



Faculty of Sciences

Department of Computer Science and Information Systems

**THE EFFECT OF THE APPLICATION OF THE MODALITY
PRINCIPLE IN E-LEARNING ON LEARNING OUTCOMES
AMONG BOTSWANA PRIMARY PUPILS' EDUCATION**

by

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Dr. Malatsi Galani

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Dedication

This thesis is dedicated to my handsome son Jaden Phenyio Chilalu, who was born during my study. My parents John Chilalu and Pelekani Chilalu who believe in the value of education.

Abstract

With the current COVID-19 pandemic, the research field of e-learning is experiencing rapid developments on the best application of e-learning in the education sector (Mastan et al., 2022). According to Mayer (2003a), there are three elements of science for e-learning; evidence, theory, and applications. This study was based on the applications of evidence which is theory-based principles that guide the best way to design electronic learning, connected with a theory of how people effectively learn in an electronic environment - Cognitive load Theory. To successfully deliver the instructional materials based on the theory principles, one has to design, develop and implement high-quality multimedia instructions (Alsadhan et al., 2014). Multimedia is a combination of various media content forms as such; video, interactivity content forms, animations, still images, and text. Mayer (2005) formulated several evidenced-based instructional principles in multimedia on how to enhance the learning outcomes of learners, and these principles take into account the effect of cognitive load and how it affects the learning process. One popular multimedia principle approach is called the modality principle.

According to the principle, when explaining the instructional material presented to learners, it is best when words are in an auditory form as opposed to a visual form (Liu et al., 2021). Studies that have investigated the impact of the modality principle on the learning outcomes of learners have yielded mixed results. Early studies have found the principles material to hold truth while recent studies are obtaining a reverse modality. Researchers have identified conditions including; visualization format (Schueler et al., 2011a), system pace versus learner pace (Leahy and Sweller, 2011, Reinwein, 2012), high elementary (Mayrath et al., 2011a), text length (Lindow et al., 2011), and matter of animation (Schmidt-Weigand, 2011, Liu et al., 2021), as some of the influences of recent yielded results that, on-screen text and images are better than narration and images.

This study was conducted to identify the conditions of narration for the modality principle that affect students' learning outcomes. The study aims to quantitatively assess the learning outcomes of learners exposed to images and narration with conditions versus on-screen text and images. These conditions of narration include; presentation mode and narration style. The quantitative research's goal is to collect a dimension of numeric data that allows researchers to conduct exceptionally sophisticated statistical analyses that cumulative the data (Ahmad et al., 2019). The study included one pilot study and one main experiment. The

experimental design provides a powerful suite of statistical methodology as it involves controlling and managing variables and relies on the use of randomization (Majid, 2018). The experiment consisted of two main groups; the VN group, the group with video and considered narration, and the VT group, the group with video and on-screen text. There was a significant difference between the different groups in the learning outcomes. The conditions of narration for the modality principle were perceived as being helpful and proved once again that narration with images is better than on-screen text with images as initially defined by the principle.

The modality principle's ability to reduce extraneous cognitive load during learning was slightly found in this study. The reported average cognitive load from the two different groups had a slight difference. Although the two groups reported a statistically significant difference in the cognitive load and the learning outcomes, a correlation was not established between the overall performance and the reported cognitive load in both groups.

This study shows that paying attention to the narration presented to learners for modality instructional materials is crucial for producing significant results in the learning outcomes of learners during e-learning. For future studies on the modality principle, researchers may focus more on identifying conditions of narration that would present a correlation between the performance of each test assessment and the measured cognitive load. The study has contributed to the field of e-learning with multimedia by identifying and analysing different conditions of narration for the modality principle. The results of this study can assist designers, developers, and e-learning management coordinators in successfully delivering high-quality instructional material that can effectively improve the learning outcomes of learners.

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List of abbreviations

CLT - Cognitive load Theory

CTML - Cognitive theory of Multimedia Learning

VN – Video with conditions of Narration

VT – Video with on-screen Text

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Chapter One Introduction

This chapter provides a brief overview of e-learning as a frame of reference to the thesis topic, followed by the research problem background clarification, the research objectives, the purpose of the study, the significance of the study, and the study's limitations. The last section of this chapter presents a summation of how the rest of the dissertation is organized.

1. Introduction

The inauguration of e-learning systems in the education sector has grown since the emergence of Information and Communication Technology (ICT). With the outbreak of the current COVID-19 pandemic, there has been a more rapid growth of e-learning in the world of education (Mastan et al., 2022). Despite the sudden transformation, educational institutions have been forced to switch from traditional educational methods to e-learning, to avoid social gatherings and flatten the curve spread of the virus (Maatuk et al., 2022). E-learning has reshaped how knowledge is transmitted, and how the learning process is facilitated. As attested by Alsadhan et al., (2014), e-learning is defined as an educational system that offers content through the use of information technology resources such as multimedia applications, satellite broadcast, intranet, and the internet. In most cases, e-learning is used in distance learning by students to access learning online from different countries. The number of learners enrolling in online courses is increasing each day. Therefore, the design and delivery of high-quality instructions in e-learning are becoming very crucial (Alhomod and Shafi, 2013). One way of ensuring the effective delivery of e-learning is to plot, develop and implement impeccable multimedia instructions (Alsadhan et al., 2014). There are different forms of multimedia to select from and infuse into e-learning to increase the learning interest amongst all learners.

Multimedia involves the application of different media content forms. These include video, interactivity content forms, animations, still images, and text. According to Mayer (2017) multimedia environment promotes meaningful learning by featuring different media presented to students and also by the degree of interactivity. Students understand lessons faster and easier when using an interactive multimedia learning strategy that bring into effective action visual and audio annotations (Matias and Agapito Jr, 2022). Interactivity serves as one of the most crucial components of computer-based learning and teaching.

Varying forms of media presentation during a multimedia computer-based environment can provide excellent support for the requirements of the educational curricula to promote competency and performance. Ginns (2005) has further argued that a single form representation is less effective in facilitating learning than multimedia forms representation which are more effective. According to Mayer (2017), multimedia learning provides a more in-depth understanding of concepts amongst learners. It involves a combination and synchronization of nonverbal presentation (video, animation, interactive illustrations, images, and charts) with verbal presentation (spoken text and written text).

Learning outcomes in multimedia learning can be assessed with two distinctive tasks, which are retention tasks and transfer tasks. The retention tasks are used to measure the learner's capability to retrieve relevant content from what they were taught immediately after the treatment (Liu et al., 2022, Kim and Lombardino, 2017). Retention is about remembering and the ability to duplicate the material presented. Transfer tasks are used to measure the learner's capacity to apply what they were taught to solve a problem. Kim and Lombardino (2017) argue that knowledge transfer is about understanding and the ability to make use of the material presented in new situations. For better retention and knowledge transfer, words on multimedia instructions should be delivered as spoken text rather than written text (Mayer, 2014b). Narration is the ability to tell or give an explanation about something.

Multiple studies have been carried out on how to design instructional material in multimedia (Mayer, 2005). As a result of this research, evidenced-based instructional principles on how to enhance learning outcomes have been formulated. One popular multimedia principle approach is the modality principle. According to the modality principle (Oberfoell and Correia, 2016, Ye, 2018, Chen and Yang, 2020, Liu et al., 2021), the multimedia presented to students is better narrated rather than presented visually.

The modality principle has shown that narration could lessen the cognitive load on learners and promote effective learning due to the multimodal presentation. According to Ayoob et al., (2020) and Sweller et al., (2019), cognitive load is the weight that is placed on the limited memory by information or a task during learning or problem-solving. Based on Sweller et al. (1998)'s Cognitive Load Theory (CLT) and Mayer (2014)'s Cognitive Theory of Multimedia Learning (CTML), the modality principle has been explained in a series of research on the capacity of multimedia in science and technology education (Mayer, 2005). The cognitive theory of multimedia learning's major argument is that the use of technologies

to design instructional materials should minimize the possibility of overloading learners' cognitive systems, and maximize effective learning.

However, recent studies have found that narration is not sufficient for students during multimedia learning as compared to on-screen text. Recent studies' results show what is called a reverse modality. Consequently, the modality effect is disappearing (Leahy and Sweller, 2011, Ye, 2018), and there are some questions about the most effective ways of delivering narration on modality instructions (Sandoval, 2016). Several studies focusing on the modality principle have yielded mixed results, some due to a lack of consideration of narration presentation.

Understanding the conditions of narration for the modality principle can assist the education management, instructional designers, and software & systems developers in providing high-quality narration when designing materials for e-learning to improve the learning outcome of students. The quality output of narration affects retention and transfer of knowledge among learners. With many developments concerning multimedia instruction and learning, it is very crucial and beneficial to understand various effective ways of presenting multimedia instructions to improve the learning outcomes of students during e-learning. This study intends to provide evidence-based conditions of narration for the modality principle that reduces cognitive overload and effectively improves the learning outcomes of learners.

2. Problem statement

Researchers have investigated the effectiveness of the modality principle and different conclusions about the principle were reached. Recent researchers are obtaining reverse results, therefore researchers are examining the principle instructional material in different conditions. These conditions considered the presentation of text to participants, the pace at which instructional materials are presented, the presentation of non-verbal forms, and so on.

The modality effect argues that written text, which is referred to as on-screen text in this study is less effective as compared to narrated text for retention and transfer of knowledge. Mayer and Moreno (1998) concluded that the text length presentation during the principles materials affects the learning process of the learner. Lindows et al., (2011) hypothesized to find the effect on single text only and disappear on a block of multiple sentences, however,

no modality effect was found in their experimental conditions. In an earlier study, Mayer and Moreno (1998) indicated a strong modality effect under a similar study. Wong et al., (2012) reported a true modality effect with the short segments. While Schöler et al., (2013) have further demonstrated that with longer text segment a reverse modality occurs regardless of the learning environment. Sweller et al.,(2011a) explained that lengthy text segments cannot be held and processed in the working memory hence causing a reverse modality.

Other researchers have considered the pace of presentation, this involves learner-paced learning versus system-paced learning. For instance, Ginns (2005) showed that the modality effect occurred with system-paced learning than with learner-paced learning but Leahy and Sweller (2011), Wong et al.,(2012), and Schöler et al.,(2013) have concluded that system-paced learning contributed to a reverse modality.

There are other studies available on the modality principle concerning the conditions established and investigated. Others include; level of interactivity, type of visualization, the matter of animation, and so forth. None of the identified conditions focuses on the narration of the modality principle for instructional development. Therefore studies have incorporated different features of narration which have led to different results obtained concerning the effect of the modality principle. Therefore, there is no evidence about the conditions of narration to consider for the modality's instructional materials for e-learning.

3. Aim of the study

The study aimed to generate conditions of narration to consider when using the modality principle during e-learning to improve students learning outcomes and reduce cognitive load.

4. Specific objectives

1. To assess the available conditions of narration used for designing modality principle instructional materials.
2. To develop modality principle instructional materials with the formulated conditions of narration.
3. To execute the learning process on students using the developed material.

4. To evaluate the learning outcomes of students after an e-learning lesson.
5. To measure the cognitive load experienced by students post-presentation of the instructional material.

5. Research questions

To achieve the research aim, the research questions examined are:

1. What conditions of narration are used in instructional design for the modality principle?
2. What are the learners' perspectives about the presentation of narration featured in e-learning?
3. How do the identified conditions of narration for the modality principle affect the performance of learners and their cognitive load?
4. Is there a relationship between the performance and the reported cognitive load of learners during e-learning?

Research questions number three and four were used to formulate hypotheses to be tested.

Question 3. How do the identified conditions of narration for the modality principle affect the performance of learners and their cognitive load?

H1. Learners in the narration group will outperform learners in the on-screen text group on the retention task.

H2. Learners in the narration group will outperform learners in the on-screen text group on the transfer task.

H3. The narration group will report a lower cognitive load compared to learners in the on-screen text group.

Question 4. Is there a relationship between the performance and the reported cognitive load of learners during e-learning?

H4: The different groups' performance will have a substantial degree with the reported cognitive load.

6. Justification for this study

Earlier research has cited that narration improves the efficiency of learning and reduces cognitive load rather than onscreen text. However, featuring the modality principle materials in multimedia design has not generated empirical support as the instructions of the guide produce a reverse modality (de Oliveira Neto et al., 2015). According to Oberfoell & Correia, (2016) and Liu et al. (2021), reverse modality is where the materials for on-screen text are more effective than the materials designed with narrated text on transfer and retention of knowledge. Therefore further research is needed to identify why narration for modality materials is less superior as compared to on-screen text.

The purpose of this study is to identify conditions of narration that should be considered when using the modality principle to improve learners' performance and reduce cognitive load. The research on the modality principle has not been detailed on the conditions under the principle's narration. But unconsidered narration can impose an unnecessary extraneous cognitive burden and take away the learners' capability to effectively retain and transfer knowledge. Therefore, it is crucial to have conditions of narration that support the development of instructional materials for the modality principle.

7. Significance of the study

Studies on the modality principle effect have not considered investigating the narration features on the instructional materials of the principle. Leahy and Sweller (2016) have mentioned that learning material with long and complicated narration accompanied by graphics can lead to written text accompanied by graphics learning material better than narration. This study has contributed to the field of e-learning with multimedia by identifying and analysing different conditions of narration to consider when developing instructional materials for the modality principle. These conditions try to eliminate complicated features like long-spoken text and difficult text which may overload learners working memory and (Oberfoell and Correia, 2016) take away learners' ability to effectively retain and transfer knowledge.

Many conditions affecting the effect of the principle have been identified and investigated including; the pace of presentation, the learning environment, the type of visualisation, and many more but none have focused on testing the narration presented to learners which also contributes to how learners retain and transfer knowledge. Liu et al., (2021) added that the nature of the spoken text can lead to a reverse modality effect.

The results of this study can assist designers, developers, and e-learning management coordinators in successfully delivering high-quality instructional materials that can effectively improve the learning outcomes of learners. The study may also benefit researchers by providing a new direction for future investigation on the modality principle.

8. Operational definition of terms

Cognitive load theory

Sweller (2020), defined it as “an instructional design theory based on our rapidly expanding knowledge of human cognition, as well-suited to provide guidance suggesting which educational technologies are likely to be effective and how they should be used.” This theory is applies to technology-assisted learning.

Cognitive theory of multimedia

A theory comprised of Mayer’s 12 multimedia learning principles (2009) that aim to guide the design of effective instructional multimedia (Liu et al., 2022). According to Mayer (2014a) in the cognitive theory of multimedia learning, (CTML) effective learning occurs when there is diligent learning in which a learner hold and makes use of different cognitive processes to comprehend the information delivered

Extraneous cognitive load

Cognitive load type originates from the layout and design of instructional materials in conditions that do not contribute to learning (Ayoob et al., 2020).

E-learning

A formal teaching method with the assistance of electronic resources inside or outside the classroom (Maatuk et al., 2022).

Instructional material

Multimedia messages contains images that can be diagrams, video, illustrations, animation ,or photos, and words that can be written or narrated (Mayer, 2014b)

Knowledge retention

The retention tasks are used to measure the learner's capability to retrieve relevant content from what they were taught immediately after the treatment (Liu et al., 2022, Kim and Lombardino, 2017).

Knowledge transfer

Kim and Lombardino (2017) argue that knowledge transfer is about understanding and the ability to make use of the material presented in new situations.

Modality effect

"People learn more deeply from multimedia lessons when words explaining concurrent graphics are presented as speech rather than as on-screen text."(Clark and Mayer, 2016) p.121

Modality principle

"According to the modality principle, students learn better from graphics + audio than graphics + text."(Liu et al., 2022) p.2

Working memory

"The central processing component of the human cognitive system."(Zhu et al., 2020) p 267. Working memory has a limited capacity and processes secondary knowledge before being stored in long-term memory.

9. Dissertation organization

To address the main objective of this study, this dissertation is organized into six chapters. The first chapter is the introduction which summarises the need for the current research. The second chapter comprises the literature review, on the theoretical frameworks which outlines the relevance of the human cognitive architecture and how human processes information during multimedia for the context of this study and the study's conceptual framework. The third chapter discusses several studies pertinent to the current research,

which has led to the identification of the existing research gap. The fourth chapter covers the methodology, which discusses the research approach used to address the research questions. The fifth chapter presents results obtained from T-test analysis, ANOVA analysis, and correlation analysis. The sixth chapter is the summary and the contribution of the study, concluding with the implications of the study and further research directions.

