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(Araştırma Makalesi)

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Öz

Eğitsel oyunlarla öğrenme ve öğretim etkinlikleri eğitimsel senaryolarda pek çok engelle karşılaşsa da, eğitsel oyunların eğitimi kısıtlı bir sürede bir adım daha ileriye götürmesi potansiyeli gözardı edilemez. Bugünkü eğitsel oyunlar yansıma ve gerekli becerilerin geliştirilebilmesi için yeterli fırsatı vermemekte ve düşük düzeyde öğrenme çıktıları ile değerlendirilmektedir. Bu yüzden üstbiliş eğitimi ya da eğitsel oyunlarda üstbiliş kullanımı için oyun-temelli araştırmalara gereksinim duyulduğu gözlemlenmiştir. Bilgisayar-temelli üstbiliş stratejilerini içeren araştırma çalışmalarının azlığı ve bu çalışmalarda kesin genellemeden çok bireysel durum çalışmaları şeklinde gerçekleştirildiği için bu alanda genel bir incelemenin gerekli olduğu kanısına varılmıştır. Bu araştırmanın amacı üstbiliş stratejilerinin eğitsel oyunlarda nasıl kullanıldığını ve oyun mekaniklerinin bu stratejileri oyunlara nasıl yerleştirdiğini anlamaktır. Araştırma modeli olarak literatür taramasına göre daha çok güncel konulara odaklı ve belli bir amaca hizmet edecek bir model olan literatür araştırması örnek alınmıştır. Bu modele dayanarak, eğitsel oyunlarda üstbiliş stratejilerinin kullanımını, bu kullanımın kavramsal kökenleri ve bunların öğrenme ve oyun mekaniklerinin tasarımına olan etkilerini irdeleyen bir araştırma yapılmıştır. İncelenen araştırmalar üstbiliş strateji kullanımına göre analiz edildiğinde modelleme, hatırlatma, yansıma ve izleme kategorileri ortaya çıkmıştır. En çok kullanılan üstbiliş stratejileri, yanlış düzeltme, güven geliştirme, yansıma ve problemleştirmedir. Bu bulgulara göre, oyun mekanikleri kullanılarak üstbiliş stratejilerinin nasıl kolaylaştırılacağına ilişkin öneriler ile gelecek araştırmalar için yönlendirmeler geliştirilmiştir.

***Anahtar Kelimeler**: Üst Biliş Stratejileri, Eğitsel Oyunlar, Oyun Mekanikleri, Yansıma, Izleme, Modelleme.*

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Metacognitive Strategies in Serious Games: A Literature Survey

Abstract

The practice of teaching and learning with games presents many obstacles in the educational scenarios while the potential of games to take education one step further in limited time cannot be ignored. Today's educational games fail to offer sufficient opportunities for reflection, as well as usage of skills, and they are assessed with lower levels of learning. That is why, need for games-based research is observed for teaching metacognitive skills or using metacognitive skills to teach with serious games. Due to the scarcity of computer-based research studies involving metacognitive support and the fact that these studies exist as case studies rather than generalizations, it is decided that a thorough examination in this field is necessary. The aim of this study is to understand how metacognitive strategies are used for learning in serious games and how they are accommodated by game mechanics. As a model of research, for this purpose, a literature survey, which is more focused on contemporary topics than literature review and which serves a predefined purpose is used. With this model, the usage of metacognitive strategies in serious games, the conceptual origin of this usage affecting both learning and design of game mechanics are examined and evaluated. The categorization of research according to the metacognitive strategy used are modeling, prompting, reflection and monitoring. Most used metacognitive strategies in these studies are found to be error correction, confidence building, reflection, problematization. According to these findings, suggestions on how to accommodate metacognitive strategies in games using game mechanics and directions for further studies are developed.

Keywords: *Metacognitive Strategies, Serious Games, Game Mechanics, Reflection, Monitoring, Modeling.*

1. Introduction

Research about game-based learning focuses on cognitive and skill-based learning outcomes, however, there is not much research dedicated to metacognitive support (Azevedo et al., 2011) and metacognition studies go on as stand-alone cases rather than generalizations (Braad, Degens & Ijsselsteijn, 2020). Orvis, Horn, & Belanich (2009) stress the need for research about the capability of games for metacognitive training. Azevedo (2005) suggests more research in various topics for the use of computers as metacognitive tools to foster learning.

Arroyo et al., (2014) show that learners' metacognitive needs can be compensated by customizing forms of support through educational technologies, suggesting that intelligent adaptive learning environments are alternative ways to support students' self-regulation skills as well as teaching those skills. These environments can provide the monitoring, feedback and reflection activities that students can use in an open model.

Games do not offer enough opportunities for reflection however; learning depends on reflection and feedback. Games need activities that can balance the thinking and reflecting of the conditions of task at hand for success and acting on task. To avoid superficial learning, game mechanics are linked with cognitive and emotional processes through feedback in the game and the objectives of the game are aligned with learning objectives. However, the problem grows when we think of the disconnection between achievement and learning through games especially in transferring methods or knowledge that is gained in one game to other games or real world.

To acquire higher order learning cognitive processes, a smooth transition between the learning and application of concepts with varying degrees and alternative ways must be implemented in games. This requires the higher-level assessments techniques and complex gamification effects in games. Yet games are being assessed with lower-level learning outcomes and complex gamification techniques are rarely used (Boyle et al., 2016; Clark, Tanner-Smith, & Killingsworth, 2016).

Research on educational games focus on content, function and genre while it offers design patterns that align game mechanics with learning goals. This alignment needs scaffolding mechanisms when multiple representations of critical information are present in a game. This scaffolding is very crucial in linking the game to the learning part for the educational benefit of learners.

Realizing the gap between learning and gaming performance, metacognitive strategies are a good way for serious games to contribute to education. Considering this perspective, the aim of this study is to understand the types of metacognitive strategies that are used in serious games and to offer suggestions for designing serious games and game mechanics to find best accommodations of metacognitive strategy use in serious games.

