Investigating the effects of multimedia learning and learner generated drawing

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Abstract

Research suggests multimedia learning (images and text) and learner-generated drawing (constructing illustrations to support key relationships in text) are beneficial strategies to aid learning (Mayer 2001; Van Meter & Garner, 2005). Within this research the multimedia and learner generated drawing approaches are explored to distinguish which instructional method is most beneficial for initial learning and long term retention. Year 8 students (N = 73) aged between 13 and 14 years read a piece of scientific text under four conditions: text only (control); multimedia; learner generated drawing with no support; and learner generated drawing with support. The reading material was followed by two post-tests to measure how much of the science text was understood: one was completed immediately after the experiment; and the other a week later to examine the long term effects. On the first post-test participants within the learner generated drawing conditions performed significantly better than those in the multimedia condition and the control group. On the second post-test participants within the learner generated drawing with support condition performed significantly better than the control and the learner generated drawing condition with no support. Thus, in line with previous research the results emphasise the importance of support in learner generated drawing and indicate that supported learner generated drawing is the most beneficial strategy for initial learning and long term retention.

KEY WORDS:	MULTIMEDIA	LEARNER GENERATED DRAWING	LONG TERM RETENTION	LEARNING

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Investigating the Effects of Multimedia Learning and Learner Generated Drawing

Introduction

Diversifying teaching methods is becoming ever prominent within schools to ensure children partake in different learning strategies, to enable them to have the most satisfying and successful academic career (Gass, 1996). However, the effectiveness of different teaching approaches and thus, students' learning methods is often not fully understood. Therefore, this research aims to establish the effectiveness of two learning methods in particular: the multimedia approach and the learner generated drawing approach.

Many approaches have been developed in order to aid and improve students learning and text comprehension (e.g. Shwamborn, Thillmann, Opfermann & Leutner, 2011). Interpretational illustrations within text have been found to facilitate learning by increasing motivation, attention and clarification (Peeck, 1993; Carney & Levin, 2002). For example, the "multimedia effect"- a combination of verbal and pictorial representations, proposed by Mayer (2001; 2005a; 2005b; 2005c), can activate deep learning. Several studies have revealed that when students are presented with good quality multimedia, including text and pictures, students learn more deeply, in comparison to being presented with text alone (Mayer, 2001; Carney & Levin, 2002; Mayer 2005a). However, this is seen by many as a passive form of learning and research suggests there is a significant advantage to learning by doing. An active or effortful involvement in the learning process is seen to be more beneficial for the student (Slamecka & Graf, 1978; de Jong, 2005; Kirschner, Sweller, & Clark, 2006; Klahr & Nigam, 2004; Lillard, 2005). Thus, the "Generative Theory of Drawing Construction", developed by Van Meter and Garner (2005) arguably provides a more efficient learning experience, allowing students to construct relationships between verbal and pictorial presented material.

Moreover, which learning method is most effective? To answer this, the primary goal of this research is to compare the two learning methods with students in secondary school and measure their effectiveness for learning in the classroom. The secondary goal is to assess how effective each method is to aid long term retention of the material and thus, produce deeper learning.

The Multimedia Effect

Mayer (2001) argued many traditional forms of teaching i.e. "chalk and talk"- verbal only methods to be insufficient, providing students with an unsatisfactory learning experience. He found students who were presented with verbal only methods of teaching were unable to locate important information within the presented material and apply new information successfully. Multimedia approaches present students with verbal and pictorial representations, enabling them to foster deep learning and become more engaged with the material (Schlag & Ploetzner, 2011). There is a need to present information both verbally and visually because human cognition comprises of a working memory with limited capacity which contains partially separate visual and auditory channels (Paivio, 1986; Baddeley, 1992; Sweller, 2005). Representing information both verbally and visually activates both channels of the working memory, contributing to 'intactness' of the information without exceeding the capacity limits of our working memory (Larkin & Simon, 1987; Clark & Mayer, 2008).

Multimedia approaches enable students to deal with large amounts of information efficiently. Providing visual representations within the material can summarise textual data, allowing learners to comprehend information adequately resulting in active learning (Clark & Mayer, 2008). Mayer (2005) argues multimedia approaches induce active learning whereby students learn through three processes which aid appropriate cognitive processing: Firstly, learners must select the relevant pictorial and verbal information to aid the acquisition of new knowledge and skills; organisation follows, whereby the learner organises the information into coherent verbal and pictorial mental representations; finally, integration occurs, combining the verbal and pictorial information with one another from the two channels of the working memory and with prior knowledge from the long term memory (Wittrock, 1990; Mayer, 2009). Thus, if the integration process is successful and there is a correspondence between both representation systems, the learner has engaged in appropriate cognitive activity and generative processing, increasing understanding of the material (Paivio, 1990).

Overall, multimedia methods should aid cognitive activity and learning by minimising cognitive load and managing essential load to free working memory capacity for learning (Clark & Mayer, 2008). Cognitive load theory, originally developed by John Sweller (2005), describes the effectiveness of instructional learning methods, such as the multimedia effect, in terms of how they successfully or unsuccessfully accommodate the capacity of working memory. Mayer (2005) specifically describes three variations of cognitive processing, also known as the triarchic theory of cognitive processing, which can contribute to cognitive load: extraneous processing, in which the learner engages in cognitive processing that is not related to the learning goal and is caused by ineffective instructional design, e.g. irrelevant visual representations; essential processing originates from the complexity of the material which effects the learners mental representation of the information; and generative processing, in which all multimedia aims to achieve, results in the learner engaging in deep, active learning which produces adequately integrated material.

Multimedia approaches aim to reduce cognitive load and engage in generative processing by enabling the learner to access both channels of their working memory. However, Mayer (2005) specifically proposes two methods in which multimedia approaches can reduce cognitive load further: the coherence effect, whereby any extraneous information or loosely relevant information is removed from the learning material; and the spatial contiguity effect, whereby students develop deeper learning when verbal and pictorial representations are presented near to one another rather than the visual representations being far from the textual information. For example, students who read information containing illustrations placed near or next to the corresponding words generated 65% more useful solutions on a problem solving transfer test than the students who were presented with text alone (Mayer & Gallini, 1990). Similarly, students who received information explaining how a pump worked with images closely situated near the text generated 75% more useful solutions on a subsequent problem solving transfer test than students who read the same text but with the images presented on separate pages (Mayer, Steinhoff, Bower & Mars, 1995). In terms of coherence, Moreno and Mayer (2001) found that students who received a concise multimedia presentation, that did not contain extraneous verbal information, performed significantly better on problem solving transfer tests in comparison to their peers who received an embellished multimedia presentation, with unnecessary verbal and pictorial information. Therefore, these studies highlight the efficiency of well-designed multimedia presentations for learning - they reduce cognitive load and aid students to engage in active learning, resulting in sufficient integration of verbal and visual mental representations of the information.

However, research has found that learners do not always process the text and picture combinations appropriately. Many learners struggle particularly to integrate the verbal and pictorial representations of the information together (Ainsworth, 1999; Seufert, 2003) and some researchers argue providing contiguity within instructional materials is not sufficient enough to ensure integration occurs (Kozma, Russell, Jones, Marx & Davis, 1996). Tabachneck-Schiff and Simon (1998) found that when learning about economic supply and demand principles, students did not integrate the text and graphical representations. Similarly, research found that students do not integrate textual and pictorial information unless experimental manipulations force them to do so (Scevak & Moore, 1990). Thus, Van Meter, Aleksic, Schwartz & Garner (2006) suggest multimedia approaches may not improve text learning through integration but rather through the storage of independent verbal and visual representations. Learners may organise the verbal and visual information without the added process of integration, unless the instructional method forces the learner to do so. Therefore, performance and learning may seem enhanced when using multimedia approaches, not due to integration, but rather because the learner can access either representation to locate needed information without necessarily integrating the two (Tabachneck-Schiff & Simon, 1998; Van Meter et al., 2006).

Moreover, simply presenting students with verbal and pictorial representations, although more effective than text alone, may not be sufficient to ensure the student engages in active learning, which is a vital process in aiding the learner's cognitive development (Ainsworth, 1999). Therefore, learning by doing may provide a more active learning experience for the student, allowing them to personally construct relationships between verbal and mental visual representations which facilitate the integration process more appropriately (Stull & Mayer, 2007).