Chapter two Literature Review

1. Introduction

To understand the present study, a literature review was undertaken. This chapter describes Cognitive load theory and the Cognitive theory of multimedia learning and its relevance to the current study. It is necessary to show the theoretical context in which instructional materials in e-learning can be delivered to learners to enhance students' learning outcomes. A conceptual framework for the study is provided. The chapter proceeds to describe how to measure cognitive load and issues surrounding cognitive load on younger learners.

2.Theoretical framework

This study is anchored from the theoretical support of Cognitive load theory (Sweller et al., 2011c) and Cognitive theory of multimedia learning (Mayer, 2022). According to Chen and Yen (2021), both theories highlight that during knowledge construction on the available cognitive capacity, learners become involved in cognitive processing. Below is an explanation and discussion of both theories in more detail.

2.1 Cognitive Load theory

Cognitive load theory is a theoretical framework that is based upon the human cognitive architecture that is made up of limited memory and unlimited memory (Sweller, 1988, Sweller et al., 1998). According to the theory, learning relies mainly on the limited processing capacity of an individual cognitive architecture and the amount of cognitive load imposed on the individual by a task (Chandler and Sweller, 1991). Atkinson and Shiffrin (1971), contend that the cognitive architecture comprises a limited memory that is very limited in both capacities (4 ± 1 element) (Baddeley and Hitch, 1974, Cowan, 2001, Miller, 1956) and in duration (Peterson and Peterson, 1959), which interacts with a virtually long-term memory which is unlimited. The limited memory should be used effectively so that schema construction is optimized, and relevant learning activities occur in an unlimited memory. Schemas allow the storage of learned materials in the long-term memory and lessen the load on the limited memory. Thus, the theory emphasizes working memory as the determinant of effective instructional design (Mutlu-Bayraktar et al., 2019).

The primary research on this theoretical framework is to investigate and evaluate the instructional design methods to suit the learner's mental capacity better.

Cognitive load

Cognitive load occurs when a learner processes the information which they need in their working memory. Chandler and Sweller (1991), defined cognitive load as a multidimensional construct symbolizing the mental effort and the mental load imposed on a learner's cognitive system during problem-solving execution.

The mental load is a task-based dimension; it refers to the burden imposed by instructional content such as the sequence of information, the task structure, and content complexity (Paas et al., 2008, Morrison et al., 2014). The task-based measurement is used to give out the prediction of the foreseen cognitive capacity demand.

Mental effort is a learner-based dimension; it refers to the capacity that a learner allocates to instructional or task demands (Morrison et al., 2014). The learner-based measurement can be considered to be the overall volume of the working memory assigned by a learner during learning or task performance (Inan et al., 2015).

Both dimensions affect a learner's performance. Performance can be defined as a reflection of mental effort, mental load, and causal factors. Causal factors are the characteristics of a learner, the environment, the task, and their relationships (Paas and Van Merriënboer, 1994). In this research, performance is determined by the number of correct answers to the learner scores. It is determined after a learner completes a particular task.

A high cognitive load can occur when a learner puts too much mental effort into a task or problem-solving. A higher cognitive load leads to cognitive overload. To avoid mental overload, the cognitive load can be divided amongst group members during group work so that individual gear is lower (Kirschner et al., 2009).

Since most learning occurs individually, most studies' main focus is on individual cognitive load. Therefore it is crucial to consider the capacity of cognitive load for individuals when designing effective instructions. Instructional management of cognitive load is very vital to effective learning. Although CLT distinguishes different kinds of CL, cognitive load is generally defined as one notion.

Sources of Cognitive load

There are three types of cognitive load processing that contribute to the cognitive load of a learner during the learning process: 1) extraneous cognitive load, 2) intrinsic cognitive load, and 3) germane cognitive load (Paas and Sweller, 2014, Sweller et al., 2019).

Extraneous cognitive load

The extraneous cognitive load type originates from the layout and design of instructional materials in conditions that do not contribute to learning (Ayoob et al., 2020). Many instructional materials were advanced without the consideration or understanding of the human cognitive architecture, therefore imposing an extraneous cognitive load (Sweller, 2020). For instance, they were presenting a complicated visual with its explanation text fixed far off from the graphic. This instance requires the learner to try to merge the two sources of information to make sense of the whole presentation. Hence the learner is likely to exhaust much of the limited cognitive processing capacity available without contributing anything to the learning process.

High extraneous load is caused by “bad” instructional designs, which ignore the limited processing capacity (Mutlu-Bayraktar et al., 2019). Mental activities and information that does not directly support learning and use the limited processing capacity obstruct the results of schema acquisition or automation.

Intrinsic cognitive load

The intrinsic cognitive load type is caused by the complexity of the instructional goals and their content (Sweller, 2020). A learner can experience the magnitude of intrinsic load which is caused by attempting to associate crucial elements of information that need to be learned to understand new information.

After learners receive the learning material, the crucial factor is the complexity of information that the learners have received (Paas and Sweller, 2014). The complexity of the material is called element interactivity. That is, learning materials are made up of several elements, and if the details have a relationship, they interact, and this interaction increases the complexity of the material (Wong et al., 2019). This interaction is needed for effective learning to occur. For instance, low element interactivity can be when studying vocabulary, and high element interactivity can be when talking in an alien language.

A high intrinsic cognitive load imposed on the limited memory of the learner can be a result of a high number of the interactions of elements processed simultaneously. However, a higher intrinsic load does not only result due to element interactivity; it can also depend on the expertise of a learner. Certain learning materials can cause high element interactivity in some learners if they have not yet developed sophisticated schemas.

This cognitive load is reduced if suitable schemas have already been constructed and stocked in the unlimited memory. Schema construction can be complicated for novices as they have to deal with more element interactivity. Therefore, novice learners can quickly overload their working memory (Chen et al., 2017).

Germane cognitive load

The germane cognitive load type emerges from the pattern of instructional materials in means that contribute to knowledge acquisition (Mutlu-Bayraktar et al., 2019). In germane load, the learner is engaged in deep cognitive processing such as figuring out the learning material by reconstructing it into a coherent structure and merging it with compatible prior knowledge (Paas and Sweller, 2014).

It is very crucial to understand the level of the learner's prior knowledge when creating the instructional strategies to increase the germane load. According to Sweller (2011c), germane cognitive load is considered limited by the intrinsic cognitive load. That is, intrinsic cognitive load is needed by learners to learn new material and germane load is the required load devoted to learning novel information and understanding it.

Intrinsic load is primarily imposed by the complicity of the learning material, unlike extraneous load and germane load, which are inflicted by the design of instructional material. So "The greater the proportion of germane cognitive load, the greater the learning potential is." (Wernaart, 2013). Therefore it is crucial to note the effect that the instructional materials impose on learners.

Cognitive Load theory effects

The Cognitive Load Theory theorists have developed numerous predictions concerning the way students can learn to lower the extraneous cognitive load and enhance performance on learners. These predictions have led to the development of a few techniques that they have

indicated pose two major risks: split attention and redundancy. These techniques have led to the development of instructional formats that focuses on keeping the extraneous load low to create the working memory space for effective learning to occur. There are a few cognitive effects that are apply to technology-assisted instruction and they include the following:

i. *Worked example*

According to Sweller and his colleagues (2011c), the worked example is a technique that ministers a step-by-step way of solving a problem or particular task whilst reducing the cognitive load on learners. The worked example assists with storing schemas in unlimited memory. The effectiveness of storing schemas in unlimited memory depends on how learners concentrate their cognitive resources on the crucial step-by-step solutions to a problem (Renkl, 2002). When the schemas are stocked in the long-term memory, they can be used by the learner to solve any related problem. It is very crucial to ensure that the worked examples are carefully structured to avoid unnecessary cognitive load that can hinder the learning process of learners (Cooper and Sweller, 1987).

Worked example reduces extraneous cognitive load, unlike solving an equivalent problem exclusively through (Sweller, 2020). Unlike learning solely on problem-solving, which takes longer to get the concept, worked example increases the possibility of successful learning with less time because of studying the examples first. Research by Kissane et al. (2008), has demonstrated how worked example is more effective as compared to problem-solving. The worked example helps the learners to understand the critical aspects of problem-solving and use them whenever they have to solve a similar situation. The primary attention of the learners has to be on the step-by-step solutions.

Figure1 below shows a worked example by Copper and Sweller (1987), where learners were expected to study the norm, and then solve an indistinguishable problem using the acquired knowledge from the example.

$e(a + b) = g$ divide both sides by e $e(a + b)/e = g/e$ cancel out e top and bottom $a + b = g/e$ subtract b from both sides $a + b - b = g/e - b$ cancel out $+b$ with $-b$ $a = g/e - b$

Figure 1 Worked example in Geometry

Renkl and Atkinson (2010) pointed out that worked examples are most prominent for instructional material with structured learning such as geometry and physics.

According to Serin (2018), geometry is a very crucial mathematical area that develops a student's problem solving and critical thinking capacity. The subject produces high element interactivity causing high intrinsic cognitive load on the learner, delaying schema acquisitions and automation. Previous studies (Sweller, 1999b) in this field have indicated the advantages of appropriately constructed worked examples in offering creative problem-solving opportunities for geometry students. A worked example of geometry provide a better general understanding to student hence students are able to utilise more sophisticated schema to understand the content of the instructional materials (Maxwell, 2008).

ii. *Split attention*

The split attention effect is the most relevant instructional effect in our current study. This effect occurs when learners are expected to split their attention among the separated basis of information and have to mentally integrate either spatially or temporally the separated source of information for an essential understanding of the entire content to be studied (Sweller et al., 2011c). For learning to reach the peak, learners have to separate their attention to all disparate basis of different information and mentally integrate those several bases of information. An elevated extraneous cognitive load usually occurs in split attention when learners are required to mentally merge multiple bases of information that are parted by space and time. Therefore, it is best to present a diagram with the explanation text below or above it.

Numerous studies have examined the split attention on different domains which include: physics (Ward and Sweller, 1990), mathematics (Sweller et al., 1990), and recently music

instruction (Owens and Sweller, 2008), electrical engineering by (Chandler and Sweller, 1991) who found similar results as (Tindall-Ford et al., 1997), that learners in engineering exposed to the integrated format of information significantly outperformed on learners using the split –attention format. In the computer science domain, when (Sweller et al., 1990) examine the split attention on learners they argued that using a paper-based computer software manual that is physically integrated was more effective than using a paper-based manual whilst interacting with the computer program. In addition, Moreno and Mayer (1998) examined split attention on multimedia lessons. They found out that narrating text while displaying the diagram produced better learning outcomes than creating text and a diagram at the same and having narration, text, and the graph at the same time.

The most effective way of managing split attention is through integrating instructional materials. Paas et al. (2010), emphasized that the split attention technique would require instructors-manipulated interventions that would represent some form of instructor-management influenced by cognitive load.

iii. Redundancy effect

The redundancy effect takes place when various sources of information which can be self-evident in isolation are all presented all together to a learner in different forms (Hughes et al., 2019, Sweller, 2020).

For example, describing a diagram to learners with narration and on-screen text concurrently. Either the narration or on-screen text adds unnecessary strain on the working memory, resulting in confusion for a learner (Leslie et al., 2012, Morrison et al., 2014). The additional information makes the multiple sources redundant, imposing an extraneous cognitive load on a learner (Sweller et al., 2011c). Adding two different forms of explanations to a diagram is unlikely to be beneficial; therefore only one source of information is necessary to explain the graph.

The learner's level of knowledge usually determines whether the sources of information are redundant or necessary. Presenting different forms of information (diagram, written text, and spoken text) may be deemed as redundant information by experienced learners. In contrast, for novice learners, this more information is required to maximize their learning. Integrated formats could be ineffective for professional learners as they have established schema for the information but are deemed effective for novice learners. Novice learners

benefit from integrated diagrams but become redundant when learners are knowledgeable (Mayer, 2017).

Blayney et al., (2016) pointed out that having the redundant element of information also increases the aspect of interaction for novice learners. They are unlikely to be aware of which elements are redundant and which are necessary.

Each effect discussed above imposes a certain capacity of cognitive load on the students. It is crucial to understand how much each imposes. To obtain the imposed cognitive load, the load needs to be measured.

2.2 Cognitive theory of multimedia learning (CTML)

In the cognitive theory of multimedia learning (CTML), effective learning occurs when there is diligent learning in which a learner holds and makes use of different cognitive processes to comprehend the information delivered (Mayer, 2014b). Information presented is multimedia instructional messages that are designed and positioned on our knowledge of human cognitive architecture (Liu et al., 2021). The cognitive theory of multimedia learning is established on the cognitive load theory and it indicated that the human information processing system composes three assumptions.

Numerous studies investigating the cognitive structures have revealed how humans process information during learning. The studies postulate that the human cognitive structure is constructed of sensory memory, working memory, and long-term memory (Zhu et al., 2020), see figure 2 below.

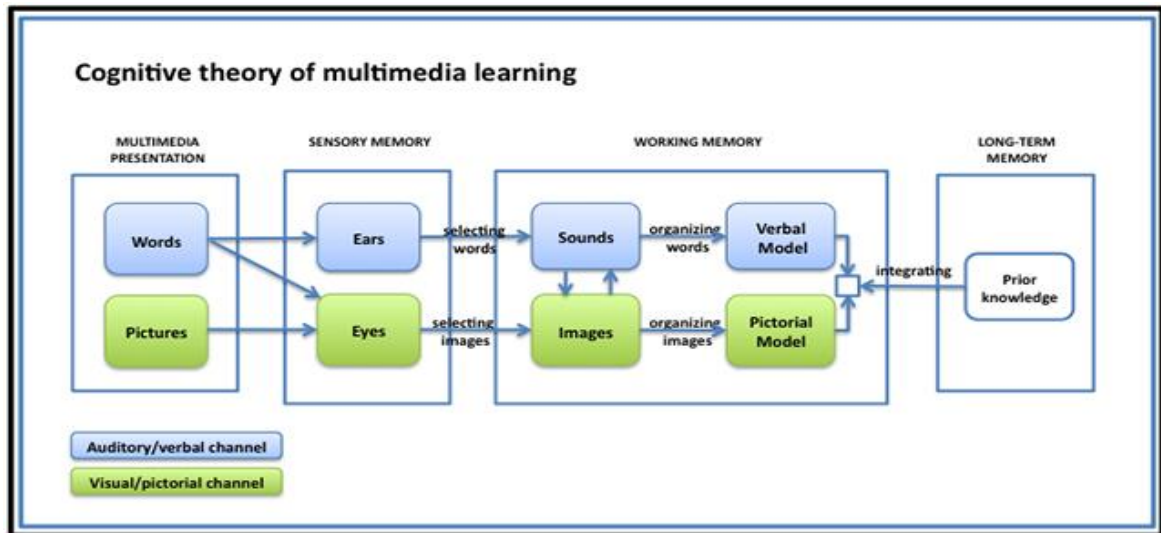


Figure 2 Cognitive theory of multimedia learning

Sensory memory

The sensory memory deals with a set of registers relating to the various human senses which include; olfactory (smell), visual (see), auditory (hear), tactile (touch), and gustatory (taste). In the sensory memory, incoming stimuli from the environment are transformed into information to make sense of them (Eysenck and Keane, 2010, Woolfolk and Margetts, 2007)

The sensory memory can hold everything the body is capable of hearing, seeing, or sensing due to its large capacity (Cowan, 2005). Weiten (2013) explained that although sensory memory does not hold information for long, its capacity is unlimited. The duration that the sensory memory can hold information depends on the different human senses. According to Henson and Eller (1999), the sense of touch information is held between 2 to 3 seconds, the sense of seeing is approximated to last less than 1 second, and the sense of hearing words can last up to 4 seconds. Maintaining enough time for each; tactile, auditory, and visual stimulus usually results in data being recognized, classified, and processed to the working memory or forgotten.

Working memory

This cognitive structure is where mental activities take place. The working memory has the two most essential features, which are; 1) the limited duration as investigated by Peterson & Peterson (1959) and 2) the limited capacity as demonstrated by Miller (1956). A learner

can only suffer from these limitations if the material is not learned well or if it is not understood.

