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Participatory multimedia learning: Engaging learners

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The purpose of this paper is to present a participatory multimedia learning model for use in designing multimedia learning environments that support an active learning process, creative participation, and learner engagement. Participatory multimedia learning can be defined as learning with systems that enable learners to produce part of the learning materials themselves. The aim of the model is to represent the human information processing system more exhaustively than its predecessor, the cognitive theory of multimedia learning, and to support the transformation of free cognitive resources into a germane cognitive load needed for knowledge construction. Flow theory is used as a framework to facilitate positive user experience and engagement in order to maximise the impact of digital learning environments. The proposed model is studied through an educational game, *IT-Emperor*. In this game university level students (n = 18) worked in a virtual production company as trainees who were hired to produce learning material about usability. The focus of this paper is on studying the usefulness of participatory multimedia learning tasks included in *IT-Emperor* and factors that have an influence on flow experience. Questionnaires and interviews revealed that content creation was reported as the main activity causing flow. Additionally, a positive connection between flow and learning was found. Although these results support the proposed model, more research on the topic is recommended.

1. Introduction

One of the challenges of designing digital learning materials is that of engaging students. Hosting a web based course should not be only about providing information but also about facilitating students' experiences. Unfortunately, it seems that the web is used mainly as an information distribution channel that is controversial to ideas of constructivism. According to constructivists, individuals make sense of their world by constructing their own representations of their experiences (Tytler, 2002). Unfortunately, technologies are too often used as substitute teachers that deliver information to learners rather than as learning tools that support the active learning process. This also applies to multimedia environments that are usually passive and offer only limited capability for learners to be creative. According to Shneiderman (2003), we have to do more than teach learners to surf the Net. We have to encourage learners to be creative and teach them to make the waves for surfing. According to Jonassen, Peck & Wilson (1999), technologies can support the construing of meaning by learners, but this can happen only if learners learn with technology, not from it. In fact, learning sessions that lead to satisfying and concrete outcomes become engaging and effective (Mitchell, Andreatta & Capella, 2004).

The purpose of this paper is to present a participatory multimedia learning model for use in designing multimedia learning environments that support an active learning process, creative participation, and learner engagement. Participatory multimedia learning can be defined as learning with systems that enable learners to produce part of the learning materials. The aim of the model is to represent the human information processing system more exhaustively than its predecessor, the cognitive theory of multimedia learning (Mayer, 2001), and to support the transformation of free cognitive resources into the germane cognitive load needed for knowledge construction. Flow theory (Csikszentmihalyi, 1991) is used as a framework to facilitate positive user experience in order to maximise the impact of digital learning environments. Finally, the usefulness of the model is studied through an educational game, *IT-Emperor*. The focus of this study is in examining the effectiveness of student generated learning materials, ie. participatory multimedia learning tasks.

2. A theoretical basis for the participatory multimedia learning model

In recent years, a number of models and theories have been developed that concern multimedia learning and the principles of learning from different modes of presenting information. The most relevant theories on the design of multimedia environments are the cognitive theory of multimedia learning (Mayer, 2001) and the cognitive load theory (Sweller, 1988). These theories are partly redundant and rely on human cognitive architecture that provides a promising source of research hypotheses associated with instructional design principles. This section reviews relevant aspects of multimedia and instructional design literature that have been generated by the cognitive theory of multimedia learning and the cognitive load theory, in order to generate a participatory multimedia learning model. It begins with a brief discussion of flow theory before turning to an overview of human cognitive architecture and theories concerning multimedia learning.

2.1 Flow theory

Csikszentmihalyi (1975) introduced the *flow* state through the study of people involved in activities such as rock climbing, chess and dance. Flow describes a state of complete absorption or engagement in an activity and refers to the optimal experience (Csikszentmihalyi, 1991). During optimal experience, a person is in a psychological state where he or she is so involved with the goal driven activity that nothing else seems to matter. Past research has shown that the flow state has positive impact on learning (Webster, Trevino & Ryan, 1993) and should be taken into account when designing digital learning materials.

The original flow activities, such as rock climbing, diverge from activities performed with computers. Thus, Finneran & Zhang (2003) have argued that an activity performed in computer mediated environments needs to be broken down into the main task and the artifact used to accomplish the activity. Artifact is a broad term that covers both tools and toys. It is apparent that the mastering of complex artifacts cannot be taken for granted. Furthermore, Finneran & Zhang (2003) have proposed a person-artifact-task (PAT) model that conceptualises the major components of a person working on a computer related activity. According to the model, the likelihood of experience flow is dependent on the interplay between the person, the task and the artifact. The main contribution of the PAT model to flow theory is to provide a means to consider what really influences experiencing flow: the task itself, the use of artifacts, or individual differences.