The research questions this study aims to answer are as follows:

1. What are the types of metacognitive strategies used in serious games?
2. How can game mechanics accommodate the metacognitive strategies used in serious games?

2. Conceptual Framework

In this section, metacognitive strategies, self-regulated learning, serious games and game mechanics are defined and the relationship between these concepts and how they form an instructional framework for creating educationally viable serious games is examined and evaluated.

2.1. Metacognitive strategies

Metacognition is thinking about one's own knowledge (McKeachie, 2000) and thinking and actively monitoring and regulating the thought processes (Flavell, 1976).

Metacognitive strategies are known as the instructional directives that make learning conscious by controlling and monitoring the progress of learning by correcting errors. Flavell (1979) thinks that learners develop metacognitive monitoring through knowledge, experience, goals and actions.

Pressley (1990) supports the idea that metacognitive strategies have to be taught as in the implementation stage interruptions should be kept to a minimum whereas Georghiades & Parla-Petrou (2001) think that metacognition is a skill to be activated and developed rather than taught. When we combine these definitions in learning, one has to monitor in a judgmental way, reflect on and evaluate the process of his own learning to manage learning. O'Neil, Baker & Perez (2016) show that metacognition contains metacognitive beliefs and strategies. Beliefs comprise self-efficacy as well as epistemology, strategies represent self-regulation. The importance of metacognitive knowledge is better understood with Swanson's (1990) study that finds learners with high metacognitive knowledge about problem solving outperformed learners with low metacognitive knowledge making obsolete their aptitude levels.

Metacognition is simply what a learner knows or feels about experiences which are formed by cognitive events and projections towards commencing learning. Nelson & Narens (1990) view metacognition as two levels consisting of a meta-level and object level and these levels communicate with each other through control and monitoring. Metacognitive skills consist of monitoring the progress of learning and taking appropriate measures whereas reflection evaluates learning in terms of its strengths and weaknesses. Monitoring shows progress and control spans the direction and allocation of resources in a task.

To be able to use metacognitive strategies, conscious experiences that learners face must be also interpreted as in the form of reflection. This is the main difference between learners who are successful and unsuccessful in using metacognitive strategies (Flavell, 1987).

Metacognitive strategies have the potential to cause effective learning outcomes when they are taught explicitly. Learning becomes much more effective when learners develop habits of evaluating themselves and they can make sense of metacognitive processes putting them in control of their own learning. Transfer of learning from one context to another depends on learners' ability to achieve learning goals and their control over learning (Zheng, Warschauer, Lin, & Chang, 2016). So far it can be said that learners' achievement of learning goals and control over their learning can be realized through helping learners form a mental model, prompting them about their skills or knowledge, inventing mechanisms that achieve self-monitoring activities and giving them chances to reflect on their own skills in different stages of implementation.

Developing a mental model of any complex learning activity enables the learner to self-control and regulate his actions and make abstractions out of concrete experiences. Also, the learner realigns his goals and critically evaluates his current situation and progress in the activity depending on his self-efficacy by maintaining motivation.

Mental models initiated in games or any learning situation are important because they are associated with identifying task requirements and deduction of events and objects that occur. Serious games also have mental models that show rules, procedures, objects, and properties (affordances) and the mechanics of the game. It is said when the learner discovers the mental model of a game, he is ready to engage in metacognitive and self-regulatory strategies. According to literature, mental models serve as predictors of accurate learning and knowledge transfer. A study by Wouters, van der Spek, & van Oostendorp (2011) show that level of expertise is an important factor in deciding the usefulness of mental models. Also mental models of a game constitute the engagement protocols whether they are emotional, cognitive or behavioral. Self-regulated learning (SRL) training before intervention and giving sufficient control to learners affects mental model development and cognitive gains.

Lane (2009) uses virtual agent to support metacognitive processes by giving information at critical times of interaction that confirm learners' prediction and interpretation of events that occur in immersive learning environment built to teach cultural differences. They use modeling as well as encourage the learner to think about his own decisions.

Mental models form a framework for the learner to engage in metacognitive activities such as discerning critical and non-critical elements for learning and develop motivation through self-efficacy to modify learning goals on changing game environment.

Prompting is an indirect form of metacognitive scaffolding as opposed to training about metacognitive strategies. It is the attempt to recall necessary information when learners are faced with a learning situation. Prompts in games facilitate the processing of content to promote learning and motivation (Erhel & Jamet, 2013). It is also possible to use several prompts that target specific activities and different forms of prompts such as action and process-oriented activities exist. Prompts can be in the form of summarizing events, judgment of learning, activation of knowledge and planning of time. The use of visual or textual prompts and a collaborative medium where learners can interact with each other has been shown to exist in literature of metacognition and self-regulated learning. Such interactions and prompts help learners to evaluate their own work and reflect on the reasons behind their success or failures. Learners only benefit if they make most out of the prompts such that they may skip prompts or give nonsensical answers to prompts. We can see that occurrence in study by Charles, Hanna, Paul, & Charles (2012) where learners complete task without evaluating their learning. Prompting during learning phase instead of prompting before starting a game is more beneficial (Kim & Peterson, 2011; Piksööt & Sarapuu, 2015; Thillmann, Künsting, Wirth, & Leutner, 2009).

Monitoring learners or enabling learners to monitor themselves is an important strategy that fosters self-regulated learning. Self-monitoring works in checking of progress, what a task is and how close one is to achieve a task. As such, self-monitoring requires constant feedback and clues about the most effective ways to accomplish a task or setting short term and long-term goals. According to Cleary, Zimmerman, & Keating (2006) computer-based learning environments can support phases of self-regulatory processes and produce sustainment of learning. The value of self-explanation in learning media has been supported by many studies (Fonseca & Chi, 2011). While effective in this sense, self-explanations should be used with caution as they can slow the process of learning if they are disconnected or cause extraneous processing or learners might ignore them as they are trivial. But they are more effective if they can focus on learners' attention on specific parts of tasks and initiate reflection. That is why self-explanations should be neither easy nor too difficult but just enough for explicit guiding touching both procedural and conceptual information. Thinking aloud protocols has significant effect on learning via problem solving abilities as self-recording and modeling are significantly related to achievement.

