Multimedia and Cognition: Examining the effect of applying cognitive principles to the design of instructional materials

Abstract

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ABSTRACT

The human cognitive system possesses a finite processing capacity, which is split into channels for various modalities, and learning can be inhibited if any of the cognitive channels is overloaded. However, although the amount of e-learning materials is increasing steadily, the design of instructional material has been largely based on intuition rather than cognitive principles. This research investigated if it is possible to improve the effectiveness of an established e-learning system by the application of cognitive design principles. And if so, does the increased development time and resources yield a substantial effect on learning. Quantitative data collecting during the experiment supported the cognitive principles based design and demonstrated that significantly better quiz scores were obtained in transfer and retention tests when compared against a more traditional design. The results of the study also indicate that the cognitive principles based design was both practical and feasible to apply in terms of necessary resources.

INTRODUCTION

The amount of e-learning related tools and resources has been increasing dramatically over the past two decades. This growth was set in motion by the huge developments in hardware and software technology enabling the support of complex user interfaces and multimedia presentation modes (Huk, Lipper, Steinke, & Floto, 2002). From the perspective of the organization or educator, there are numerous benefits of an electronic learning approach; these include high availability, increased accessibility,

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simplified management and reduced ongoing costs (Block & Dobell, 1999). The use of computers in learning also simplifies the use of multimedia and the ability to accommodate individual learning styles.

However, design of multimedia is still mostly based on the intuitive beliefs of designers rather than on empirical research (Mayer, 2001), and as a consequence some of the potential benefits of e-learning may not be fully realized or implemented. Furthermore, information technology supported education very often involves simply porting traditional teaching methods (and materials) onto the web intact, along with any problems that they may have (Hughes & Attwell, 2002).

Cognitive load theory (Sweller & Chandler, 1994) is widely accepted by educational psychologists and instructional designers and is strongly backed by empirical research and real-world applications. According to this theory, the human cognitive system possesses a finite processing capacity, which is split into channels for various modalities, and learning will be inhibited if any of the cognitive channels is overloaded.

Mayer (2001) has proposed, and tested in isolation, a series of design principles by which multimedia presentations can be designed to maximize learning. The research described in this paper was carried out to investigate the applicability and effect of these design principles in a realistic e-learning environment setting to evaluate their practicability and to determine whether any benefits were obtained by applying cognitive principles to an established e-learning system.

Multimedia and E-learning

Tannenbaum (2000) defines multimedia as **"***an interactive computer-mediated presentation that includes at least two of the following elements: text, sound, still graphic images, motion graphics, and animation"*. In this paper, the term e-learning refers to the delivery of any education or training material by electronic means. This does not indicate a particular mode of delivery, and may be online, in the form of an Internet based course, or offline, as would be an interactive presentation on a CD ROM. The choice of media is also flexible; this may incorporate audio, video, animations and text in varying quantities. E-learning systems may be used for independent study, or facilitated by a teacher or mediator, and also may incorporate computer supported collaborative workspaces enabling groups of learners, and/or teachers, to work together on a task.

Cognitive Load Theory

The human cognitive system consists essentially of a limited working memory, a powerful long term memory, and learning mechanisms which reduce the burden on working memory by utilizing previously known facts. Cognitive load theory proposes that optimum learning occurs when the load on working memory is kept to a minimum to best facilitate the changes in long term memory (Sweller, 1988). When elements of a task can be learned in isolation they are described as having a low element interactivity. The level of "element interactivity" refers to the extent to which elements of a task can be learned without having to learn the relations between other elements. It is proposed that the amount of interactivity between elements of the material is closely related to the cognitive load that is generated by the activity – for example when learning (the syntax of) a language, it is impossible to learn a single

word in isolation as the material is highly interactive and must be learned in conjunction with several other elements with which it is related. This creates a high cognitive load and therefore the material is harder to learn. This effect is seen even when the number of elements to be learned is small, so long as the number of elements that must be learned simultaneously is relatively high (Sweller & Chandler, 1994).