The working memory is restricted to hold about 5 to 9 elements of unfamiliar new information, and it can hold less subject to the nature of the processing (Miller, 1956), for instance, whether some information needs to be combined or contrasted. In addition, Peterson & Peterson (1959) have emphasized that instructions have to be modelled in a strategy that compensates for the limited duration of the working memory when novel information is presented to the learner; otherwise, the information will disappear within seconds.

Information accesses the limited memory via two channels; 1) from the sensory memory if it is new information, and 2) from the long-term memory if it was previously stored information (Schueler et al., 2011b). The way data is processed in the working memory depends on where it comes from, and this leads to instructional design implications. The data that comes into the working memory from the sensory memory differs from the data that comes into the working memory from the long-term memory in terms of characteristics. There are no scopes to the load of information that enters the working memory to be processed from the long-term memory (Sweller, 1999b).

Long-term memory

Long-term memory is a repository memory of previously learned information. Unlike limited memory, long-term memory; 1) permanent storage of worth experience and knowledge (St Clair-Thompson et al., 2010), 2) has an unlimited capacity as it can store very complex information, procedures, and facts. The stored information is very essential to other cognitive abilities such as problem-solving.

When more information is received in the long-term memory, it forms large, complicated structures that will assist learners in complex environment. Long-term memory can automate and construct cognitive structures called schemas (Liu et al., 2019).

Schema development

Information is classified corresponding to how it is going to be utilized in a schematic form when stored in the unlimited memory (Agostinho et al., 2014). According to Sweller et al,

(2011c), a schema is a cognitive system that allows humans to view diverse elements as a sole element depending on how it is categorized to be used.

Numerous studies have demonstrated that schemas assist learners with the capability to analyse multiple elements of information as a single element of information and this can expand the capacity of the limited memory available for learning (Chi et al., 1981, Larkin et al., 1980). Since the working memory is limited, only a certain amount of elements can be processed, but that does not limit the size of a component. Therefore “two functions of schemas can be summarized as, the storage and organization of information and a decrease of working memory load” (Agostinho et al., 2014). Decreasing the working memory load is one crucial function for schemas apart from storing and organizing information.

To process and use schemas once they have been constructed is called schema automation.

Schema automation

Information can either be processed automatically or consciously. Information processed consciously involves previously described characteristics, but automatic processing circumvents working memory. Automaticity usually happens after practice, typically after extensive training. With ample practice, minimal conscious effort is needed to carry out procedures. Because of the minimal working memory load. For example, an adult can read books that make up the prose being read without consciously processing each letter. The procedure of reading the letters was automated during childhood. Unlike adults, children process each letter consciously when beginning to learn how to read.

Automation is a critical aspect of schema construction as it can assist to free the working memory capacity so that other activities can be processed (Agostinho et al., 2014). Familiar tasks are usually performed fluidly and accurately with automation, but unfamiliar tasks need automated processes and learning can be done with maximum efficiency because of the available maximum working memory capacity. A job that was previously encountered can be completed without automation, but the performance is most likely to be slow.

Instructional designers should consider the construction of schemas and the automation of schemas that guides those aspects of an activity that are rational from problem to problem (Mutlu-Bayraktar et al., 2019).

Human information processing system assumptions

According to CTML, the human information processing system comprises three assumptions which include; the active processing assumption, the dual-channel assumption, and the limited capacity assumption.

1. Dual-channel assumption

According to CTML, the presentation and processing of multimedia instructions in the human information processing system are handled cognitively by two separate channels; an auditory channel which is accountable for handling the verbal materials, and the visual channel which is accountable for handling pictorial material and nonverbal sounds, as depicted in Figure 2.

The information humans handle through the pictorial channel is information produced to the eye such as video, on-screen text, and illustrations, and when information such as nonverbal sounds or narration is presented to the ear, humans handle that information in the verbal channel. The separated information processing channels are closely associated with Paivio's dual-coding theory (Clark and Paivio, 1991).

Cognitive overload is most likely to take place when learning involves interactive presentations which are not troubled by the limited capacity of each channel.

2. Limited capacity assumption

According to this type of assumption, each channel has a limited processing capacity; therefore, only a certain amount of information can be handled at one time. An interactive multimedia presentation may pose a problem as the processing demand required may surpass the processing capacity of the cognitive system and hence intercept effective learning (Mayer and Moreno, 2003).

The limitations of our processing capacity force us to pay attention and be selective about incoming information to build a connection between the selected pieces of information and our previously stored knowledge. This integration of information can lead to active processing.

3. Active processing assumption

The assumption states that meaningful learning occurs only when learners employ active cognitive processing during learning and that includes; paying attention to verbal materials and relevant visuals, mentally classifying the selected learning material into a systematic representation, and incorporating the incoming material with prior existing knowledge.

The process of integrating selected materials with existing knowledge involves the activation of knowledge existing in the unlimited memory and transferring it back to the limited memory. Meaningful learning requires cognitive processes.

Processes in the cognitive theory of multimedia learning

According to Mayer (2005), five major processes lead to significant learning. These processes do not necessarily have to occur sequentially. It depends on whether the learner might shift from process to process in various conducts. The learner has to coordinate and monitor these processes to learn successfully.

1. Selecting relevant words

This process involves concentrating on the words delivered during the multimedia instruction as it passes via the sensory memory. In case the words presented are narrated then this stage starts to take place in the verbal channel, but if the words are presented as printed text, then the process starts in the pictorial channel.

The learner must focus attention on selecting only a part of the words presented due to the limited capacity of each channel. If the capacity were unlimited, the focus of attention on choosing would not be necessary.

2. Selecting relevant image

This process involves the external presentation of images; it could be an illustration or animation to the sensory memory. The presentation is the unanalysed external visual to an internal presentation in the working memory.

The learner has to pay attention to a part of the image presented in the instructional material. Paying attention to a selected portion of the image arises from the restricted capacity of the cognitive system. The learner must judge and choose the most relevant image to assist with making sense of the instructional material presented.

3. Organizing selected words

Once a word sound base is formed from the instructional material presented, the learner has to organize the words into a coherent presentation. That is, the learner has to build a connection with the pieces of verbal knowledge received. The input of this process is the word sound base, and the output is the verbal model.

The learner must concentrate on establishing a simple construction because of the limited capacity, which hinders the possibility of building all the possible connections. This process mostly occurs in the auditory channel. This process focuses on the reflection of the effort of making sense of a cause-and-effect.

4. Organizing selected images

This process is parallel to the process of selecting words. Once an image base is formed from the arriving illustration of the display, the learner has to organize the images into a coherent representation. The input is the visual image base on the presentation, and the output is the pictorial model.

The learner has to make connections with the pieces of pictorial knowledge in this process. A learner must focus on creating a simple relationship due to the restricted capacity in the limited memory to build all possible connections with all images. The process focuses on the effort of building a simple relationship that can make sense.

5. Merging word-based and image-based representations

This is the most critical process which involves connecting image-based and word-based representations. This process changes from two separate representations to one integrated representation. The input for this process is the visual model and the auditory model constructed by the learner thus far, and the gain is an integrated model of the two representations.

The integrated model includes prior knowledge connection. The learner can use prior knowledge from unlimited memory to limited memory to assist with the integration process. The process demands effective utilization of cognitive capacity. This step focuses on the epitome of sense-making.

To successfully design and develop a technology-enhanced learning environment and produce effective instructions, it is very crucial to take into concern the significance of cognitive load and how it affects the learning process (Oberfoell and Correia, 2016). That

is because the capacity of the limited memory is restricted, therefore not all the information processed is useful for effective learning. Learners can experience overload once the cognitive demands of instructional materials surpass the capacity of the working memory (Ayoob et al., 2020).

Mayer (2005) formulated several evidenced-based instructional principles in multimedia on how to enhance the learning outcomes of learners and these principles take into concern the impact of cognitive load and how it affects the learning process on all learners.

3. Conceptual framework

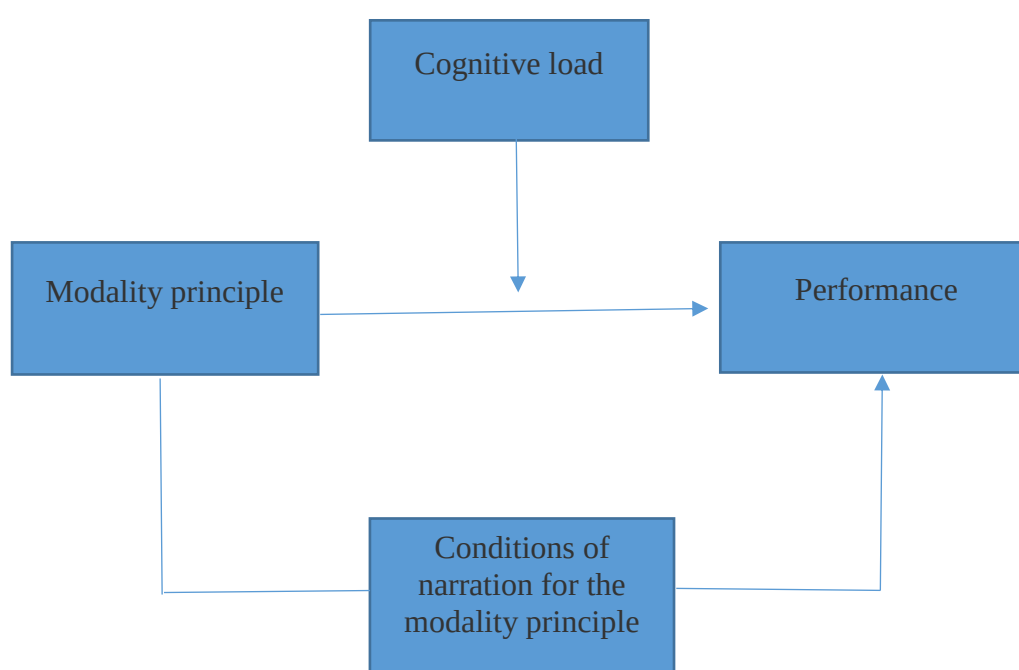


Figure 3 Conceptual framework

Due to the pandemic, some institutions have switched to e-learning as the new normal. Therefore it is very crucial to pay attention to the multimedia content presented to the learners. The content of multimedia affects their performance.

This study conceptualises the most effective way of presenting narration on the modality principle instructional material on e-learning. The modality principle states that students learn better through images and spoken text rather than images and printed text. Spoken text reduces the cognitive load on learners due to information being shared amongst the verbal and auditory channels. How the spoken text is presented influences the performance of learners. Thus, the narration has to be presented in a way, learners can engage and

effectively remember the educational content presented to them. Therefore certain conditions of narration have to be featured to produce multimedia content that affects the performance of learners.

4. Measuring cognitive load in an e-learning environment

Three recognized types of the cognitive load must be managed well in any learning environment to lower the load on the limited memory and promote effective learning. In an e-learning environment, a large amount of complicated information can be presented to unfamiliar learners, and this can impose a high amount of cognitive load (van Mierlo et al., 2012).

Measuring the mental load when utilizing these e-learning environments is very crucial as it assists designers in estimating the effect of their inventions on learners during learning. Designers should iterate their designs until they support the conditions of the learning space based on the estimated load to control the cognitive load of learners. The cognitive load imposed by processes and does not lead to any contribution to learners should be reduced and the cognitive load imposed by processes and facilitated learning should be ideally maximized to the total cognitive.

According to Sweller (2011b), various approaches that can be utilized to access the cognitive load of a learner, and are divided into two dimensions; 1) Objectivity; which involves two ways (Subjective and Objective), 2) Casual relationship; which also involves two processes (Direct and Indirect), as depicted in Table 1. One of the frequently used methods of accessing mental effort in the e-learning environment is a subjective, indirect measure through self-report questionnaires (van Mierlo et al., 2012, Paas et al., 1994). The subjective and indirect measure is used to report the mental effort experienced in comprehending the instructional materials. A lower invested mental effort report is an outcome of less cognitive load, or possibly, a high cognitive load that learners decreased the mental effort expended on trying to understand the material (Leahy and Sweller, 2016).

OBJECTIVE	CASUAL RELATIONSHIP	
	Indirect	Direct
Subjective	❖ Self-reported on invested mental effort	❖ Self-reported stress level ❖ Self-reported difficulty of the material
Objective	❖ Physiological measures such as heartbeat or pupil dilation ❖ Behavioural pattern measures ❖ Analyse performance outcomes measures	❖ Brain activity measures ❖ Dual-task performance

Table 1 Approach for measuring cognitive load

More objective measurement of CL in online learning, albeit indirect and unspecific, can be through analysing chains of behaviour or physiological functions and relating them to a learner's learning process. For instance, the time-on-task, which is an indication that the time a learner spends on the kinds of multimedia materials is calculated to be the outcome of a different amount of cognitive load. Another example is the track of eye movement, in which the dilation of a learner's pupil provides enlightenment into the mental effort applied by the learner during learning.

One of the best methods to sample mental effort directly in virtual e-learning is using the dual-task paradigm. A range of e-learning research has successfully utilized the dual-task paradigm. According to van Mierlo, Jarodzka et al. (2012), the dual-task paradigm is usually recommended when estimating the CL of new e-learning settings because it is direct, objective, and easy to implement.

5. Cognitive Issues in Primary school science education

For effective learning to occur, a schema needs to be constructed and automated with already existing prior knowledge guarded in unlimited memory. The ability to connect previously-stored insights with the latest information can be challenging for a learner with no previous knowledge about the concepts. In schools, learners are not always familiar with the new information or topic presented to them. But it has been shown that having prior

knowledge connected to new knowledge is efficient for learning. Therefore, learners in the current study are not expected to get all questions correct on tests.

Many studies have investigated the cognitive load of learners during multimedia learning. Studies have found that learners with a lesser level of reported cognitive load performed significantly better than learners who reported a higher cognitive. Sandoval (2016) emphasized that the learners' curriculum should avoid technical concepts which cause extraneous load but instead focus on conceptual understanding, which induced less mental effort.

6. Conclusion

This chapter was to discuss the CLT, which is also featured on the CTML, and its implications for learning. The chapter first discusses the human cognitive architecture based on the cognitive load theorist. Following the dissimilar types of cognitive load and the different ways of measuring cognitive load. A summary of redundancy effect, worked example effect, split attention, and worked example effect. That was followed by the discussion of CTML relevant to the current study. CTML whose main objective is that effective learning with multimedia during e-learning can only occur when paying close attention to how knowledge is stored and processed in the human senses during instructional design. Remarkably, the limited memory is assumed to be the crucial memory in multimedia learning considering that all information has to be processed first in the limited memory before it could be stocked in the unlimited memory. Information is delivered and processed in two different modalities (verbal and visual) instead of one. Both channels are administered, and the total working memory capacity might become less or more efficient. Reducing the extraneous load on the multimedia material during design can result in significant learning for learners. Evident-based principles we developed to sample the design of multimedia instructions and reduce cognitive load and one central focus which has proved to reduce cognitive load is the modality principle which will be discussed in the next chapter.

Chapter three Literature Review on Modality principle

1. Introduction

This chapter presents a literature review of the modality principle in multimedia and the cognitive load related to its instructional designs. A discussion regarding the results of the principle according to various studies follows.

2. The modality principle

The modality principle can be explained through the theories of Cognitive load theory (CLT) and Cognitive Theory of multimedia learning (CTML), which suggest that learning during multimedia can be effective when paying attention to how information is stored and processed in the human cognitive architecture. Notably, the limited memory is assumed to be the crucial memory in multimedia learning, because all data has to be processed first in the limited memory before it could be stocked in the unlimited memory.

Through CLT and CTML, the modality principle has been explained in multiple research on the role of multimedia in technology and science education. The CTML's primary assumption is that the working memory has two separate sub-components for processing auditory and visual information (Hughes et al., 2019, Oberfoell and Correia, 2016). Thus, according to CLT, the degree to which how instructional information is delivered on both sub-component determines cognitive load efficiency. It is similar to the modality principle which asserts that learning would be enhanced when students learn from images and spoken text rather than from images and written text (Ye, 2018, Zhu et al., 2020, Liu et al., 2021).