In computer mediated flow studies, the following stages related to flow are distinguished: flow antecedents, flow experience and flow consequences (Hoffman & Novak, 1996; Chen, Wigand & Nilan, 1999; Finneran & Zhang, 2003; Skadberg & Kimmel, 2004; Webster et al., 1993). In Figure 1 a framework of flow in computer mediated environments is presented (Kiili, 2005). The framework comprises the factors of each stage of flow and the components of the PAT model. All three components, person, task and artifact, should be taken into account when designing digital learning materials. Generally, the aim of a learning material is to provide students with challenges related to the main task so that flow experience is possible. When both the task and the use of the artifact are complex, then the artifact and the task may detract from the user's attention (Pearce & Howard, 2004). Bad usability decreases the likelihood of experiencing task based flow, because the user has to sacrifice attention and other cognitive resources to inappropriate activity. Because the information processing capacity of working memory is limited (Miller, 1956), all possible resources should be available for relevant information processing rather than for the usage of the artifacts. In an ideal situation artifacts are transparent and allow the user to focus on the higher order tasks.

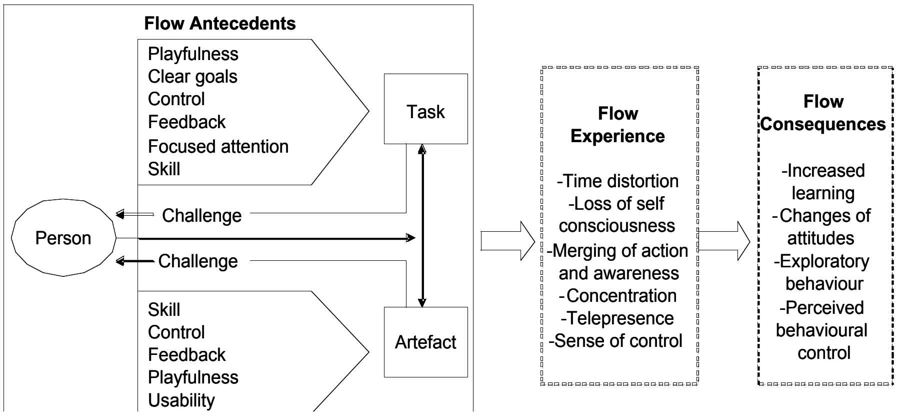

Figure 1: Framework of flow in computer mediated environments

A user's prior knowledge and experiences affect how the user experiences and perceives a learning material. If the system can offer a user such challenges that are in correspondence with his or her skills, the possibility of experiencing flow is higher. It is important that the challenge that a user faces is closely matched to the skill level of the learner. If the challenge is significantly greater than user's skill level, he or she may feel anxiety. In contrast, if the challenge is significantly lower than user's skill level, the user may feel bored. In order to keep a user in flow state, designers of learning materials should ensure that as a learner's skill level increases, the challenges also should become more difficult.

2.2 Human cognitive architecture

This section discusses some aspects of human cognitive architecture relevant to multimedia design. Generally, human cognitive architecture can be divided into sensory memory, working memory and long term memory (Baddeley, 1990). Mental activity takes place in the working memory which is very limited in both capacity and duration (Carlson, Chandler & Sweller, 2003). According to Miller (1956), we can deal with no more than seven plus minus two elements of information at a time without overloading the information processing capacity and decreasing the effectiveness of processing. However, age related differences on processing capacity have been reported (Swanson, 1999). Baddeley (1998) has presented a three-component model of working memory, comprising an attentional control system, the central executive, and two slave systems.

One slave, the visuo-spatial sketchpad holds and manipulates visual information and the other, the phonological loop, deals with auditory and speech based information. The promise of multimedia learning rises from the assumption that in certain conditions, the working memory capacity may be increased by the use of both slave processors simultaneously rather than by a single, working memory processor (Mousavi & Sweller, 1995; Sweller, van Merrienboer & Paas, 1998). Inappropriate design of instructional material prevents successful processing in the working memory, and therefore hinders learning and understanding. Thus, limited working memory may be the most critical factor that needs to be considered in instructional design (Carlson, Chandler & Sweller, 2003).

Limited working memory can be contrasted with extensive long term memory which stores information that is successfully processed through working memory. The knowledge structures that form long term memory are often referred to as hierarchically organised schemata (Gick & Holyoak, 1983; Winn, 2004; Kalyuga, Ayres, Chandler & Sweller, 2003). Schemata can be defined as general knowledge structures that encapsulate numerous elements of information into a single element (Carlson et al, 2003). According to the schema theory, our knowledge of the world is constantly interpreting new experiences and adapting to them. Skilled performance develops through constructing an increasing number of ever more complex schemata by combining lower level schemata into higher level schemata (Sweller, 1994). Usually, this acquisition of schemata is the constructive process.