While these strategies and inventions help learners in controlling their learning, there are forms of learning that embody these strategies and develop learners, socially, and help them gain confidence in their educational endeavors. Since learning with serious games is considered as learning by oneself, it will be good to mention self-regulated learning as it is important for learners to sustain their learning.

2.2. Self-regulated learning

Self-regulation is very closely related to metacognition as learners are aware of their own learning and they actively direct their learning according to their choices. Self-regulated learners plan, set goals and organize information through what they observe and do in their learning task. Self-regulated learners' dependence on themselves for confidence and their beliefs and views about themselves is important for success as they form a proactive view of their self-efficacy.

SRL assumes that learners are constructors of their own strategies for learning and means of control. Learners' assessment of their learning according to a model or a criterion and their ability to control learning can be deficient due to contextual factors. Games can support this kind of impediment by becoming individually adaptive and setting good contextual parameters.

It is suggested by Zimmerman (2013) that learner transforms the way he learns to become a self-regulated learner. But emulation is not enough to become a self-regulated learner, rather the learner must practice these skills on new tasks by focusing on learning processes. Zimmerman (2000) separates learners into two categories as proactive and reactive learners according to their actions taken in the SRL phases. Table 1 displays the differences between proactive and reactive learners.

Table 1. Differences Between Proactive and Reactive Learners.

Phases	Proactive Learners	Reactive Learners
Cyclic phase	High Quality forethought and performance phase	Rely on postperformance reflections
Goal setting	Challenging goals	Setting vague, distal goals
Task Analysis	Effective task analysis	Superficial task analysis
Self-efficacy	High self-efficacy beliefs,	Less self-motivated
Goal Orientation	Mastery goals	Unplanned goals
Evaluation	Self-evaluation	Evaluation in respect to other learners
Attribution of errors	Ineffective Strategies(controllable)	Ability (Uncontrollable)

2.3. Serious games

Today games allow coding, debugging, recording, and evaluating learner skin conductivity, gestures, and eye movements by various monitoring devices, immersing the learner in media that do not exist in real life so that the learner can experience the needed emotional, motivational and behavioral stimuli for learning. If we think of serious games as metacognitive tools as a branch of computers, serious games must bear properties (Greene & Azevedo, 2010) such as modeling, prompting, and supporting learner's self-regulatory processes and their participation through tasks where they learn different kinds of skills. Researchers like Ke (2016) and Sitzmann (2011) support the idea that serious games can be used to further develop learners' metacognitive skills and knowledge. Examples from literature support the importance of guidance and receiving direct extra instruction in simulation and games (Neulight et al., 2007; Biswas et al., 2005).

According to Braad (2018), STEM education represents the next step in using metacognitive strategies and self-regulation elements of learning and research in this respect is valuable for design of educational games. Learning with serious games has positive outcomes when compared to traditional learning (Clark et al., 2016), however, new evidence suggests that it is not enough to compare serious games with non-gaming environments but other treatments or interventions such as comparing with other games or with different media becomes a necessity if we truly want to assess skills that learners use while learning. Moreover, instructional methods must be developed that are embedded in story of a game rather than prompts for learning that disrupt the game flow (Wouters, Nimwegen, Oostendorp & van der Spek, 2013). Relying on post-measures of self-report can be misdirecting motivational research on serious games. Backlund & Hendrix (2013), de Smale, Overmans, Jeuring, & van de Grint (2015), Tsekleves, Cosmas, & Aggoun (2014) and Wouters & van Oostendorp (2013) report positive outcomes of using serious games in education with limited evidence from study of Young et al., (2012). Yet there are many studies that find no difference between traditional teaching and teaching with games or studies that favor traditional education, so to be as successful, games require promotion of metacognitive skills and student participation (Rajan, Raju, & Sankar, 2013).

Zimmerman (2000) lists how games can foster self-regulatory behavior within serious games as:

- Observation: Observing model to grasp its rules and learn strategies to keep engagement.
- Emulation: Emulate the model to understand components of the game using strategies
- Self-control: Being able to synthesize their own understanding of the expert model and gain more self-control.
- Self-regulation: Learners develop a mental model of the game and can adapt it to different contexts.

Games help learners expand their metacognitive abilities by performing adaptive feedback so that learners can focus attention on their mistakes and correct them according to their needs. Also display of task-related information shown visually keep learners' attention on the task and about their progress and make out the common elements of these tasks. Games can implement instruction about when and why to participate in setting goals, planning how to do tasks as well as monitoring and evaluating performance.

2.4. Game mechanics

Game mechanics are considered as the actions that are allowed for the learners to perform. Rules form the restrictions that form interactions between the game and learners as well as behaviors. If a learner is interacting with the game, then he is using game mechanics. Reward systems, feedback systems and actions that learner can take are all game mechanics. If given chances, learners can deeply uncover the learning attributes and their interactions using game mechanics. Game mechanics can be as simple as drag-drop, point-click, hover-over operations or can be complex as creation of tools or the mechanics that are used in games that require voice or gesture recognition. Game mechanics can create impact on learning outcomes by increasing interest and responding to learners' emotions in the way they are designed (Graesser, D'Mello, & Strain, 2014).

Learning mechanics become an integral part of learning activity in games. Salen & Zimmermann (2004) define learning mechanics as actions that form learning activity, and they are the means that enable learner interaction. Learning mechanics become game mechanics when they are shaped into reality. This is how learning mechanics adapt game mechanics for learning activities to be meaningful. Learning mechanics are the gist of how learners discover a subject or learning about it with actions and rules. Silva (2020) believes that not all game mechanics can be used as learning mechanics as the game requires more fun and engagement. He suggests the addition of new layers to the game such as mini games. While the researcher does not ignore the creation of learning mechanics through mini-games, narrative is better at problem presentation, showing consequences of actions and summarizing important points of content. It can be said that the relation between learning mechanics and game mechanics answers questions such as what, why and how about the learning subject.

