
References	Graesser (2017), Habgood & Ainsworth (2011), Ke (2016), Nietfeld & Shores (2011), Plass et al. (2015).	

Table 4.2. Design dimensions for gameplay in GBLEs with metacognitive objectives (table continues on the following page).

(1) To what extent does the game involve social or individual interactions?		
Opposites	**individual**	**social**
Definition	a single player interacting with a GBLE	a range of players interacting within or outside of a GBLE
Rationale	allows learners to apply metacognition in their own way and at their own tempo	playing in groups is one of three most salient factors in effective GBL
	lack of social comparison promotes learners to experiment and risk failure	metacognition can be facilitated through social interactions within GBL
	individual debriefing of GBL is more effective than group-based debriefing	
References	Kim et al. (2009), Usart, Romero & Almirall (2011), Van der Meij, Leemkuil, & Li (2013), Wouters & Van Oostendorp (2013).	
(2) To what extent does the game involve competition or collaboration between agents?		
Opposites	**competitive**	**collaborative**
Definition	artificial conflict between agents	agents working together towards their goals
Rationale	produces motivation through challenge	collaboration in games can improve metacognition
	allows performance comparisons	collaboration fosters modelling metacognitive strategies from others
		collaboration fosters explication of otherwise covert metacognition
References	Ke (2008b, 2008a), Kim et al. (2009), Nietfeld & Shores (2011), Sanchez (2017), Schraw, Crippen, & Hartley (2006), Ter Vrugte et al. (2015), Usart et al. (2011), Vlachopoulos & Makri (2017), Zheng, Li, Zhang, & Sun (2019).	
(3) To what extent does the game involve deliberate or reactive responses from the player?		
Opposites	**deliberate**	**reactive**
Definition	players can deliberately consider and effectuate a choice	player must react quickly to changes in the game
Rationale	articulates thinking and allows learners to relate in-game choices to underlying principles	integrating learning content with action-based gameplay could hamper learning
References	Habgood & Ainsworth (2011), Martinez-Garza & Clark (2017), Mayer (2016).	

Table 4.2 (continued).

(4) To what extent does the game physically represent the target learning situation?		
Opposites	**physically fidelitous**	**physically fictitious**
Definition	the game environment looks, feels, smells, tastes, and/or altogether appears like the real world	the game environment deviates from representing reality
Rationale	strengthens the link between in-game and real-world concepts and situations, thereby improving transfer of learning	can emphasize relevant learning content by offering a more effective representation can improve motivation through fantasy and curiosity
References	Ke (2016), Mayer (2016), Rooney (2012).	
(5) To what extent does the game functionally represent the target learning situation?		
Opposites	**functionally fidelitous**	**functionally fictitious**
Definition	the game environment responds similar to interactions in the real world	the game environment deviates from simulating reality
Rationale	the game environment deviates from simulating reality	shifting rules can trigger metacognitive processing
References	Gallagher & Prestwich (2013), Ke (2016), Rooney (2012).	

2.2 Application in Practice

The question now remains whether these initial dimensions aid the description and comparison of GBLE-designs for metacognition in practice. Therefore, the dimensions were applied to a number of example cases. From a recent literature review of metacognition in GBL (Braad et al., 2020), five example cases, as dissimilar as possible in metacognitive objectives and mechanisms, were selected to represent a wide range of approaches to embedding metacognition in GLBEs.

For each example case, an in-depth learning task analysis was conducted, distinguishing between metacognitive activities, other instructional activities, and play activities. For each case, a labelled visual and structural analysis of the system elements and dynamics was constructed. Furthermore, any proposed metacognitive outcomes were indicated and linked to any active mechanisms implemented to address them.

With the results of this analysis, each of the dimensions was applied to each of the cases, and the results were visualized as a set of sliders with the position for that case indicated. Such design dimension dashboards show an *a priori* application of the design dimensions. Subsequently, it was confirmed that the dimensions could be applied to each case (i.e., the dimensions can be used to describe these widely differing cases) and that all salient aspects of each case were addressed (i.e., the dimensions cover the relevant design areas of these cases). The dashboards, along with a case description, are presented in the following sections.

Case #1: MMORPG

An MMORPG named Gersang (see Figure 4.3) is used to train economic concepts (Kim et al., 2009). The metacognitive objective is to increase knowledge and use of metacognitive strategies. Strategies are trained through direct instruction before play, can be applied as desired during play, and are self-explained after play. The game is set within a Korean medieval fantasy setting but contains a fidelitous economic simulation. The game is played online with other players and has a battle and an economic mode. Both competition and collaboration may occur and both reactive and deliberate gameplay is needed.