This principle states that there is more significant knowledge acquisition when the textual information is presented in an auditory model concurrently with visuals rather than when all the information is presented visually. The principle reduces cognitive load because the multimodal presentation uses both ways of the working memory, the auditory and the visual (Liu et al., 2021). The modality principle proponents argue that if words on instructions are delivered as on-screen text, the visual channel of the limited memory is more probable to become overloaded. From the viewpoint of the theory of cognitive load of multimedia learning, on-screen text interrupts the technique of coordination within the pictorial channel but with narration, cognitive overload is avoided in the sense that the burden is shared

amongst the two channels in the same amount of time. Therefore, there are sufficient cognitive resources to apprehend the spoken text and visual data effectively.

3. True Modality principle

Several classic experiments (Mousavi et al., 1995, Jeung et al., 1997, Mayer and Moreno, 1998) have been done to demonstrate that audio improves the learning process of learners rather than written or on-screen text. Mousavi et al., (1995) provided evidence that the dual presentation modalities increase the limited memory by activating both visual and auditory limited memory instead of just one. Jeung et al., (1997) and Tindall-Ford et al., (1997) demonstrated that learners scored higher marks with lower mental effort and used less time during problem-solving when using instructional materials which use dual channels. In contrast to using instructional materials with a single channel for visual text and visual diagrams. Mayer and Moreno (1998) emphasize the importance of using textual information in an auditory format to activate the dual channels, as this improves the performance on matching, retention, and transfer tasks.

When replicating the study concluded by Mayer and Moreno (1998) to discover the impact of visual and audio on learners, Haskamp, Mayer, and Suhre (2007) reported that with a recorded learning time between two groups of illustration-and-narration and illustration-and-text, the illustration-and-narration group performed better. The modality impact was strong on transfer tasks and did not affect retention because printed text challenges learners to participate in some extraneous processing within the pictorial channel which leads to reduced cognitive capacity for intrinsic and germane processing. They concluded that the modality principle is useful when learners have less time to learn. Aldalalah and Fong (2010) added that narrated text with animation plays an active role as it can lessen the cognitive load and increase the limited memory capacity, resulting in better understanding. They demonstrated the effectiveness of narrated text featuring pupils with different anxiety levels during a music theory lesson. The modality principle promoted better learning of music than the redundancy principle because the printed text in a presentation overloaded the visual channel of learners (ALdalalah and Fong, 2010).

Clack and Mayer (2011) completed a controlled experiment which showed that with on-screen text the learners' attention is split between holding pictures and text in the visual memory, therefore resulting in fewer resources to build a connection between the two. The

study explains that there are greater additional resources available for creating a connection when the learner uses both channels, that is, printed text processing in the visual memory and the word text processing in the auditory memory. The modality principle promotes schema development due to the free working memory space created during learning (Clark and Mayer, 2011).

Brunken et al., (2003) found empirical evidence by eliminating the irrelevant elements and redundant materials in the instructional design presented to the learner, supporting the modality effect during a learner-paced lesson. Moreno and Mayer (2007) explained learner-pace as the ability of learners to choose when to play and pause interactive instructions during a presentation. A few studies have provided evidence supporting narration over on-screen text during learner-paced instructional lessons (Moreno et al., 2001, Atkinson, 2002, Mayer et al., 2003). There is rarely an evident experiment obtained that deals with learner-pacing versus system (Mayer and Chandler, 2001, Ginns, 2005, Hasler et al., 2007) that influences the actual effect of the modality or those that use instructions of learner-pace only (Evans and Gibbons, 2007). Early research about learner-pace showed inconsistent results regarding the modality effect; there are some cases, for instance (Stiller et al., 2009) revealed that learner-paced instructions favour on-screen text over narration.

Only a few recent studies still found the modality effect to hold truth (ALdalalah and Fong, 2010, Savoji et al., 2011). de Oliveira Neto et al., (2015) discovered that online learners in the auditory group performed better than learners in the on-screen text group on transfer tasks and found that learners in the on-screen text group reported a higher cognitive load in comparison to the auditory group. The lesson took place in a computer laboratory with a self-paced setting. A more recent study (Liu et al., 2021) hypotheses were partially supported, results indicating that learners perform better when animation is accompanied by spoken text than written text.

4. Reversed Modality principle

On the contradictory, evidence from early studies by Tabber et al. (2004) showed that students perform better in a condition where visual text is used rather than when audio is used. These authors claim that the reason their results differ from earlier research is that the instructions employed in their experiment had a subject matter unusual to the technological domain used in previous experiments. They also learned that the mental effort used by the

student during instructions is equal for all conditions. The difference between the conditions was minimal. That the measurements were too sensitive to note and students compensated for a lesser extraneous load with a high learning effort which resulted in a corresponding effort rating (Tabbers et al., 2004).

Researchers continue to work towards the goal of effective processing by using instructions with words and pictures (Witteman and Segers, 2010). Therefore, there is a surfacing body of evidence that is opposing the legitimacy of the modality principle. Recent studies are obtaining reverse modality effect results, in which the on-screen text is found to be superior in retention and knowledge transfer to the narrated text (Witteman and Segers, 2010, Constantinidou et al., 2011, Oberfoell and Correia, 2016, Sandoval, 2016, Fethi A. Inan, 2015). In many studies with a reversed modality effect, researchers suggested that learners are given time to control the pace of the presentation, hence better retention and knowledge transfer when given on-screen text because of the available time for processing (Sandoval, 2016).

An investigation by Witteman et al., (2010) on a naturalistic setting with eighty elementary school-age students showed a reversed effect during a learner-paced lesson. They concluded that a classroom setting might have instituted unpleasant additional high-fidelity and hence made the narration content less effective during class. The findings are consistent with research by Oberfoell and Correia (2016), which replicated the authentic study completed by Mayer and Moreno (1998). The original research showed that the narrated text foster higher retention, matching, and transfer of information among learners. The focus of their research was to determine the impact of words on today's students in a multimedia presentation which is presented either auditory or visually to promote effective learning on lower-experienced learners. The results indicated that narrated text does not foster higher retention, matching, and transfer of information on the students as compared to on-screen text students. Students with low-level experience in narration and technology benefit from visual multimedia presentation more than an auditory presentations, narration benefits learners with a piece of background knowledge on technology and multimedia learning formats (Oberfoell and Correia, 2016).

Other researchers suggested that the explanation for the reversed modality effect may be that the narrated text might contain complex words which learners found hard to understand (Leahy and Sweller, 2011, Clark and Mayer, 2016). According to Leahy and Sweller (2011),

more cognitive resources would be required if the narrated words are complex and unfamiliar because learners direct their attention to the transient narrated word. That can impose a higher extraneous cognitive load on the learner's cognitive systems and decrease the learning performance because the learner had to allocate their cognitive resources to holding information in the limited memory.

The information that is received from spoken text quickly disappears, imposing a high cognitive load when comprehending the spoken text with other variables causing overloading on the working memory thereby exacerbating learning (Wong et al., 2019). The same effect result explanation has also been described in Inan et al. (2015) emphasizing that in contrast to narration, on-screen text is more permanent. Therefore allows learners with on-screen text to track the learning guidance at their own pace during the manipulation of simulation (Liu et al., 2021). On-screen text is recommended when utilized to signal learners in simulations-assisted learning environments (Liu et al., 2021). Liu et al. (2021) found that participants grasped more when a simulation coexisted with on-screen text than narration.

4. Conditions on Modality principle

According to Ginns (2005), the modality effect seems only to appear when certain boundary conditions are included. The author emphasized that the effect is limited to high interactive instructional material and system-paced materials. However, he pointed out that since these findings were achieved through a relatively small number of participants, there is a need for further research regarding certain conditions to take into consideration when using the effect. Furthermore, other researchers (Gyselinck et al., 2008, Doolittle et al., 2009, Leahy and Sweller, 2011, Mayrath et al., 2011b) replicated Ginns's (2005) work and investigated the two conditions (high elementary and system-paced) in more details but found a reversed modality effect. There seem to be more conditions that need to be considered when dealing with the modality effect because other variables might moderate the effect during experiments (Schueler et al., 2011b).

When investigating the conditions and boundaries of the modality effect, Tabbers and van der Spoel (2011) conducted two tests which resulted in a double failure that raised questions about the design of the principle's theoretical and practical use. In the first experiment, students were given instructional materials with the same system-pace, procedures, and dependent variables on the formation of lighting as Mayer and Moreno(1998) & Moreno

and Mayer (1999). The multimedia learning material consisted of animation with spoken text versus animation with written text. The experiment was executed with the assumption that the spoken text and on-screen text are taxed differently on the working memory. Fifty percent of the participants formed a dual-task throughout learning that taxed the phonological loop in the limited memory. The learning performance was equal between the on-screen text and spoken text participants. Therefore, no confirmation was discovered that learning using narration taxes the limited memory differently in comparison to using on-screen text.

In the second experiment, the authors tested whether the modality effect is the product of split attention when delivering written text with pictures. The learning materials were delivered with a slow version and a fast version with either narration or written text but with the same animation. The hypotheses were that there would be a strong modality effect on a fast version presentation and no effect on the slow version presentation. But surprisingly, the results did not support the assumptions; therefore the investigation by (Tabbers and van der Spoel, 2011) provided evidence that modality instructional material presentation pace does not affect or influence the learning outcomes of learners. However, van den Broek et al., (2014) ascertained that learner-pace presentation contributed to a reversed modality effect but de Oliveira Neto et al.(2015) found the modality effect during a learner-pace presentation

Schmidt-Weigand (2011) conducted a study concerning the conditions of the modality principle. The study had two experiments to explore whether the modality effect is affected by the case of animation. The author adapted the same measures and instructional materials used by (Mayer and Moreno, 1998, Moreno and Mayer, 1999). In the first experiment, the author varied the visualization format (dynamic and static). The study hypothesized that the dynamic animation would result in a powerful modality effect compared to static visualization because of the perceptual demands under on-screen text conditions. The learning outcomes measurements used were retention and transfer tests. The author also used the eye movement measure to observe the learners' split attention during the learning. The modality effect was revealed only for visual retention measurement in the first experiment. However, with the same replicated material but at a faster presentation pace in the second experiment, no modality effect was revealed. In all, Schmit-Weigand's animation failed to verify the modality effect in five out of six learning outcomes.

Schueler et al.,(2011a) examined the condition of text content on the modality principle, to whether text content can change the effect of the principle. Students were presented with text containing spatial versus text containing pictorial information. Built on the findings by (Postle et al., 2006) indicating that there might be interference on the visuospatial Sketchpad when text contains spatial information, therefore the researchers expected a strong modality effect from the text containing spatial and no effect on text with visual information. With a design of text content (visual vs spatial) and text modality (written vs spoken) as experimental conditions, the authors adapted the picture recognition performance to measure the learning outcomes of students. Moreover, they recorded the eye movement of students throughout learning. The outcome did not validate the anticipated findings. Contrarily, no modality effect was remarked with the explanation of visuospatial load and split attention. During picture recognition, the effect was limited, but with text recognition, the effect did not appear. Schueler and his colleagues (2011a) confirm that spoken text is always found to be superior compared to written text in multimedia learning because of the availability of pictorial information and not because of overloading the working memory (visuospatial).

In their attempt to find out the validity of the modality principle, just as Tabber and van der Spoel (2011), Lindow et al. (2011) replicated the original research by (Mayer and Moreno, 1998, Moreno and Mayer, 1999) with the same material and measures and added other conditions on their experiment. In the first experiment, the authors infused text length (single sentence vs multiple sentences) along with the existence of animation (absent vs present) with the presentation of sequential text and animation. Neither way, there was no modality effect found between the interaction of animation presence and text length; however, a small on-screen text modality was found over spoken text modality. In the second experiment, the authors also replicated Moreno and Mayer's (1999) experiment 1 and modified the condition of placing the visual text and integrating it into the animation. Again, no modality effect was found, and the conclusion was that the alleged robustness of the modality effect originates from the publication bias. Even with the same materials and procedures, researchers have failed to duplicate the modality effect under standard conditions when trying to identify certain conditions and boundaries for the explanation of the effect.

Regardless if the learning setting is system –or learner-paced, Schüler et al (2013) ascertained that the modality effect fade when featuring longer text segments on the material. Schüler et al indicated that during the learner-paced condition, participants in the on-screen text group replayed segments repeatedly conversely participants with narration hardly ever replayed single segments.

Liu et al, (2021) study showed a modality effect when participants gain knowledge with animation co-occurring with spoken text and a reverse modality when participants learned from simulation accompanied with spoken text. Nonetheless, no effect was established on cognitive load.

5. Conclusion

Authors have explained their results about the modality effect referring to the two separate channels for processing pictorial and auditory information on the working memory. The multimedia material of the modality principle has been supported by numerous studies and has yielded diverse results. Earlier studies have demonstrated that the effect has the capability of improving the learning outcomes of learners. Recent studies investigating the learning outcomes of the modality effect on students are finding the effect to be invalid, that is, a reversed modality effect. Few studies have identified certain specific conditions to consider when featuring the modality, but they still found a reverse modality. Consequently, the modality effect is disappearing (Leahy and Sweller, 2011), and questions about the most effective ways of delivering narration on multimedia instructions remain (Sandoval, 2016).

The question that can be asked is: what kind of narration was presented to learners, how the narration was presented, who narrates the text, and when the narration was present concurrently with images during the presentation? That could lead to recently obtained results that narration is not effective in retention and knowledge transfer compared to on-screen text.

This study postulates that the narration presented to learners during the investigation was not considered but affected how students learn in a computer-based environment. There is no guide on how the narration should be presented for the modality effect instructions; hence researchers use any form of unconsidered narration which has led to studies obtaining different results. Unconsidered narration in the sense that researchers have not mentioned

or explained specifically the narration used in their studies. For example, how was the spoken text delivered to the learner and who narrated the material during instructional development, no details were provided. Different conditions concerning mostly written text are identified in the literature on how to present the modality instruction material to improve the learning outcome of learners. However, no conditions have been identified regarding the modality principle's narration.

The modality principle along with the Cognitive Theory of Multimedia learning has many unresolved effects. The main reason for the current study is to shed greater light on the considered conditions of narration for the modality effect among primary school students being assessed in a school library. Furthermore, the study seeks to investigate the cognitive load of participants using a self-report subjective measurement after an e-learning presentation.

The following chapter presents the approaches used to address the issue identified in the literature above.

Chapter four Research Methodology

1. Introduction

As outlined in Chapter three, further investigation is needed on how to present the modality effect designed material to learners during e-learning to improve their learning outcomes. This section aims to discuss the research design and methodology. This chapter is divided into two sections, as shown in Figure 4, and the discussion will follow as such.

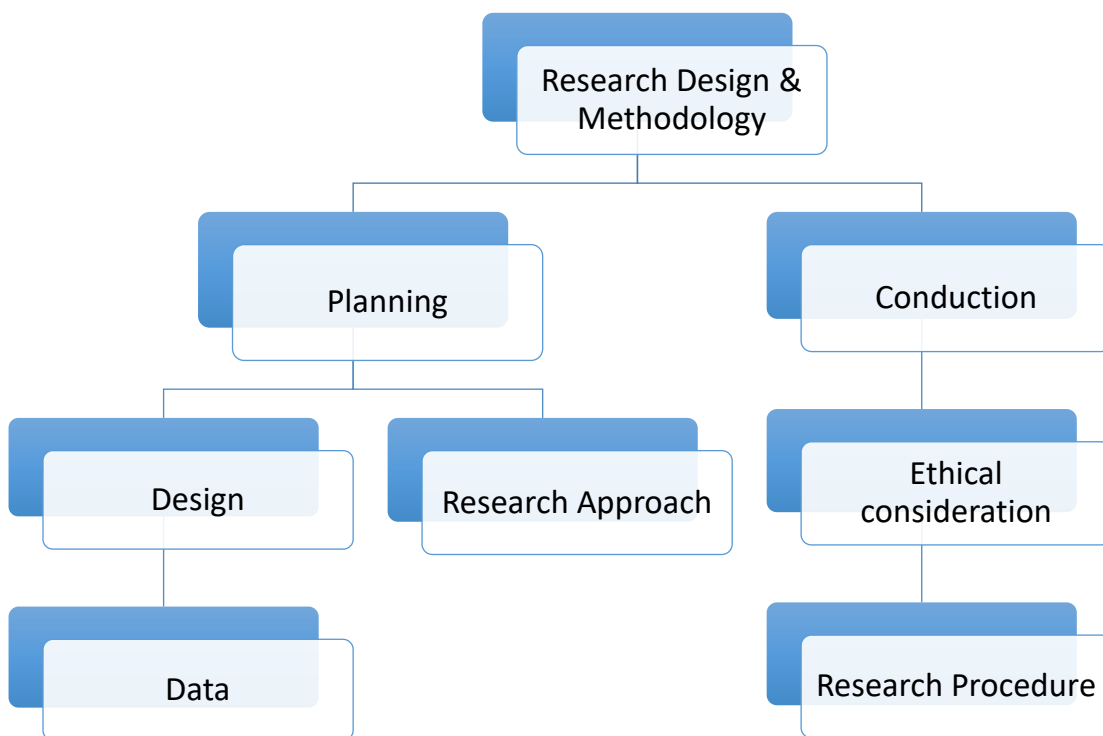


Figure 4 Chapter four structure

2. Planning the research

2.1 Purpose of the study

The intent of this study has twofold; firstly to identify conditions of narration for the modality principle to improve the learning outcomes of learners during e-learning and secondly to measure the cognitive load of learners during e-learning as postulated that the generated conditions of narration for the modality instructions will reduce extraneous load and improve the learning outcomes by focusing the learners on schema acquisition and automation.