Automation plays an important role in the construction of schemata. Information can be processed either consciously or automatically (Winn, 2004). Conscious processing, occurring in working memory, requires conscious effort, but automatic processing mainly bypasses working memory. Automatic processing may occur after sufficient practice and can be carried out with minimal working memory load (Sweller, et al., 1998). For example, experienced chess players can move chessmen without conscious processing of how each chessman can be moved. In fact, long term memory provides the basis for human intellectual skill (Sweller & Chandler, 1994). Research has shown that experts are better able to recognise and reproduce briefly seen problem situations than novices (Sweller, 1994; Kalyuga et al, 2003). This can be explained with the schema theory. Experts have an enormous number of domain specific schemata that allow them to categorise multiple elements of related information as a single, higher level element. The processing of high level elements in working memory requires less working memory capacity than many lower level elements that it incorporates, thus reducing the burden on working memory. In addition, the ability of experts to bypass working memory limits by automated schemata also reduces the burden on working memory, freeing up cognitive resources to bear on novel problems and experiences. Thus, schema acquisition and transfer from controlled to automatic processing are major learning mechanisms (Carlson et al., 2003) that should be supported by instructional design.

2.3 Multimedia learning

It seems that the main problem of multimedia learning materials is that the working memory capacity of learners is often overloaded due to inappropriate ways of presentation. To overcome this problem, Mayer (2001) has presented a cognitive theory of multimedia learning that is mainly based on the cognitive architecture presented in the previous section. The cognitive theory of multimedia learning assumes that working memory includes dual channels for visual and auditory (verbal) processing, that each channel has a limited capacity for processing, and that active learning entails carrying out a set of cognitive processes. The limited capacity assumption refers to cognitive load theory, stressing that working memory capacity limits the amount of information that can be processed in each channel at one time (Tindall-Ford, Chandler & Sweller, 1997; Sweller, 1994). Working memory capacity may be increased by the use of both channels simultaneously. According to the active learning assumption, humans actively engage in cognitive processes in order to construct schemata of their experiences. A learner has an active role in learning and can generate relationships between different elements in the environment or between information and the learner's prior knowledge (Wittrock, 1990). The essential processes for active learning are selecting relevant material, organising selected material, and integrating selected material with prior knowledge (Mayer, 2001).

According to the cognitive theory of multimedia learning (Mayer, 2001), the selection process occurs while a learner pays attention to appropriate information in the learning material. First, a learner selects relevant verbal and visual information and then constructs an image and a text base of them. Secondly, the learner organises this information into a coherent model both verbally and visually. The learner mentally builds connections that organise the words and images into a cause and effect chain. Thirdly, the learner integrates constructed representations, by creating connections between corresponding verbal and visual information along with relevant prior knowledge. This integration process can be successful only if the corresponding verbal information is held in the verbal working memory at the same time as the visual information is held in the visual working memory. Because the integration of verbal and visual representations requires cognitive resources, the learner's capacity for the cognitive system sets limits for the integration process. (Plass, Chun, Mayer & Leutner, 2003; Mayer & Moreno, 2002.) Meaningful learning can be achieved if learning material consists of such visual and verbal information that can be connected and integrated together with prior knowledge (Mayer, 2001).

Cognitive load theory (Sweller, 1994) is quite redundant with the cognitive theory of multimedia learning, but it offers some aspects that Mayer has not exhaustively elaborated. Cognitive load theory stresses the importance of the automation of schemata. Although the construction of schemata reduces cognitive load, automation offers a means to bypass working memory. In fact, due to the limited capacity of working memory (Miller, 1956), the main concern of cognitive load research has been on reducing the cognitive load on working memory in order to free resources for both the construction and automation of schemata. Mayer also stresses the importance of taking cognitive load into account in designing multimedia learning environments, but he does not fully elaborate the sources for it.

Sweller et al. (1998) identified three separate sources of cognitive load. Cognitive load may be affected by the intrinsic nature of the material (intrinsic cognitive load), the manner in which the material is presented (extraneous cognitive load), or the effort needed for the construction of schemata (germane cognitive load). Intrinsic cognitive load refers to the inherent nature of the task or the subject matter of the learning material. If the learning material consists of numerous elements that are related to one another, the intrinsic cognitive load is high. In contrast, if the material is simple, including only a few connections between elements, the intrinsic cognitive load is low. According to the cognitive load theory, instructional design cannot change the intrinsic cognitive load. Therefore the most important aspects of the cognitive load theory for multimedia designers are extraneous cognitive load and germane cognitive load.