3. Method

As the aim of this study is to find out how metacognitive strategies are used in serious games and how they affect the design and building of game mechanics. This literature survey includes only serious games that use metacognitive strategies and is based on the reachable research since a search term "metacognitive strategy" + "serious games" does not reveal any research. That is why, the study is based on categories of metacognitive strategy from previous literature reviews. The study is categorized according to the type of metacognitive strategy and from there, summarizing and comparing research within its type and along the lines of educational theories. Also, how game mechanics can accommodate metacognitive strategies is discussed.

3.1. Research Design

As it is not possible to understand which metacognitive strategies a game contains by the title of the research, the survey is limited to several criteria:

1. It covers the publications within the last ten years, from 2010 to 2020.

2. It focuses on studies that have empirically evaluated the learning effect of serious games in some way.

3. It includes papers published in scientific journals and conference proceedings as conferences can provide quite novel and inspirational information in terms of games for learning.

The literature survey was carried out in between March and July 2020 and Google Scholar, Science Direct, Eric, ResearchGate and Ebscohost databases were used for the topic researched. Any perspective on metacognitive strategies with games, any pieces of research that have game and metacognitive strategies that affect learners' abilities and skills as well as learning are included. Literature survey about game mechanics is searched separately for an overview on game mechanics and background.

These keywords and different combinations of them are searched in the databases mentioned above: Serious games, digital game-based learning, metacognitive strategies, prompts, game mechanics, reflection, monitoring, mental models.

Particularly, studies that use different methods within metacognitive strategies to increase motivation, knowledge, reflection, and confidence on the learner part were searched. Reading the abstract of research that is found, further research is reached through books about games, metacognitive strategies, and self-regulatory theory. After results are refined with measures such as quality and clarity, in the final selection, 32 studies are identified as relevant to the survey. These articles included studies that compare metacognitive strategies, the relations between games and metacognitive awareness, the teaching of metacognitive strategies, studies that influence performance via self-regulated learning and feeling of knowledge, scaffolding techniques such as problematization as well as immersion and engagement. The researcher excluded studies that do not use games but included games that are in military, business and vocational training domains.

3.2. Data Analysis:

Although the search strategy the researcher used is selective in terms of quality and representative as indicated in the inclusion criteria, books, conference proceedings and theses are not excluded. As the literature in this topic is scarce, the quality of articles becomes important for generalizations and catching trends. The articles collected are analyzed in terms of their clarity about the underlying research base, the metacognitive strategy they use in the game and how they support this strategy. The researcher aims to use content analysis of the articles examined, where data synthesis this way utilizes the organization of studies into subgroups and perform a coding format to develop themes as well as solid evidence to help answer the research questions. The coding is deductive within a flat coding frame as codes are pre-defined for the qualitative data and every article is treated as text for analysis, however, the type of metacognitive strategies is predefined and articles are selected for literature survey are based on mainly having one of those metacognitive strategies. Articles are read and the codes are used to cover important parts. As similar research appears under the same code, they are united.

In addition to this, the researcher first looks at patterns of metacognitive strategy use in games throughout years but there is no valid pattern, the studies are performed with different subjects and supporting different kinds of metacognitive strategies. While reflection studies tend to be accumulated in previous studies, it is difficult to set a pattern for the selected articles through time. Then the researcher checks whether the articles compare one metacognitive strategy over another, and this is not the case as games are difficult to build and aiming for one metacognitive strategy and supporting it through game is challenging enough. There is only one study included that takes metacognitive strategies as a whole and the researchers in that study try to understand whether it is better to give prompts or to train learners about metacognitive strategies. Later, the researcher checks if the studies compare in-game and in-class activities using the game as a mediator. While there are some cases where prompting of learners occurs after or before the game suggesting that the process of learning occurs with in-game and in-class sessions, the researcher avoided research that most of learning occurs in class as the focus is on learning with game and game mechanics. Out of game interventions and support are only included if they are crucial for learning. Then the researcher checks how much control learners are given in the research as self-regulatory learning is an important component of metacognitive strategies. Learner control is related to the larger population samples and the need to do studies on a longer period. This is the main reason why most of these studies require larger population samples to be generalized as the time with games is always limited. Then the researcher checks what kind of measures are used in the selected studies and their compatibility in different learning situations. In line with the research question about the types of metacognitive strategies it seems logical to categorize the articles under the main metacognitive support they seek to employ in their studies.

3.3. Research Ethics:

The study named as "Metacognitive Strategies in Serious Games: A Literature Survey" has been carried out within the rules of scientific, ethical and citations. The data gathered throughout the study are not tampered with and this work has not been sent to another academical publication media for evaluation.

4. Results

The concepts presented in the framework are examined in the literature and analyzed searching for different modes of supporting serious games with metacognitive strategies. The predefined codes with the same name as themes are measures, learner control, methods, results, problems and suggestions and the researcher treated every article as document and looked for these themes in all articles for deep analysis. Learner control is chosen because it is important that learners take as much time as they need with the game and try different approaches to learning and finishing the game. Games can have mods for further teaching content, and it is supported by literature that multiple sessions of gameplay and longitudinal studies are needed in serious games. The measure theme is chosen as it is important what kind of data is being used to reach conclusions. Problems and suggestions from these articles are crucial for future directions as it is in the interest of the researcher to link these results to game mechanics and offer suggestions with serious games and metacognitive strategies.

Table 2. Themes.