2.2 Research Approach

A quantitative research approach was used in this study. According to Ahmad et al., (2019) quantitative approach establishes the relationship between two variables by using statistical methods, computational and mathematical. The study featured one pilot study and the main study. The pilot study was done to collect data and guide how to design instructional materials for the main study. Table 2 (Goertzen, 2017) presents the fundamental characteristics of the current study research approach.

Quantitative characteristics	Apply to this study
Deductive logic	√
Generalize-able intervention	√
Numeric data	√
Objective approach	√
Systematic design	√

Table 2 Characteristics of quantitative research

This study meets the quantitative approach conditions, which were discussed by (Cortina, 2019) in Table 3 below.

Quantitative conditions	Relevant to this study
Quantifiable data	The data collected was used to articulate facts for the study.
Reveal pattern	A correlation relationship was assessed between the cognitive load and performance.
Statistical analysis	The data collected is analysed statistically using statistical tools to derive results.
Various data collection methods	Methods of data collection included paper (For instance, Distributed questionnaire and Documents or archival reviews) and/or online (For instance, e-mail survey and web-based survey)

Table 3 Conditions of quantitative approach applicable

2.3 Research design

The research design includes information on the research type, interventions, and measurement instruments. The purpose of the design is to answer the research questions.

There are several possible quantitative research designs as discussed by (Trochim, 2006) and summarised in Table 4.

Quantitative research design	Description
Descriptive design	Subjects usually are measured once, and the relationship between variables is established.
Experimental design	Determines the cause and effect, the manipulation of variables, and the random assignments are used.
Non – experimental design	A study’s completed research findings are used.
Quasi – experimental design	The subjects are not randomized while specific experimental methods are used.
Randomized or true experimental design	Random assignment of participants is used.

Table 4 Types of quantitative research

For this research, two main quantitative research design approaches have been adopted, that is, experimental design and non-experimental design.

The Experimental design

Experimental is a strong comparison design in which subjects are randomly appointed to comparison groups (Gribbons and Herman, 1996). This design involves the controlling and managing of variables to be assigned to either the experimental group or the control group (Rutberg and Bouikidis, 2018). Randomization ensures that the different groups are comparable or equivalent in terms of characteristics that could affect the difference in post-test scores.

Experimental was adopted as it was deemed to provide optimal means for the delivery of instructional materials for the modality principle and to access the impact of the conditions of narration on academic performance. This design seeks to determine whether a specific treatment or condition influences the outcomes. In this study, whether the specific

conditions of narration identified influence the learning performance of the students. The identified conditions had to be assessed and analysed to demonstrate their cause and effect on the learning outcomes of the students. Similar studies including (Chen and Yang, 2020, Zhu et al., 2020, Liu et al., 2022) have also utilized experimental design to examine their hypothesis concerning the cause and effect related to modality principle instructional materials.

The non-experimental design

Survey

A survey is used to explain the methods of collecting information from a specific sample of organizations or individuals (Scheuren, 2004). A survey is used in this study, as according to Creswell (2014), survey provides a numeric description of the attitude, opinions, or trends of a population by studying the segment of the population. According to Scheuren (2004), the sample size needed for the survey mainly depends on the statistical quality required for the research findings.

This study generalized from a sample of a population using a closed questions questionnaire. A questionnaire is a survey tool used to gather information from people concerning themselves or the social units such as a church or school (Siniscalco and Auriat, 2005). A closed (or multiple choice) is the type of questionnaire that allows the respondents to only choose the response that represents their viewpoint amongst the possible sets of answers (Siniscalco and Auriat, 2005).

Standardized questionnaires were used as they are often used in the education sector as a way of collecting data concerning the different aspects of the school system. The standardized questionnaires were considered as all participants in this study were exposed to the same questionnaire and the same system of coding. The data collected from the participants was via self-administered questionnaires. The survey questionnaires were selected as it was easier to use and it allowed a larger sample to be covered concerning the participants' attitude towards the narration presented during e-learning lessons.

The study's questionnaires were developed by the author. Before the questionnaires were administered to participants to answer, content validation was undertaken. According to Yaghmaie (2003), content validity is "a subjective judgment of experts about the degree of

relevant construct in an assessment instrument ”. Therefore five teachers from Palapye primary school were selected by the school to do a content assessment on the questionnaires. The study’s objectives and the purpose of the CVI were explained to them. The participants were provided with the paper-based scale to make a judgment within a few days.

A four-point content validity index (CVI) developed by Waltz and Bausell (1981) was used for judgment by the participants, see Appendix G. The four-point scale rates items based on relevance, clarity, simplicity, and ambiguity. Lawshe’s (1975) proposed formula was used to calculate the content validity ratio (CVR) of each question. $\text{CONTENT VALIDITY RATIO} = (n_e - N/2) / (N/2)$. After analysing the results of the content validity of the scale, the number of questions decreased from 10 to 6. The items that had CVI less than 0.6 were discarded and the remaining items were modified. The results were as depicted in Table 5 below. The blue boxes indicate which judges rated each item as “Crucial”.

Items	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	CVR
1						1
2						0.2
3						0.6
4						1
5						1
6						0.6
7						0.2
8						0.6
9						-0.2
10						-0.6
					CVI	0.44

Table 5 Content Validity Index results

Pearson Correlation coefficient

Correlation helps us to understand the direction and the degree of the relationship between two random variables under one study (Plass et al., 2010). In addition, it deals with two or more variables for analysis. In the current study, a correlation analysis was carried out to

find whether there is a relation between the performances of participants with their recorded self-rated mental effort.

A correlation analysis with a negative (-) sign does not mean bad results and a positive (+) sign does not mean good results, but rather, both just signify the direction of the correlation. The correlation is represented by Pearson's r , by values ranging from +1.0 to -1.0, and with 0 suggesting that no relationship exists between the two variables (Plass et al., 2010). Diagram 1 below simplifies the index of correlation known as the correlation coefficient.

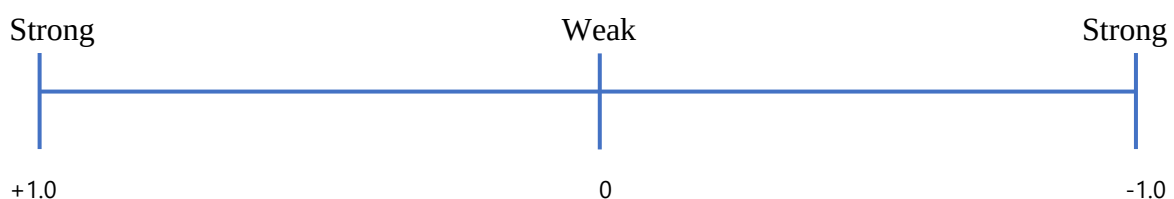


Diagram 1. The value of the correlation range

This study's correlation involves the academic performance of learners and examining their association with mental effort rating.

2.4 Data collection plan

According to Trochim (2006), the instruments used to collect data can be copied from other sources, or they can be designed specifically for that research on quantitative research. Data collection can be via semi-structured interviews, instructions, surveys, experiments, questionnaires, or tests (Ahmad et al., 2019).

For the pilot study, a paper-based questionnaire specifically designed for the study was used. For the main study, the data was collected using two different paper-based writing tests that were also specifically designed for the study. For measuring the mental effort of participants, a paper-based self-report was adopted from other sources. A paper-based self-report is a rating scale which offers the reflection of participants' perception on their cognitive load. Participants use a pen to highlight on the paper scale (see Appendix D) the amount of load they supposedly measure up to the mental effort they used during a task.

3. Conducting the study

3.1 Ethical considerations

The two tests, one questionnaire, CL self-rating scale, information sheet, and consent form were first approved by the Human Research Ethics Committee at BIUST. Thereafter, similar documents with a research paper describing the research study were submitted to the Botswana Ministry of tertiary education, research, science & technology, and permission to conduct the study was approved.

The ethical issues considered in this current study were the anonymity of the participants; this was done to ensure that the participant's rights are protected and to avoid any harm during the study. To maintain the anonymity and confidentiality of the participants, all the participants' names were only known by the investigator, and the data collected was stored in a secured place.

The head teacher for the school was contacted to request permission and participants for the project and to check for their availability as well as the computer environment. After several meetings discussing the project, the school approved permission to involve a group of standard six students in the study. The students were addressed in groups to explain the objectives, procedures, and all the steps involved during the experiment. This was done to ensure that students understand what the research involves so that they know what they are consenting to if ever they decide to take part in the study. Students who indicated their willingness to be participants in the study were asked to sign the consent form. All the participants were notified about their right to resign from participating in the study at any time. The consent form and information sheet are found in APPENDIX E and APPENDIX F.

After the study, all participants were granted access to all the learning material in a different format.

3.2 Research Procedure

Figure 5 Displays the sequence in which the study was conducted.

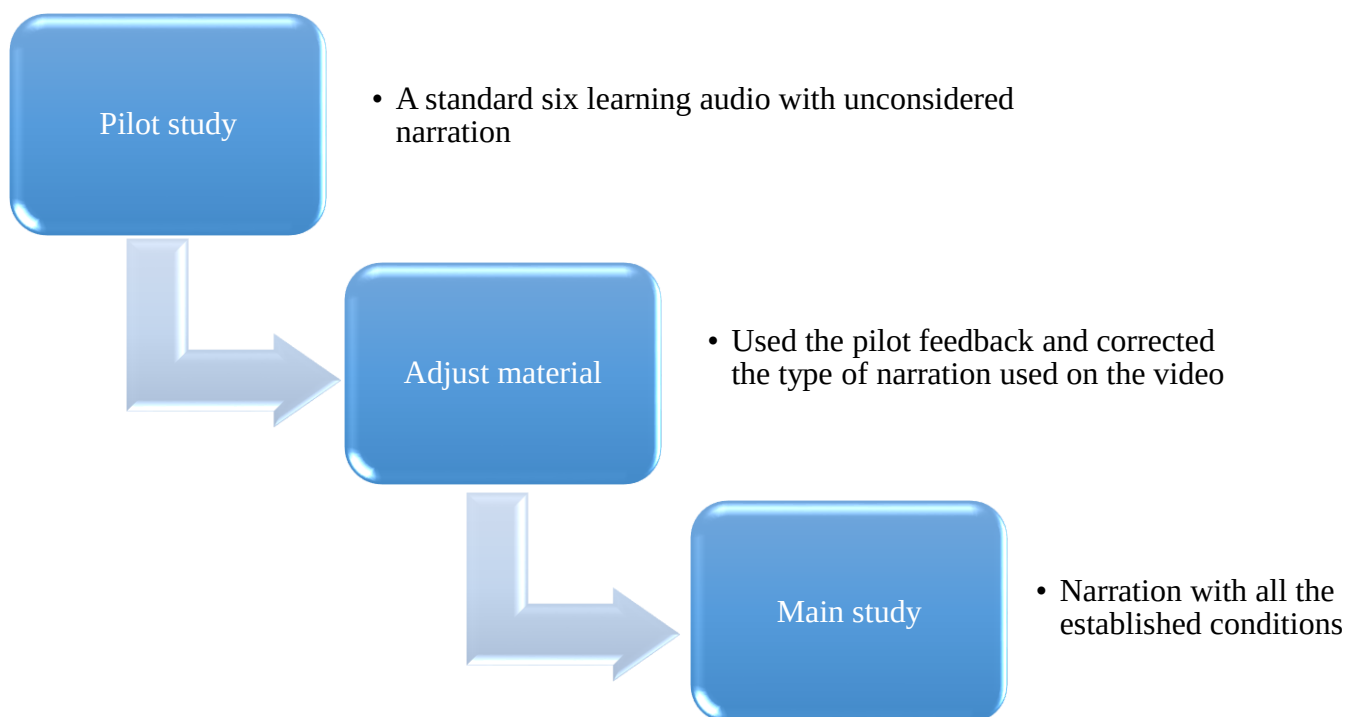


Figure 5 Conduction of the study

The study included seventy-four Standard six students and participants were randomly allocated to two large groups, either the VN group or the VT group. Just like in the previous studies, due to the limited number of computers available, each large group had subgroups to accommodate 15 participants per session. Each participant sat separately at a desktop computer to complete the process. The experiment took place in a school library where computers were based.

4. Clarifying of concept

Concepts related to statistical analysis ought to be unambiguous, Table 6 describes the statistical terminology used to enhance the understanding of the interpretation of the data in this study, according to information from the book Practical Statistics for Educator (2019).

Terms	Explanation
Cohen's <i>d</i>	A standardized measurement of effect size. It is the ratio of the distinction between the two average scores divided by the standard deviation.

Correlation	A linear statistical relationship between two variables to measure their direction and strength other than their relationship.
Degree of freedom (df)	How many options exist for the variation in the data? The degree of freedom vary
Hypotheses	An idea that can be testing
Mean	The equal set of numbers, is divided by how many numbers are there in the set. The mean considers all the values and can be corrupted by an additional amount.
Median	The value of a middle number when the data set is arranged from least to greatest. 50% of the observed data lies below the median value, and 50% lies above.
Pearson's r	The measurement of linear dependency between two variables.
Post hoc test	A follow-up after comparing the mean of different groups.
p-value	The probability of obtaining a result is at least as extreme as a given data point. P-values are used in hypothesis testing.
Standard deviation	A measure that is used to quantify the amount of variation of a particular set of data values. A lower standard deviation suggests that the points turn to be proximate to the mean. A higher standard deviation suggests that the data points are spread out of a broader range of values.
Statistical significance	This indicates the probability that the difference between a variation and control isn't due to chance.
T-tests	Hypothesis tests are used to analyse the average score of one or two samples.

Variable	An entity that can assume different values. Variables record the measurements we are interested in. There are two types of variables; Dependent and Independent.
-----------------	--

Table 6 Statistical concepts

5. Summary

This chapter presented clear portraiture of the quantitative research approach adopted as well as the experimental research design and the non-experimental designs applied in the study. The data collection plan was described, which included technology tools and pen and paper instruments. A brief explanation of the ethical issues considered, following a descriptive illustration of the research procedure of the study was described. This was followed by a statistical terminology table which gave a clarification of the concepts for easy understanding for analysis.

The following chapter exhibits the actual investigation and the results of the study.

Chapter five Empirical Investigation

1. Introduction

This chapter explains the methods, the materials, and procedures, and discussion of the presented result for both the pilot and the main study. The pilot study involved the survey questionnaires, followed by the main study which involved a true experiment design two weeks after the pilot study.

2. Pilot study

2.1 Method

Participants

A sample of seventy-six students from standard six (approximately 11-12 years old) of Palapye primary school participated in this study. They were allocated into two equivalent large groups of thirty-eight participants each with a random selection of gender in each group.

