J. EDUCATIONAL COMPUTING RESEARCH, Vol. 47(3) 329-349, 2012

COGNITIVE LOAD AND GOAL BASED SCENARIO CENTERED 3D MULTIMEDIA LEARNING ENVIRONMENT: LEARNERS' MOTIVATION, SATISFACTION AND MENTAL EFFORT

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ABSTRACT

This study investigated the learners' satisfaction, motivation, and mental effort in Goal Based Scenario centered 3D multimedia learning environment (GBSc3DM). The design of the GBSc3DM was based on the Cognitive Load Theory (CLT) principles. Two versions of the GBSc3DM were developed. While Cognitive Load Theory principles were taken into account and implemented in the design of the first version (+CLT), those principles were not applied in the design of the second version (–CLT). A total of 82 9th grade high school students participated in the study. Mixed methods were used to gather the data. The findings of the study revealed that the learners were satisfied with the Goal Based Scenario components and the CLT principles implemented in the first version of GBSc3DM. The learners pointed out that GBSc3DM and CLT principles motivated them to learn the topic. However, not only were the learners not satisfied with the second version (–CLT), but they also found it distracting. The findings showed that the learners invested higher mental effort in the second version (–CLT) of GBSc3DM.

doi: http://dx.doi.org/10.2190/EC.47.3.e
http://baywood.com

INTRODUCTION

Constructivist philosophy offers a different point of view about how learning occurs and how efficient learning environments can be designed (Duffy & Cunningham, 1996). The constructivist paradigm, which is based on the interpretivist view, assumes that learners can construct their knowledge when they make sense of their knowledge (Driscoll, 2000). Goal Based Scenario (GBS) is one of the instructional methods in the constructivist paradigm. GBS offers realistic environments for complex learning tasks, and thus has the potential to motivate learners. High task complexity is, however, a serious risk of this approach. If the learners cannot handle the task complexity due to the overload on their working memory capacity, this might hinder their learning (Van Merriënboer, Kirschner, & Kester, 2003). It could also be expected that this overload might negatively affect students' motivation and satisfaction in learning from the goal based scenario and decrease their involvement. To eliminate the overload that results from the task complexity, the limitation of learners' working memory should be taken into account. Cognitive Load Theory (CLT) provides valuable guidelines on how to deal with the overload (Van Merriënboer et al., 2003). Several instructional formats have been proposed to overcome the overload. Among them, the instructional formats reducing extraneous cognitive load have been widely investigated by the researchers. Instructional design research, however, still needs to further investigate motivation, satisfaction, and invested mental effort in a learning environment where GBS approach and instructional formats reducing extraneous cognitive load are integrated in (Van Gog, Ericssion, Rikers, & Paas, 2005). Therefore, this study aimed to investigate the learners' opinions about motivation, satisfaction, and invested mental effort when the goal-based scenario is used as a general instructional approach with or without instructional formats reducing extraneous cognitive load.

Goal Based Scenario

GBS is one of the instructional methods that the constructivist paradigm offers for designing learning environments (Driscoll, 2000). GBS emphasizes developing a model which provides environments for learner to learn "how" to rather than learn "what" (Schank, Berman, & Macpherson, 1999). By knowing "how," students eventually learn the content knowledge in the service of accomplishing their task. Then, they know not only why they need to know something but also how they use the knowledge (Schank, Fano, Bell, & Jona, 1994). GBS is a type of pedagogical approach used in generative learning environments for optimizing e-learning (Naidu, 2003). Developing effective GBS by using computers increases the opportunities to benefit from the advantages of the method because computers' capabilities make it easier to meet the needs of prerequisite conditions which are mandatory for the appropriate use of GBS and which are very difficult to achieve in the classroom.

Many studies show that GBS is an effective way of teaching by providing opportunities for learners to understand why and how they use the knowledge they learn (Bell, Bareiss, & Beckwith, 1993; Schoenfeld-Tacher, Persichitte, & Jones, 2001; Zumbach & Reimann, 2002). Similarly, Zumbach and Reimann (2002) state that GBS provides intrinsic motivation. Additionally, Schaller, Bunnell, and Nagel (2001) indicate that GBS provides extrinsic motivation for uninterested but potential learners especially when the appeal of GBS is increased by narratives, games, simulations, and creative play activities. Similarly, Foster (1994) states that GBS approach eliminates some deficiency in traditional methods, and makes learning more motivating for the students. Foster and Bariess (1995) mentioned that the traditional case method has some shortcomings such as lack of logistics and unwillingness, and GBS architecture has the ability to eliminate these shortcomings. Naidu, Ip, and Linser (2000) investigated the effectiveness of GBS in their study. They found that students have positive attitudes toward GBS. The studies generally show that GBS has a positive effect not only on the teaching and learning processm but also on students' motivation.