Sweller and Chandler describe cognitive load as belonging to two categories, and the above example refers to intrinsic cognitive load. Intrinsic cognitive load is determined by the element interactivity within the material. High element interactivity results in high cognitive load whether or not the number of elements to be learned is high or not. Cognitive load may also be introduced within instructional media simply by using instructional techniques which unnecessarily increase element interactivity. This second category of cognitive load is termed extrinsic cognitive load and it is this cognitive load that may be reduced with the application of design principles to the design of instructional materials. A fundamental principle described in cognitive load literature is the split-attention effect, and several cognitive design principles are built upon this theory (Mayer & Moreno, 1998; Moreno & Mayer, 1999a; Tuovinen, 2000).

Split-attention effect
Attention is commonly viewed as a process which involves some measure of mental effort in order to selectively process information from a wide range of different sources and modalities (Bearne, Jones, & Sapsford-Francis, 1994). Therefore, by definition, if a large amount of effort is required to attend to a stimulus, somewhat less mental resources will be left available to perform other tasks.

Paivio's dual coding theory states that there are two cognitive sub-systems, one specialized for dealing with non-verbal objects (events or imagery) and another for dealing with language (spoken or written) and that equal weights may be given to these two types of processing (Paivio, 1986) Instructional material often requires students to split their attention between two or more sources of information. An example of this is the common, "diagrams + text" organization found in many texts and multimedia presentations. Both of these sources of information must be mentally integrated in order to acquire new knowledge, therefore there is an extrinsic cognitive load imposed upon the learner which will compete for cognitive resources, thus reducing the ability for the learner to assimilate and acquire knowledge from the material. This is termed the split-attention effect (Sweller & Chandler, 1994).

Therefore, the widespread assumption that adding images, pictures and sound to text will enhance the information product (Large, Beheshti, Breuleux, & Renaud, 1994), is sometimes misleading. In actual fact, the consequences of adding more and more sources of information may actually not be beneficial, or may even be detrimental to the learning process (Sweller & Chandler, 1994). Large et al. (1994) found that multimedia presentations did indeed produce the largest relative improvement (as compared to single media) in recall and inference, but the extent of the improvement was proportional to how well integrated the text, images and sound were in the multimedia presentation. This supports cognitive load theory, as well integrated materials reduce the need for the learner to 'split' his or her attention between the different sources of information.

This effect can be measured experimentally using dual-task methodology, whereby a cognitive load is created by creating a classic split-attention effect and the variation in the test subject's task performance is measured. Brunken, Steinbacher, Plass, and Leutner (2002) have demonstrated this effect, and found in their experiments that, as predicted by cognitive load theory, the simultaneous presentation of text and pictures induces a higher cognitive load than audiovisual presentation of the same materials.

Mayer and Moreno (1998) demonstrated this effect by presenting materials through different modalities to groups of e-learners. In the first group, learners viewed a presentation which consisted of animations and accompanying text annotations. Whilst these are two sources of information, they still must still both be received via the visual memory space. A classic split-attention effect was seen, whereby learning was impaired as the test subjects had to divide their cognitive resources between the two competing stimuli, i.e. the animation and the text. In the second group, this situation was avoided simply by replacing the text annotations with narration. By changing the modality, the stimuli occupied different memory spaces: the animation could occupy the visual channel and the narration could occupy the auditory channel. Therefore, the learner did not need to split his or her attention between stimuli and learning was facilitated.

Cognitive Theory of Multimedia Learning

In the design of a multimedia system, issues of layout, transmission or pure aesthetics are commonly considered – if a system is to be used to facilitate learning then the dimension of human cognition should also be factored into the design. In many information technology design projects, trade-offs are routinely made when limitations of the resources become apparent. In an e-learning system, these must be

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considered very seriously as the cost, in terms of effectiveness, may not be immediately apparent.