The purposive sampling method was used to select the unit of analysis. Purposive sampling is the deliberate selection of participants considering the qualities that the participants possess (Etikan et al., 2016). Unlike random studies, this study concentrated on participants with particular qualities who will better be able to empower with the relevant research. Individuals or groups of individuals involved in purposive sampling can communicate experiences and opinions expressively and reflectively. The population was made up of all the students who take Integrated Science.

2.2 Material and procedure

The survey questionnaire had six questions, and each question had three multiple choices. According to Depover and Orivel (2013), three options for multiple-choice questions appear easier for novice learners as they require less time to cover the content. The participants were given questions to try and understand their level of experience after listening to the narration presented to them during their weekly radio science lesson.

The questionnaire content provided learners with the opportunity to voice their opinion regarding the narration. One sample of the questions includes:

“How best can you describe the pace used for narrating?” (See APPENDIX A)

The feelings of the participants were scored by counting how many times a particular answer was chosen from the multiple-choice by the participants.

All participants answered the same questionnaire at the same time. On the day of the study, the two large groups occupied separate classrooms. Participants were guided to their seats and were seated approximately 0.5 meters apart to prevent collaboration. The groups were given a brief clarification of the process of the study. The participants were given 30 minutes to complete answering the questionnaire.

Participants had to complete the survey questionnaire using paper and pen. Once completed, participants indicated by raising their hands, and a teacher would pick the pen and paper. In each group, a teacher walked around to assist participants who needed assistance and also check the participants' progress.

2.3 Results and discussion

The data was collected using a paper survey and analysed using Google forms due to its usability and functionality. Google forms are one of the top recognized academic research online tools that generate reports using an automated analytic platform (Ercan, 2014). Google forms are also an excellent tool that offers a quick process of analysing input data manually as depicted in the screenshot below (Figure 6).

MY SCHOOL PROJECT SURVEY

Pilot study questions given out to students to get their opinion on the narration that was presented to them during an e-learning lesson.

1. Which narration voice would you prefer to be used during e-learning lessons? *

☐ A male voice

☐ A female voice

☐ My teachers voice

2. How would you describe the way narration was presented? *

☐ Not interesting

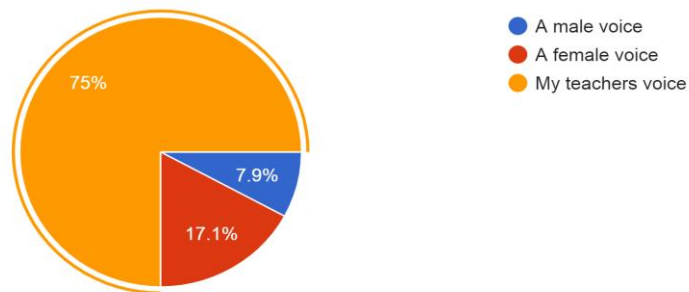
Figure 6 Google Form screenshot

The results below show the analysis of each question generated from google forms.

Question one

1. Which narration voice would you prefer to be used during e-learning lessons?

76 responses

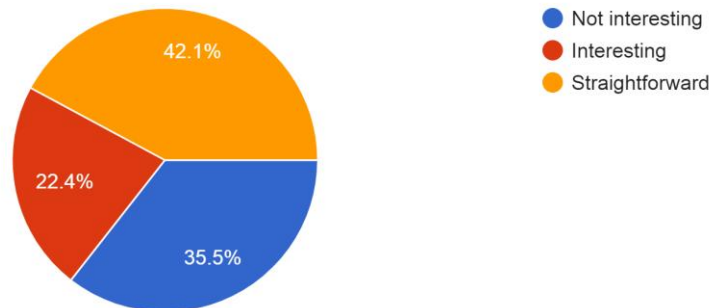


The highest frequency of participants prefers their teacher's voice instead of any other stranger's voice regardless of gender.

Question two

2. How would you describe the way narration was presented?

76 responses



The participants found the narration presented to be neither enjoyable nor not intriguing to listen to. Most of them found it to be straightforward which is concerning because a lesson should be interesting to grab the learners' attention.

Question three

3. The English grammar used in the narration was....

76 responses

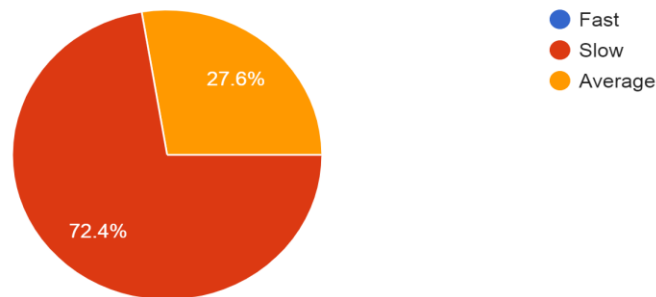


The grammar used in narration should be simple for the students to understand the concepts presented to them, but according to analyses, a higher percentage of 61.8% indicates that most participants found the words used to be complicated and simple.

Question four

4. How best can you describe the pace used for narrating?

76 responses

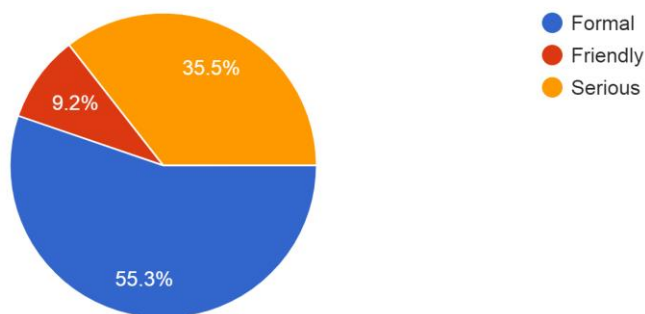


The results from the question above posed a concerning response as the majority of the participants indicated 72.4% that the narration pace was slow. A slow pace leads to boredom in young learners. The rest of the other participants found the speed to be average.

Question five

5. The voice used for narration was ...

76 responses

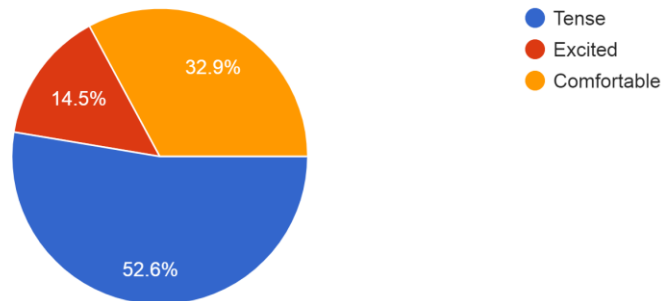


The narration during e-learning is expected to be friendly, but unfortunately, that option obtained the least votes as most of the participants indicated that they found the voice of the narration to be formal, followed by a serious voice.

Question six

6. How did you feel while listening to the narration during the lesson?

76 responses



The voice of narration can correlate with how students feel during the lesson. The majority of the participants felt tense during class which can distract their learning process.

The results from all the questions were further assessed to form conditions of narration to be featured when developing instructional material for the modality principle.

Conditions of narration for the modality principle derived from the questionnaire

From the analysis of the survey, two conditions for the narration of modality principles were established; 1) presentation mode and 2) narration style.

Presentation mode

Presentation mode was identified as an essential condition that should be considered when developing modality narration materials. The presentation mode is concerned with the speed and vocabulary of the narration. This condition states that the speed of the presentation should be neither slow nor fast, but it should be presented with an average speed concurrently with the image. The slow or fast pace of narration can cause a shift of attention from narration to concentration on images only or unimportant things for learning purposes. Slow or fast speed can also lead to split attention which results in extraneous cognitive load and hinders germane cognitive load from occurring (Costley et al., 2021). An average-speed presentation grabs learners' attention and keeps them interested. It promotes correct integration of audio and image, resulting in better learning outcomes for learners.

Better learning outcomes can also be achieved by using simple grammar during narration. The grammar used differs depending on the intended audience. Using big words or complicated words during narration on young learners can lead to them not understanding the learning material presented. When the instructional material presented is too simple, learners can retain the information regardless of how it was presented (Sandoval, 2016). Tricky expressions can also result in boredom and loss of interest in learning which hinders the learning process. During the survey, 61.8% of the learner pointed out that they understood some of the grammar used. Learners can face the difficulty of mental integration between the pictorial and the auditory with unfamiliar or complicated words.

Narration style

This condition suggests that the narration presented to learners during the modality principle material should be a familiar voice with a friendly tone. In most cases, one voice can be featured on much multimedia content for different students' content. According to the survey, 75% have indicated that they prefer their own teacher's voice instead of any voice. An unfamiliar voice has also been shown to make them feel tense during learning. A familiar voice that the students hear daily proposes that human-to-human conversation which prime a sense of belonging (Mayer, 2017). A human-to-human conversation keeps learners interested hence the focus of schema construction takes place. Using a friendly voice on learners primes a sense of social presence which leads to meaningful learning (Mayer, 2014b). A formal voice for young learners can lead to boredom; hence, no effective learning would take place.

One female teacher with a standard accent voice was recorded and featured when developing the instructional material with narration. After developing the material, it was given to the participants. Thereafter, two tests were administered to check their level of understanding during the main study.

3. Main study

3.1 Method

Participants

The unit of analysis was still students from Palapye Central Primary School who are in standard six. The population was made up of the same students who also participated in the pilot study.

The group of students was selected because the instructional materials used for the study were one of the topics on their syllabus. The majority of the participants had experience with operating the computer but were less exposed to e-learning. The topic of the study was lightning, which participants had minimal knowledge about and had not yet covered according to their academic syllabus.

The sample for the pilot study was seventy-six standard six students. The main study sample was seventy-four sixth-grade students, who are both girls and boys approximately aged eleven-twelve years. Originally there were seventy-six participants, one participant decided to withdraw from taking part in the study while the other participant was transferred to a different school.

A random assignment process was adopted and used in this study. A random assignment is a process in which study participants are assigned to experimental groups using a random procedure (Ifcher and Zarghamee, 2011). Participants were randomly allocated to any of the two groups. The two groups were the VN group (the group that viewed the video alongside Narration with identified conditions) comprised thirty-seven students, and the VT group (the group that viewed the video with on-screen text) comprised of thirty-seven students.

3.2 Material

Two different types of materials were adapted during the study. The participants used paper and pen and technology. The paper and pen materials included assessment tests and a self-report for students. Two assessment tests were to be completed by all participants from both groups: the retention and transfer test. A self-report is to be completed by all participants for mental effort.

Featured technology tools: Fifteen desktop computers were available and provided to the students. For the group with narration, the participants were encouraged to use the compatible headphones connected to their computer to hear the verbal indication properly.

The multimedia presentation: The multimedia program used was specifically designed and developed for this study by the author. The topic of study, lightning, was adopted from Mayer and Moreno's (1998) study. The images and text for the current study program differ from the original story as they were developed specifically for the current study experiment by the author. The program illustrated how lightning is formed. Specifically, the text read, "Lightning is caused by small bits of ice bumping into each other as they move round in the air. This bumping creates an electric charge, and after a while, the whole cloud is filled up with electronic charges. The positive charges form at the top of the cloud, and the negative charges form at the bottom of the cloud. The opposite attraction causes a positive charge to build upon the ground under the cloud. The ground electrical charges concentrate around anything that sticks up, such as mountains, tall trees, or people. The charge coming up from these points eventually connects with a charge reaching down from the clouds and lightning strikes. The connection creates thunder. Thunder is simply the noise lightning makes. Since lightning travels much, much faster than sound, you will see lightning before you hear thunder".

The narration version included the reading of the text in spoken words by a familiar female voice at an average pace. The on-screen version had the same words and text presented as on-screen text words using the same timing as the narration version. The multimedia programs were developed using Wondershare Filmora9 version 9.14.12, and below is a sample of a selected frame from the video with on-screen text, Figure 7.

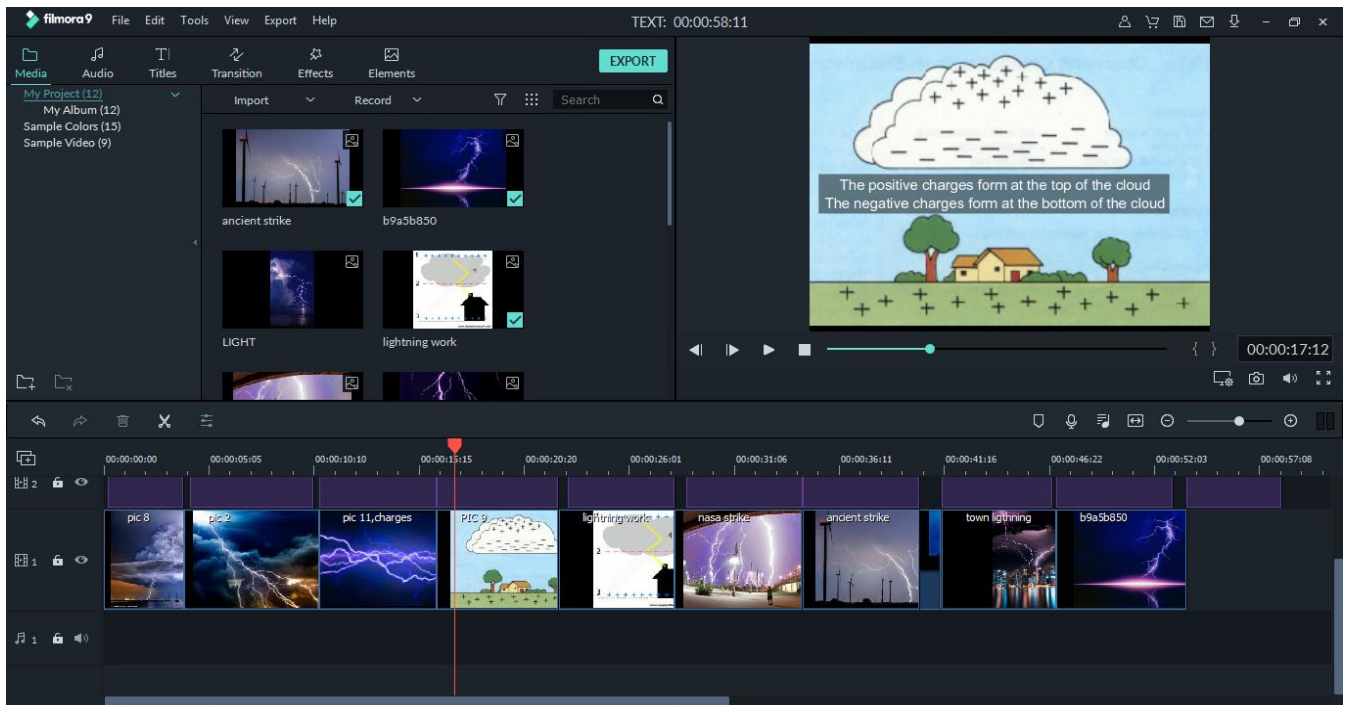


Figure 7 On-screen text screenshot

Paper and pen: The paper and pen items were involved in one retention and transfer, the pre-survey, and a self-report rating scale. All the paper items were printed on A4 paper. All the participants were required to use the paper format of assessment tasks and self-report.

The retention test and transfer test formats: Both tests were printed on A4 sheets of paper. The retention and the transfer test materials were identical for both the on-screen text and narration groups. (See APPENDIX B and APPENDIX C).

The retention test: The retention test comprised of ten questions in one sheet, the first five questions were multiple-choice questions, and the last five questions were true or false questions. At the top of the sheet of paper, it was stated as follows: “Please circle the correct answer.”

The multiple-choice questions were as follows;

1. What is lightning?
2. Lightning strikes when charges in the clouds connect with on the ground.
3. When water and ice particles bump into each other, they create..... .

4. The negative charges concentrate on the of the cloud.
5. Lightning comes from..... .

The true or false questions were as follows;

1. Thunder is the noise lightning makes.
2. Sound travels faster than light
3. Telephone lines and tall trees are extremely dangerous during a lightning storm.
4. Lightning is an electric current.
5. The clouds are filled with negative charges only.