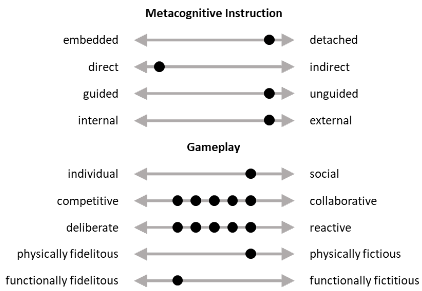

Figure 4.3: Design dimension dashboard for Case #1 (MMORPG).

Case #2: Construction Simulator

A 3D Construction Simulator (see Figure 4.4) is used to train construction project management (Castronovo, Van Meter, & Messner, 2018). The metacognitive objective is to encourage metacognitive monitoring and reflection, using cueing prompts and response prompts to self-explain scores. Learners can make choices at ease within a realistic 3D environment simulation. Prompts are presented in terms of and during domain-specific training but in between episodes of gameplay. Learners receive no further metacognitive support or feedback. Scores are awarded for achieving construction goals efficiently.

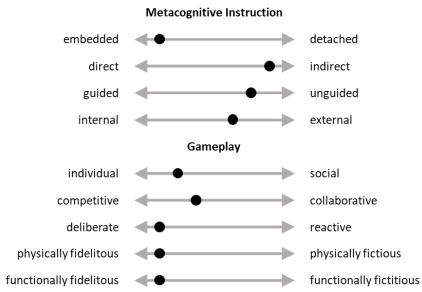

Figure 4.4: Design dimension dashboard for Case #2 (construction simulator).

Case #3: Circuit Game

A custom-made Circuit Game (see Figure 4.5) consists of compiling electrical circuits from electrical components to satisfy particular properties (Fiorella & Mayer, 2012). The metacognitive objectives are to encourage metacognitive monitoring and regulation through metacognitive cueing prompts and metacognitive scaffolding in the form of paper worksheets. The worksheets are in domain-specific wording and are continuously available. Prompts within the game encourage learners to self-explain current understanding but no further metacognitive support or feedback is provided. Players can make choices and selections at ease, receive feedback and scores. The game depicts the circuit in a standard abstract form of a circuit diagram. The game correctly simulates the effects of connecting the circuit as such.

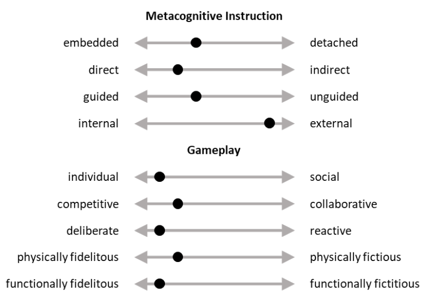

Figure 4.5: Design dimension dashboard for Case #3 (circuit game).

Case #4: Adventure Game

A story-driven adventure game (see Figure 4.6), set around the time and person of Galileo Galilei, is used to train physics (Verpoorten, Castaigne, Westera, & Specht, 2014). The metacognitive objective is to improve metacognitive knowledge in the form of accuracy of confidence in answer correctness. The metacognitive mechanisms are self-explication of confidence and metacognitive feedback on confidence. The game accurately simulates physics experiments which are not period correct. The confidence explication is presented as a sperate control on the physics experiment machinery. Feedback on confidence accuracy is provided separately from domain-specific feedback and as part of the narrative. To advance in the game, sufficient confidence must be gathered to convince Galilei to take you on as an apprentice.

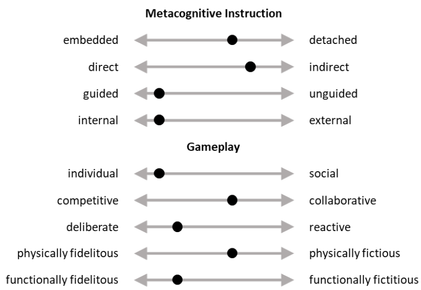

Figure 4.6: Design dimension dashboard for Case #4 (adventure game).

Case #5: Math Challenge

In this case (see Figure 4.7), problem-solving in mathematics is augmented with game challenges (Sun-Lin & Chiou, 2017). The metacognitive objective is to increase metacognitive awareness in algebra learning. The metacognitive mechanism is a self-explanation prompt, presented in terms of the problem, which asks to compare the learner's own solution against a correct or incorrect example. No other support or instructions during learning are provided. Specific challenges, points, and levels are awarded based on performance and progression.