Cognitive Load Theory

CLT "is concerned with the development of instructional methods that efficiently use people's limited cognitive processing capacity to stimulate their ability to apply acquired knowledge and skills to new situations" (Paas, Tuovinen, Tabbers, & Van Gerven, 2003, p. 63). The major assumption underlying the CLT is that an individual's working memory has limited capacity (Kirschner, 2002). Cognitive load "is generally considered a construct representing the load that performing a particular task imposes on the cognitive system. It can be conceptualized as a task-based dimension (i.e., mental load) and a learner based dimension (i.e., mental effort), both of which affect performance" (Sweller, Van Merriënboer, & Paas, 1998, p. 266). There are three types of cognitive load: intrinsic, extraneous, and germane load. Intrinsic cognitive load is attributed to inherit structure and complexity of the instructional materials. The other two are imposed by the instructional design. Extraneous cognitive load is the result of implementing "instructional techniques that require students to engage in activities that are not directed at schema acquisition" (Sweller, 1994, p. 299). Extraneous cognitive load is an ineffective type of load for learning (Van Gog, Paas, & Van Merriënboer, 2006, 2008). It is the effort required by the learner to process poorly designed instruction (Kirschner, 2002; Sweller et al., 1998). Germane cognitive load reflects "the effort that contributes to the construction of schemas" (Sweller et al., 1998, p. 259). The basic assumption behind the germane load is that the available working memory capacity resulting from low intrinsic and/or low extraneous cognitive loads reduced by instructional techniques may be used to engage learners in activities to improve the process of schema acquisition (Sweller et al., 1998).

The relationship between intrinsic, extrinsic, and germane cognitive load is that they are additive. This reveals why reducing extraneous cognitive load is important when the intrinsic load is high (Paas & Kester, 2006). To reduce extraneous cognitive load, the powerful CLT-instructional formats—split attention, redundancy, modality effect (Bannert, 2002), multimedia, and coherence (Mayer, 2001)—were applied in designing the multimedia learning environment in the current study. Spilt attention refers to presenting words and pictures separately. Learners need to use their limited cognitive resource to mentally organize and integrate the materials when they are separated from each other on the screen. Conversely, if the materials are integrated, learners can combine them in their working memory and make meaningful connection between them (Clark & Mayer, 2003; Mayer & Moreno, 2002, 2003; Sweller et al., 1998). Redundancy means presenting words in both text and audio narration which hinder learning. To eliminate redundancy, either text or narration should be used. Redundancy is a major effect that should be considered because of its negative consequences on instructional design (Sweller et al., 1998). Modality stands for placing material into spoken forms of words rather than the printed words whenever the graphic and/or animation is the focus of the words and both are given simultaneously (Clark & Mayer, 2003; Mayer & Moreno, 2002; Sweller et al., 1998). Multimedia presentation refers to any presentation that contains printed/spoken text and static/dynamic illustrations (Clark & Mayer, 2003; Mayer & Moreno, 2002). Coherence indicates presenting irrelevant sound, picture, and graphics which can harm learning in learning materials. In line with the coherence principle, extraneous pictures and words should be eliminated (Clark & Mayer, 2003; Mayer & Moreno, 2002).

Goal Based Scenario, Cognitive Load Theory, and Motivation

Since extraneous cognitive load can be manipulated by the instructional designer, many studies are conducted to find out ways to reduce extraneous cognitive load for meaningful learning in multimedia environment (Clark & Mayer, 2003; Kalyuga, Chandler, & Sweller, 2004; Mayer & Moreno, 2003; Seufert & Brünken, 2006; Tabbers, Martens, & Van Merriënboer, 2004; Van Bruggen, Kirschner, & Jochems, 2002; Van Gerven, Paas, Van Merriënboer, & Schmidt, 2002). There are, however, very few studies that combine these instructional formats with different instructional methods, and investigate its influence on students' motivation, satisfaction, and invested mental effort. As pointed out by Van Gog et al. (2005), the relationship among motivation, invested mental effort, and different instructional formats needs more attention in instructional design research.

Motivation is defined as a construct which is "primarily concerned with activation and persistence of behavior and is partly rooted in cognitive activities"

(Bandura, 1977, p. 193). Motivation can influence how, when, and what we learn (Schunk, 1991). There are two types of motivation: intrinsic and extrinsic motivation. "Intrinsic motivation is the natural tendency to seek out and conquer challenges as we pursue personal interest and exercise capabilities" (Woolfolk, 2004, p. 351). Extrinsic motivation "is based on factors not related to the activity itself" (p. 388), and created by external factors. GBS has been developed based on a goal which assumes to increase intrinsic motivation. In other words, it is assumed that an effective learning environment, in which learners have a goal, creates conditions that produce strong intrinsic motivation to learn (Schank et al. 1994).