Learner Generated Drawing

Van Meter and Garner's (2005) theory of generative drawing construction is an example of learning by doing, in which learners draw their own illustrations to correspond with the main elements and relationships within textual information. This strategic process encourages learners to actively engage in cognitive and metacognitive processing, which ultimately improves learning acquisition and fosters higher forms of knowledge and deep learning (Van Meter, 2001; Schamborn, Mayer, Thillmann, Leopold & Leutner, 2010). Learner generated drawing has been found to promote students' memory, observational processes and imagination when studying scientific text (Stein & Power, 1996). Students' affective processes have been found to be positively influenced through drawing construction (Moore & Caldwell, 1993) as well as stimulating greater engagement with textual information (McConnell, 1993) and assisting deep learning and problem solving (Britton & Wandersee, 1997; Van Meter & Garner, 2005). Thus, learning by doing can have many beneficial effects upon a student's learning experience.

This theory complies with Wittrock and Carter's (1975) early research of the generative theory whereby learners construct relationships between new information and prior knowledge in order to aid comprehension of complex material and foster deep learning. Wittrock and Carter discovered generative processing facilitated recall and long term retention, as construction required more meaningful processing resulting in a higher level of retention (Craik & Lockhart, 1972). Other early research supports these findings. For example, Jacoby (1978) found that working through a problem to its solution enhances memory compared to when the solution to the problem is provided. Jacoby argued generative construction is necessary for learning, as it stimulates consciousness and arousal in a way that effortlessly remembering does not, producing differing levels of retention. Similarly, Slamecka and Graf (1978) found when comparing memory for words between participants who generated the words themselves and those who only read the words, participants in the generate condition performed significantly better than those in the read only condition. Thus, the researchers argued learning by doing provides learners with an especial advantage in comparison to those who merely passively accept the same information. Generative construction provides increased cognitive effort and heightened attention, thus, enhancing memory for a sufficient learning experience.

Recent research suggests learning strategies should result in the creation of personally meaningful relationships (Woo Lee, Yon Lim & Grabowski, 2010), posing learner generated drawing as an advantageous process in comparison to multimedia approaches, where illustration and text are provided instead of constructed by the learner. When participating in learner generated drawing, the learner engages in active learning- selection, organisation and integration- as learners do through multimedia approaches. However, the active learning process differs slightly with learner generated drawing, particularly enhancing the mental integration of verbal and pictorial models which act as a foundation for generating external illustrative representations- a particular difficulty found within multimedia approaches to learning (Van Meter & Garner, 2005; Ainsworth, 1999).

Similar to Mayer's (2009) model of active learning, learner generated drawing also begins with selection of key elements, however, as learners are not provided with illustrations, only elements within the verbal text are available for selection. These elements are then organised to construct verbal representations of the text. The selection and organisation of verbal elements are vital within learner generated drawing because the verbal representation provides a foundation for the construction of the learner's illustration (nonverbal representation) (Van Meter, Aleksic, Schwartz & Garner, 2006). Learner generated drawing heightens the attention paid to the selection and organisation processes, as the student must determine the spatial location of structures within their drawing and ensure they include all important information from the text within their nonverbal representation. This produces a recursive process, whereby students are redirected to the verbal representation and re-inspection of the textual information takes place to provide learner's with sufficient information for their drawing construction (Van Meter, 2001; Van Meter et al., 2006).

This procedure engages learners in more efficient self-monitoring processes and increases the detection of comprehension errors (Van Meter, 2001).

As previously stated, multimedia approaches do not guarantee student's engagement in the integration process which is needed for active learning. Drawing by contrast, demands integration as the verbal representation forms the foundation for the nonverbal representation, the student's drawing (Van Meter & Garner, 2005). This suggests learner generated drawing provides a deeper learning experience for learners (Van Meter, Aleksic, Schwartz & Garner, 2006). For example, Van Meter et al., (2006) presented a study which explored both learner generated drawing and multimedia approaches. To ensure that students who participated within the multimedia condition attended to the provided illustrations sufficiently, they asked specific questions in relation to the nonverbal representations which the students had to answer. The researchers argued that if the students within this condition attend to the illustrations appropriately by answering the questions, the learners should engage in integration and no added benefit of learner generated drawing would be found. However, they found the students within the learner generated drawing condition performed significantly better on retention and problem solving transfer tests than those within the multimedia condition, concluding learner generated drawing is a more effective learning strategy. Thus, this study suggests integration is the specific process credited for the additional benefits of learner generated drawing (Van meter & Garner, 2005).

Conversely, student generated drawing does not automatically guarantee deep learning, as the logistics of the drawing strategy may impose extraneous cognitive load which interferes with the generative process of active learning (Schwamborn, Mayer, Thillmann, Leopold & Leutner, 2010). The mechanics of drawing may be too complex for learners, leaving fewer cognitive resources available to enhance deep understanding and enable integration of the verbal and nonverbal representations (Mayer, 2005; 2009; Mayer & Moreno, 2003). Furthermore, research on learner generated drawing has produced somewhat inconsistent empirical results (see Van Meter & Garner, 2005 for overviews), where some research highlights positive effects of learner generated drawing for learning (e.g Hall, Bailey & Thillman, 1997; Van Meter, 2001; Van Meter, Aleksic, Shwartz & Garner, 2006) and others have not (e.g. Leutner, Leopold & Sumfleth, 2009; Tirre, Manells & Leicht, 1979). Research suggests this is due to an inconsistency in methodology used to implement the drawing strategy which may impose extraneous cognitive load on student's learning experience, affecting the results gained from the research (Schwamborn, Thillman, Opfermann & Leutner, 2011). For example, some research instructed participants to draw nonverbal representations according to key elements within the text with no support from the researcher or the resources given (Leutner, Leopold & Sumfleth, 2009). Whereas, other research presented participants with instructional support (Van Meter, 2001), which provide the learner with guidance to aid construction of their illustrations, such as providing the learners with cut-out figures to structure their drawings (Lesgold, Levin, Shimron & Guttman, 1975) or semi-completed drawings (backgrounds) for learner's to complete the illustrations (Schwamborn et al., 2011).

Despite the inconsistencies within research investigating learner generated drawing, studies which provide learners with instructional support to construct their drawings generally show a benefit of the drawing strategy (Schwamborn, Mayer, Thillmann, Leopold & Leutner, 2010). Leutner et al., (2009) suggest students do not benefit from pure learner generated drawing with no support because the logistics of managing the drawing activity significantly increases the learners cognitive load affecting their ability to engage in active learning. Thus, effects of learner generated drawing seem to depend upon whether the instructional support for drawing promotes appropriate cognitive processing during learning, by increasing generative cognition and reducing extraneous cognitive load (Schwamborn, Thillmann, Opfermann, Leutner, 2011). Moreover, both multimedia and learner generated drawing strategies depend upon adequate instructional design to invoke appropriate cognitive processing.

Several studies support the importance of instructional support for learner generated drawing. For example, Van Meter (2001) found participants who were most supported in their drawing construction scored significantly higher on free recall tests than those who had no support with their drawing construction and those who were provided with illustrations (multimedia). However, Van Meter found there were no condition effects on the recognition post-test, concluding that learner generated drawing qualifies learners to engage in a deeper form of learning which consequently only aids the processes of higher order thinking, such as problem solving, rather than lower order knowledge, such as recognition. This was also confirmed within further research by Van Meter (Van Meter, 2005; Van Meter, Aleksic, Shwartz & Garner, 2006).

Similarly, Schwamborn, Mayer, Thillmann, Leopold and Leutner (2010) also found instructional support to be beneficial for learner generated drawing. Over one hundred and fifty 9th grade German students read a scientific text explaining the chemical process of washing clothes with soap and water. The research consisted of two conditions: a multimedia condition and a learner generated drawing condition, where the participants where provided with instructional support, comprising of drawing prompts and a partially pre-drawn background for their drawing. Findings discovered students gained a deeper understanding of the scientific text when their own drawings were generated, resulting in higher performance on problem solving transfer tests and retention tests. Therefore, learner generated drawing, although a fairly new concept, when designed appropriately can be found to have many beneficial effects, aiding the integration process of active learning and enhancing higher order forms of knowledge (deep knowledge) and retention.