If the human mind is viewed as an information processing architecture, then as with any automated system, the levels of load imposed upon this architecture will affect its working capacity. Therefore, the application of cognitive load theory (Sweller & Chandler, 1994) is of relevance to those aiming to improve the efficiency of mental processes such as integrating and assimilating new knowledge. Those familiar with user interface design will have encountered the work of G.A Miller (1956) in which he coined the term "the magic number seven plus or minus two", to describe the length of a list of items that a person could hold in working memory at any given time. In practice, this number varies based on environmental conditions, age, fatigue and so forth (Tuovinen, 2000) but it is very clear that the actual working capacity of the human memory is very limited. Therefore, the broad goal to be considered when designing a multimedia system, is to minimize this cognitive load so that more working memory is available to be devoted to the process of learning new information (Mayer & Moreno, 1998).

Mayer utilized cognitive load theory and split-attention effects and applied these to the context of multimedia learning, proposing the cognitive theory of multimedia learning (Mayer, 2001). Based on a series of experiments by Mayer and colleagues, a number of principles have been derived which provide support for the theories (e.g.Mayer & Anderson, 1992; Mayer & Moreno, 1998). These principles may be considered during the design of a multimedia project to aim to maximize the

usefulness of the product. The principles can be broadly categorized into three areas, those of contiguity, modality, and redundancy.

Contiguity Principle

The contiguity principle states that multimedia instruction is more effective when words and images are presented contiguously (Mayer & Anderson, 1992). This applies to both time and space, and hence results in two effects: the temporal-contiguity effect and the spatial-contiguity effect.

The spatial-contiguity effect is the positive effect found when pictures and text are physically combined or in close proximity to each other rather than physically separated. Moreno and Mayer (1999a) reviewed 10 studies on the effectiveness of multimedia and found consistent evidence for the contiguity effect – students generated a median of 50% more creative solutions to transfer tests when verbal and visual information was integrated rather than disparate (Moreno & Mayer, 1999a).

The temporal-contiguity effect refers to learning enhancement when visual and spoken materials are temporally synchronized (i.e. simultaneous). Mayer and Anderson (1992) carried out an experiment in which groups of students were shown an animation depicting the operation of a bicycle pump with narration either before or during the animation. The words with pictures group outperformed the words before pictures group on transfer tests of problem solving. This contiguity principle is founded in cognitive load theory and is based on the split-attention effect described above.

Modality Principle

According to the modality principle, words should be presented as narration rather than visual on-screen text. Penney (1989) found a modality effect in short term memory whereby auditory presentation resulted in a higher recall than visual presentation, and went on to suggest that the effective capacity of memory can be increased by using the visual and auditory channels together.

Similar to the case with short term memory, a modality effect occurs in multimedia learning if students who study from visual presentations with narration outperform students studying the same visual presentation with text. This may be attributed to split-attention effects as described previously. In split-attention situations, the learners' cognitive resources are used to hold words and pictures in visual working memory leaving little resources for building connections between them (Sweller & Chandler, 1994).

Mayer and Moreno (1998) found substantial increases in performance in retention tests for students presented with an 'animation + narration' presentation when compared with students given an 'animation + text' presentation. Their findings also provided further clarification of the contiguity effect, by showing that the effect of presenting words and pictures at the same time depends on the modality of the words. If all the information is presented to the visual channel, a split-attention effect will occur, hindering learning.

Redundancy Principle

A common theme in the design of multimedia is to include on-screen text, alongside the narration, based on the assumption that the addition of still images of text will increase the availability of information by providing two sources, thus making it easier for the viewer to learn. From the point of view of information delivery, this may be a logical move, however from a cognitive point of view, the addition of redundant information may provide an unnecessary load on the learner which may hinder their learning (Mayer, Bove, Bryman, Mars, & Tapangco, 1996; Mayer, Heiser, & Lonn, 2001). Mayer et al. (2001) termed this the redundancy principle.