In addition to the motivational aspects of GBS, CLT researchers try to find out the relationship between motivation, performance, and mental effort in the learning environment. They assert that mental effort, performance, and motivation are positively related (Paas, Tuovinen, Van Merrriënboer, & Darabi, 2005). Motivation and mental effort are the important issues both in GBS and CLT. Thus, this study investigated the learners' perceptions of learning from GBSc3DM, motivation, satisfaction, and level of mental effort displayed in the two versions of GBSc3DM. More specifically, the following research questions were inquired:

- What are the learners' opinions about learning through GBSc3DM?
- What are the learners' opinions about the effects of cognitive load in GBSc3DM on their motivation and satisfaction?
- Is there a significant difference between the learners' mental efforts invested in the first and the second versions of GBSc3DM?

METHOD

Design

A mixed method design was used for this study. The purpose of this design is to obtain different but complementary data on the same phenomena to compare/contrast or validate/expand quantitative results with qualitative result (Creswell & Plano-Clark, 2007). Quantitative and qualitative data were collected concurrently and analyzed separately. Reflective journals were gathered and semi-structured interviews were conducted to investigate the learners' motivation and satisfaction, and the learners' opinions on learning through GBSc3DM. A subjective rating scale was used to investigate the difference between learners' mental effort invested in the first and the second versions of GBSc3DM.

Participants

Eighty-two 9th grade high school students (52 females and 30 males) participated in the study. Two criteria were considered in the selection of the school. The first criterion was the experience of the teacher in the constructivist approach. The biology teacher at the selected high school had experience in using the constructivist approach in her teaching. She also had taken part in the constructivist curriculum development process at the Ministry of Education. The second criterion was the appropriate computer laboratory infrastructure in the school. The high school where the study was conducted met the two criteria determined for this study.

Software Development

The literature indicates that high school students have difficulty in learning and have misconceptions in mitosis and meiosis subjects in Biology (Atilboz, 2004; Bahar, Johnstone, & Hansell, 1999; Tekkaya, Özkan, & Sungur, 2001). Therefore, cell division processes consisting of two units which are mitosis and meiosis were included as the content of GBSc3DM (see Figure 1). While developing GBSc3DM, participatory and user-centered design (Corry, Frick, & Hansen, 1997) approaches were used. The design/development team consisted of one subject area teacher, two instructional designers, one graphic designer, and one programmer. In the design and development of the multimedia, series of formative evaluation were conducted with the students who had similar characteristics with the participants of the study. Think aloud method was used to test the understandability of the software. Based on the feedback gathered from the formative evaluation process, some revisions were made in the design of the software.

GBSc3DM was developed as a game-based learning environment. Since GBSc3DM is a complex learning environment that requires engagement in investigation and decision making processes, a motivational mission was given to the participants. The goal was to restart the mitosis and meiosis processes which could not begin because of viruses' attacks at the cells. Although the mission was somewhat imaginary, the events occurring in the scenario were developed based on the scientific facts (see Figure 2). To achieve the goal, the learners had to sequence the main phases and sub-phases of mitosis and meiosis in the correct order. GBSc3DM also included a library of resources about the topic to provide support for the learners.

Two versions of GBSc3DM were developed. The development of the first version (+CLT) was based on "split attention, multimedia, modality, coherence and redundancy" principles that reduce extraneous cognitive load. In the second version (–CLT) these principles were not implemented. Other than these mentioned differences, the remaining design and the content were the same in both versions. Whether the CLT principles were incorporated or not in the two versions are presented below in Table 1.