Measures	Learner control	Method	Article
Video transcription of think aloud interviews	free	Discourse analysis	Games (2010)
Finish time Knowledge	restricted	Pretest-Posttest	Sandberg, Wielinga, & Christoph (2012)
Anxiety, gestures, eye contact	restricted	Observational rating.	Gebhard et al. (2019)
Mental model elicitation and conceptual and procedural knowledge	restricted	Pretest-Posttest	Van der Spek, Wouters, & Oostendorp (2011)

ICT knowledge, feedback	restricted	Pretest-Posttest	Coucerio, Papastegiou, Kordaki, & Veleso (2013)
Logs, problem solving performance, metacognition,	restricted	Pretest-Posttest	Liu & liu (2020)
Knowledge, cognitive load, mental effort.	restricted	Pretest-Posttest	Moser, Zumbach, & Deibl (2017)
Educational gains	restricted	Pretest posttest	Castronovo, Van Meter, & Messner (2018)
Problem solving, perceived learning	free	Posttest	Barzilai & Blau (2014)
Button press logs, knowledge	restricted	Posttest	Mayer & Johnson (2010)
Transfer of knowledge	restricted	Posttest	Fiorella & Mayer's (2012)
Progress, fewer deaths and resets in game.	restricted	Posttest	O'Neil et al. (2014)
			Johnson (2018)
Highest level, total engagement, average actions per attempt and attempts per level.	restricted	Pretest posttest	Clark, Virk, Barnes, & Adams (2016)
Perceived ability, engagement, cognitive load	restricted	Pretest posttest	Law & Chen (2016)
Knowledge	restricted	Pretest posttest	Halpern et al., (2012)
Knowledge	restricted	Posttest	Zeglen & Rosendale (2018)
Record of dialogues		Posttest	van der Meij, Lendkamp, & Meilkuil (2020)
Knowledge		Prestest posttest	Zumbach, Rammerstorfer, & Deibl (2020) /
Behavior engagement and self-monitoring	free	Pretest posttest	Reimer & Schrader (2016) /

Learner moods, self-regulatory behaviors, SRL score		Pretest posttest	Sabourin et al., (2013)
Confidence levels.	restricted	Pretest posttest	Verpoorten, Castaigne, Westera, & Specht (2012)
Answers to questions	free	Content analysis	Lin & Tu (2012)/ interviews
Video feed, log of activities		Posttest	Hämäläinen (2010)
Self-explanation ability, motivation, attitude, self-efficacy, enjoyment.		Pretest posttest.	Jackson & McNamara (2013)
Willingness to redo activities, rate of experience, knowledge	free	Posttest	Bellotti, Berta, De Gloria, & Fiore (2011)
Motivation, experience, learning outcomes. Self-report.		Posttest	Garcia, Pacheco, Leon, & Calvo-Manzano (2020)
FOK explicitness, individual and dyad performances		In game-test.	Usart, Romero, & Almirall (2011)
Metacognitive awareness	Free	Posttest	Braad, Degens, & Ijsselsteijn (2019)

Table 3. Themes continued.

Problems	**Suggestions**	**Article**
Too few people		Van der Spek, Wouters, & Oostendorp (2011), Castronovo, Van Meter, & Messner (2018), Mayer & Johnson (2010), Law & Chen (2016), Verpoorten, Castaigne, Westera, & Specht (2012), Hämäläinen (2010).
Prior Gaming experience		Van der Spek, Wouters, & Oostendorp (2011)

symptoms of cybersickness		Van der Spek, Wouters, & Oostendorp (2011).
	More levels, difficulty, less textual dialogs, more animations, active player participation, collaboration, customizable players.	Coucerio, Papastegiou, Kordaki, & Veleso (2013).
Not generalizable		Liu & liu (2020), Barzilai & Blau (2014), Hämäläinen (2010).
	Investigate long-term scaffolding, samples with different prior knowledge and ages keep the balance between guiding the learning process	Moser, Zumbach, & Deibl (2017).
	Multiple playing sessions	
	compare the outcome of game playing to the outcome of learning	Mayer & Johnson (2010).
	Find the minimum required prompting	Fiorella & Mayer's (2012).
No control group	Collection and analysis of log data	Law & Chen (2016)
Game and mental model concepts may be different.	Other types of engagement, such as cognitive and motivational engagement can be analyzed.	Reimer & Schrader (2016)
	Role of directed and undirected prompts, different gaming environments.	Sabourin et al., (2013)
Lack of individual perspectives on learning,		Hämäläinen (2010)
	Incorporate multiple time scales of measurement.	Jackson & McNamara (2013)
	qualitative and quantitative methods must be used to improve the reliability and validity.	Garcia, Pacheco, Leon, & Calvo-Manzano (2020)

Table 4. Themes continued.

Support Type	Results	Article
Mental models/ modeling	Developing systematic thinking and distributed intelligence practices	Games (2010)
Mental models/ modeling	Procedural knowledge increase	Sandberg, Wielinga, & Christoph (2012)
Mental models/ modeling	Interview performance increase	Gebhard et al. (2019)
Mental models/ modeling	Mental model composition did not significantly improve	Van der Spek, Wouters, & Oostendorp (2011)
Mental models/ modeling	Positive effect on knowledge	Coucerio, Papastegiou, Kordaki, & Veleso (2013)
Mental models/ modeling	Metacognition level affects problem solving	Liu & liu (2020)
Prompting	Metacognitive prompt group outperformed metacognition training group	Moser, Zumbach, & Deibl (2017)
Prompting	Transfer of metacognition into real world is established.	Braad, E., Degens, N., & Ijsselsteijn, W. (2019)
Prompting	Increased problem solving skills.	Castronovo, Van Meter, & Messner (2018)
Prompting	Scaffold before the game performed significantly better in the post-game problem-solving assessment	Barzilai & Blau (2014)
Prompting	Prompt increased score	Mayer & Johnson (2010)
Prompting	Prompt increased score, decreased difficulty.	Fiorella & Mayer's (2012)
Prompting	Focus prompts had positive effects while abstract and recall prompts had negative effects on posttest.	O'Neil et al. (2014)
Prompting	Prompting is more effective when given by human facilitator.	Johnson (2018)
Prompting	Adaptively adjusted prompts scored higher than abstract prompts, Higher degrees of model based thinking with prompts	Clark, Virk, Barnes, & Adams (2016)
Prompting	Knowledge prompts outperformed application prompts.	Law & Chen (2016)