Extraneous cognitive load is unnecessary cognitive load and is determined by the instructional design. If the learning material is poorly designed, the extraneous cognitive load is high because learners have to engage in irrelevant cognitive processing. Mayer has primarily examined different presentation formats in order to reduce the extraneous cognitive load of learning materials. However, the reduction of the extraneous cognitive load by an ideal instructional format does not guarantee that all free cognitive resources will be allocated to a deeper knowledge construction process (Bannert, 2002), as is the aim of Mayer. Thus, methods for imposing a germane cognitive load that is required for schema construction should be examined. Unused working memory capacity should be used by optimising the germane cognitive load, by stimulating the learner to process the learning material more deeply. According to Kirschner (2002), the approach of encouraging learners to engage in appropriate cognitive processing can work only if the total cognitive load of instructional design is within working memory limits. If a learner's cognitive system is overloaded, it might impact negatively on learning.

One problem of the cognitive theory of multimedia learning is the set of cognitive processes involved. How does the learner control selecting, organising, and integrating processes? Because of limited memory capacity, a learner has to select relevant images and words to be processed in working memory. Likewise a learner has to organise selected elements for coherent models, and finally activate knowledge in long term memory and bring it into working memory for integration process. Mayer does not offer any account as to how these processes take place and how they are controlled. One solution is to explain the regulation of working memory resources with Baddeley's (1990) central executive, which is responsible for the selection, initiation, and termination of processing routines.

In summary, the cognitive theory of multimedia learning offers a framework for designing multimedia materials. However, it concentrates on techniques for minimising an extraneous cognitive load rather than supporting ways to optimise free resources by imposing a germane cognitive load required for schema construction. Furthermore, the theory lacks an account for the cognitive processes included. In the next section I present a participatory multimedia learning model that takes into account these aspects that Mayer has neglected.

3. Participatory multimedia learning model

Before presenting the participatory multimedia learning model, I review some empirical proofs of the usefulness of the participative role of learners in multimedia learning. Several studies have shown that challenging learners as designers or producers of learning materials may increase the learners' understanding of subject matter (Stern, Aprea & Ebner, 2003; Kafai, Ching & Marshall, 1997; Mitchell, Andreatta & Capella, 2004; Hall Bailey & Tillman, 1997). The role of learners varies widely in these studies, but in some sense the participants of each study actively produced at least part of the learning materials. For example, the study by Mitchell et al. (2004) showed that the use of student generated multimedia products worked as a good pedagogical strategy to encourage learners to think more deeply about academic content, resulting in a deeper understanding and a higher level of student engagement. On the other hand, Stern et al (2003) found out that the active creation of a graphical representation based on text information was a powerful transfer tool. The findings by Hall et al (1997) are similar. Results showed that students who generated their own illustrations from written text performed better on a problem solving test than students who learned from using only text material. In summary, the results of these studies indicate that while constructing materials, learners may became more aware of representational elements and their relationships, leading to more elaborate and better organised knowledge structures.

A review of the literature indicates that there is a need for further developing the cognitive theory of multimedia learning. I venture a step forward by presenting a participatory multimedia learning model. In this paper, participatory multimedia learning is defined as learning with systems that enable learners to produce part of the learning materials. The aim of the model is to represent the human information processing system and to support the transformation of free cognitive resources into a germane cognitive load needed for schema construction. Furthermore, the model stresses the importance of considering the factors that contribute to flow experience (Csikszentmihalyi, 1975) in order to engage learners. The participatory multimedia learning model (see Figure 2) is based on Mayer's cognitive theory of multimedia learning, cognitive load theory, flow theory and experiential learning theory. The model consists of multimedia learning and active participation layers. Although these layers are separated in the model, the processes of both layers are bound to each other.