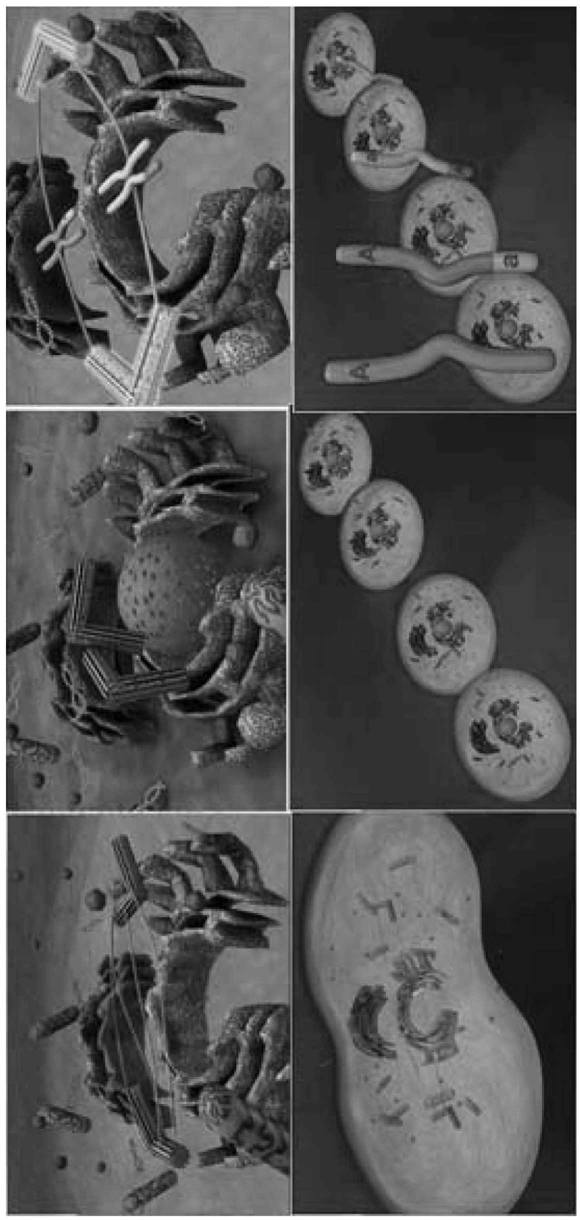

Figure 1. The multimedia content screenshots.

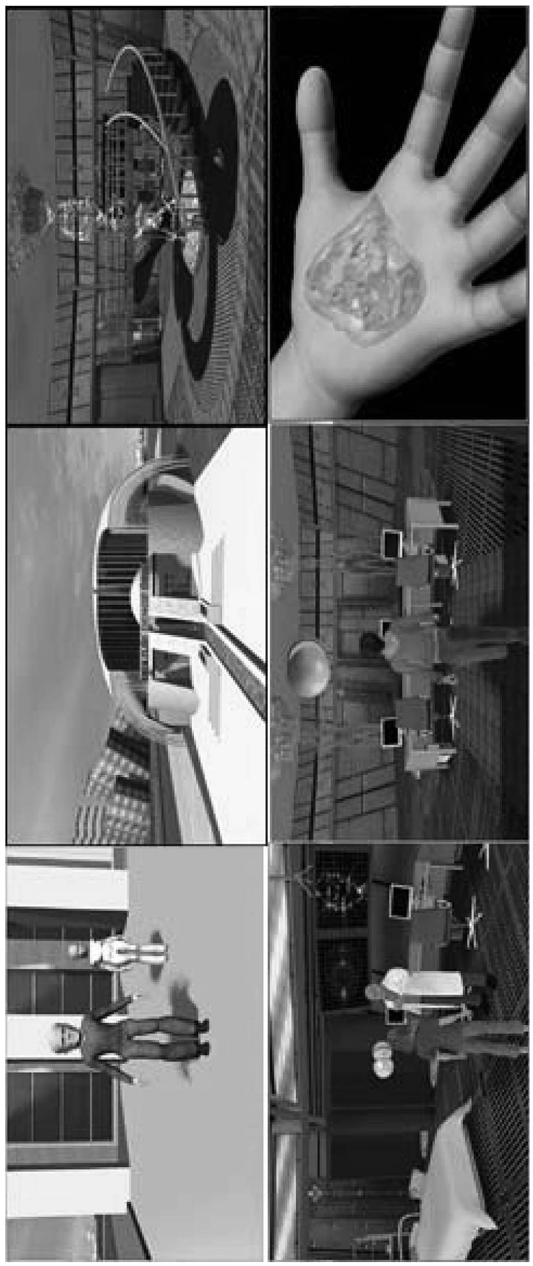

Figure 2. Goal based scenario screenshots.

Table 1. The Design Issues in the First (+CLT) and the Second (–CLT) Versions

	GBSc2DM versions	
Principles	First version (+CLT)	Second version (–CLT)
Split attention	The explanation for each button (mitosis, meiosis, library and help) on the main screen was placed next to the related button.	The explanation for each button (mitosis, meiosis, library and help) on the main screen placed at the lower side of the screen.
	Each hyperlink was opened in the same window in the library.	Each hyperlink in the library was opened in a different window in the second version.
Multimedia	Picture and text were presented together to order the main phase.	Only text was presented to order the main phase.
	Pictures and text were given together in the library design.	Text was given in the library design.
Modality	Whole 3D animation for mitosis and meiosis and all sub phases were given in audio format.	Whole 3D animation for mitosis and meiosis and all sub phases were given in text format.
Redundancy	Both text and narration were provided. The choice for switching off the text or the audio explanations was given.	Text was given with the animation. No narration and switch off options were given. Since background music was incorporated, the audio explanation was excluded.
Coherence	Irrelevant background music was eliminated.	Irrelevant background music was incorporated.