The transfer test: The transfer test comprised of the following two questions, printed on one sheet of paper:

1. List four objects that can be struck by lightning.
2. Describe how lightning is formed.

The self-report scale: The cognitive load self-report rating scale was produced on one sheet. A subjective rating similar to Paas' (1992) 9-point unidimensional mental effort rating scale was adopted in the current study for rating the overall cognitive load experienced by each learner. The cognitive capacity designated to accommodate the demands imposed by solving a problem or the task can be considered to reflect the actual cognitive load (Leppink et al., 2014). The participants were asked to tick on the corresponding number to indicate mental effort (See APPENDIX D).

3.3 Procedure

All participants were assessed in the school library environment. The school library is isolated from other school buildings; therefore, the distraction from outside during the study was minimized. One large main door was shut during the study to avoid any unfortunate disturbance. The library environment included a computer laboratory seating format with 15 well-functioning computers. It had a large space to accommodate approximately 30 to 40 students. Due to the shortage of computers, each large group had three subgroups; hence, three sessions were conducted in the library for each large group.

The participants in the VN group were utilizing the headphones to hear the narration during the video effectively and to minimize any noise that might disturb them. Each session had one teacher to assist with the experiment. Similarly, during the pilot study, the participants were directed to their seats and given a brief introduction explaining the process of the study, including the completion of the cognitive load self-rating scale, retention test, and transfer test. The participants were also given oral directions about the location of the video on their individual computers.

Scoring the Test items

Retention test score: The retention test comprised 10 questions, and one point was awarded for each accurate answer. No points were granted for an inaccurate answer. Therefore, there the highest score was 10 points.

Transfer test score: The transfer test had two questions and possible total points of 10 points. A point was granted for mentioning one of the following words;

- a) Tall buildings
- b) Tress
- c) People
- d) Poles
- e) Mountains
- f) Cause electrical charges
- g) Small bits of ice bumping
- h) Positive charges at the top of the cloud
- i) Negative charges at the bottom of the cloud
- j) Positive charges build on the ground
- k) Lightning travels faster than sound
- l) Lighting before thunder

Table 7 shows the grading system for primary schools in Botswana. The percentage of how each participant performed on the retention test and transfer test, the below table was used.

Percentage (%)	Grade
85-100	A*
75-84	A
65-74	B
55-64	C
45-54	D
40-44	E
35-39	F
30-34	G
0-29	U

Table 7 The general primary school grading scale in Botswana

3.4 Results and discussion

The data collected and its results provide the extent respond to which the hypotheses posed in the first chapter are answered. The research was guided and directed by the following hypotheses to be tested to confirm the achievement of the study's main objective:

H1. Learners in the narration group will outperform learners on the in-screen text group on the retention task.

H2. Learners in the narration group will outperform learners on the in-screen text group on the transfer task.

H3. The narration group will report a lower cognitive load compared to learners in the on-screen text group.

H4: The different groups' performance will have a substantial degree with the reported cognitive load.

Two different types of tests; the retention test and the transfer test were used to measure the learning outcomes of participants in each group, the video and on-screen text group, and the video and narration with conditions.

Pen and paper were used to collect this data, and it was entered into Jamovi version 1.2.22.0 for analysis. Jamovi is a free academic research tool that was developed by a team of

developers, namely Ravi Selker, Jonathan Love, and Damian Dropmann who branched away from JASP.

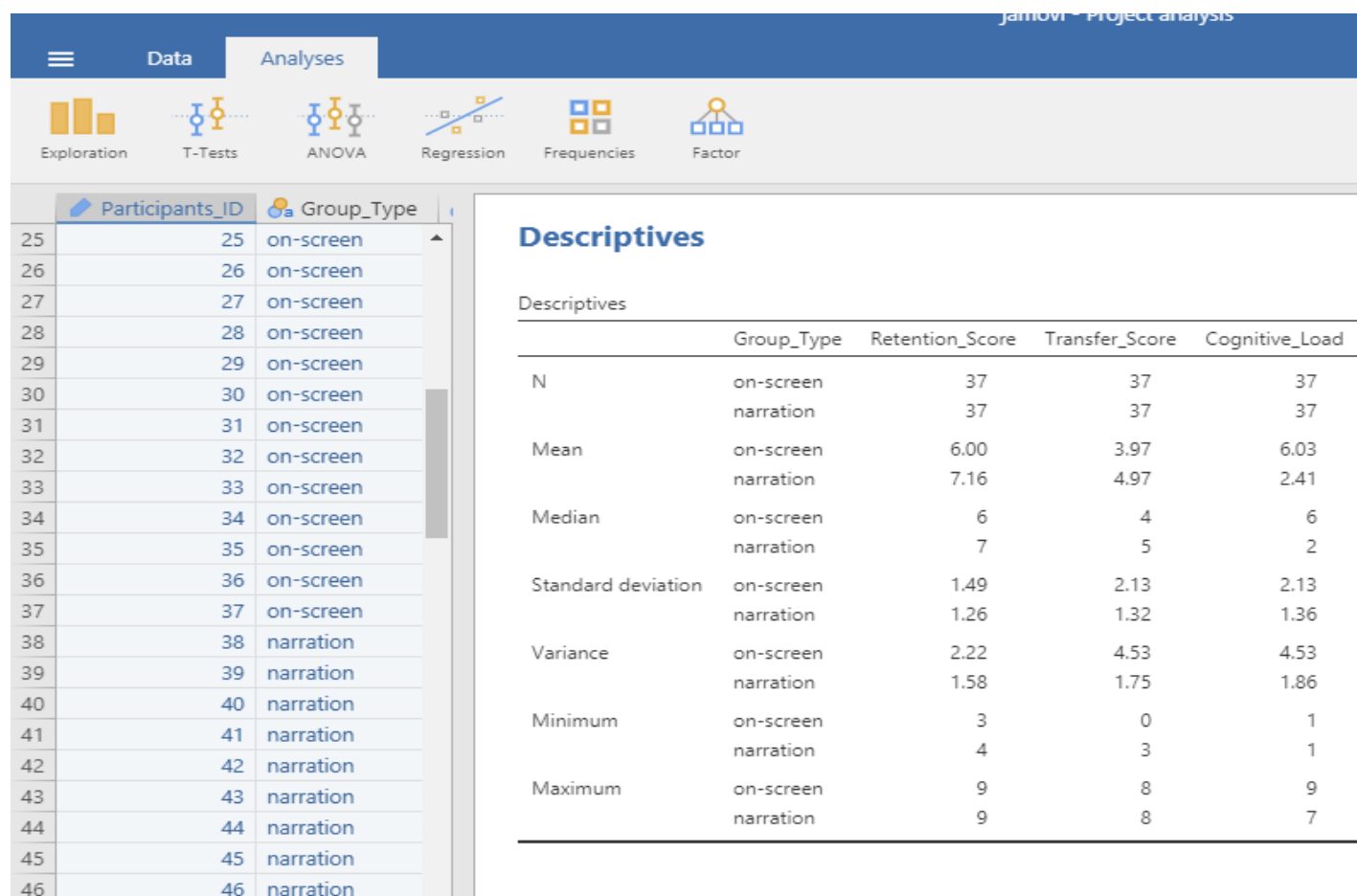


Figure 8 Jamovi working environment screenshot

Figure 8 above provide a sample view of jamovi's working environment. To reduce the data, descriptive summaries including correlation, frequency, mean and standard deviation were featured in the study as indicated on Figure 8.

Table 8 below gives an up-close general description derived from the analysis tool of how each group performed during different tests. It is easy to note, for example, in the mean and standard deviation that, the VN (the group with video and narration with conditions) outperformed the VT (the group with video and on-screen text) on both the retention test and transfer test. The table also shows the participants' self-rating effort, indicating that the VT group effort is higher than the VN group effort.

Data		Analyses			
Exploration		T-Tests	ANOVA	Regression	Frequencies
Factor					

Descriptives				
Descriptives				
	Group_Type	Retention_Score	Transfer_Score	Cognitive_Load
N	on-screen	37	37	37
	narration	37	37	37
Mean	on-screen	6.00	3.97	6.03
	narration	7.16	4.97	2.41
Median	on-screen	6	4	6
	narration	7	5	2
Standard deviation	on-screen	1.49	2.13	2.13
	narration	1.26	1.32	1.36
Variance	on-screen	2.22	4.53	4.53
	narration	1.58	1.75	1.86
Minimum	on-screen	3	0	1
	narration	4	3	1
Maximum	on-screen	9	8	9
	narration	9	8	7

Table 8 Overall Descriptives

3.4.1 T-Test Results

Dependent Test

The dependent T-test, also known as a paired sample T-test, known was completed between the two different types of tests (Retention test and transfer test) the participants took. The dependent T-test is used to measure whether the average score of the same participants improved over time, which is from the retention test to the transfer test, or whether the mean between the two different tests declined or remained the same. Table 9 shows the results.

Paired Samples T-Test						
			statistic	df	P	Cohen's d
Retention_Score	Transfer_Score	Student's t	9.52	73.0	< .001	1.11

Table 9 Results of dependent T-test

According to Oberfoell and Correia (2016), the two main outputs from the dependent T-test is the;

- i. The statistical significance, indicates shows from the above Table 8 that there is a real difference between the retention test and transfer test represents.
- ii. The effect size (Cohen's d), is the median difference in test scores between the retention test and the transfer test.

The p-value <.001 indicates a statistically significant difference between the test scores (Oberfoell and Correia, 2016). The number is so small reflecting that the null hypotheses are rejected. According to the paired sample T-test, there is a decline in performance from retention test (M = 6.58, SD = 1.49) to transfer test (M = 4.47, SD = 1.83). The data shows a statistical significance that reflects the participants performed superior on the retention test than on the transfer test as seen in Table 10.

Paired Sample T-test Descriptives					
	N	Mean	Median	SD	SE
Retention_Score	74	6.58	7.00	1.49	0.173
Transfer_Score	74	4.47	5.00	1.83	0.213

Table 10 Paired Sample T-test Descriptives results

Independent T-test

The Independent T-test was used to contrast the average score (retention test, and transfer test) from two separate groups of participants, which is the VN group and the VT group.

Retention test T-test

The VT group (N = 37), retention test scored mean M = 6.00 (SD = 1.49). By comparison to the VN group (N = 37) performance score on the retention test with a larger mean M =7.16 (SD = 1.26). The statistical significance difference is noted by df (72.0) and p-value of <.001 as seen below in table 11, the VN group outperformed learners in the VT group on the retention task.

Group Descriptives						
	Group	N	Mean	Median	SD	SE
Retention_Score	on-screen	37	6.00	6.00	1.49	0.245
	narration	37	7.16	7.00	1.26	0.207
Retention T-test						
			Statistic	df	p	Cohen's d
Retention_Score	Student's t		-3.62	72.0	< .001	-0.842

Table 11 Retention test T-Test results

Transfer test T-test

The independent t-test was completed to contrast the transfer test for the VT group and the VN group. There was significance difference df ((72.0), p-value labelled 0.018) in scores for VT group (M = 3.97, SD = 2.13) and VN group (M = 4.97, SD = 1.32). As seen in Table 12 below, the VN group performed better than the VT group on the transfer test.

Group Descriptives						
	Group	N	Mean	Median	SD	SE
Transfer_Score	on-screen	37	3.97	4.00	2.13	0.350
	narration	37	4.97	5.00	1.32	0.217
Transfer T-Test						
			Statistic	df	p	Cohen's d
Transfer_Score	Student's t		-2.43 ^a	72.0	0.018	-0.565

Table 12 Transfer test T-Test Results

3.4.2 One-way ANOVA results

The one-way ANOVA is used to establish whether there is any significant difference in the average score of a dependent group from more than two independent groups (Paas and Sweller, 2014). For this study, the VT group and the VN group are independent groups. Since we have two different types of study groups; the VT and the VN groups, the one-way ANOVA can be used, but it is predominately featured when there are three or more independent groups.

The ANOVA assumption is that;

- i. The population in each group is the same or equal (the VT group and the VN group had the same number of participants).
- ii. The dependent variable is the same as the compared group (retention test, transfer test, or cognitive load)

Tables 13-14 provide data on the dissimilarity between the two different groups on their tests and the cognitive load. Each table is paired with the Tuckey post hoc test to provide a more significant comparison of the two different groups (VT and VN).

Retention test

A one-way analysis of variance followed by Tuckey post hoc on the retention test revealed a significant difference among the two groups with P-value= <.0001, effect size $\eta^2 = 0.154$, and Mean difference = -1.16. The $P_{Tuckey} = <.001$ indicated that both the VT and VN groups differ significantly as depicted in Table 13 below.

ANOVA - Retention_Score							
		Sum of Squares	df	Mean Square	F	p	η ²
Overall model		25.0	1	24.99	13.1	< .001	
Group_Type		25.0	1	24.99	13.1	< .001	0.154
Residuals		137.0	72	1.90			
Post Hoc Comparisons - Group_Type							
Comparison							
Group_Type	Group_Type	Mean Difference	SE	Df	t	p _{tukey}	Cohen's d
on-screen	- narration	-1.16	0.321	72.0	-3.62	< .001	0.421

Table 13 Retention test ANOVA Results

Transfer test

The same analysis was completed on the transfer questions scores. It revealed a significant difference among the two groups, with P-value = 0.018, effect size $\eta^2 = 0.076$, Mean difference = -1.00

ANOVA - Transfer_Score							
		Sum of Squares	df	Mean Square	F	p	η²
Overall model		18.5	1	18.50	5.90	0.018	
Group_Type		18.5	1	18.50	5.90	0.018	0.076
Residuals		225.9	72	3.14			
Post Hoc Comparisons - Group_Type							
Comparison							
Group_Type	Group_Type	Mean Difference	SE	Df	t	p _{tukey}	Cohen's d
on-screen	- narration	-1.00	0.412	72.0	-2.43	0.018	0.282

Table 14 Transfer test ANOVA results

Cognitive load

The same analysis as the retention and transfer test was conducted on the cognitive rating between the two groups. The subjective ratings of the complexly instructional materials indicated a significant difference between the groups, $P\text{-value} = <.0001$, effect size $\eta^2 = 0.513$, Mean difference = 3.62.

ANOVA - Cognitive_Load							
		Sum of Squares	df	Mean Square	F	p	η ²
Overall model		243	1	242.65	76.0	< .001	
Group_Type		243	1	242.65	76.0	< .001	0.513
Residuals		230	72	3.19			
Post Hoc Comparisons - Group_Type							
Comparison							
Group_Type	Group_Type	Mean Difference	SE	df	t	p _{tukey}	Cohen's d
on-screen	- narration	3.62	0.415	72.0	8.72	< .001	1.01

Table 15 Cognitive loads ANOVA results

3.4.3 Pearson correlation coefficient analysis

Retention test performance and cognitive load relationship

The correlation analysis among the performance of participants on the retention test and their reported mental effort shows a moderate correlation of -0.352, as shown in Table 16 below. Therefore, the cognitive load has less impact on the results of the performance of participants on the retention tests.

Correlation Matrix			
		Retention_Score	Cognitive_Load
Retention_Score	Pearson's r	—	
	p-value	—	
Cognitive_Load	Pearson's r	-0.352	—
	p-value	0.002	—

Table 16 Retention test correlation matrix

Transfer test performance and cognitive load relationship

Table 17 below indicates the correlation between the performances of participants on the transfer test with their cognitive load. The correlation is also moderate, which is similar to the correlation of the retention test. With an indication of Pearson's $r = -0.381$, the two variables predict each other not in a weak way, neither strong, but moderate.

Correlation Matrix			
		Transfer_Score	Cognitive_Load
Transfer_Score	Pearson's r	—	
	p-value	—	
Cognitive_Load	Pearson's r	-0.381	—
	p-value	< .001	—

Table 17 Transfer test correlation matrix

VT group overall performance and cognitive load correlation

The correlation matrix in Table 18 shows that the correlation between the two variables (VT group performance and the reported cognitive load) is weak ($r = -0.255$) according to Diagram 1 in the previous chapter. Correlations are graphed on scatterplots as seen in Diagram 2 below.