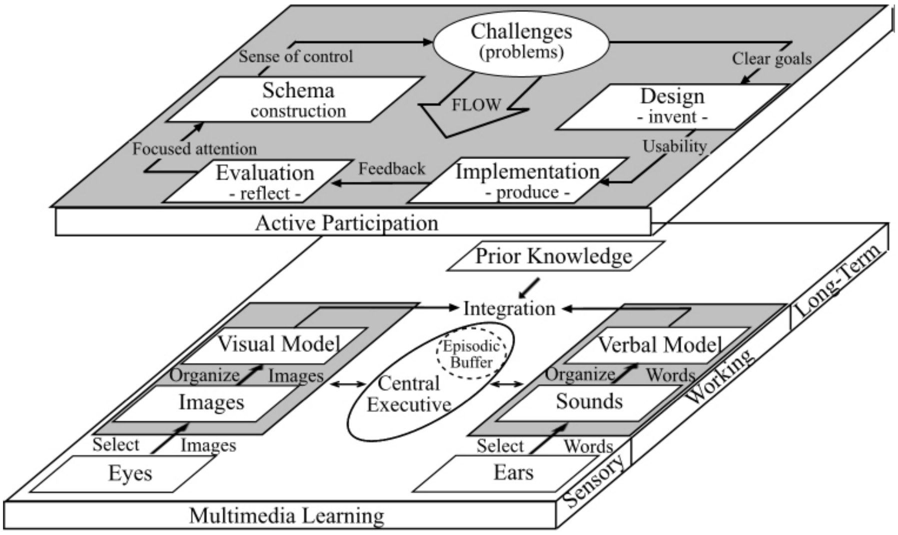

Figure 2: A participatory multimedia learning model

3.1 Multimedia learning layer

The multimedia learning layer aims to represent the human information processing system and offers a means to reduce the extraneous cognitive load in learning materials (see design principles in Mayer, 2001). The multimedia learning layer includes a revised version of the cognitive theory of multimedia learning, assuming that the human information processing system includes channels for visual/ pictorial and auditory/ verbal information processing. I have added a central executive and its multidimensional storage system along with the episodic buffer (Baddeley, 2003) into the model. These components of working memory control the use of cognitive resources and provide an account for cognitive processes included in the multimedia learning layer. Although the executive components of working memory control the use of cognitive resources, schemata stored in long term memory play an important role in the knowledge acquisition process. In fact, Neisser's (1976) perceptual cycle describes how our prior knowledge directs the way we seek information; the way we seek information determines what information we get, and finally the information received affects our knowledge. This means, according to Winn (2004), that the whole knowledge acquisition process including selecting, organising, and integrating is centered on the person, not the environment.

However, the most important process of the multimedia learning layer is integration. Firstly, an integrated representation is formed by mapping corresponding visual and verbal models onto the each other. An episodic buffer is responsible for binding information from different sources together and provides a way of combining information from different modalities into a single multi-faceted code (Baddeley, 2003). Secondly, the representation formed can be integrated into prior knowledge. This integration process refers to schema construction and can be explained in terms of Piaget (1950; 1953). According to Piaget, our knowledge is constantly interpreting new experiences and adapting to them. This is possible via assimilation and accommodation processes. If the features and structure of new experience match a schema in our long term memory, we assimilate the experience. However, if there is no match, we have to accommodate the schema to experience. Thus, learning takes place as schemata change due to interaction with new information in the environment.

3.2 Active participation layer

The active participation layer aims to impose the germane cognitive load associated with knowledge construction. The layer stresses the significance of learning through direct experience, contrasted with learning through instruction. According to Kolb (1984), immediate personal experience is the focal point for learning. Generally, learners are challenged to construct and reflect knowledge instead of reproducing what others have represented. The processes of the active participation layer are derived from the learning cycle of management situations (Isaacs & Senge, 1992) and an experiential gaming model (Kiili, 2005). The layer describes learning as a cyclic process through direct experience in the digital learning environment. Both constructivist (Phillips, 1995) and pragmatist (Kivinen & Ristelä, 2003) views of learning are adopted. The layer stresses that activity that is necessary for learning is not merely cognitive but also behavioural. Thus, learning is defined as a construction of cognitive structures through action in the digital learning environment.

The challenges based on educational objectives form the heart of the layer. The task of the heart is to sustain the motivation and engagement of the learners by pumping appropriate challenges to them. The goals of the challenges should be clear and matched to the learner's skill level. To overcome the challenges, a learner generates and designs solutions. After the design phase, the learner implements solutions in action, and evaluates the outcomes of implementation. It is important that the learning environment is usable in order to guarantee that learners can focus their attention on higher order tasks. The reflective evaluation of the feedback may lead to the construction of schemata. If this learning cycle operates effectively, new insights about subject matter will be discovered continually and improved schemata will be constructed. Because of the cyclic nature, new design decisions are invented on the basis of new schemata. Invented decisions are implemented and the outcomes are reflected, in order to produce new insights. Thus, while undertaking these processes learners may became more aware of the concepts of subject matter and their relationships, leading to more elaborate and better organised knowledge structures. Additionally, the cyclic nature of the learning process supports schema automation.

From a motivation and learning point of view, the operation of the heart is essential. The heart should provide learners with challenges that are matched to their skill levels in order to increase the likelihood of experience flow (Csikszentmihalyi, 1991). If the challenge is significantly greater than a learner's skill level, he or she may feel anxiety. In contrast, if the challenge is significantly lower than learners' skill levels, they may feel bored. In order to keep a learner in a flow state, we should ensure that while a learner's skill level increases the challenges also should become more difficult. In addition to appropriate challenges, the flow antecedents - clear goals, good usability, appropriate feedback, focused attention and sense of control - should be considered while designing participatory multimedia learning environments. Designing for flow is justified because previous research (Webster et al, 1993; Csikszentmihalyi, 1991; Skadberg & Kimmel, 2004) has indicated that flow has a positive impact on learning and learners' attitudes.