Data Collection

Subjective Rating Scale

"Subjective Rating Scale" adapted from Paas and Van Merriënboer (1993), was used to measure participants' mental effort spent in GBSc3DM. Learners expressed their cognitive load through one-itemed 9-point mental effort rating scale ranging from 1 (very, very low mental effort) to 9 (very, very high mental effort). Subjective rating scale measurement is considered as the "most promising technique for research in the context of cognitive load" (Sweller et al., 1998, p. 268). In addition, the subjective rating scales are "sensitive to relatively small differences in cognitive load and they are valid, reliable, and unintrusive" (Paas et al., 2003, p. 66). The content validity of the instrument was tested through expert opinion, and its reliability was found to be 0.78 (Cronbach's alpha) by Kilic and Karadeniz (2004).

Reflective Journals

In addition to the subjective rating scale, reflective journals were used to understand learners' opinions about how they were affected by the cognitive load principles used in GBSc3DM. It is accepted that in-depth investigation helps researchers gain a better understanding of how students are actually affected by the cognitive load (Stark, Mandl, Gruber, & Renkl, 2002). The software included two units, mitosis and meiosis, on cell division processes. At the end of each unit, students were required to write reflective journals about their experiences on using GBSc3DM. There were five questions which were developed based on the literature in reflective journals. The purpose of these questions was to explore the learners' opinions about the design principles and instructional approach used in the software. The goal of the first three questions was to reveal the learners' opinions with regard to their roles, missions, learning goals, and learning with the multimedia software. The aim of the fourth question was to investigate the learners' opinions about learning through traditional classroom instruction and GBSc3DM. The last question was asked to explore the learners' opinions about whether there were design issues that make it more difficult or easier to focus their attention on while using GBSc3DM.

Interviews

Semi-structured interviews were conducted to investigate the learners' opinions mainly on cognitive load principles applied in GBSc3DM. Out of 82, 27 students who provided detailed critiques in their reflective journals about the design of the multimedia were selected for the interview. The students were interviewed in three groups, and each group consisted of nine students. Each interview took about 20 minutes, and all groups were interviewed in the same place and on the same day. The reasons for preferring group interviews were that they allowed the interviewees to reflect on what the others in the group articulated, and then to build upon those mutual opinions. This method provided a basis for validation by quality control in data collection through multiple perspectives on the same issue. Lastly, group interviews were used to identify the strengths and weaknesses of the program (Patton, 1987). The interview protocol consisted of 10 questions. Two of the questions were asked to reveal the learners' opinions about learning with scenario and the learning environment.

The remaining eight questions were asked to explore the learners' motivation and satisfaction about the split attention, redundancy, modality, coherence, and multimedia principles used in the multimedia.

Procedures

Eighty-two 9th grade high school students (52 females and 30 males) participated in the study. Since there was a limited number of computers in the computer laboratory, the students were divided into four groups based on their course sections. Two groups were assigned to the first version (+CLT) and the other two groups were assigned to the second version (–CLT) of the multimedia software randomly. To arouse students' interests toward the topic, the biology teacher introduced the topic briefly through a PowerPoint presentation to all groups. During the first week, two groups used the first version (+CLT), and the other two groups used the second version (–CLT) of the multimedia software to learn mitosis in two class hours. To learn the meiosis during the second week, the order of the groups was changed so that each participant was exposed to both versions of the multimedia, and they could compare their experiences in both versions. The students who used the first version (+CLT) in the first week, used the second version (–CLT) in the second week, and the other two groups who used the second version (–CLT) in the first week, used the first version (+CLT) in the second week. At the end of each week, the subjective rating scale was administered individually to measure the level of perceived mental effort the students invested in the learning processes. Only 52 students' mental effort data could be recorded due to the technical problems faced in the first week. The students wrote reflective journals at the end of each week. Eighty-two reflective journals were gathered after each week's implementation. At the end of the study, group interviews were conducted.

Data Analysis

An independent sample *t*-test was conducted to find out the difference in cognitive load between the first (+CLT) and the second (–CLT) versions of the multimedia software. The data gathered through reflective journals and interviews were subjected to content analysis. The data of the reflective journals were analyzed immediately after implementing each unit to select the interview participants. To explore the relevant themes, the researchers focused on research questions and used deductive coding. Through the content analysis, main themes were determined and then the data were interpreted under these themes. In order to attain the interpretative validity, the original interview data, the reflective journals data, and all the interpretations were reviewed, and the conclusions drawn from this process were verified by the two researchers of the study.

RESULTS

Students' Opinions about Learning through GBSc3DM

The findings of the study revealed that a majority of the learners perceived GBSc3DM as an effective learning environment. More specifically, learning through mission, roles, and scenario made the learning more enjoyable and meaningful for the learners.