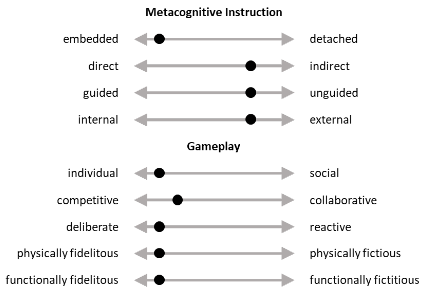

Figure 4.7: Design dimension dashboard for Case #5 (math challenge).

3. Formative Evaluation

With the set of dimensions that can, hypothetically, be used to both describe and differentiate metacognitive instruction in GBLEs, an important next step is to (i) identify which aspects are particularly relevant when considering metacognition in GBLE-design; and (ii) whether the proposed dimensions sufficiently represent these. A formative evaluation was conducted, in which a diverse range of experts was asked to discuss how the proposed dimensions apply to a number of real-world cases of metacognition in GBL. The following sections present the methodology, findings, and conclusions of this evaluation.

3.1 Methodology

Participants

From our network of professionals and researchers in relevant disciplines, such as game-based learning, instructional design, educational psychology, and metacognition in learning, 23 experts were invited. These experts were invited by mail, and reminded a few days later, resulting in 14 experts completing the evaluation.

Materials

To avoid asking the participants to read each of the corresponding papers, three of the five example cases were selected for the evaluation (i.e., the MMORPG, the circuit game, and the adventure game). A three-paragraph case description was constructed from the descriptions of instructional and gameplay elements from each original paper. The texts were edited to improve readability but kept as close as possible to the original. Each summary was augmented with screenshots of the respective GBLE (see Figure 4.8 for an impression and Appendix B for the game descriptions).

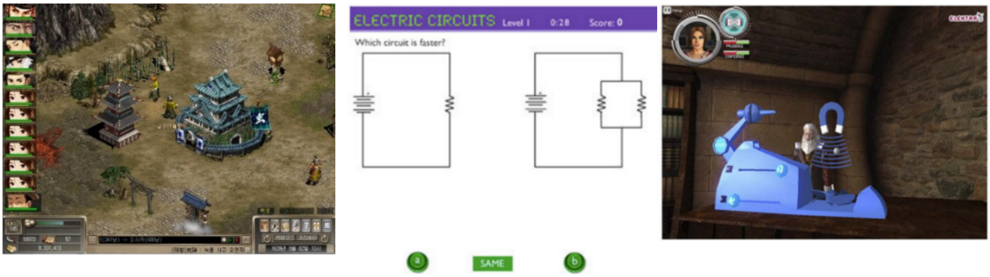

Figure 4.8: three different games employed in studying metacognition in game-based learning.

An online survey was constructed in which participants could, for each case description, rate and comment on each of the dimensions. For the dimensions of physical and functional fidelity, a brief definition and note emphasizing the distinction was provided. Ratings were requested to have participants consider and make a choice in terms of the dimensions, such that meaningful considerations would appear in the comments. Numerical ratings were requested for each dimension, on a scale from -3 through to +3 to indicate whether they found the instruction in the case description, for example, more direct (-3) or more indirect (+3). For each dimension, participants were asked to explain their choice.

Procedure

Each participant received a link to an online system guiding them through the materials. First, a brief introduction and explanation of the purpose of this study was given. Second, the participants were asked to process each of the three case descriptions. For each case, the system presented the case description, and asked participants to (a) rate and comment on the clarity of the description, (b) rate and comment on how the case relates to each of the dimensions, and (c) provide any additional comments. Participants were thus asked to motivate each of their ratings in text, to provide feedback on which of the included aspects were important, and to suggest aspects which were important but should yet be included. In this way, a discussion at the level of design dimensions was facilitated, while asking about concrete examples at the level of specific GBLEs.

Analysis

The comments were analyzed using *thematic analysis*: a structured method for identifying and interpreting meaning across the collected data (Braun & Clarke, 2012), that is suitable when experiential and explorative research questions are concerned, when responses to questions or prompts are to be analyzed, and when processing small datasets (Clarke & Braun, 2014). When applying thematic analysis, it is assumed that data analysis can never be objective, and that, rather, the choices that were made for the analysis should be made deliberately and communicated clearly. Here, a constructivist epistemology was adopted, as the analysis focused on identifying structural factors underlying the choices and motivations for choices of these experts. The data was analyzed by two researchers in an interactive discussion of analyzing, interpreting, coding, discussing, and re-coding, with the aim of identifying reoccurring themes. Since the data was collected by examining the dimensions in response to three case description, predominantly a deductive approach to collecting the comments was used. This deductive approach, combined with collecting data from knowledgeable field experts, allowed for strongly interpretative coding. Subsequently, an inductive approach was used to identify themes in the responses.