Is Multimedia or Learner Generated Drawing More Beneficial?

Multimedia and learner generated drawing approaches are both beneficial within the learning experience, yet, Stull and Mayer (2007) argue that learning by doing, and thus learner generated drawing, will not always lead to a deeper form of learning. Therefore, thus far research has not adequately investigated which strategy is more useful hence, this should be investigated further. As previously mentioned, Wittrock and Carter (1975) discovered the generative effect activates a deeper form of learning which enhances long term retention. However, recent research on learner generated drawing, which has been adapted from Wittrock and Carter's concept, fails to explore the long term effects of the learning approach. For example, within Schwamborn, Mayer, Thillmann, Leopold and Leutner's (2010) research students were tested for problem solving transfer and retention immediately after participating within their allocated condition, thus neglecting the long term retention of each learning strategy.

Therefore, this research will explore the long term retention of both the multimedia and learner generated drawing strategies, investigating which approach is more beneficial for learning. The impact of instructional support for learner generated drawing will also be explored, to investigate the prime conditions for learner generated drawing strategies. The findings may provide beneficial information for teachers within an educational environment, willing to adapt teaching methods to stimulate a more efficient learning experience. Thus, the findings from this study will contribute to existing research exploring multimedia and learner generated drawing approaches, adding a new dimension to this research area.

Overview of the Study and Research Questions

Within this research, students were asked to read a piece of scientific text for comprehension, based upon the formation of limestone caves, with either text only (control) or under one of three experimental conditions; multimedia, whereby students are presented with text and provided images; learner generated drawing with no additional instructional support; and learner generated drawing with instructional support. For the purpose of this experiment, any images and text provided within the materials served an interpretational, explanative function, helping the reader to understand the text (Carney & Levin, 2002) and were directly related to the instructional goal to aid learning effectively (see Sung & Mayer, 2012). Although other forms of knowledge are important, such as narrative and description, explanations were the focus of this material because they are often thought to be at the centre of many disciplines, especially science education (Mayer & Moreno, 2002). To minimise cognitive demands of the generating process and to increase the quality of the drawings, participants within both drawing conditions, including those in the learner generated drawing condition with no additional instructional support, were directed to specific paragraphs and sections within the instructions to facilitate the drawing process. Participants who were granted additional support were provided with a pre-drawn background and incomplete illustrations (Schwamborn, Mayer, Thillmann, Leopold & Leutner, 2010) including some blank labels for the student's to write the correct answers (Stull & Mayer, 2007).

Overall, two basic research questions have been investigated within this piece of research:

1. Which instructional approach (multimedia, learner generated drawing with no support and learner generated drawing with support) is most beneficial for initial learning?
2. Which instructional approach (multimedia, learner generated drawing with no support and learner generated drawing with support) is most beneficial for long term retention?

Method

Participants and Design

Participants were 73 English year eight students from a North West state secondary school. The children were aged between thirteen and fourteen and 52% were boys. There were four conditions within the experiment: 16 students served in the control group; 19 students served in the multimedia group; 19 served in the generated drawing condition with no support; and 19 served in the drawing condition with instructional support. The students were taken from the two highest achieving Science classes of the year group. The classes were selected by the teacher in which students volunteered to take part in the experiment. The students were assigned to each condition randomly by the teacher of their class.

Materials

The materials consisted of one prior knowledge test, four learning booklets and two post-tests. A prior knowledge test was used to determine the students had similar levels of knowledge on the formation of limestone caves, ensuring no students were at an advantage. The prior knowledge test consisted of one open ended question on comprehension of the formation of limestone caves, i.e. "In as much detail as you can explain the process of how limestone caves are formed".

The four learning booklets each included a science text about the causal explanation of limestone cave formation. The text consisted of approximately 600 words and was divided into eight paragraphs. Table 1 presents the text from the second paragraph.

The four versions of the booklet were as follows: the control version of the booklet which consisted of text only; the multimedia version which consisted of the same text as the control booklet but also included interpretational images which were placed with spatial contiguity within the text, to minimise extraneous cognitive load; the drawing version without support was presented in the same way as the multimedia booklet but instead of

Table 1
Text From the Second Paragraph of the Limestone Cave Formation Material

II. The Formation of Limestone Caves
Cave formation begins when rain water absorbs carbon dioxide as it falls through the atmosphere. On passing through the soil more carbon dioxide, from plant roots and decaying vegetable matter, becomes dissolved in the water, along with organic acids. Although pure water cannot cause limestone to weather (break down), rain water can because it has picked up carbon dioxide through the air, making it more acidic and turns the limestone into calcium bicarbonate. As the rain travels down through the ground it comes to solid rock. When this is limestone, caves can form.

provided illustrations, large empty boxes were provided for the students to draw their own nonverbal representations of the text; and the drawing version with additional support has the same layout as the two previous booklets but instead of empty boxes or provided illustrations, the boxes included incomplete illustrations and instructions for the students to complete them, using the information given. To minimise extraneous cognitive load further all materials consisted of concise information about limestone cave formation, eliminating unnecessary information to provide adequate coherence (Mayer, 2003). All learning materials were created using teaching resources to ensure the material was age appropriate and were checked by the science teachers within the school. A pilot study was also conducted with five thirteen year olds to assess whether the material was not too challenging or easy and that the material itself was coherent.

The two post-tests consisted of the same questions: one of the tests was administered to the students immediately after the material was studied; and the second post-test was administered a week later to investigate the long term retention of the material. The post-tests aimed to assess the student's problem solving transfer and retention of the material. Two transfer questions were included in the post test. An example is "If a large amount of pure water (water that does not contain any chemicals) fell onto a cliff made from limestone rock, what would happen and why?" Five retention questions were also included in the post-test to assess the students' comprehension of the factual and conceptual information within the material given to them. Three of the questions were multiple choice and the two remaining questions were single answer open questions. An example of a multiple choice question is "Acidic rain water turns the limestone into: (*a*) Calcium Carbonate, (*b*) Calcium Bicarbonate, (*c*) Calcium, or (*d*) Calcium hydroxide" with the correct answer being item *b.* An example of a single answer open question is: "When the stalactite and stalagmite meet, it produces a:_______", with the correct answer being "column".

Procedure

All participants were tested in their classroom at school, in their normal learning environment. All participants and parents of the students who took part in the experiment gave written formal consent. All students were verbally briefed and received a written brief to ensure they knew what was expected of them throughout the experiment and to emphasise their right to withdraw at any point during the experiment. Students were asked to put their names on the top of all the materials, however once the materials were matched and coded, all data was anonymised and personal information was destroyed. The experiment took place in two classes, with both classes being separated in to two experimental conditions: within the first class half of the students were randomly assigned to the control condition (text only), the other half of the class were assigned to the multimedia condition; the second class had half of the students randomly assigned to the drawing condition with no support and the other half assigned to the drawing condition with support. The conditions were grouped in this way to ensure participants within the control and multimedia condition were not distracted by the drawing activity of the generated conditions. Students within all conditions were instructed to complete all tasks on their own and in silence.

To begin, each participant was administered with a prior knowledge test and was asked to complete this in three minutes. The prior knowledge tests were collected and each student was given a booklet corresponding to their allocated condition. Students in the control group and multimedia condition were asked to carefully read the instructions and information within their booklet in enough detail to complete a short test commencing immediately after. Participants within the multimedia condition were asked to pay particular attention to the illustrations within their booklet. This was to motivate students to process the nonverbal representations of the material to evoke active learning. Participants within these two conditions were asked to complete the reading task in ten minutes. Students in the two drawing conditions were also instructed to carefully read the instructions and material within their booklet in enough detail to comprehend the information for a short test following the drawing task. It was made clear to the students within the instructions precisely where and what they had to draw. The participants within the drawing conditions were given between fifteen and twenty minutes to complete the activity, slightly longer than the other conditions to ensure students had enough time to both read and process the verbal information and draw their own nonverbal representations.