Among 82 students, 70 students were positive about learning with the *multimedia* software. Six students mentioned that they could learn in any learning environment. Two students stated that although it was a good experience to learn with the multimedia software, they preferred learning by writing. All of the students who had positive opinions conveyed that learning with the multimedia software made learning easier. They indicated that they were responsible for their own learning while using the software, and this made learning more meaningful for them. Some statements from students' responses in the reflective journals are as follows. One student stated, "Learning with the multimedia made learning more enjoyable, faster and long lasting." The other said, "I could easily lose my attention in the classroom, but it was not the case with the multimedia." Another student expressed, "I could visualize the process with the multimedia software, and so it made me understand the topic easily." One of the students expressed, "I spent so much effort to solve the problem and to complete the given task, so I had to learn the content. But, it is not the case for the lecture-based instruction, I just memorize the information."

Among the 82 students, 79 students expressed positive opinions about learning the content with *a mission and goals* in their reflective journals. Three students did not express any negative or positive opinion, and they stated that they could learn in any condition. The students having positive opinions expressed that learning the content with a *mission and goal* increased their interest toward the content. Most of them indicated that this forced them to be more ambitious to complete the given task. They also mentioned that learning the content with a *mission* makes the learning process more enjoyable and long lasting. One student stated, "While you have a mission, you feel that you have responsibility, and so you should learn better and do your best. In such a condition, you will learn better." Another student said, "You begin to do something to reach a goal. If I make a mistake, it does not make me sad, because I am aware of the fact that I learn something." The other student expressed, "Learning the content with a mission encouraged me to do the task, so this increases my ambition. I try to do my best to accomplish the task."

A "*scientist role*" was given to the students while they were using the multimedia software. Among 82 students, only three students expressed that the *role* was not important for them. Although most of the students had good impression with their *roles,* about half of them (40 students) expressed that the role was easy, and it would be better to allow them to define the role's characteristics before starting to use the multimedia. One of the students expressed: "The role gave me a sense of responsibility and made me ambitious to complete the given task." Another student stated: "The role was fun and exciting. It helped me understand the content easily. Being given the role of a scientist in the multimedia software increased my curiosity. When I finished the task, I was proud of myself, and I believed in my intelligence. In sum, giving roles is more instructive." Generally, they expressed that learning with *missions and roles* increased their motivation and encouraged them to achieve the given task.

The interview data supported the findings of the reflective journals in that all students expressed that learning with *scenario* was much better than lecture-based instruction. Learning through the scenario made the learning more meaningful for them. They also expressed that learning with scenario showed them why the content was important for them. This result showed us that the students were aware of why they were learning this content, and what the importance of the content was for the real life. One student stated, "The scenario was developed based on real life. So, I have learned why it is important for our life." Another student indicated, "It is the first time for me to understand why I need to learn mitosis and meiosis, and how it is important for our life." This finding is important. Understanding why the topic to be learned is important in real life settings is an important purpose of the goal-based scenario.

Students' Opinions about the Effects of Cognitive Load in GBSc3DM on Their Motivation and Satisfaction

The findings showed that the cognitive load theory principles (split attention, multimedia, modality, redundancy, and coherence) implemented in the first version (+CLT) of GBSc3DM contributed to most students' motivation and satisfaction in positive ways. However, not considering the cognitive load theory principles in the second version (–CLT) of GBSc3DM affected learners' motivation and satisfaction negatively.

In their reflective journals, the students were asked to articulate their opinions about the multimedia design whether there were design issues that made it more difficult or easier to focus while learning from the multimedia. They were also asked to express their thoughts and feelings about the multimedia. Only 47 students answered this question in a detailed way in their reflective journals. The students expressed positive opinions about the first version (+CLT) of the multimedia. One of the students stated: "*Narration* made it easy for me to understand the topic, because it made it easier to involve in the learning process. So, I could adapt easily, and then everything went on automatically." Another student stated: "The only thing that helped me focus was the *narration.*" The students' opinions with regard to the second version (–CLT) were different. One of the students expressed, "I could not focus my attention on because of the *classical music* in the background of the program. However, the animations made it easier for me to focus on." The other students who were exposed to second version (–CLT) of the multimedia to learn meioses indicated: "I believe that meioses should be designed as mitosis. The animations should be narrated, because narration made the learning easier." Although students expressed that using animation in both versions was very beneficial for them, they stated that violating modality and coherence principles made it difficult for them to learn from the multimedia, and decreased their motivation.

The students mostly expressed their satisfaction and motivation on the modality and coherence principles in their reflective journals. However, it was not possible to draw a conclusion from reflective journals about other principles applied in the multimedia software. Therefore, the data gathered through the interviews were used to draw the following findings for the other principles.