4. Research method and objectives

The purpose of the present study was to test the following hypothesis derived from the participatory multimedia learning model:

A. Participatory multimedia learning is a useful learning method that engages learners. This hypothesis is based on the assumption that while constructing materials, learners may become more aware of representational elements and their relationships, leading to more elaborate and better organised knowledge structures.

B. Flow experience has a positive connection with participatory multimedia learning. This assumption is based on findings of previous studies arguing that flow has a positive impact on learning (Webster et al, 1993; Skadberg & Kimmel, 2004).

4.1 Description of used learning environment

Participatory multimedia learning tasks were studied through an educational game named *IT-Emperor* (Kiili & Ojansuu, 2005). IT-Emperor is a web based game (Figure 3) in which university level students work in a virtual production company as trainees. The content of the game reflects the problems and issues that may arise in a production company. In the game, players are hired to produce learning material about usability. At the beginning of the game, each student has original, poorly designed, learning materials about usability. The original material is an unfinished output by a former employee who has been fired from the company. In order to support schema construction, the original material was designed to be isomorphic to the putative structures of the student's schemata (Winn, 2004). However, the main purpose of the original material was to activate schemata in order to provide a relevant context and prerequisites for the production of learning materials. This activation idea is quite parallel with Gagne, Briggs & Wager's (1988) instructional event, "stimulating recall of prerequisite learning".

The original material has been divided into 30 content components that can be considered as learning objects about contextual design, navigation, and information processing. Additionally, four design tasks are included. In the game students can either replace the original components with self made components, or buy from the marketplace components that other students have made, if they have enough credits available. Generally, the aim of the players is to produce learning material that is as good as possible, and at the same time earn money in the marketplace. Studying presence is supported by allowing players to produce components collaboratively and by offering a discussion area for players. Success in the component market and evaluation reports of the company's boss provide a meaningful feedback channel for the players. The outcomes of the usability project, learning material and a banking balance are used to decide what kind of job the trainee will achieve in the company.

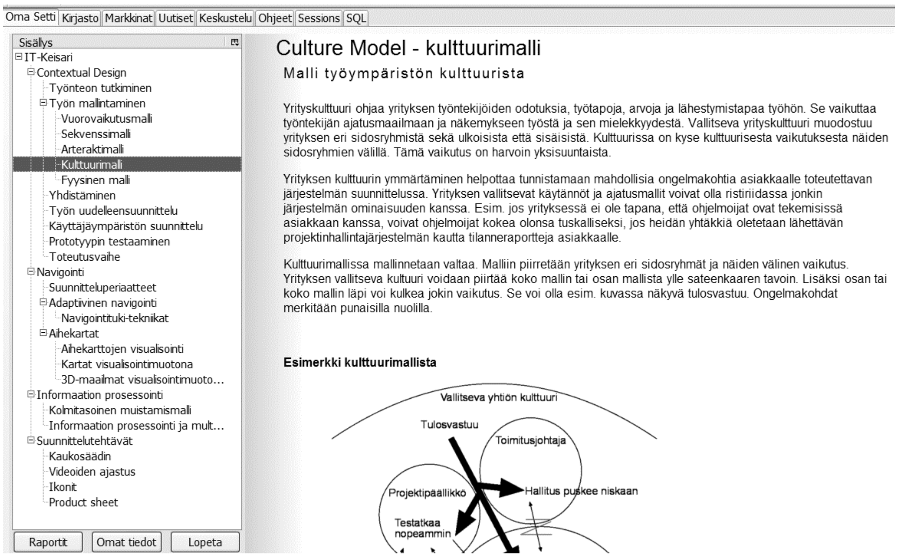

Figure 3: A screenshot of IT-Emperor

4.2 Participants

The participants were eighteen Finnish university students who had enrolled in a usability course. Most of the participants were students of Tampere University of Technology, but there were also one student from Turku School of Economics and Business Administration and two students from Open University. All participants had used the web for over five years and reported using the web daily. Fifteen of the participants were males. None of the participants had studied usability before this course or participated in courses that included an educational game.

4.3 Procedure and data collection

The intervention started with an introduction section dealing with the idea as well as the user interface of IT-Emperor. The game lasted over two months and required approximately 30 hours to complete. In order to stabilise the progress of the game, it was divided into three phases that reflected status reports used in software projects. Players had to produce and buy components for a certain amount in each phase. From status reports the game author could follow players' progress in the game. Deadlines for each phase guaranteed that actions performed were settled steadily within a two month time interval. Without these deadlines the actions performed would probably have been taken during the last weeks of the game.