Immediately following the learning booklets activity, every participant was given a post-test. To complete the post-test students were allocated 8 minutes in which they answered a series of multiple choice and short answer open questions without access to the learning materials or drawings. Finally, students were debriefed and thanked for their participation. Overall, the procedure took between thirty and forty minutes.

To complete the experiment, a week later students were asked to complete the same post-test again under test conditions and were given 8 minutes to complete the task. This was to measure the long term effects of the instructional methods under investigation. Once again, when the task was completed, all students and teachers were debriefed and thanked for their time and effort.

Results

Scoring

The experimental tests were scored as follows: The prior-knowledge test for each participant was computed using a four point rubric, similar to the five point rubric adopted by Guthrie, Van Meter, McCann & Wigfield (1996). The students could gain a maximum of three marks for the prior knowledge question and a maximum of three marks each on the two transfer questions within the post-test. The four rubric points were: 0 marks: no answer, I do not know; 1 mark: some relevant information but includes inaccuracies and key elements are missing; 2 marks: some relevant information but some key elements are missing and have a partial understanding; and 3 marks: a complete answer and full understanding.

The two post-tests were split into two sections: the retention questions and the transfer questions. The retention questions within the post-test were computed by awarding one point per correct answer and adding up the total marks within the retention questions to present a retention score (out of a total of five marks). The two transfer questions were computed in the same manner as the prior knowledge test, using a four point rubric. Students could gain a maximum of three marks on one transfer question. The marks from both transfer questions were added together to present a total transfer score (out of a total of six marks). Additionally, the retention scores and the transfer scores were added together to present a total test score for each participant, enabling each student to gain a maximum of eleven marks. Students' answers were scored by the researcher and checked by two Psychology in Education undergraduates using an expert answer produced from science resources which was checked by a science teacher. This was to increase the reliability of the marks distributed across the post-tests.

Basic Characteristics

Before analysing treatment effects, basic characteristics of the four groups were analysed to ensure they did not differ significantly and thus skew the results. A chi-square analysis indicated there were no significant differences in gender across the four groups $\chi^2(3, N = 73) = .285, p > .05$. Additionally, a one-way analysis of variance revealed the performance of the groups on the prior knowledge test did not differ significantly $F(3, 69) = .103$, $MS_{error} = .114$, $p > .05$. Therefore, the groups were equivalent on these basic characteristics, suggesting no group was presented with an advantage throughout the experimental process.

Which Instructional Approach is More Beneficial for Learning?

The first research question explored which instructional approach, whether multimedia or learner generated drawing, was more beneficial for learning purposes. Participants within the control group, who were presented with text alone, achieved the lowest total score in comparison to the experimental groups (M = 6.19, SD = 2). Participants within the generated drawing with support group outperformed the control group (M= 9, SD = 1.83) and the other experimental groups (multimedia: M = 6.95, SD = 2.34; generated drawing with no support: M = 8, SD = 2.33). See Figure 1 for the mean total scores for each condition for the first post-test.

A one-way analysis of variance indicated there was a significant main effect of treatment on the first post-test scores, $F(3, 69) = 5.82$, $MS_{error} = 4.6$, $p < .001$, $\eta^2 = .202$. A Fisher's LSD test showed the control group performed significantly worse than both generative drawing groups (with no support: $p < .05$; with support: $p < .001$) but post-test scores did not differ significantly between the control group and the multimedia condition. Participants within the generated drawing with support condition performed significantly better on the post-test than those in the multimedia condition ($p < .01$) and there was no significant difference found between the two generative drawing conditions, see Table 2 for a summary of these post hoc results.

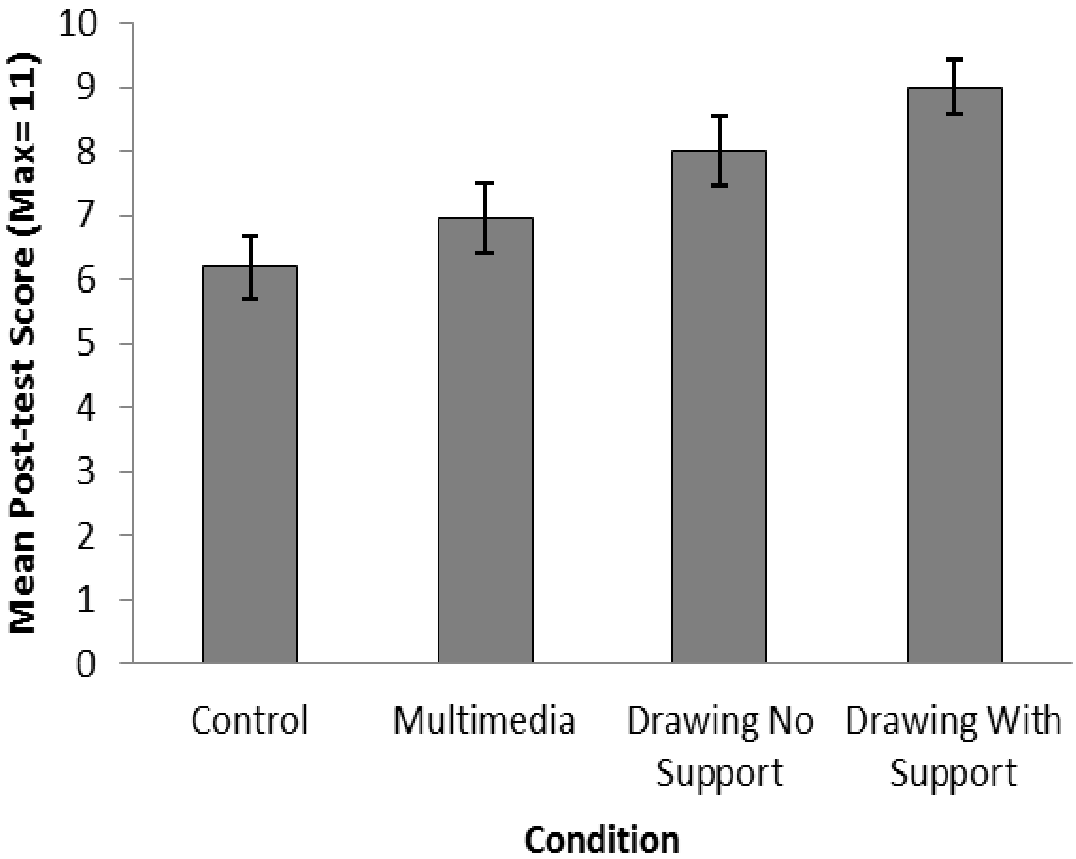

Figure 1: Graph to Show the Mean Total Scores for the first Post-Test for All Conditions

Table 2
Post Hoc (Fisher's LSD) analysis to show significant differences between conditions and the performance in the first post-test.

Group	Group	Mean Difference	Significance Value *p*
Learner Generated Drawing with no support	Control	1.81	.02
Learner Generated Drawing with support	Control	2.81	<.001
	Multimedia	2.05	.004

The post-test was divided into two sections: retention questions; and transfer questions. Table 3 summarises the mean proportion of marks for both types of questions for the control group and the three experimental groups. There was a significant main effect of treatment on the retention scores, $F(3, 69) = 3.2$, $MS_{error} = .92$, $p < .05$, $\eta^2 = .12$. A Fishers LSD test indicated participants within the learner generated drawing condition performed significantly better than participants within the control group ($p < .005$) and multimedia condition ($p < .05$). There were no significant differences between the drawing groups and no other significant differences between the remaining conditions. A one way analysis of variance also indicated a significant main effect of treatment on the transfer scores, $F(3, 69) = 4.41$, $MS_{error} = 2.81$, $p < .01$, $\eta^2 = .161$. A Fishers LSD test revealed both drawing groups performed significantly better on the transfer questions than the control group (no support: $p < .05$; with support: $p <.005$). Participants within the generated drawing with support condition also performed significantly better on the transfer questions than those in the multimedia condition ($p < .05$). There was no significant difference in performance between the two drawing groups. See Table 4 for a summary of the post hoc results for retention and transfer.