Studies of redundancy effects have shown that learning was hurt by the addition of on-screen text which contained the same words as the narration or a summary of the narration (Mayer et al., 2001). In keeping with cognitive load theory, it appears that the on-screen text competes with the images for the visual channel; narration, on the other hand, occupies the auditory channel which is processed separately than the visual channel. Therefore, removing the redundant text eliminates the split-attention effect (Mayer et al., 2001). It should be noted that removing the redundant information from the auditory channel is less likely to have a positive effect as the excessive cognitive load is taking place in the visual channel only.

The redundancy effect is not always found when the same information is presented in two channels, but only when information in these channels must compete for cognitive resources. Moreno and Mayer (2002) tested the simultaneous presentation of text and narration with identical words (termed verbal redundancy) and found that students better understood the explanation when words were presented both auditorily

and visually, on the condition that there was no other visual material. This is consistent with cognitive load theory and the split-attention effect (Sweller & Chandler, 1994). Furthermore, it is also to be noted that split-attention effects are much less likely if the activities are simple and require comparatively less cognitive resources (Bearne et al., 1994). Therefore the type of the material must be considered carefully when optimizing the presentation method, and for materials with a low intrinsic cognitive load, the extrinsic cognitive load (introduced by design and presentation) may be less critical (Sweller & Chandler, 1994).

RESEARCH AIMS

The primary aim of the study was to determine if it is possible to improve the effectiveness of an established e-learning system by the application of cognitive design principles. And if so, does the increased development time and resources yield a substantial effect on learning.

Given that in previous research the cognitive design principles have been mainly tested in isolation, the study also explored whether there any implementation issues or trade-offs which need to made for them to co-exist.

METHOD

This study used an experiment to determine whether the application of cognitive design principles improved the effectiveness of an e-learning system. As the research is intended to be directly applicable to a real-world situation, the experiment was designed around the use of a realistic e-learning lesson. For this particular study, the material consisted of a 'lesson' about the theory of flight. This was chosen as an area

which was generally found to be interesting, could be summed up in a short presentation, and participants were less likely to have specific prior knowledge about the area.

The real-world implications of the application of cognitive theory are the primary interest, rather than the theoretical underpinnings which have already been proven experimentally. Therefore, the experiment aimed to replicate a segment of an e-learning course whereby the test subjects received new knowledge and then demonstrated the extent of their learning with tests of retention and also tests of the degree to which the new knowledge could be transferred to novel situations. The independent variable in the study is application of cognitive design principles. That is, the instructional materials used by the experimental group were adapted to conform with principles from Mayer's cognitive theory of multimedia learning (Mayer, 2001). The instructional materials used by the control group were not. The two dependent variable in the study were knowledge retention and knowledge transfer.

Experimental Materials

The experimental and the control group lessons were created using the same basic material, that is, the same words and images. This made it possible to eliminate any possible variance due to differing content and to make apparent any differences between the groups resulting from the way in which the material was presented.

The presentations were created in Macromedia Director as this enabled the same "movie" file to be compiled to run under a number of different environments without the result appearing any different. This was important to ensure that participants

received the same information consistently regardless of how they accessed the presentation.

The presentations occupied 800x600 pixels of screen space, and were set up to automatically detect screen resolution and generate an error if the resolution was lower than required. Similarly when sound was required, an extra step was added at the start of the presentation advising the user how they can adjust the volume and/or restart the presentation if sound was not audible.

The presentations both consisted of seven pages, covering the most fundamental theories of flight. The aim was for the whole 'lesson' to take roughly 10 minutes to view, with the intent to maximize the amount of subject material covered whilst keeping the duration sufficiently short so as to reduce the effect of fatigue on participants.

As part of the research involved evaluating the extra development resources required for the cognitive principles based group, it was decided to split the development of the two versions of the presentation into two separate phases. First the control group materials were created; this entailed a basic online lesson, created in the commonly used style of a textbook - utilizing text and graphics with captions. The materials from this phase were then adapted to conform with principles from Mayer's cognitive theory of multimedia learning (Mayer, 2001) to be used for the experimental group.