Prompting	No difference in proportional learning/durable learning for active engagement group.	Halpern et al., (2012)
Prompting	Group with visual prompts performed better.	Zeglen & Rosendale (2018)
Prompting	Scripting lead to more dialogic acts and higher knowledge posttest	van der Meij, Lendkamp, & Meilkuil (2020)
Prompting	Metacognitive and cognitive prompting proved effective over direct metacognitive training.	Zumbach, Rammerstorfer, & Deibl (2020)
Monitoring/Reflection	Degree of self-monitoring affected mental model accuracy.	Reimer & Schrader (2016)
Monitoring/Reflection	highly self-regulated learners got higher learning gains	Sabourin et al., (2013)
Monitoring/Reflection	Confidence degrees were correlated with correct answers.	Verpoorten, Castaigne, Westera, & Specht (2012)
Monitoring/Reflection	Teamwork and sense of accomplishment found as valued by students.	Lin & Tu (2012)
Monitoring/Reflection	Scripts guided students. Post test scores correlated with game scores.	Hämäläinen (2010)
Monitoring/Reflection	Enjoyment and motivation increased with game version.	Jackson & McNamara (2013)
Monitoring/Reflection	Game version performance was better but not significant.	Bellotti, Berta, De Gloria, & Fiore (2011)
Monitoring/Reflection	positive perception of students and teachers	Garcia, Pacheco, Leon, & Calvo-Manzano (2020)
Monitoring/Reflection	Fok explicitness group and control group showed no statistical difference.	Usart, Romero, & Almirall (2011)

As for the explanation of the themes, in Table 2, we see that the research method used in almost all articles is pretest-posttest and posttest method. There are two studies that uses discourse or content analysis and another study that depends on expert view ratings. This shows that the researchers tried to check the effect of their games in a direct and efficient way. Also, one study used interview to understand what male and female learners value most in games.

The measures used in the articles support this in the way that there are not many variables included. 7 articles use no variable other than that is checked in pretest and/or posttest. 14 articles used knowledge coupled with an ability or performance. Only two articles use self-report forms as measures but that is because they were avoided by the researcher as explained earlier in the problem statement part. 3 articles show logs related to game. It can be said for the measures that performance in game and performance in tests need more variables to be related to each other. There is the need for more logs of data and other learner interactions in game to link learning in game to learning of concepts. There are two video records and one record of dialogues (chat) used for further analysis to understand models, dialogues and learning processes. One study used eye movements, gestures and anxiety for improving interview skills which are modeled in immediate feedback in the form of responses from a virtual learning companion.

The results of the studies show significant improvement of performance of one group or one group over the other/s while two studies show no statistical difference, and one study shows insignificant improvement. It can be said that metacognitive strategies are effective means of improving skills and knowledge when they are used properly within serious games. Metacognitive strategy used in the game and not used in the game makes a significant difference for educational gains. Two studies report improvement of problem-solving skills with metacognitive strategies. This is solid evidence for improvement of usage of metacognitive strategies as long as there are no interfering computer gaming/ using self-efficacy and prior knowledge of concepts. That is why the frequency of pretest posttest method is high and the researchers always collect demographics of learners in most of the studies. Some researchers also state that their game requires minimum knowledge of computer game or computer usage to eliminate advantage of experienced users over others. In Table 3, we see a research study that shows prior gaming experience as a problem and this should be avoided as possible in future studies by coming up with novel and challenging games which are neither too hard nor too easy. One result uses timing of prompt and 3 studies compare different prompts over the others. 2 studies compare metacognitive prompt with metacognitive training. It is apparent literature needs more studies with prompts and the researcher thinks that it is not enough to compare prompts with each other or with presence of prompts but also same prompts in different games should be compared.

Learner control is chosen to understand how free the learners in exploring the game world as it is related to self-regulated learning, but as it is seen, the games used in these studies are difficult to build so they are not complicated and even if the learners are free to explore and exhaust gaming practice, the games are easy to understand, and they can be finished mostly by the time set by the researchers. Learner control would work more if there are different paths to learn or different characters the learner can use and experience different quests and learning materials. This seems to be the main reason why some researchers prefer to use different modes of commercial games to teach skills or certain concepts.

In Table 3, we see that 6 studies use small sample size and 3 studies that report their research as not generalizable. This is the main reason why studies in this respect happen as a single case. Building a game that goes global is difficult and requires collaborating with other researchers with similar interest. A game should be played by lots of people with different backgrounds and data from those games could be used to make the game better for learning concepts. This is emphasized by researchers stating their game should be played with more people with different ages in long term studies. 6 studies suggest longitudinal studies while multiple sessions with games using multiple scales of measurement including qualitative and quantitative data for better evidence are emphasized. It is also suggested to compare the outcome of gaming with outcome of learning.

We also see the customization of players for the motivation of learners and the need to understand how much metacognitive strategy is required to keep balance between learning and guiding processes.

According to the research questions, the types of metacognitive strategies are categorized under mental models/modeling, prompting and monitoring/reflection. The results according to Table 4 are summarized under relevant themes. Also, the relation between game mechanics and metacognitive strategies is explained with the literature survey and recommendations are made in discussion.

4.1. Mental Models/Modeling

According to the analysis, using mental models as metacognitive support works best when there are increasing and different levels of challenges, exploration opportunities, and being able to monitor learner progress in a serious game. Also model development or understanding learner mental model needs repeated engagement and comparison in order to provide learners the abilities to articulate complex ideas into action.

The presence of a model whether it is a task model, or a theoretical model also influences learning and makes automation processes of different kinds of knowledge easier. It can be said that this kind of metacognitive support is more suitable for studies that use virtual agents and virtual/mix reality as they can handle automations and spotting misconceptions easier. These automations decrease the cognitive load and remove unnecessary information from learning material. Models help students how to acquire knowledge by showing how to solve problems. Also, if the model has clear instructions on how to apply procedural knowledge to declarative knowledge, it helps automation of routines and transfer of learning.