Table 3
Mean Scores on the Retention (max=5) and Transfer (max=6) Questions for the second post-test completed a week after the initial experiment for all four groups

	Type of question				
		Retention		Transfer	
Group	*n*	*M*	*SD*	*M*	*SD*
Control	16	3.38	1.08	2.81	1.79
Multimedia	19	3.58	1.12	3.37	1.74
Learner Generated Drawing with no support	19	3.78	.86	4.21	1.72
Learner Generated Drawing with support	19	4.32	.75	4.68	1.45

Table 4
Post Hoc (Fisher's LSD) analysis to show significant differences between conditions and the performance in the first post-test for retention and transfer questions

Group	Group	Mean Difference	Significance Value *p*
Retention			
Learner Generated Drawing with support	Control	.94	.005
	Multimedia	.74	.021
Transfer			
Learner Generated Drawing with no support	Control	1.4	.017
Learner Generated Drawing with support	Control	1.87	.002
	Multimedia	1.31	.018

Overall, the results clearly indicate that learner generated drawing is the most beneficial learning strategy for students and is even more efficient when instructional support is presented to the learner.

Which Instructional Approach is More Beneficial for Long Term Retention?

The second research question explored which instructional approach was most beneficial for long term retention and thus more efficient for learning purposes within the classroom. Figure 2 presents the mean total scores for each condition for the second post-test, administered to the students a week after the initial testing period. Similar to the initial post-test, students within the control group, who received text only, achieved the lowest total score in comparison to the experimental groups (*M* = 5.31, SD = 1.78). Participants with the learner generated drawing with support group (*M* = 8.05, *SD* = 1.68) achieved the highest score and outperformed the control group with their second post-test scores and both of the other experimental groups. However, unlike in the first post-test, participants within the multimedia condition (*M* = 6.74, *SD* = 1.88) performed better on the second post-test than the learner generated drawing group with no support (*M* = 6.52, *SD* = 2.8).

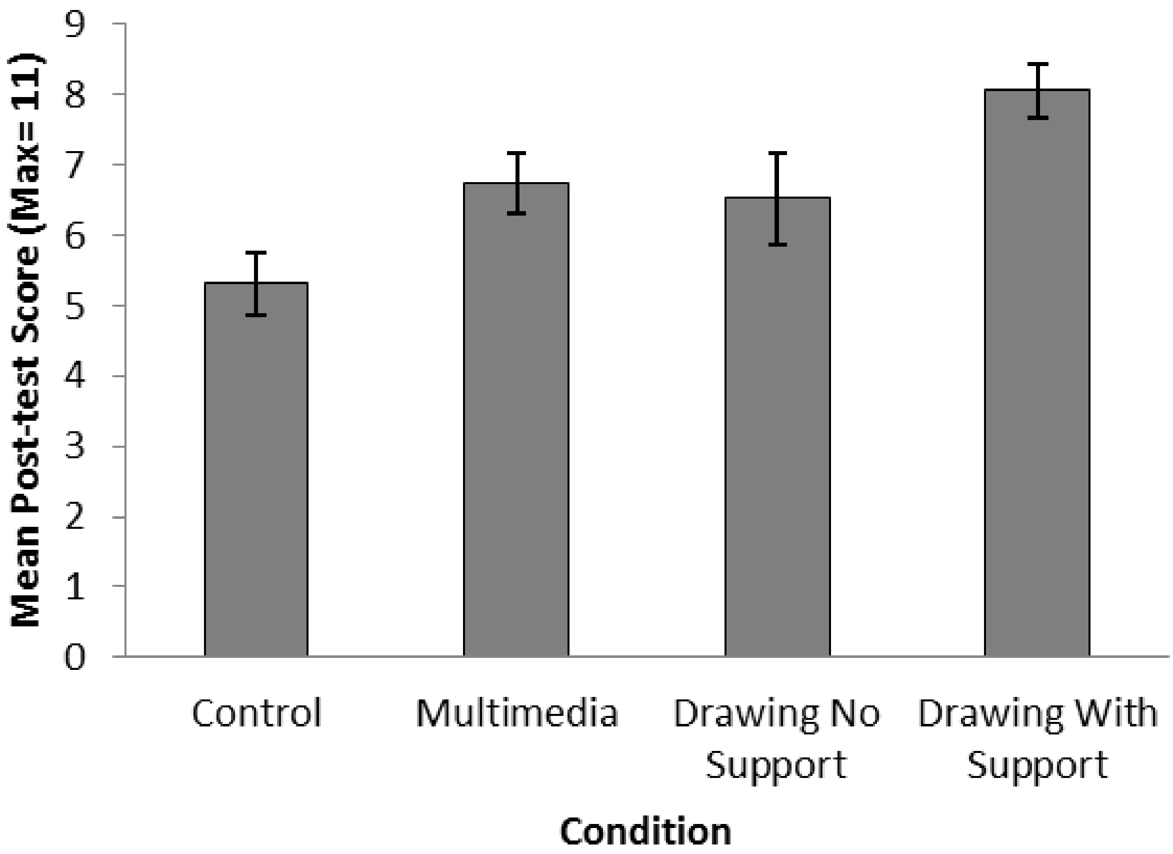

Figure 2: Graph to Show the Mean Total Scores for the second Post-Test, Administered a Week after the Initial Post-Test, for All Condition

A one- way analysis of variance indicated there was a significant main effect of treatment on the second post-test scores, $F(3, 69) = 5.03$, $MS_{error} = 4.39$, $p < .01$, $\eta^2 = .179$. A Fishers LSD test showed the control group performed significantly worse than the multimedia condition ($p <.05$) and the learner generated drawing with support condition ($p < .001$). However, unlike the first post-test, there was no significant difference between the control group and the learner generated drawing with no support condition. Students within the learner generated drawing condition with support also performed significantly better in the second post-test than the students within the learner generated drawing condition with no support ($p < .05$). However, a significant difference was not found between the two drawing groups in their performance on the first post-test, thus, this suggests that learner generated drawing is more effective with instructional support for aiding long term retention of material, rather than pure unsupported learner generated drawing. See Table 5 for a summary of these post hoc results.

The mean proportion of marks distributed for both types of questions presented in the post-test for the four conditions are summarised in Table 6. There was a significant main effect of treatment on the retention scores, $F(3, 69) = 4.11$, $MS_{error} = .937$, $p < .01$, $\eta^2 = .15$. A Fishers LSD test indicated participants within the learner generated drawing with support condition performed significantly better on the retention questions than the control group ($p < .001$) and the two other experimental groups (multimedia: $p < .05$; learner generated drawing with no support: p < .01). There was also a significant main effect of treatment on the transfer scores, $F(3, 69) = 3.38$, $MS_{error} = 2.33$, $p < .05$, $\eta^2 = .13$.

A Fishers LSD test indicated participants in the learner generated drawing with support condition performed significantly better on transfer than those in the control group (p < .05) but there were no significant differences between any of the other conditions. The post hoc results for the treatment effects upon retention and transfer scores are summarised in Table 7.

Table 5
Post Hoc (Fisher's LSD) analysis to show significant differences between conditions and the performance in the second post-test.