The students had to sequence the main phases in mitosis and meiosis. In the first version (+CLT), both pictures and text were given to students, In the second version, however, only the text was presented. With regard to the multimedia principle, 14 students stated that they would prefer to use "the text-only condition" while 8 students indicated that they preferred pictures. Five students mentioned that the text and picture formats together were convenient for them. They expressed that they were engaged in learning deeply when visuals and text are involved. This increased their interest towards the material. One student mentioned: "When I worked with the pictures, I invested more effort to understand." They expressed, however, that if they knew the content, working with the text only condition would be more beneficial for them. One student indicated: "If I know the content, I do not need to look at the pictures to sequence the phases in the correct order."

The multimedia principle was applied in the design of the library, as well. Although most of the students expressed their opinion about the design of sequencing the main phases, only some students who used the library expressed their opinions about the *multimedia principle* applied in the design of the library. In the library design of the second version (–CLT), each hyperlink appeared on a new window. Nine students expressed that this feature, which is called *split attention*, hurt their motivation and attention. This made the learning process more stressful for them. So it affected their satisfaction of the multimedia negatively. One of the students indicated: "When a new page was opened each time on the screen, it made the process stressful for me, and seeing the information on the same page would be more beneficial."

In regard to *redundancy*, the choice was given to the students for both subtitle and audio narration in the design of the first version (+CLT). They could select one of them or use both. However, in the second version (–CLT), there were only subtitles and background music without choice. For the first version (+CLT), 11 students stated that they followed only audio narration and ignored the subtitles. One of the students expressed: “The audio narration was enough for me to understand the animation. The tone of the voice used was very good, so I could easily focus on the content.” Two of them stated that both reading subtitles and hearing voice made it difficult for them to understand the content so they preferred only the narration condition. Eight students preferred both subtitles and audio narration. Although students watched animation either with narration or with subtitles, all of them stated that narration was much more preferable for them, and it increased their motivation toward learning. For the second version (+CLT), one student stated: “My interest decreased while I learned meiosis. When I tried to read subtitles, I felt that I could not catch up with the content and this made it even more difficult for me to learn.”

Difference between the Learners’ Mental Effort Invested in the First and the Second Versions of GBSc3DM

For mitosis, the data were collected only from 52 participants because of the technical problems. Among those, 28 students used the first version (+CLT), and 24 students used the second version (–CLT) of the multimedia. An independent sample *t*-test was conducted to compare the mental effort spent for the first (+CLT) and the second (–CLT) versions. The results of the independent sample *t*-test assuming equal variance (p = .09 larger than .05) showed that there was a significant mean difference between the mental efforts spent for the first (M = 3.85, SD = 1.67) and for the second (M = 5.20, SD = 1.55) versions. The magnitude of the difference in the means was large (Cohen d = .83). The result is presented in Table 2.

For meiosis, the data were collected from 76 participants. Thirty-seven students used the first version, and 39 students used the second version of the multimedia. An independent sample *t*-test was conducted to compare the mental effort spent for the first (+CLT) and the second (–CLT) versions. Even though the mental effort invested in the second version was higher than that invested in the first version, the result of independent sample *t*-test assuming equal variance (p = .3

Table 2. Students’ Mental Efforts for Two Versions of the GBSc3DM for Mitosis

	Version	*N*	Mean	*SD*	T	*Df*	Effect size	*p*
Mental	I (+CLT)	28	3.85	1.67	2.996	50	.83	.004
Effort	II (–CLT)	24	5.20	1.55				

Note: Effect size is Cohen *d*.

Table 3. Students' Mental Efforts for Two Versions of the GBSc3DM for Meiosis

	Version	*N*	Mean	*SD*	T	*Df*	Effect size	*p*
Mental	I (+CLT)	37	3.64	1.76	1.823	74	.39	.072
Effort	II (–CLT)	39	4.35	1.83				

Note: Effect size is Cohen *d*.

larger than .05) showed that there was not a significant mean difference between the mental efforts spent for the first (*M* = 3.64, *SD* = 1.76), and for the second (*M* = 4.35, *SD* = 1.83) versions. The magnitude of the difference between the means was medium (Cohen *d* = .39). The result is presented in Table 3.

DISCUSSION AND CONCLUSION

The findings showed that GBS was perceived as an effective approach for designing a multimedia learning environment. Most of the students revealed that GBS motivated them to finish the task. Some stated that learning with a mission forced them to finish the multimedia, which is the result of extrinsic motivation. Similarly, Schaller et al. (2001) found that GBS provided extrinsic motivation for uninterested, but potential learners. This is the case, especially when the appeal of the program is increased by narratives, games, simulations, and creative play activities. Although GBS provides extrinsic motivation for the students, the findings indicate that there is intrinsic motivation that comes from GBS. Some students mentioned that the scenarios gave them responsibilities. This made them intrinsically motivated to learn and achieve the mission. In line with this finding, Zumbach and Reimann (2002) found that the goal-based scenario increased intrinsic motivation of the students compared to tutorial and strategy group. It can be concluded that the goal-based scenario increased both intrinsic and extrinsic motivation of the students in this study.