As it has been seen, developing, or exposing mental models of game or learners has many applications in serious games and researchers try to extract the learning process of problem solving, knowledge acquisition, time-related operations. Sometimes learners are given more freedom encourage them to use tools for these operations and sometimes they restrict learners and shape them according to the wanted operations. The interactions in these studies depend on game mechanics and models are built through these interactions. The efficiency of serious games in teaching depends on the quality of these interactions. It is also seen that most of these studies are case-based and in need of larger learner groups to be generalized.

4.2. Prompting

Literature supports either training or supporting learners at one point of instruction or gameplay as if each support is applied then it will increase the learners' cognitive load (Eckhardt, Urhahne, Conrad, & Harms, 2013). Timing is critical with the application of prompts in games as more research is needed to find out if detailed prompts in the form of feedback like waiting for input from players, pausing of gameplay or auditory cues (Van Meter, Cameron, & Waters, 2017). The analysis shows that prompts are more effective when they are explanatory rather than abstract that is why they should be short, simple but they should have enough details as they are only viewed for a short time mostly during gameplay. Scripted collaboration and prompts in the form of visual hints allow learners to remember concepts and activates prior knowledge.

In summary, it can be stated that prompting is a trending way of metacognitive support and presents variability according to the game and the skills or knowledge that is presented in the game. The comparison of prompts with metacognitive training and the application of prompts before or after gameplay is largely scrutinized. Prompts are mixed with reflection and it is very important that the game is not interrupted during the initialization of prompts. It is understood that visual hints coupled by feedback, giving choices from the learner rather than waiting for response from the learner and critical timing of prompting are crucial. These represent great challenges for game mechanics used in the game as they depend on a lot of variables embedded in quests, activities, and learner responses. To give prompts, game mechanics must be able to reach all parts of the game hence they require a messaging system and the ability to change learning pathways with other mechanisms on critical parts of the game.

4.3. Monitoring/Reflection

Monitoring activities such as learner moods, actions, ways of utilizing information and tying them to certain patterns of behavior shows how leaners make use of effective metacognitive strategies and how they organize knowledge. The purpose of monitoring and reflection in a game is to keep the learner in a deliberate rather than a reactive manner and sustain learning by letting learner interpret their own actions and make them aware of their progress.

Motivation and enjoyment are effective means that games have to include monitoring and reflection, that is why, according to data analysis, game version of teaching material and intelligent tutoring systems are being tested for them. There are also games that let teachers monitor student work and support the necessary skills.

It can be concluded that the monitoring and reflection tools or strategies used in serious games ensure the expectations of teachers and direct learners by making them continuously see their own progress using visual aids that work real time in the game. This way learners can gain confidence, they can be monitored via the data about their quests, achievements, collaborations, and problems can be solved. This kind of mechanisms separate learning in conceivable fragments and accordingly sustain learning in a step-by-step manner. This time the game mechanics work more in the background to present data in meaningful and comprehensible visualizations supporting the learning achievements. Game mechanics here must record critical actions and have mechanisms that compare real time data into particular scores for evaluation and detect improvement and failures.

4.4. The Relation between Game Mechanics and Metacognitive Strategies

Literature on game mechanics suggests that game mechanics must be aligned with learning outcomes or the game will not be motivating. Integration of metacognition in games intrinsically with the help of narrative and game mechanics creates alignment between learning and playing. This is rarely seen in research as it is hard to achieve in gameplay. It is expected that future research should give more examples of the integration of metacognitive strategies in games that help with challenges in the game by emphasizing resource management, affordances, adoption of strategies learned and encouraging thinking in learners. Zhonggen (2019) discovers in his literature review that relationship between learning attribute and game mechanics is important for improving learning in serious games. Therefore, narrative or story becomes far more important than learning subject both to be engaging and embedded in game.

Interaction and feedback are named amongst the factors that assisted learning in serious games. Game mechanics are the main functions that take role in both these factors. For game mechanics to keep interaction and feedback, easiness of games is also a critical factor. A study on a game called Cells of War done by Konstantara & Xinogalos (2018) proves its acceptance because it is short, easy to play with increased replayability, but instructional support is also important as it should be ready when needed. The suggestions reported by the participants mention that it is important to view a complete history of actions done or to see what is available as resource and strategies as these should be embedded in the game mechanics.

A literature review by Lameras et al., (2017) finds that the role of the instructors during gaming in terms of guidance is fuzzy and the elements of learning embedded into the game cause misconceptions about design and applications of learning activities. This literature review exposed categories of learning elements and game mechanics to be used in serious games. The authors recommend in-game authoring scaffolds and visual representation of drag-drop learning attributes to be used in game authoring environments. For game mechanics and metacognitive strategies to work effectively, generic descriptions of design features and process of integrating serious games in form of mini games or other forms into lesson plans should be developed. This affects the facilitation of design and student learning and the activities that are developed that serve as metacognitive tools. Furthermore, matching learning and gaming attributes and involving teachers in the process to create learning instances is a way for game mechanics to accommodate metacognitive strategies. The link between learning attributes and game mechanics is considered to be the key to enhance learning via activities that involve metacognitive strategies.

5. Discussion, Conclusion and Implications

This research study defines in detail what activities are considered as metacognitive in serious games and presents a survey about the studies in this field that tries to understand the process of learning with these activities in gaming. The results reached by the literature survey are supported by previous research about games and metacognitive strategies in points like adaptability, learners being proactive meaning they take charge when they learn, the importance of motivation, immersion, guidance and problem-solving activities in games. Adaptability is important for serious games in terms of their metacognitive capabilities. We see prompting and scaffolding in MetaTutor (Azevedo, Witherspoon, Chauncey, Burkett, & Fike, 2009) and Betty's Brain (Vanderbilt University) and adapting to level of the learner through real time data such as amount of time spent on a problem or attempts made to finish a task and make the learner proactive and the program reactive. The loss of motivation in games can be caused by the tools used in game systems to amplify reflection when they interfere with narrative and immersion of learners in the game. However, if this amplification is short-termed and is in line with the flow of the game, it can support first-order learning task.