Group	Group	Mean Difference	*p* Significance Value
Multimedia	Control	1.42	.049
Learner Generated Drawing with support	Control	2.81	<.001
	Learner Generated Drawing with no support	1.53	.028

Table 6
Mean Scores on the Retention (max=5) and Transfer (max=6) Questions for the first post-test for the four groups

	Type of question				
	Retention			Transfer	
Group	*n*	*M*	*SD*	*M*	*SD*
Control	16	3.06	.85	2.25	1.57
Multimedia	19	3.47	.96	3.26	1.24
Learner Generated Drawing with no support	19	3.37	.96	3.26	1.24
Learner Generated Drawing with support	19	4.16	.60	3.89	1.37

Table 7. Post Hoc (Fisher's LSD) analysis to show significant differences between conditions and the performance in the second post-test for retention and transfer questions

Group	Group	Mean Difference	*p* Significance Value
Retention			
Learner Generated Drawing with support	Control	1.1	.001
	Multimedia	.68	.033
	Learner Generated Drawing with no support	.79	.009
Transfer			
Learner Generated Drawing with support	Control	1.64	.002

The difference between performance on the first and second post-test was also significantly different depending upon the condition, $F(3, 69) = 3.36$, , $MS_{error} = .758$, $p < .05$, $\eta^2 = .128$. The mean scores for the first and second post-test for all conditions are presented in figure 3. T-tests were used to tease apart the interaction and indicated there was a significant difference in performance in the first and second post-test for the control group and both learner generated drawing groups, see Table 8 for a summary of the *t*-test results. However, there was no significant difference in performance between the first post-test ($M = 6.95$, $SD = 2.34$) and the second post-test ($M = 6.74$, $SD = 1.88$) for the multimedia condition, $t(18) = .721$, $p = > .05$. Thus, although participants in the learner generated drawing with support condition gained the highest mean scores in the first ($M = 9$, $SD = 1.83$) and second ($M= 8.05$, $SD = 1.68$) post-test, it is clearly indicated in figure 3 and the t-test results, that within the multimedia condition less information was forgotten from the first post-test to the second post-test, suggesting the information was better retained.

Overall, the results suggest that learner generated drawing with instructional support is the most beneficial learning strategy for long term retention in comparison to being presented with text only (control) or learner generated drawing with no instructional support. However, no significant difference was present between learner generated drawing with support and the multimedia approach, suggesting both of these instructional approaches are effective for long term retention and aid student's learning.

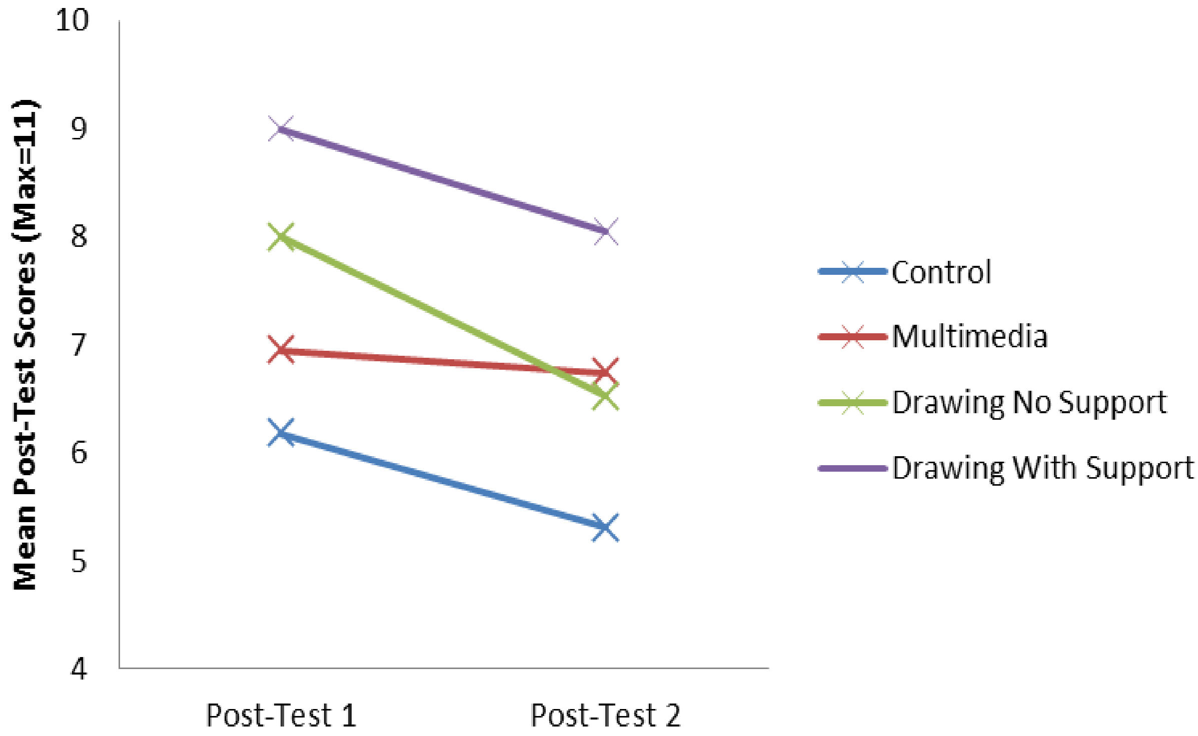

Figure 3: Graph to show the mean total scores for the first and second post-tests for all conditions.

Table 8
t-test analysis comparing the performance of students in the first and second post-test for all conditions.

Group	*df* Degrees of Freedom	*t* T-test value	*p* Significance Value	*CI* Confidence Intervals Lower	Upper
Control	15	2.27	.039	.05	1.69
Multimedia	18	.721	.480	-.41	.82
Learner Generated Drawing with no support	18	5.27	<.001	.89	2.06
Learner Generated Drawing with support	18	4.87	<.001	.54	1.36

Discussion

Empirical Contributions

Within the present research the results clearly show that students within the two learner generated drawing conditions perform significantly better than students in the control and multimedia groups. When exploring long term retention, students in the learner generated drawing with support condition, performed significantly better than the control and learner generated drawing group with no support. Thus, the results emphasise the importance of learner generated drawing and indicate that supported learner generated drawing is the most beneficial strategy for initial learning and long term retention.

The first research question explored in this study was ‘Which Instructional Approach is More Beneficial for Learning?’ The results indicated participants within the control group (text only) performed significantly worse on the first post-test than both generative drawing groups, and the generated drawing with support condition performed significantly better on the first post-test than those in the multimedia condition. The results clearly indicate that learner generated drawing is the most beneficial learning strategy for students for initial information retention and is even more efficient when instructional support is presented to the learner.

The second research question explored was ‘Which Instructional Approach is More Beneficial for Long Term Retention?’ The results indicated that participants within the learner generated drawing with support group performed significantly better on the second post-test than the learner generated drawing group with no support. There was no significant difference between the two drawing conditions in performance on the first post-test, suggesting that learner generated drawing is more beneficial with instructional support for aiding long term retention of material, rather than pure unsupported learner generated drawing. Participants within the control group and both learner generated drawing groups performed significantly worse on the second post-test, completed a week later, than on the first post-test. However, there was no significant difference between the performance on the first and second post-test for the multimedia condition, therefore, although learner generated drawing with support may provide the highest scores and thus, a greater understanding of the material, within the multimedia approach less information was forgotten from one post-test to the next, suggesting information was better retained.

A secondary finding within the results explored the difference in performance on retention and transfer questions within the post-tests for all conditions. Overall, for the first post-test both learner generated drawing groups performed significantly better on retention and transfer questions. On the second post-test the learner generated drawing group with support performed significantly better than all other groups on the retention questions and significantly better than the control group on the transfer questions. Thus, it would seem learner generated drawing with support is the most beneficial approach for long term retention and transfer, although it would seem retention in particular.

Overall, both learner generated drawing and multimedia aid learning efficiently in comparison to the presentation of text only, however, learner generated drawing with support appears to be the most beneficial instructional approach for learning and long term retention.

Theoretical Contributions

The results showed that both instructional approaches (multimedia and learner generated drawing), were more beneficial than the presentation of text only, which supports the findings of previous research mentioned in the introduction (Mayer, 2001; Van Meter & Garner, 2005). This suggests both instructional approaches aid the stimulation of active learning, whereby students select relevant information from the text, organise the information and integrate verbal and nonverbal representations with relevant prior knowledge. Thus, this encourages generative processing which results in a deeper form of understanding (Mayer, 2005). Arguably, presenting students with text only does not utilise the dual coding system of the working memory (Paivio, 1986), resulting in extraneous cognitive processing and effecting the overall retention and understanding of the material presented to the students.