The data was collected in three stages. All game activities were observed virtually and recorded on web logs. When the game was finished a student's knowledge level was measured with a post-test (n = 15) that was implemented as an exam. Post-test consisted of lecture, game and flow questions. The first essay question was a control question that measured knowledge that was presented in lectures and was included in the exam material. The second essay question measured knowledge that was needed to complete the game. In other words, the question measured knowledge about components that players had created during the playing session. Additionally, the following description of flow (Novak, Hoffman & Yung, 2000) and two questions measuring flow were included in the exam:

> Description of flow: "The word flow is used to describe a state of mind sometimes experienced by people who are deeply involved in some activity. One example of flow is the case where a professional athlete is playing exceptionally well and achieves a state of mind where nothing else matters but the game; they are completely and totally immersed in it. The experience is not exclusive to athletics – many people report this state of mind when playing games, when engaging in hobbies, or working. Activities that lead to flow completely captivate a person for some period of time. When in flow, time may seem to stand still and nothing else seems to matter. Flow may not last for a long time on any particular occasion, but it may come and go over time. Flow has been described as an intrinsically enjoyable experience."
>
> Thinking about your own use of IT-Emperor and related activities:
>
> A. Do you think you experienced flow while playing IT-Emperor?
> B. What were the activities that caused a flow experience?

Players' perceptions about experiencing flow while playing IT-Emperor were categorised into three classes; 2) strong flow experience, 1) medium flow experience and 0) no flow experience. These categories are used to study the connection between flow and learning.

Finally, the participants (n = 12) were interviewed in groups of 1-4 participants. Semi-structured interviews concentrating on usefulness of participatory multimedia learning tasks and flow experience were conducted. Participants were encouraged to talk about their opinions and experiences on the topics above. All interviews were recorded and coded using a *HyperResearch* program.

5 Results

5.1 Usefulness of participatory multimedia learning tasks

Players were engaged in creating content which is positive because players experienced content creation as an effective way to learn things. For example, player X stressed that the game was effective from a learning point of view:

> By creating content one can learn things without noticing it.

The results of the post-test supported this experience. Players performed significantly better on the game based task ($M = 4.6$, $SD = 0.706$) than on the control task ($M = 2.25$, $SD = 1.004$), $t(14) = -8.612$, $p<.001$. The participatory multimedia learning tasks worked as a good pedagogical strategy to encourage players to think more deeply about the subject matter. While creating content components, players had to organise information and make connections between concepts leading to more elaborate and better organised knowledge structures. This result is consistent with a participatory multimedia learning model and the findings of earlier studies (Stern et al., 2003; Kafai et al, 1997; Mitchell et al., 2004). The following statement from player A reflects the level of players' engagement as producers of learning materials:

> The components in the market place are so trashy that I should make all content components myself, but I do not have enough resources for that.

Those players who felt the game was too laborious did not catch the whole idea of it. Generally, one aim of the game was to simulate a situation where the player is obligated to optimise all available resources in order to get the job done. Sometimes one has to make compromises and accept the best of the 'half baked' outputs available. Further, a trend, according to which of the produced components improved when the game proceeded, was found. As a conclusion these findings support hypothesis A arguing that participatory multimedia learning is an useful learning method that engages learners.

5.2 Flow experience and learning

This section starts with considering IT-Emperor in flow framework before focusing on the relationship between flow and learning. Although there was some confusion among players in the beginning of the game, the goals of the game were well understood. Players were satisfied with the feedback that the game provided, and in spite of some usability problems players stated that they could focus their attention on the game and concentrate on playing. Furthermore, most of the players felt that they could achieve control over IT-Emperor. Additionally, the interviews pointed out that the challenges that the game provided were appropriate and quite well matched to the players' skill levels. These results indicate that IT-Emperor provided such an environment for players that experiencing flow was possible. However, only 8 of the 15 players reported that they had experienced flow while playing IT-Emperor. Six players experienced strong flow experiences and 2 experienced medium flow experiences while playing the game. Content creation was reported as the main activity causing flow experience, but also action in the marketplace was reported as being a flow activity.

According to previous studies, flow tends to bring about learning (Webster et al, 1993; Skadberg & Kimmel, 2004). In order to test this proposition, the connection between a player's flow experience (2 strong, 1 medium, 0 none) and performance on the game based task (GBT, 1-6 points) was studied. This connection can be seen from distance weighted curves (Figure 4). Curve 1 indicates that the connection between flow and learning is weak. However, the player who got 6 points from the game based task is an outlier and distorts the curve. The outlier's attitude toward the game was very negative from the very beginning so there is a justification for removing this player from the analysis as an exception. Curve 2 shows the same relationship without the outlier. Curve 2 is ascending, which refers to a strong connection between flow and learning. The correlation between these variables was significant ($r = 0.552$; $p = 0.041$). Strong correlation supports hypothesis B and is consistent with results of previous studies, indicating that flow has a positive affect on learning. However, the sample in this study is so small that these results cannot be generalised for other groups of people. Hence, more research on this topic is required.