3.2 Results: Numerical

The numerical ratings provided by the experts were visually compared to the *a priori* ratings using a design dimension dashboard (see Figure 4.9). For most of the dimensions, the *a priori* rating is in the same direction and of comparable valence to the median expert rating, providing merit to the method. The largest differences occur within the dimensions *direct/indirect*, *guided/unguided*, and *extrinsic/intrinsic*.

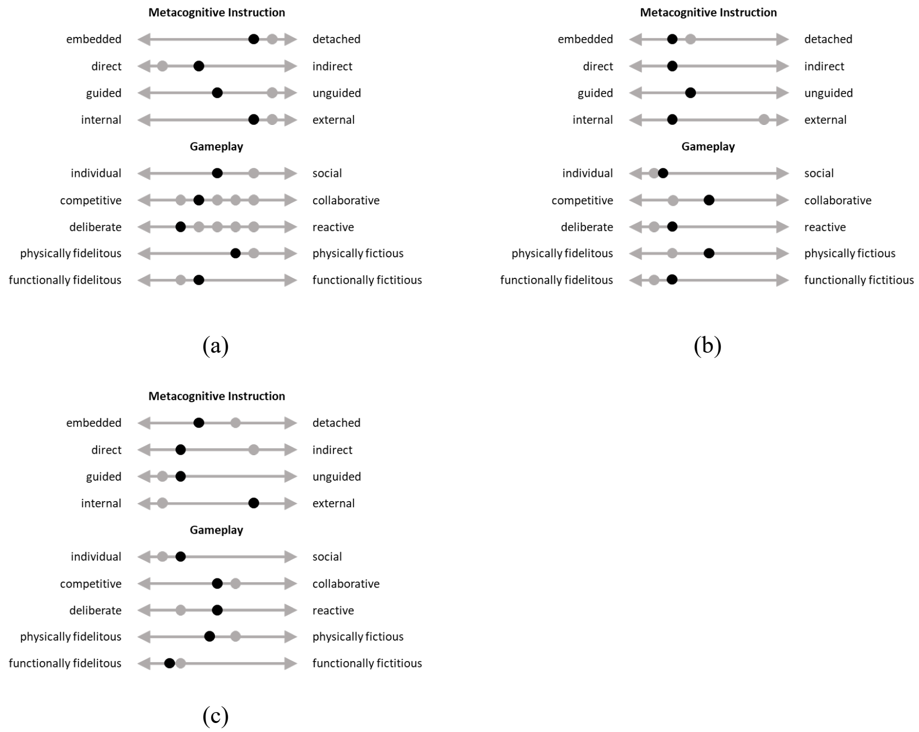

Figure 4.9: Design dimension dashboards comparing median expert ratings (black) to a priori ratings (grey) for each case: (a) MMORPG, (b) Circuit Game, and (c) Adventure Game.

3.3 Results: Contextual Information

The remaining results are separated into contextual information and themes. The contextual information, presented in this section, discusses the definitions of key terms with regards to the instructional and gameplay dimensions and, as such, they aid to demarcate and define the domain of discussion.

Dimensions for Metacognitive Instruction

A few respondents struggled to find metacognitive instruction altogether in some of the case descriptions. These respondents had adopted a narrow definition of instruction congruent with 'direct instruction' or 'explicit instruction' only. In a broader, and intended, definition, instruction encompasses 'indirect instruction' such as through feedback, prompts, or scaffolds.

Three distinct interpretations of the term 'direct' were identified among the responses: (a) learners having to do as the instruction says or being steered in a particular direction (i.e., directive; e.g., when a response is required to a prompt before one can proceed); (b) whether the instruction is simple, concrete, direct, and immediate (i.e., straightforward; e.g., immediate feedback on actions). The third, intended, interpretation was (c) direct as in explicit instruction: being concrete and upfront about what a learner needs to do. This approach to metacognitive instruction is also known from literature to be effective, as one respondent emphasized.

The distinction between metacognitive instruction being embedded in or detached from domain-specific content was widely supported. Additionally, it was suggested that metacognition can be general (i.e., in absence of domain-specific content, and aimed at affecting future learning situations).