Although both instructional approaches seem to aid active learning in comparison to the control condition, resulting in higher retention and understanding, the results indicate that the learner generated drawing with support group performed significantly better on the first post-test than the multimedia condition, suggesting that it is a more efficient learning approach for students. Therefore, in answer to the first research question explored within this study, the results clearly indicate that learner generated drawing is the most beneficial instructional approach to aid students' learning and is even more effective when instructional support is present. This proposes that learners gained a better understanding of a scientific text when they were instructed to draw representative illustrations rather than passively view them, thus, reflecting the theory of generative drawing construction developed by Van Meter and Garner (2005). Therefore, it seems there is a unique property within learner generated drawing construction which aids generative processing further than the multimedia approach. As research has previously stated, integration of verbal and nonverbal representations within multimedia proves to be a difficulty for students (Ainsworth, 1999; Seufert, 2003) reducing the beneficial effects of the multimedia approach and restricting generative processing. Yet, when learners draw, they must develop a nonverbal representation from the verbal representation, forcing integration across verbal and nonverbal modalities. Therefore, it would seem integration is the specific process credited for the additional benefits of drawing (Van Meter & Garner, 2005). However, as the students within the multimedia condition were only asked to pay particular attention to the illustrations within the text and not forced to answer questions about the illustrations for example (see Van Meter, Aleksic, Schwartz & Garner, 2006), there is no guarantee that the images were completely attended to. Thus, this may negatively affect the role of integration in generative processing and potentially affect the students' performance on the initial post-test. Consequently, although this research is consistent with other findings that have confirmed integration is the additional benefit of learner generated drawing (Van Meter et al., 2006), in this research, although likely, it cannot be assumed.

The second research question explored the long term retention of the multimedia approach and learner generated drawing, which does not seem to have been explored in previous research on instructional approaches. The results showed that the learner generated drawing group with support performed significantly better on the second post-test than the control group and the learner generated drawing group with no support. There was also no significant difference present between the control group and the learner generated drawing with no support condition on the second post-test. Therefore, although having some positive initial effect upon learning, pure learner generated drawing with no instructional support does not seem to have a beneficial effect upon learning and long term retention, which supports Leutner, Leopold & Sumfleth's (2009) conclusions. Learner generated drawing with no support does not seem to have evoked deep learning, unlike learner generated drawing with support. Thus, for those who had no instructional support whilst drawing, the logistics of the drawing strategy itself may have been too cognitively demanding for the learner. This may have affected the generative process of active learning and their long term retention of the material because they were too concerned with the drawing task rather than learning the material they were presented with. Thus, in line with previous research (Mayer, 2005; 2009; Schwamborn, Mayer, Thillmann, Leopold & Leutner, 2010), the mechanics of unsupported drawing leaves fewer cognitive resources available to enhance deep understanding and enable integration of the verbal and nonverbal representation effectively, affecting long term retention and providing an inadequate learning experience for students. Van Meter (2001) found when learner generated drawing was supported the drawing group engaged in self-monitoring processes more readily, thus, it may be the re-inspection of material to aid drawing construction which increases the detection of comprehension errors and attention, resulting in increased retention and understanding. Subsequently, learner generated drawing with support produces appropriate cognitive processing, not exceeding cognitive demands, thus, aiding learning and retention efficiently. As it was an effective approach for long term retention, it suggests deep learning and generative processing was activated, producing a greater understanding of the material.

Moreover, although the learner generated drawing with support was the most efficient instructional approach for learning and long term retention, the multimedia approach was the only condition that did not have a significant difference in performance from the first post-test to the second post-test. Subsequently less information was forgotten, suggesting information initially learned was better retained. Wittrock (1974) emphasised in order for learning to be retained, understanding of information must be evoked through generative processing and thus, active learning (Mayer, 2010). Therefore, the multimedia approach seems to have adequately promoted active learning in order for the information learned to be so efficiently retained. Mayer (2005) argues the spatial contiguity effect (presenting illustrations close to the relevant material) minimises extraneous cognitive load to encourage deep learning. Thus, the layout of the verbal and nonverbal representations within the material which was presented in a spatial contiguous manner, may have also minimised extraneous cognitive demands for learner, further increasing the retention of the information. However, despite this, learner generated drawing with support aids greater initial retention and understanding, and although the difference in performance between the first and second post-test was significantly different, the participants within this condition still gained greater understanding in both post-tests. As a result, although the multimedia approach is beneficial for retention and is significantly more efficient for long term retention than learner generated drawing with no support, it is secondary to learner generated drawing with instructional support.

Additionally, Van Meter and Garner (2005) argued learner generated drawing only had an advantage on higher order knowledge (deep learning) measured by transfer and did not aid lower order forms of knowledge such as retention in comparison to other instructional approaches. They argued integration provides a mental model of the information which provides more flexible applications of knowledge (Kintsch, 1994) and thus, does not retain the entirety of the text precisely (Van Meter, Aleksic, Schwartz & Garner, 2006). However, the secondary results of this research indicate that learner generated drawing with support performed significantly better on: retention questions within the first and second post-test in comparison to the control group and other experimental conditions; transfer questions in the first post-test in comparison to the control and multimedia conditions; and transfer questions in the second post-test in comparison to the control group. Thus, this contradicts Van Meter and Garner's (2005) findings as learner generated drawing aided retention more than the conditions within the experiment. In Wittrock and Carter's (1975) research they found learner generated processing of information aids long term recall due to constructive and semantic processes, encoding the meaning of the information (Craik & Lockhart, 1972). Therefore, learner generated drawing with support may evoke appropriate cognitive and semantic processing, allowing the learner to construct their own meaning to the information they are learning. Thus, this could enable the learner to retain the majority of the text more easily than other instructional approaches, which may be hindered by cognitive load. Therefore, learner generated drawing may enhance constructive and semantic processing, which could positively affect retention as well as aid transfer. As a result, within this research the learners lower and higher forms of knowledge were assisted when using supported learner generated drawing, producing deep learning, positioning this instructional learning method as the most effective.

Overall, the results are consistent with the theory of generative drawing construction, suggesting drawing activity with instructional support fostered additional generative processing whilst minimising extraneous processing. As a result, participants within this condition achieved greater understanding of the scientific text on limestone cave formation, not just following initial learning but also providing long term retention. Thus, this research extends previous research in this area, exploring long term effects of the instructional approaches whilst indicating that learner generated drawing with support is the most efficient learning approach.

Educational Implications

On the basis of these findings and earlier results reviewed in the introduction, teachers and learners may find learner generated drawing a beneficial learning strategy to aid retention and understanding of material. In order for learners to benefit from this strategy an important boundary condition is the drawing activity should involve instructional support from the teacher or within the material. This would ensure there is minimal extraneous cognitive load which would negatively impact the student's learning experience (Schwamborn, Mayer, Thillman, Leopold & Leutner, 2010). Thus, learner generated drawing could be used as a valuable tool to aid children's understanding of difficult concepts and information, as the drawing strategy encourages re-inspection of the material, increasing attention and self-monitoring strategies which are imperative skills for learning (Van Meter, 2001). Teachers could use this strategy as a variation from text books which are usually presented in a multimedia (text and illustration) format. However, learner generated drawing is a more time consuming activity for the student and as teachers now have high amounts of curriculum content to teach, the demands of the classroom may expose this strategy as unsuitable within classroom teaching time.

Nevertheless, learner generated drawing could be used within homework tasks to further understanding and knowledge of the teaching topic. Drawings could then be used by the teacher as a formative assessment to determine the nature of the student's present understanding and misconceptions (Hall, Bailey & Thillman, 1997). Teachers can use the learner generated drawings to inform their future teaching instruction and lesson plans, to recap any areas in which students are struggling.

As instructional support is needed to accompany learner generated drawing, teachers could potentially use instructional support as a scaffolding technique (Wood, Bruner & Ross, 1976), supporting the students learning of difficult material and concepts. Gradually as the child begins to understand the material, the instructional support during learner generated drawing could be minimised to aid the students construction of new ideas and deep understanding of the material. This method is called fading and is coupled with scaffolding to enable students' to gradually develop their own representations of knowledge (Ghefaili, 2003).

Therefore, as many researchers emphasise the importance of constructivism (Wittrock, 1974; Vygotsky, 1978), encouraging students to construct their own knowledge and relationships, it seems appropriate that learner generated drawing is used to facilitate the student's representation of knowledge.