The modality principle indicates that visual information, in the form of on-screen text should be replaced by narration. This is to avoid a split-attention effect. If on-screen

text containing the exact same wording as the narration was also present, it would have a negative effect (Mayer et al., 2001). However the potential for a negative effect is diminished if other visual information is of low complexity or when users have sufficient time to mentally integrate the information before progressing to the next topic (Moreno & Mayer, 2002).

W a web-based presentation system it is impossible to guarantee the kind of local resources that the learner will have at their disposal. Furthermore, electronic learning courses are very often not viewed in private, noise free environments and may be used in classes or general computing laboratories.

For these reasons relying solely on the audio track for the majority of the material is likely to be infeasible in a real-world setting, therefore this was retained. As the text and narration consisted of identical material there would be less possibility of a negative effect as noted previously.

To reduce the possibility of a split-attention effect, other visual information was modified to make it present less cognitive load as detailed below:

- Captions were removed from images

- Images depicting any movement were animated.

Whilst the material was standardized in terms of content, one of the effects of interactivity is that the overall pace of the presentation was under the control of the learner. To minimize the effect of this variable, the same control was given to both groups.

Figure 1: Sample screen from Control Group Presentation

Figure 2: Sample screen from Experimental (Lower Cognitive Load) Presentation

Procedure

In order to obtain a wide range of participants, recruitment was carried out from staff

and students at an Australian University.

Recruitment of participants was carried out both by announcements in lectures and by

e-mail messages.

Participants were informed that to participate in the research, all that was required was for them to view a short presentation and answer a quiz. The total time required being 10 to 15 minutes. They were also advised that no personal information would be collected which could link them to their results, and if they were students that their instructors would not know who had participated.

Visitors to the survey website were provided with a link to begin the study. The link was setup to randomly redirect to either the experimental or control group without their knowledge. The URLs of the various pages on the survey website were also obscured so that participants would be unaware which group they were participating in. This ensured that neither the researchers, nor the participants were aware of which group they had been placed in. Hence, although this was a convenience sample an attempt was made to minimize any variances in results caused by individual differences of the participants by recruiting from a broad population and randomizing allocation between groups.

At the completion of the presentation, participants were given a link to an online quiz covering the subject matter. This produced quantitative data to be used for comparison both between and within groups to explore any differences. Two kinds of questions were included, those which tested 'retention', or recall of facts presented in the lesson, and those which tested 'transfer', which is the ability to apply the information to novel situations. As demonstrated by Mayer and Chandler (2004) the transfer test is a better measure than retention when the goal is to demonstrate how well learners understand a multimedia explanation. It has been shown that across test groups it is possible to

have the same scores for tests of retention, but results on transfer tests may vary (Mayer & Chandler, 2004). Therefore, in an attempt to gain a fuller understanding of the level and type of learning that has taken place, both types of tests were employed in this study. The first part of the quiz was a test of retention, which included basic multiple choice questions relating to facts from the presentation. The second part was a transfer test, where participants were given the opportunity to justify their answers.

The first 10 questions formed the retention portion of the quiz and one mark was awarded for each correct fact as presented in the presentation. The remaining four questions formed the transfer test. In this section marks were awarded for justification of answers, and therefore there may have been more than one correct answer for a given question. The exercise in this section was to gauge how well the participants understood the material and it was demonstrated by their ability to justify answers. For example when asked which airplane would travel faster, acceptable answers would have included "The X29 because it has less drag" or "The Boeing because it has more thrust from engines. Unjustified answers such as "The X29 because it looks fast" were not accepted. This part was used as an indicator of deeper learning as it tested how well the new material can be applied to new situations (Mayer et al., 2001).