Two distinct interpretations of the term 'guiding' were found. First, guiding can be interpreted, as intended, as supporting learners during playing and learning (e.g., through game-specific instructions, scaffolding, progress indicators, or scoreboards). Second, guiding can be interpreted as directing thoughts and actions of learners, (e.g., guiding learners into a specific direction through feedback).

Several specific remarks were made with respect to integrating metacognitive instruction extrinsically or intrinsically with the gameplay. Overall, metacognitive instruction was considered extrinsic to the gameplay if it is separated in time from gameplay or if it could be described separately from the gameplay. If links between metacognitive skills and the gameplay can be made, the balance shifts towards intrinsic. Metacognitive instruction was considered intrinsic to the gameplay if it is direct and domain-specific, tailored to this specific game, required to progress in the game, and when active elements in the gameplay encourage metacognition.

Dimensions for Gameplay

Respondents were divided over whether interaction with virtual agents can be interpreted as social gameplay. A narrow definition limits social play to interaction with other human players, whereas a broader interpretation includes NPCs agents to collaborate (e.g., work together with a master) or compete (e.g., overcome a master's stubbornness) with. Competition can also be internal to the player, rather than between (other) agents. Depending on internal or external motivation of the player, feedback as delivered by an in-game agent could also be perceived as competitive or collaborative. In absence of other agents that can influence players' actions there is no competition or collaboration between agents. In other words: individual play is neither competitive nor collaborative if the provided definition is used.

The proposed time-based interpretation of reactive versus deliberate play was supported: if less time is available to respond, the response is less deliberate and more reactive. An additional interpretation read: the more thought is required for a response, the more deliberate the gameplay is. A gameplay loop that supports thinking, then acting, and embeds this within a feedback loop to further encourage thinking before acting was suggested. A lack of using insight to look forward makes gameplay reactive – which was suggested as a hook for metacognition to prevent this from happening.

For one respondent, the terms fictitious and fidelitous were not clear enough to be applied. The provided definition of physical fidelity ("whether the game appears like the concepts-to-be-learned in the real world") was found too broad in that it does not make concrete what it applies to: the game as a whole, the visual aspects of the game, or something else. One respondent provided a narrower definition pertaining to the setting of the game only. Various comments indicated that respondents did not distinguish between physical or functional fidelity: some of the responses were literally the same (e.g., that the context seems fictitious) or reversed (e.g., remarking under functional fidelity that the electrical circuits appear as a in reality). How the game, the gameplay, and the interactions represent the real world is important for how fidelitous the game is to the target learning situation. This holds for the domain learning content (e.g., whether the game represents electrical circuitry, or diagrams thereof) as for metacognition (e.g., whether confidence is represented accurately).

3.4 Results: Themes

In this section, the themes uncovered through thematic analysis are presented. Six themes were identified, where each theme represents respondents' views related to the same area of design of GBLEs for metacognition.

Theme #1: Combining Metacognitive Instruction with Learning Content and Gameplay

A main theme that re-occurred throughout respondent comments was the complexity of the relationships between (a) metacognitive instruction, (b) learning content, and (c) gameplay.

The relationship between metacognitive instruction and learning content (a-b) was included as an initial dimension and was confirmed by respondents. It was suggested that the reverse, whether any domain-specific learning content is present in the metacognitive instruction, is also relevant.

The relationship between learning and gameplay (b-c) was often mentioned and related to the design principle of striving to maximize integration between learning content and gameplay. However, as this principle of intrinsic integration does not necessarily apply to promoting metacognition, this was not included among the initial dimensions. Nonetheless, apparently it was hard for respondents to distinguish metacognitive from non-metacognitive content, which further underlines the need for more clarity.

The relationship of metacognitive instruction to gameplay (a-c) was included as an initial dimension extrinsic/intrinsic. The gameplay dimensions were intended to further specify this relation, however, respondents discussed many of these aspects early on when asking themselves whether the gameplay lends itself for metacognition (see deliberate/reactive), whether there are any mechanisms in the game that contribute to metacognition (see guided/unguided), and whether the amount of fantasy precludes metacognition (see fidelitous/fictitious).

Theme #2: Considering the Game within its Layered Context

A related theme is how metacognitive instruction is related to GBL. An initial dimension of extrinsic/intrinsic integration was included, however, respondents considered different ways of integrating metacognitive instruction. Respondents distinguished between metacognitive instruction (a) within the game, (b) within the digital system in which the game is presented, but outside of the game itself, and (c) within the real-world context of learning. For example, a metacognitive prompt could be disguised as part of the gameplay or, alternatively, be presented digitally after a gameplay episode or physically within a classroom. Furthermore, (d) the target learning situation, in which the concepts-to-be-learned are to be applied, needs to be considered if transfer of learning or metacognition is expected. Altogether, these different layers help to take into account the structural relationship between gameplay activities and learning activities.