Limitations and Future Directions

The present study is limited in some areas that should be investigated in future studies. First, the children used within this study were all considered high achievers and were within the top two sets of their year group (of which there are five academic sets). Therefore, it cannot be generalised that the learner generated drawing strategy with support is the most beneficial instructional approach for all learners. Those who are considered as lower achievers or who have special educational needs may find it more or less beneficial than typically developing children. For example, Wang, Yang, Tasi and Chan (2012) studied the effects of learner generated drawing with dyslexic students and found that it was a particularly useful learning strategy, with the potential to use in the classroom for teaching text reading to dyslexic students. Frith (2003) who has completed vast amounts of research on children with autism found one key feature of autism is their inability to process information as a whole and instead focus on constituent parts, struggling with the concept of integration. Therefore, it may be that learner generated drawing is a highly beneficial learning strategy for children with autism as learner generated drawing forces integration of verbal and non-verbal representations. Conversely, autistic children may find this approach exceptionally challenging. For example, within this piece of research there was one child, although not statemented, who was regarded by the teachers as having special educational needs, with very similar deficits to children with autism. Although the child did not get all questions wrong in the post-tests, he did struggle to adapt to the learner generated drawing condition as it was out of his normal routine and the procedure was highly unfamiliar to him, thus this seemed to negatively affect his performance on the post-tests in comparison to other high achievers in the class. Therefore, further research would be needed to determine clearly who these instructional approaches are most beneficial for and if learner generated drawing is as beneficial for children with a lower academic ability and special educational needs as it is for higher achievers.

Additionally, although children were all at the same standard in terms of basic characteristics to ensure no child was at an advantage, the results were found for low prior knowledge learners. Although children had learned about acid rain within their class (which featured within the text about limestone cave formation) they had limited prior knowledge of how a limestone cave formed. Thus, it may be suggested that student's cognitive processing was overwhelmed as the information and the drawing technique was unfamiliar to them. Therefore, drawing without support far exceeded cognitive demands for retaining information learned. However, if the same information was given to learners who had high prior knowledge, those who constructed drawings without support may have found the approach more beneficial, as cognitive load would be minimised, enabling greater understanding and retention of the text. Consequently, it would be useful to repeat this study with high prior knowledge learners and compare the results to examine which instructional approach was more beneficial.

Training was not given to students within the learner generated drawing conditions. These students would therefore be disadvantaged in comparison to the multimedia condition, as multimedia participants would be used to the material layout, as multimedia presentations are highly similar to information presented in textbooks. If training was given to the learner generated drawing conditions before participating in the experiment, ensuring the method was familiar, this may have minimised extraneous cognitive load more and highlighted further benefits of the learner generated drawing approach. Thus, researchers should consider providing training for learner generated drawing when investigating this approach further.

Although this research begins to unfold the long-term effects of the multimedia and learner generated drawing approaches, it would be more beneficial to extend the time between the first and second post-tests, as a week may not reveal the full extent of the benefits of the approaches involved for long-term retention.

Another limitation within this research is that differing levels of instructional support were not investigated for learner generated drawing. Thus, although it is clear that instructional support is beneficial for learning and long term retention of the learning material, the amount of support needed to help learners cannot be distinguished. Instructional support is based upon a continuum from no support at all to complete drawing support (Van Meter & Garner, 2005), therefore, more conditions with varying degrees of support would be needed to establish what support is needed.

Moreover, this research only explored the effects of instructional approaches on one age group. Thus, although there is indication within this study that learner generated drawing with support is a beneficial learning strategy to implement within an educational setting, it would be inappropriate to assume that this would be the case for all aged learners throughout their educational career. For example, within Van Meter, Aleksic, Shwartz and Garner's (2006) research there was an indication that younger learners, for example those in primary school, did not benefit sufficiently from learner generated drawing. Thus, this is an area which should be developed further.

The results of the present research were found with a specific learning content, a piece of science text on limestone cave formation for comprehension, and specific types of images and text that served an instructional, explanative function. Thus, it remains questionable as to whether these results hold for other subject matters and representations of images and text. However, scientific content and explanative text and images have been used in many studies to explore instructional learning methods (Mayer, 2001; Schwamborn et al., 2010; Van Meter et al., 2006), and so it would seem that instructional methods are beneficial to aid scientific learning.

Potentially reducing the validity of this research further, is the question of whether the conclusions found within this research really compare to the majority of Mayer's work. Mayer's work on multimedia often used computer based images (e.g. Moreno & Mayer, 2001; Mayer & Moreno, 2002; Mayer, 2003) rather than paper based images which were used within this experiment. Thus, it is difficult to conclude that learner generated drawing is more beneficial than the multimedia approach, when it is possible that having computer based images may reduce cognitive load further and aid learning more efficiently, possibly enhancing the benefits of the multimedia approach. Thus, it may have been more appropriate to have used a computer based environment for this research. However, Schwamborn, Thillmann, Opfermann & Leutner (2011) used computer based environments to investigate the effects of learner generated drawing. They found that students did not benefit from learner generated drawing when using a computer based environment, as the programme used was difficult for drawing construction which increased cognitive load and resulted in less cognitive resources for generative processing. Therefore, using a computer based environment may not have provided a true representation of which instructional approach was more beneficial and represents the importance of training for learner generated drawing. As Mayer's earlier work used paper based images (e.g. Mayer & Gallini, 1990) when investigating the multimedia approach and still found added benefits of the instructional learning method, the results and conclusions found within this research are still arguably valid and comparable to Mayer's work.

Finally, the transfer questions within this research may be considered by some as insufficient, posing as questions of transfer when they are not. However, this depends upon one's definition of transfer. Transfer can be divided into near and far transfer, with near transfer questions defined as close to the topic or information being taught and far transfer questions defined as applying the information given to a completely different context (Clark & Voogel, 1985). Thus, the transfer questions within this study are arguably near transfer, yet, they still require a higher level of knowledge and understanding in comparison to lower forms of knowledge represented within the retention questions. Consequently, it depends upon one's definition of transfer as to whether the questions used within this research are considered as transfer questions, however, the questions were based upon the same format of transfer questions represented within Van meter et al.,'s (2006) work, thus, arguably the transfer questions within this research are adequate for measuring learners transfer of knowledge. Despite this, in future research it would be beneficial to include a higher number of transfer questions, representing near and far transfer, to grasp the full depth of understanding and knowledge acquired through different instructional methods.

Moreover, the limitations mentioned could potentially cast doubt on the validity and reliability of this research. However, arguably the limitations do not detrimentally affect the overall conclusions, but rather the conclusions present further contribution to the vast amounts of research investigating the effects of instructional learning approaches.

Conclusion

Overall, despite the limitations, this study is in line with earlier studies reviewed in the introduction that showed the positive effects of learner generated drawing under the condition that instructional support is present to minimise extraneous cognitive load. Seventy three year 8 students read a piece of scientific text under four conditions: text only (control); multimedia; learner generated drawing with no support; and learner generated drawing with support. The reading material was followed by two post-tests including questions of transfer and retention: the first which was completed immediately after the experiment; and the second a week later to examine the long term effects of the instructional approaches. From this the results clearly indicate that learner generated drawing with support is the most beneficial learning strategy for students, outweighing the unsupported learner generated drawing group and emphasising the importance of instructional support during generative drawing. Supported learner generated drawing aids understanding and knowledge, both in the initial learning phase and for long term retention. Although multimedia is beneficial for learning and does seem to retain knowledge and understanding over time, this is subordinate to the supported learner generated drawing approach.

Therefore, this research offers a dynamic contribution to the research on instructional learning methods. It provides an understanding of the longer term effects of such learning strategies including which of the methods, either the multimedia approach or learner generated drawing, is most beneficial for student's learning experience. Thus, the findings may prove beneficial to teachers who are willing to adapt their teaching methods to provide a more efficient learning experience for their students. Thus, although Stull and Mayer (2007) found no support for the proposition that learning by doing (learner generated drawing) will lead to deeper learning than learning by viewing (multimedia), within this research this is clearly not the case. Instead this research supports vast amounts of research in this area, presenting the necessity of learner generated construction, which stimulates consciousness and arousal in a way that learning by viewing simply does not (Jacoby, 1978; Van Meter, Aleksic, Schwartz, Garner, 2006).

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