6. Conclusions

This paper presents a participatory multimedia learning model providing a means to design multimedia learning environments that support an active learning process, creative participation, and learner engagement. The model represents the human information processing system more exhaustively than its predecessor, a cognitive theory of multimedia learning (Mayer, 2001), by providing an account for cognitive processes included. Furthermore, the model does not concentrate only on reducing an extraneous cognitive load, but it also supports the transformation of free cognitive resources into a germane cognitive load needed for knowledge construction, by challenging learners as producers of learning materials. In addition, flow theory is used as a framework to motivate and engage learners. Appropriate feedback, clear goals, sense of control, good usability, and challenges that are matched to learner's skill level are stressed in particular. However, the model does not try to offer any exact way to arrange learning situations. Pedagogical solutions, except for the idea of learners as the producers of learning materials, are left open. Other pedagogical and technological questions are so context sensitive that it is not meaningful to embed them in the model. However, the following questions should be considered at the very least: what the role of the teacher is, what the state of collaboration is, what the state of learner control is, what programs are used, creating a classroom culture that supports participatory multimedia learning, and how feedback is delivered.

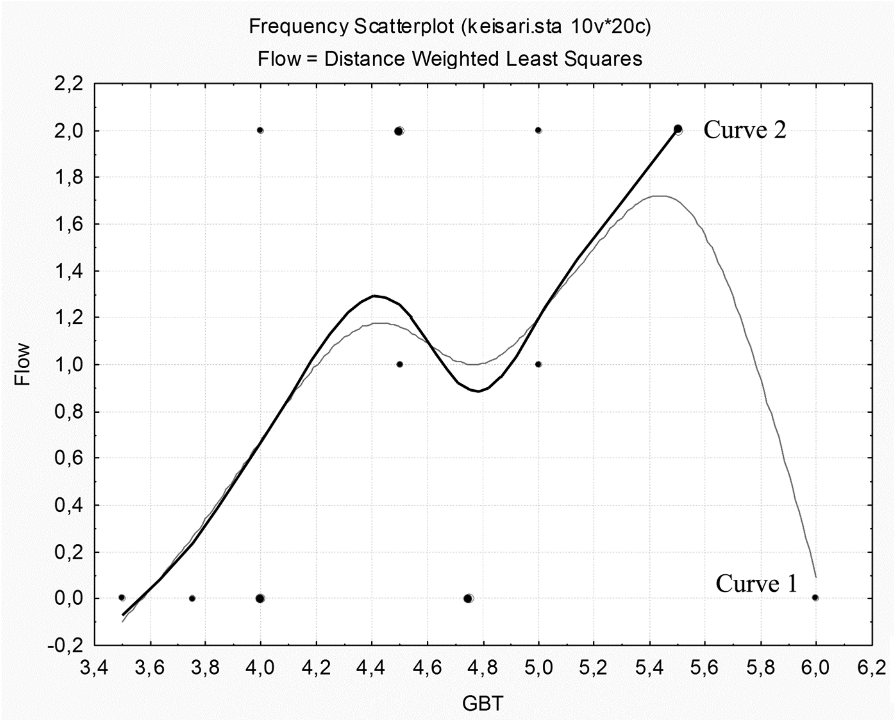

Figure 4: The relationship between game based task (GBT) and flow experience (curve 1: n = 15; curve 2: n = 14)

The proposed model was studied through an educational game, IT-Emperor. The focus was on evaluating the usefulness of participatory multimedia learning tasks and flow experience. The results indicated that participatory multimedia learning model has clear implications for designing digital learning materials because IT-Emperor turned out to be an effective and engaging learning environment. It seems that when instructional design requires learners to produce part of the learning materials, then the processes employed to produce these materials are likely to engage students and enhance learning in certain conditions.

However, the factors that contribute to flow experience should be also considered in design process. It is apparent that flow experience cannot be guaranteed to learners, but learning environments such as IT-Emperor can provide the possibility of experiencing flow. The reward of flow is obvious: it has a positive affect on learning. Another important finding was that content creation in particular was considered as being a flow inducing activity which supports the ideology of participatory multimedia learning model. Thus, it can be argued that the proposed model provides a good design framework for multimedia learning environments.

Generally, the work reported in this paper is still in the early stages. Because the sample for this study was very small (n=18), the results cannot be generalised to suit other groups of people and thus more research on this topic is required. Further, the multimedia learning layer of the model has to be revisited and extended. In fact, the focus of the future research will be on studying the usefulness of haptic technology in multimedia learning environments. The use of haptic technology can simulate cutaneous and kinesthetic sensations so that learning materials not only look but also feel (McGee, 2002) and may provide a means to reduce external cognitive load in visually and auditorily demanding learning materials (Münch & Dillmann, 1997). Thus, I want to propose that in the future we should consider supplementing the multimedia learning layer with the haptic channel in order to be able to design more effective, engaging, and realistic learning materials.

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