Theme #3: Considering the Temporal Aspects of Metacognitive Instruction and Gameplay

Various comments referred to how metacognition, learning, and playing occur over time. For example, there can be time between (pre-play) instruction and (during play) application of metacognitive instructions. This would require a learner to near-transfer the instructions to play. In contrast, (metacognitive) feedback can be immediate within the gameplay. One respondent specifically suggested being more specific about the temporal aspects, for example by indicating the consecutive order of tasks, levels, or episodes of GBL.

Responses may also develop learner insight over time. For example, simply trying out different solutions in a reactive way may lead to more deliberate responses later on, provided that trial-and-error is followed by more informed strategy adaptations. Such adaptations, to inform future responses, are interpreted as reactive by some respondents. According to respondents, any metacognitive instruction needs to adapt to such changes in the player in order to provide sufficient but not too much guidance.

Theme #4: Taking Player Autonomy into Account

Social or individual play depends, according to the respondents, not only on the gameplay but also on how one plays. For example, an individual game can be deployed in a social way (e.g., when playing in dyads in a classroom), and a player that focuses on the goals (i.e., what is best rewarded within the game) will seek out competition or collaboration as needed. Even with the same game, players may respond differently or have a different experience. In some games, both reactive and deliberate responses may be needed to progress, while in other games the agency a player experiences may be so limited that it cannot be considered deliberate. Altogether, how much autonomy the player has in responding to the game needs to be taken into account.

A related observation was that any guidance needs to be connected to learners, and the type of guidance matters in how well metacognition is supported. Aspects that qualify guidance are how overt, present, and explicit guidance is with respect to metacognition.

Theme #5: Level of Analysis

To some extent, the initial dimensions were connected to specific game mechanics by the respondents. For example, multiplayer real-time battles can be described as social, reactive, and competitive play. Similarly, a leaderboard can be characterized as social and competitive. However, as respondents remarked, the analysis of design cannot always be at the level of specific game mechanics. For example, a typical MMORPG will contain individual and social types of play. An analysis per gameplay mode, as was suggested, does not fully resolve the issue. For example, players can collaborate to compete with another group of players, and players can combat each other but collaborate with other agents. Some mechanics are even inherently multi-faceted: trading can involve elements of competition as well as collaboration.

Theme #6: Limitations to Integrating Metacognition with Gameplay

Some respondents questioned whether metacognitive instruction can be made fun enough to be a proper part of the gameplay. Even if metacognitive instruction were integrated to become a part of the gameplay this may adversely affect enjoyment. A similar mismatch could occur if metacognitive instruction does not clearly support the learning content, or if the amount of fiction precludes metacognition. Perhaps fully integrating metacognition in gameplay may inherently not be possible due to its introspective nature and, perhaps, it may not be altogether desirable.

In terms of fidelity, one respondent wittingly remarked that in the real world there will be relatively few metacognitive prompts. Joking aside, indeed, certain elements that aid learning are not there in the real-world – such as prompts – and make such approaches inherently non-fidelitous to some extent. Also, as gameplay is experienced through a device mediating interaction, it does not involve the real-world experience and interactions. Finally, gameplay is bounded in time and possibilities and hence cannot be fully fidelitous.

Respondents emphasized the importance of a link between the metacognitive approach and real-world learning, with one respondent stipulating that metacognition is not fully independent of either the learning content or the context of the game.

4. Design Framework for Metacognition in GBL

The goal of this work is to reduce the complexity of design when designing GBLEs for metacognition. Based on the theoretical background and the results of formative evaluation, the adjustments leading to an initial design framework for metacognition in GBL are now discussed.

4.1 Adjustments

The results show that key concepts must be clearly defined. The results also show that a dimensional perspective, alone, cannot convey the complexities of design. Often, interrelations between such dimensions play a role. For example, the integration of metacognition into gameplay could not be seen apart from embedding metacognitive instruction in domain content or from integrating domain content into gameplay itself. Furthermore, the results show that the dimensions cannot be completely separated from the intended outcomes. For example, metacognitive instruction aimed at general, rather than at domain-specific, metacognitive outcomes is in itself domain-general instruction. Altogether, this led us to conclude that the design space of GBLE for metacognition is better described as a framework that combines key concepts, design dimensions, relations between design dimensions, and relations between design dimensions and real-world outcomes.