It is apparent that games must teach learners to become thinkers to make their engagement stronger as in a study by Anderson (2002). Tasks become more efficient when they are divided in steps, where learners can absorb knowledge by planning, control and revision of concepts (Saldana, 2004). Games should also contain mechanisms that involve searching and discerning information, negotiation and decision making processes (Lin, 2001). Therefore, games mechanics should include the flexibility that allow learners to practice these mechanisms. To make learners better thinkers, serious games should target the representation of problems on a higher level of abstraction which enables learners to transfer their knowledge to other games that are not similar.

Braad et al., (2020) suggest that games should create balance between freedom and guidance and should give time for learners to carry out metacognitive strategies for their own self-assessment rather than being evaluated within a time frame. Keeping their attention at task becomes possible with problematizing game content as it reduces perceived learning and helps articulating ideas to make transfer of knowledge possible through different explanation of events with metacognitive functions (Molenaar, Boxtel, & Sleegers, 2011). Consequently, problematizing scaffold makes learners use more resources for problem solving and keep their attention at task.

Transfer of learning is one of the most critical problems to handle in serious games and it becomes clearer that it is a threat to teaching due to the contextual dissimilarities between classroom and gaming environment (Morris et al., 2013). To ensure transfer of learning, instructional tasks and transfer tasks must be explicitly embedded in serious games. It is important that learner's perception of a learning environment leads to process of learning through his interactions in the game. Game mechanics play an important role through the step by step embedding of these tasks in the serious game.

As the aim is to improve education and furnish students with 21st century skills the researcher believes that serious games can deliver a huge impact in this respect whether through teaching metacognitive and self-regulatory skills or through supporting these skills with game elements that lead to improved assessment. Games can either focus on skills and teach usage of these skills in different situations or they can focus on learning content and provide collaborative work and emotional characteristics of games to inspire learners to explore and sustain their learning. It is the learner who should be responsible for his own learning and serious games can back this up by giving alternative scenarios, reaching objectives via different routes, give out different endings based on many variables and chance. This way the learner will come back and take a different route, use different dialogs, play as different characters and so on. The important thing is that the learner has plenty of opportunities to learn and to satisfy his curiosity because by dictating his actions and the steps he takes in completing missions, solving problems, he is asking questions and using metacognitive strategies for retention without realizing it. The usage of reflection, monitoring, mental models and prompts will enhance retention and help the learner control and optimize his learning. Having a flexible design in a game in terms of tasks and scenarios enables the use of autonomy and control with preferred goal settings.

The place where game mechanics in serious games fits encouraging help seeking, acting as cognitive tools and providing enough information in the form of feedback so that monitoring and controlling of learning can exist.

When designing game mechanics some points below should be considered:

- What can be done in a game (what is controllable, destroyable, etc…) ?
- What are the relations between skills in a game (what the player has to know to do something)?
- What will be the consequences of actions conducted in the game?
- Can multiple paths of gameplay or learning be chosen or one has to choose one over the other?
- What is the benefit of one choice when over the other when making decisions?
- What is the scoring mechanism and rewards?

For metacognitive strategies and game mechanics to work in tune with each other a few characteristics of serious games must be considered. Nietfeld (2018) draws our attention to importance of collaborative work in game-design process with teachers and experts from different fields to get the best consideration of matching learning goals with game mechanics in school and other learning media. The importance comes from the need for staying within the limits of teaching and teaching with emphasis on what is important. He also emphasizes the role of teachers in determining the skills to be taught as well as their roles in aligning game goals and learning goals. It is also crucial to gather data such as learning time, success rate, frequency of errors, etc… about the learners' usage of game mechanics to be able to analyze the game and decide if more mechanics for practice as well as more content depth is needed. Nietfeld (2018) also thinks that this process should be repeated with other groups of learners hence it will be easier to understand the challenges game must provide and the differences between teaching mechanisms and game mechanics that are used. This way the game can be leveled for a larger population and a base for teaching is accomplished. This will in time remove the effects of learners with prior gaming experiences or higher computer game self-efficacy and decrease the learning cycle time. Reflection system is also important as it causes the learner to repeat gameplay and pay attention to details. Asking reasons for events and how they can be improved leads to a satisfactory learning situation for learners.

For future research about the development of serious games and better performance with metacognitive strategies in games, the following points are recommended:

- Games that target important academic skills should have prompts, monitoring, reflection and feedback mechanisms.
- Confounding factors in research such as prior knowledge, computer game self-efficacy should be removed by making the game adaptive within a short period of time.
- Games that use prompts must pause the game and suggest alternative actions, processes at the time of tasks.
- Time of delivery of prompts is critical and it changes according to every other context.
- Previous important actions and choices must be shown to learners for engagement. That is why serious games should allow for opportunities for self-monitoring by keeping history of actions/quests and offer alternative pathways to finish tasks dependent on the skills to learn.
- Story and characters of the game must be introduced gradually to promote conscious and meaningful choices.
- Debriefing after gameplay sessions may not be sufficient for helping learners form connections between the game and what they learn in school. That is why scaffolding for learning with serious games should be between game-based learning and formal learning.
- Self-explanation and self-recording are more appropriate for situations where games are used in conjunction with in-class sessions. Otherwise, they can be embedded in conversations in games.
- As a proof of learning, the game mechanics must be developed around the assessment types and procedures.
- Feedback should be part of the game and should not interrupt the flow of the game. It should evolve according to learner behavior and imagination.
- The learning objectives should be small but connected to each other so that they can allow prompts, monitoring and modeling to work for that specific objective and see progress within time in manageable quantities.

- It would be better if game mechanics are used with decision trees and after-action reports in games which are important for reflection afterwards.
- Future research should focus on experimental and longitudinal studies that focus on comparison of different monitoring, feedback and prompting strategies.
- Multiple game play sessions are better for understanding effects of metacognitive interventions on learning and crucial for providing the learners with many options in their decisions in handling problem-based tasks.

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