Q6 Lift or drag can only exist in the presence of a

○ moving fluid
○ solid
○ stationary fluid
○ vacuum

Q7 In the longer path explanation, it is stated that as the speed of a fluid flow increases, its pressure
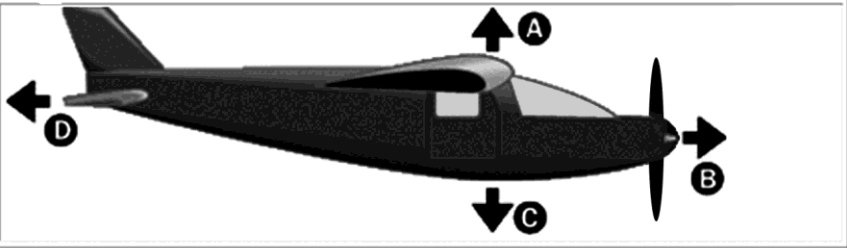
○ decreases
○ stays the same
○ increases
○ fluctuates

Figure 3: Sample Retention Test Questions

Q13 In the same scenario as above, if you decrease the amount of drag force on an airplane, leaving everything else the same – what effect would you expect this to have on the distance that the airplane can travel on a single tank of fuel?

Why do you think this would happen?

Q14 You have been asked to modify a plane for racing purposes. In the diagram below, which of the areas of force would you expect to have the most effect?

○ A
○ B
○ C
○ D

Why did you choose this one?

Figure 4: Sample Transfer Test Questions

In order to establish the content validity of the measurement of knowledge retention

and transfer, a pre-test was first conducted with several academics. A pilot study with

two representative participants was then carried out in the final stages prior to launching the experiment. As a result of the pilot study, one of the diagrams in the presentation was modified and two of the quiz questions re-worded as they were reported to be difficult to follow.

RESULTS

A total of 69 participants took part in the experiment; one participant was excluded as she did not fully answer the quiz. Of the remaining participants 33 (48.5%) were in the control group and 35 (51.5%) in the experimental group. The sample consisted of 52 male (76.5%) and 16 female (23.5%) participants, with a mean age of 30.4 years (minimum 18, maximum 64). The distribution by age and gender was compared between the experimental and control groups and no significant differences were found (age: $t(65)=-1.135$, $p=0.26$; gender: $\chi^2(1)=1.635$, $p=0.201$).

The complete dataset was initially screened for outliers using a cut-off criterion of +/- 2.5 z scores; no outliers were found by this criterion and therefore the data was unchanged. The data was also checked for normality and found to be normal with acceptable skew and kurtosis.

Mean scores for each of the tests were calculated for each group and are presented in Table 1. T-tests were carried out to analyze differences in the mean scores for both retention and transfer tests between the control and experimental groups. The experimental group scored significantly higher results on both the retention test ($t(66)=-2.093$, $p=0.04$) and the transfer test ($t(66)=-2.370$, $p=0.02$). The correlation

between transfer and retention scores for each participant was not significant (r=0.23, p=0.59).

	High Cognitive Load (control group)			Low Cognitive Load (experimental group)			
	N	Mean	SD	N	Mean	SD	Sign.
Retention score	33	8.94	0.97	35	9.40	0.85	0.04
Transfer score	33	4.73	2.55	35	6.11	2.27	0.02

Table 1. Mean Scores for Transfer and Retention Tests for Control and Experimental Groups

While the cognitive principles have been assumed to apply to both genders, there is some evidence to suggest that females respond to assessment instruments differently (Moreno & Mayer, 1999b)

Further exploratory analysis was carried out to investigate the potential roles of age and gender. No significant correlation was found between the age of the participant and their retention score (r=-0.045, p=0.72), or between age and the transfer score (r=0.077, p=0.53). However significant gender differences were found, whereby the control group males scored higher in the retention test (t(31)=-2.244, p=0.032) and in the transfer test (t(31)=-2.434, p=0.021). Males in the experimental group also scored higher on the transfer test (t(33)=3.003, p=0.005) but not in the retention test (t(33)=1.283, p=0.209).