While the evaluation confirmed that an important part of metacognition in GBL revolves around integration of metacognitive instruction, it was not sufficiently clear how the dimensions helped to describe this relationship. To provide more clarity, the relationships between metacognitive instruction, domain-specific learning content, and gameplay is now more clearly represented by explicitly describing the dimensions as three different but related views on integration. The relationship between learning content and gameplay is now included.

The dimension *extrinsic/intrinsic* integration is now more clearly specified: integration can occur at different layers (i.e., gameplay, GBLE, digital system, real-world context) and at different times of interactive learning (i.e., before, during, after).

The dimension *domain-general/domain-specific* metacognitive instruction is introduced to reflect the additional option of domain-general metacognitive training. This dimension is linked to metacognitive and domain-specific outcomes. To avoid confusion, the dimension of *direct/indirect* instruction is renamed to *explicit/implicit*.

The dimension *guided/unguided* instruction caused some confusion. Upon further reflection, this dimension also coincided too much with simply the presence or absence of any metacognitive support. More relevant, however, is to what extent the system or the learner is the active agent in metacognitive learning and how autonomously the learner can operate. Therefore, this dimension is replaced by a new dimension *system-controlled/learner-controlled* instruction. This dimension can also further characterize the extent to which instruction is static or adaptive.

The two fidelity dimensions are now combined as *fidelitous/fictitious*: the distinction between physical and functional fidelity proved more confusing than helpful in describing GBLE designs.

An updated overview of the dimensions of the framework is provided in Appendix C.

4.2 Overview of the Framework

The design framework for metacognition in GBL relates learner outcomes of GBL to gameplay, learning content, and metacognitive instruction within the GBLE (see Figure 4.10).

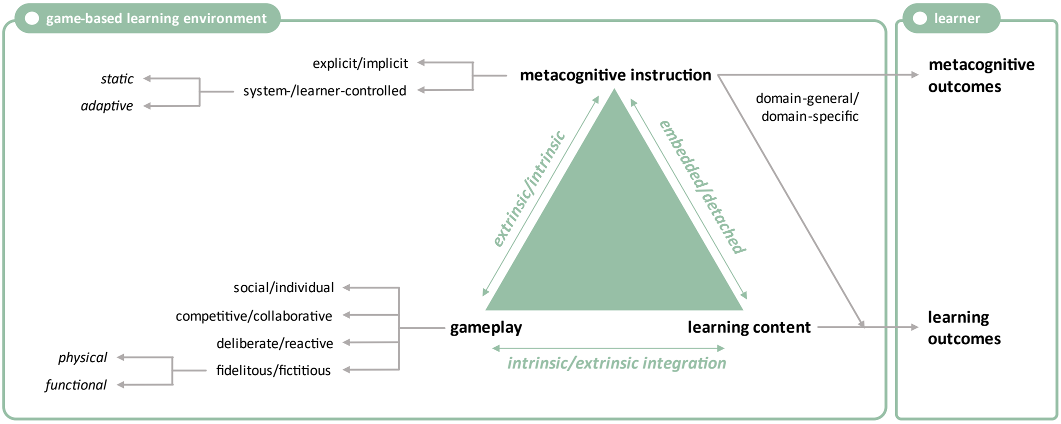

Figure 4.10: Design framework for metacognition in GBL.

Concepts and Objectives

The goal of GBL is to help a learner to achieve learning outcomes in the real world (right hand side of figure), for which a GBLE is designed (left hand side of figure). The design of a GBLE combines *gameplay*, domain-specific *learning content*, and *metacognitive instruction* (triangle). Here, metacognitive instruction is be defined as any mechanisms implemented within the GBLE with the goal of encouraging metacognition in learners, whereas metacognitive objectives are defined as the desired metacognitive effects of the GBLE on the learner. Metacognitive objectives can relate to the domain-specific learning outcomes or stand on their own as separate outcomes.

The design space of GBLEs for metacognition can be described as three distinct areas: integration, metacognitive instruction, and gameplay, with each characterized by more specific design dimensions.

Dimensions for Integration

Metacognitive instruction can be *extrinsically integrated* or *intrinsically integrated* with the gameplay. This relationship is further characterized by structural aspects (i.e., within the game, the GBLE, the digital system, the real-world context) and temporal aspects (i.e., before, during, after learning). Both extrinsic and intrinsic integration of metacognitive instruction may be effective, although fully integrating metacognition with gameplay may not always be possible or desirable. Metacognitive instruction can range from *embedded in* to *detached from* domain-specific learning content. For domain-specific metacognitive goals, metacognitive instruction is best embedded in domain-specific learning content.