Applying cognitive load theory principles in designing multimedia learning environment contributed to students' motivation and satisfaction in positive ways. Although GBSc3DM is considered as an effective instructional approach for most of the students, the students expressed that violating modality, coherence, and split attention principles in the second version (–CLT) affected their motivation and satisfaction negatively. However, Tabbers et al. (2004) did not find any difference in motivation between audio and text condition in multimedia presentation. The findings of meta-analysis about the modality effect on achievement conducted by Ginns (2005) indicated moderate to large average effect for more complex, system-paced instructional materials, but smaller average effects for self-paced or less complex instructional materials. The findings of the current study support the meta-analysis findings in that the two multimedia versions used in this study were self-paced, although the animations in both versions were system-paced. That is why the effects of the modality principle, which was applied in designing animation, were found between versions. Modality principle was considered only in the first version. As students indicated, that was one of the reasons why they were more satisfied and motivated with the first version of the multimedia.

The earlier research findings about multimedia principle showed that presenting both words and pictures are better for increasing learner understanding than presenting words alone (Mayer & Moreno, 2002). However, using multimedia and choice principles in the multimedia did not affect students' motivation and satisfaction much in this study. Some students indicated that pictures became redundant for them when their knowledge level increased. This finding might be explained by the expertise reversal effect which has been studied in CLT framework in that some instructional formats become ineffective when the learners' knowledge increases during the learning phase (Kalyuga et al., 2004). Another reason for this finding could be the characteristics of the students. The students were accepted to this school as a result of a very competitive exam. They are high achiever students. For those types of students, having multimedia principle after a certain number of trials may not contribute to their motivation and satisfaction. It can be concluded from this finding that using both pictures and text has been beneficial for the learners in terms of increasing their interest, and engaging them in deep learning. However, when the learners' knowledge level increases, the pictures may become redundant, and may not affect their interest towards learning with the multimedia.

Violating split attention principle affected the students' satisfaction negatively. In other words, students expressed that it was stressful for them when each page was opened in a new window. This matches many other similar studies. For example, when links in on-screen reference appear in second browser windows that feature the related information it impedes the learning process (Clark & Mayer, 2003). The findings of this study indicate that this may also affect the learners' satisfaction in negative ways.

It can be inferred from the findings that applying principles that reduce extraneous cognitive load for the first version (+CLT) resulted in lower mental effort compared to the second version (–CLT). This finding might be explained by the expertise reversal effect (Kalyuga et al., 2004) as indicated above. Mitosis and meiosis are two sub-units of cell division process and mitosis was given before the meiosis in biology textbooks and school curriculum. Although mitosis is not a prerequisite content that needs to be learned before meiosis, mitosis was given to the students before meiosis in line with the biology curriculum. However, there are some similarities between the mitosis and meiosis process;

hence, it can be inferred that having learned mitosis, the students' knowledge level was increased and that might have eliminated the benefits of instructional formats reducing extraneous cognitive load for meiosis which was found during mitosis. Combining qualitative data with the quantitative, it can also be inferred that applying cognitive load principles increased the participants' motivation and satisfaction. This alleviated the amount of mental load imposed by the learning processes.

This study attempted to reveal how the learners' motivation, satisfaction, and invested mental effort were affected by two different versions of GBS centered multimedia which were designed with CLT principles and without CLT principles. Even though the findings of this study cannot be generalized, it can be concluded that applying CLT principles that reduce extraneous cognitive load resulted in lower mental efforts for the first version of the multimedia compared to the second version. It can be inferred from the findings of the qualitative data that even though the instructional approach (GBS) used in the multimedia increased students' motivation and satisfaction, when extraneous cognitive load principles were not implemented in the design, it reduces students' motivation for and satisfaction of the multimedia learning environment.

Paas et al. (2005) stated that motivation, mental effort, and performance are positively related. They pointed out that the relationship between motivation and mental effort can be further investigated by task involvement equation. As pointed out by Corbalan (2008), the mental effort is used as a general concept in task involvement, and there is no distinction between the invested mental effort of extraneous, intrinsic, and germane load. Germane load was used as a mental effort in adaptive learning system and produces significant results in terms of task involvement (Corbalan, Kester, & Van Merriënboer, 2008). Therefore, more research should be conducted to find out more comprehensive findings on the relationships between motivation, task involvement, performance, and mental efforts resulting from different cognitive load for different instructional conditions. It is also suggested that experimental findings should be supported by qualitative data to validate and optimize the findings in depth.

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