DISCUSSION

A positive effect on learning can be expected if narration is used as opposed to on-screen text. This is termed the modality effect. This in isolation may be applied to

most e-learning situations; however for a web based presentation, making assumptions about the availability of resources such as sound capabilities may be detrimental and may diminish the number of individuals able to access the materials.

However, preserving both on-screen text and adding narration may cause a split-attention effect, and hinder learning. The redundancy principle states that removing duplicated information (such as the extra text in the above example) will have a positive effect on learning (Mayer et al., 2001), although the redundancy effect is not found in the absence of other visual information , or when users are able to control the pace of the presentation so that they have sufficient time to mentally integrate the information before progressing to the next topic (Moreno & Mayer, 2002) .

In this experiment, the modality principle was applied by adding an audio track containing the exact wording from the presentation slides. The on-screen text was left intact, however users were able to control the pace of the presentation with navigation buttons, and other on-screen visual information was modified to make simpler to integrate. The results of the experiment showed a significant improvement in the retention test and an even stronger effect in the transfer test. Most interesting at this point is the large impact of design on the transfer test – the transfer test was designed to test deeper learning and the way which new knowledge is applied to novel situations, it was expected that a cognitive principle based design would have a greater impact on this type of learning. This is consistent with prior research regarding the effect of modality on learning (Moreno & Mayer, 1999a). This finding indicates that the investment of additional development time and resources required for application of cognitive principles in multimedia development are justified.

The results also indicate that even though it was not feasible to remove all on-screen text in accordance with the redundancy principle (Mayer et al., 2001), potential negative effects can be reduced or removed by ensuring that other visual information is kept minimal, and that learners have control over the pace of the presentation. These findings support Moreno and Mayer's (2002) hypothesis regarding redundancy effects.

Overall the findings are consistent with the Mayer's cognitive theory of multimedia learning (Mayer, 2001) and have demonstrated that cognitive principles may be applied together and balanced in an e-learning system to yield a positive effect on learning.

Post hoc analysis was carried out to explore the roles of age and gender within the groups. It was seen that age had no effect on the quiz scores; however significant gender differences were noted in all tests except for retention test in the experimental group. The level of prior knowledge in the male participants may well have led to this result, as this was not tested for in the experiment. Future studies could be improved by incorporating a measure of prior knowledge into the test. However, in the experimental group there were no significant gender differences in the retention test, indicating that the cognitive principles based design may have had enough of a positive effect to overcome the prior knowledge differences, at least for surface learning.

Given that in previous research the principles have been mainly tested in isolation, the study also explored whether there any implementation issues or trade-offs which need to made for them to co-exist. It was noted during the development that often a trade-off must be made between which types of principles to apply and how to match these with the available resources. Further research must be carried out to compare magnitude of the effect found by each of the principles to indicate to designers which areas must be prioritized. Furthermore, the role of individual differences and cognitive style must be explored with regard to how a cognitive principle based design may be tailored to accommodate the diversity of learners.

CONCLUSION

Cognitive load theory (Sweller, 1988) states that the human cognitive system possesses a finite processing capacity, which is split into channels for various modalities, and that learning will be inhibited if any of the cognitive channels is overloaded. However, although the amount of e-learning materials is increasing steadily, the design of instructional material is still largely based on intuition rather than cognitive principles (Mayer et al., 2001). Mayer (2001) proposed a series of design principles by which multimedia presentations can be designed to maximize learning. This research investigated the applicability and effect of these design principles in a realistic e-learning environment setting to evaluate their practicability and whether any benefits could be obtained when these cognitive principles are applied to a real world e-learning system. The results of the study indicate that the cognitive principles based design was both practical and feasible to apply in terms of necessary resources. Quantitative data collecting during the experiment supported the cognitive principles based design and demonstrated that significantly better quiz

scores were obtained in transfer and retention tests when compared against a more

traditional design.

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