Dimensions for Metacognitive Instruction

Metacognitive instruction can range from *domain-specific* to *domain-general* (Derry & Murphy, 1986; Osman & Hannafin, 1992; Veenman et al., 2006). Domain-general metacognitive instruction aims to transfer to future learning situations, whereas domain-specific metacognitive instruction usually aims to aid the attainment of domain-specific learning objectives.

Metacognitive instruction can range from *explicit* to *implicit*. While novice learners benefit from explicit instruction (e.g., direct instruction on metacognitive strategies), more advanced learners may benefit from implicit instruction (e.g., feedback and cues regarding strategy use).

Metacognitive instruction can range from *system-controlled* to *learner-controlled*. While predominantly system-controlled instruction may initially force learners to engage in metacognitive processing, increased learner control is eventually required to practice with self-initiating and automating metacognition. As the need for explicit or implicit instruction, as well as for system- or learner-controlled instruction, varies with the level of learner experience, GBLEs may need to adapt metacognitive instruction to individual learners (Azevedo et al., 2012; Nietfeld & Shores, 2011).

Dimensions for Gameplay

The game design, and in particular the gameplay mechanics and the setting, needs to accommodate metacognition: a game that does not allow for, support, encourage, or require metacognition will not be at the core of a successful GBLE for metacognition. Gameplay can range from *social* to *individual*, and from *competitive* to *collaborative*. This depends, in part, on how the game is employed within its context and how players act and interact within the GBLE.

Gameplay can range from *deliberate* to *reactive*. Here, sufficient time for decision-making is important for metacognition, but the amount of thought required can progress from little (e.g., trial-and-error) towards strategic (e.g., through metacognitive feedback).

Gameplay can range from *fidelitous* to *fictitious*. Here, fidelity is subdivided into the game's appearance (i.e., physical fidelity), and the game's dynamic interaction (i.e., functional fidelity). Fidelity to the target situation also pertains to metacognition: the metacognitive content must be applicable to the learning task or domain of learning at hand.

5. Discussion

In this chapter, the development of a framework to support metacognition in the design of GBLEs was discussed. Theoretical insights from literature were combined with practical insights from concrete cases, and elaborated the findings through a formative expert evaluation. The resulting framework aims to reduce design complexity by indicating which design dimensions are relevant to consider when addressing metacognition within GBLEs. The framework, along with the design dimension dashboard diagrams, further aids comparing designs, as relevant differences and similarities can be more easily identified along the provided dimensions. If current and novel approaches can be described in such underlying and commonly shared terms, this area of research can advance towards making links between different approaches and their effects on learning, motivation, and metacognition.

There are inherent limitations to the adopted approach. For example, the results from the formative evaluation did not completely match our expectations: the discussion of the gameplay dimensions was less focused on metacognition than anticipated.

While it is promising to see some confirmation that this important consideration is now becoming a commonly held design guideline, it should not prevent or preclude other important considerations.

Another limitation is that our approach of using existing cases to perform a formative evaluation bears in it the risk of these cases comprising an ill-formed representation. While real-world cases were selected and presented carefully, perhaps more different cases could have probed more variation in responses. The validity of working with real-world cases, and deriving these from the original publications as included in an up-to-date review of the literature, however, should sufficiently address the presented risks.

The formative evaluation uncovered that a lack of shared understanding and terminology is still a key issue in GBLE-design: even among experts, there is disagreement over how different aspects of games and learning are discussed. Based on the evaluation results, some of the terms used during the evaluation, were reverted to an earlier version (see Braad, Degens, & IJsselsteijn, 2019b). As words only go so far in communicating the design of a dynamic interactive system, and with this issue present in almost any paper on GBL, if anything, this underlines our premise that a more formal approach to designing and discussing GBLEs is of added value (see also Nadolny et al., 2020).

A key benefit of the framework is that it can be used to inform design (which choices to make) as well as research (which areas to research). With a design framework in place, a logical next step is to identify, investigate, and verify specific design guidelines for metacognition in GBLEs. Even though motivation has salient interrelations with metacognition, it did not fit within the focus of our work. This demonstrates that, while our focus is on metacognition, our contribution and approach could extend beyond. The authors encourage others to adopt a degree of formalism and support well-informed decision making and clear communication about GBLE designs.

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