Correlation Matrix			
		VT Group-Overall Performance	Cognitive_Load
VT Group-Overall Performance	Pearson's r	—	
	p-value	—	
Cognitive_Load	Pearson's r	-0.255	—
	p-value	0.127	—

Table 18 VT group correlation matrix results

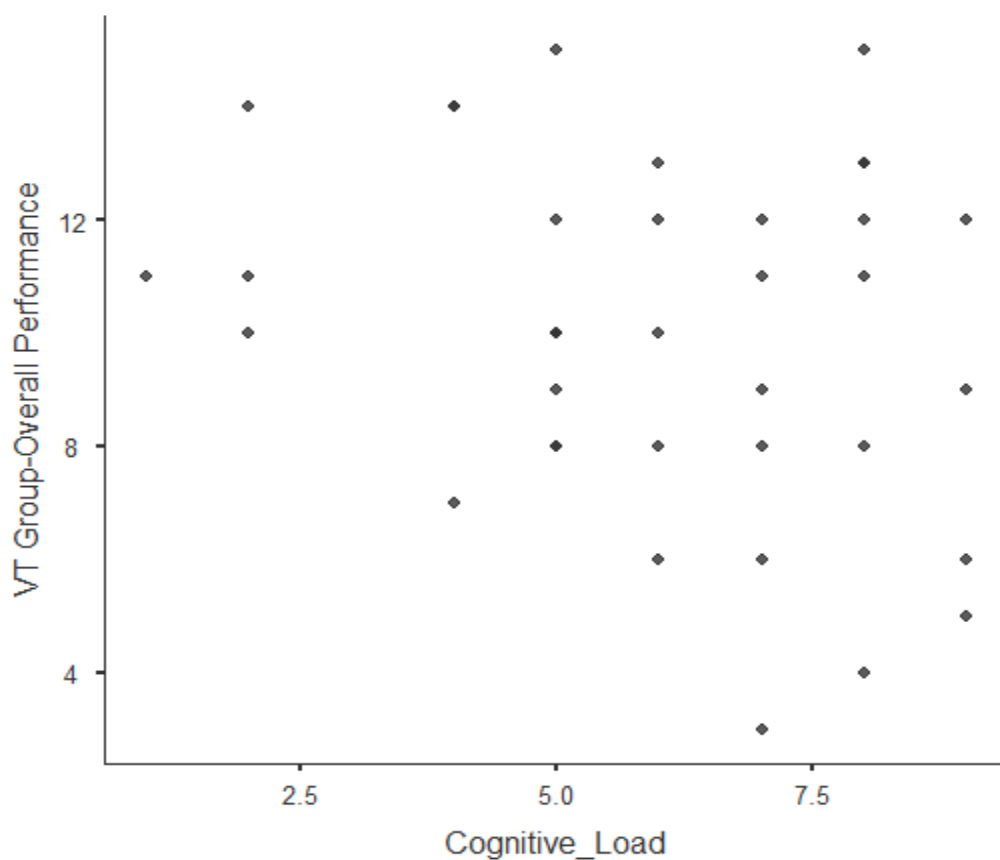


Diagram 2 VT group Correlation scatterplot

VN group performance and cognitive load correlation

The results indicate that there is also a weak correlation ($r = -0.243$) between the VN group performance and the reported cognitive load as indicated on the correlation matrix in Table 19 below. Diagram 3 further shows how weak the correlation is with scatter points on the scatterplot.

Correlation Matrix			
		VN Group_Overall Performance	Cognitive_Load
VN Group_Overall Performance	Pearson's r	—	
	p-value	—	
Cognitive_Load	Pearson's r	-0.243	—
	p-value	0.146	—

Table 19 VN group Correlation matrix results

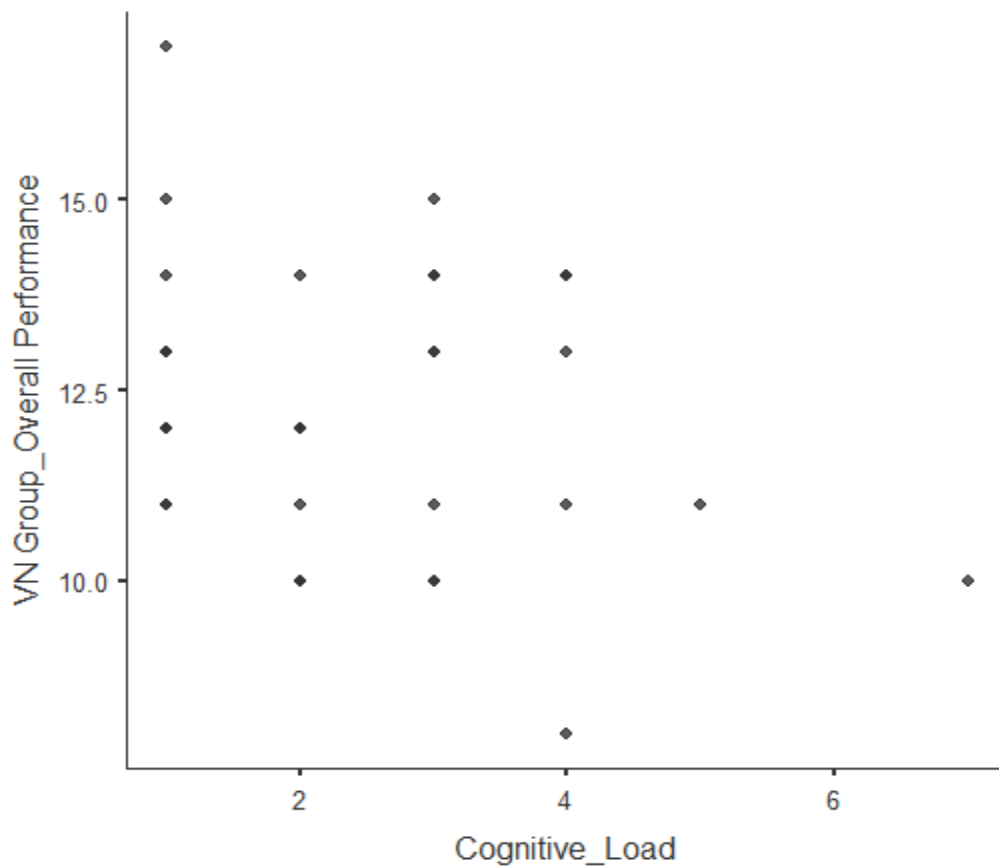


Diagram 3 VN Group Correlation Scatterplot

The first hypothesis; Learners in the narration group will outperform learners on the on-screen text group in the retention task, which is concerned with the performance of the different groups on retention addressed, as shown in Table 13 Participants from the VN group participants attempted better than the VT group participants. The modality effect did occur. There is a

statistical significance of $p = <.001$ between the VT group and the VN group on the retention test and a mean difference of -1.16.

The second hypothesis is; Learners in the narration group will outperform learners in the on-screen text group on the transfer task, which compares the performance of participants on the transfer tests results addressed in Table 14. The VN group performed above the VT group. With a statistically significant difference of 0.018 and a mean difference of -1.00, the VN group achieved better than the VT group again on the transfer test. These results reflect the effect truth, that narration is better than on-screen text.

The third hypothesis; the narration group will report a lower cognitive load compared to learners in the on-screen text group, which reflects on the participants' ability to self-rate their mental effort. The modality effect asserts participants who receive spoken text should report a low cognitive load than written text. Table 15 shows that there is a statistical significance for the self-rating mental effort between the two different groups. There exists a statistical significance among the VN group and the VT group in their reported cognitive load with a p-value of $<.001$, and a mean difference of 3.62.

The fourth hypothesis; the different groups' performance will have a substantial degree to the reported cognitive load. The inspection of the correlation matrix in diagrams 2 and 3 reveals that the overall performance in each group does not correlate with the participants' self-rating measures. The matrix reports a weak relation of $r = -0.243$ for the VN group and $r = -0.255$ for the VT group. The findings are contrary to the study's hypothesis.

4. Summary

This chapter presented the data of the pilot study and the main study involving two experimental groups with different instructional materials of the modality principle. All the data analyses data included a discussion of the outcomes. The overall results of the present study confirm earlier research finding that narrated text is more effective than on-screen text and reduces the cognitive load of learners as compared to on-screen text. The current study was considering the narration presented to low-experienced learners. The experiments carried out in this chapter also confirmed the hypotheses of the current study that, the VN group will outperform the VT group on both the transfer and the retention tests. The following chapter presents the limitations and future studies' suggestions.

Chapter Six Conclusion and Discussion

1. Introduction

This chapter provides the discussion of the study findings in the context of the literature, contributions of this research for future implementation of the modality instructional materials on e-learning, and the study's implications. It completes with recommendations and further research directions.

2. Summary of the study

This study identified some conditions of narration to consider when developing instructional materials for the modality principle that improve the performance of learners during e-learning.

The modality principle is explained with the help of Mayer's (2005) conceptualized theory of cognitive load of multimedia learning, which describes how instructional material is processed inside the human's information processing architecture. Figure 2 at page 18, is an illustration of the theory.

The modality principle focuses on the utilization of the dual-channel assumption and the limited capacity assumption. The limited memory has a restricted capacity, therefore, presenting multimedia of the on-screen text alongside images can result in the pictorial model being overloaded. Overloading causes some crucial information needed for integration to be lost. But with the modality principle, the issue of overloading is avoided by presenting images and spoken text on both channels (Sandoval, 2016). The modality presentation materials are shared equally among two sensory modalities: the verbal model and the pictorial model. They utilize sensory results in the availability of information storage and further processing.

The modality effect is said to be instituted on the cognitive load theory of Sweller et al, (2011b), which states that the right instructional design of multimedia materials should have two main focuses;

1. Avoid overloading by creating a more significant amount of limited memory that can be utilized for schema construction by decreasing the extraneous load.
2. Raise the germane cognitive load.

The unconsidered narration on modality principle designed materials causes an increase in the extraneous cognitive load and a decrease in the germane cognitive load. This led to the recent research findings that, on-screen text and images are better than using spoken text and images. Presenting unconsidered spoken text can lead to undesirable results of either cognitive overloading or split attention. Unconsidered narration such as the individual who narrates the text (voice), the speed of presentation, and the English vocabulary used can cause extraneous load as learners would need a specific time to convey and process the narration which can hinder the learning process.

The study presented conditions of narration that should be considered when using the modality principle to reduce learners' cognitive load and improve their performance. These conditions include presentation mode and narration style. The experiments carried out in the current study have shown that to reduce learners' cognitive load and improve their performance, the narration is the best option for multimedia material for primary school learners during e-learning rather than on-screen text. According to the current study's experimental result, learners in the VN group outsmart learners in the VT group in both the retention and transfer knowledge tests. The experimental results have also confirmed the following study's hypotheses;

H1. Learners in the narration group will outperform learners in the in-screen text group on the retention task. The current study's experiment results have shown that learners in the VN group recorded a mean of 7.16, while the VT group recorded a mean of 6.00 on the retention test.

H2. Learners in the narration group will outperform learners in the in-screen text group on the transfer task. The two groups recorded a close mean difference of 1.00 with the VN group recording a mean of 4.97, performing better than the VT group.

The results indicate that the on-screen text and image group performing worse than the spoken text and image might indicate split attention and shift of attention (Liu et al., 2019, Herrlinger et al., 2017). Learners' attention might be split between the presented on-screen text and the images. The shift of attention is to say, learners who receive on-screen text and images might supposedly have paid more attention to images than to on-screen text, which can disturb the proper integration of pictorial information. Splitting attention between text and images increases learners extraneous cognitive processing load and hinders the students ability to process information (Kizilcec et al., 2015). Herrlinger et al, (2017) conclusion about why on-screen text groups are outperformed by spoken text groups are the same reasons that might

have also spoiled that modality effect from taking place in the current study. Young learners tend to disregard on-screen information and focus on images instead, unlike adults who have higher reading ability.

The experimental results also confirmed one of the current study's hypotheses concerning the amount of cognitive load reported by different groups, which states that;

H3. The narration group will report a lower cognitive load compared to learners in the on-screen text group. Everyone in the different experimental groups reported their mental effort. T-test analysis was completed to compare the average total of the groups. The VT group reported a higher mental effort than the VN group, with a greater mean difference of 3.62. The VT group reported an average score of 6.03 while the VN registered an average score of 2.41. Similar results were found by Inan et.al (2015) and Zhu et.al (2020) with participants on the narration group reported a lower mental effort scores than the on-screen text group. This supported the modality principle's claim that students utilise less mental effort on narrated material than on written text material (Tabbers et al., 2004).

Too much mental effort can be an excessive extraneous cognitive load which can hinder the learning process. As stated by Liu et al. (2022) that the principles aims is to reduce cognitive load and promote learning. Less mental effort can be an indication that learners are not struggling to understand the concept of the instructional material, hence good performance.

The study's last hypothesis;

H4: The different groups' performance will have a substantial degree with the reported cognitive load. The hypothesis was not confirmed in the study, different results were obtained instead. A correlation between the performance of learners and their reported mental effort is indicated to be weak in both experimental groups, meaning there is a little or small relationship between the two variables. That is, lower or higher cognitive load does not predict the best or worse learning outcomes of learners, according to the results of this current study. Contradictory to the studies by ALdalalah and Fong (2010) and de Oliveira Neto et al., (2015) that postulated that narrated text enhances performance and also reduces cognitive load as compared to on-screen text.

3. Contribution of the study

The modality principle is the central principle of multimedia learning and has been studied for over thirty years. It is proven to be an effective principle in instructional design. Further modality principle instructional design have shown that the application of the dual channels allows free working memory space and improves the learning processes of learners. This study contributes to the body of knowledge on the modality principle. This study support the modality principle as a guiding principle and encourages instructional designer of multimedia for e-learning content to utilise the conditions of narration that considers the cognitive load of learners as this can benefit students.

The modality effect was found on this study on low experience users, however on the contrary Oberfoell and Correia (2016) found no modality effect on low experienced content users and concluded that narration does not always promote better retention and transfer knowledge.

Ginns (2005) has noted that only a few research so far have explored the effect of the modality principle on young students. The current study is an addition to the few studies which investigated the modality effect on young learners of recent research.

The current study included the pilot study which most studies in this field of the study do not consider. The pilot study chosen for this study was focused on the participant's experience with the narration used on multimedia for e-learning. The pilot study assisted in identifying suitable conditions that were used for developing learning materials that are learner-based. One study urged that to optimize learning, instructional designers and educators should efficiently engage and support learners with the learning materials (Agostinho et al., 2014) and this study demonstrated the importance of engaging learners when designing instructional materials using evidence-based principles.

This study provide the first research to investigate the type of narration presented to learners when using the modality principle material for e-learning. The study provides scientific evidence that paying attention to the narration delivered to learners on modality material does promote better learning outcomes. Liu and his colleagues (2021) also concluded that learners can simultaneously process two source of information when presented with spoken text and animation and have better learning performance. Castro-Alonso and Sweller (2022) emphasized that, under well-defined conditions information presented partly on the visual

model and other information partly on the auditory model can increase effective working memory and reduce cognitive overloading as compared to information presented in a single model (either visual or auditory).

Many studies including (Tabbers et al., 2004, Ginns, 2005, Reinwein, 2012) have found a stronger modality effect via system-paced compared to a reversed modality effect under learner-paced learning. However, it was shown by (Leahy and Sweller, 2011, Schüler et al., 2013) that the modality effect disappears or reverses with system-paced material. The current study demonstrated that the modality effect occurred through learner-paced learning. According to Mayer (2009) learner-pace assist learners to manage their cognitive load. Despite the amount of time the participants on the VT group had to pause and replay the video as many times as they could and reread the on-screen text, a reverse modality was not found. Participants on the VT group and on the VN group were given the same amount of time to watch the video. Learners do not benefit from on-screen text with animation during learner-pace by spending more time (Liu et al., 2021).

In addition, the study confirms that the modality principles need certain conditions or require to be combined with other already existing principles such as the voice principle and personalization principle. Furthermore, it is crucial to note that the modality principle cannot produce results on its own.

4. Implications of the study

4.1 Theoretical

This study contributes to multimedia learning theory by recognising and testing conditions of narration for the modality principle that creates a better way to support students with better retention and transfer of knowledge. This study identified conditions of narration and examined whether the modality effect would be observed in the context of multimedia learning in e-learning. This involved video with narration versus video with on-screen text in the study's experiment. Students can concurrently build a connection between mixed resources, from the auditory model and visual model in the working memory (Ye, 2018).

This study contributes to the modality principle research as it provides the first study to identify conditions of narration for the principle in the pilot study and examined the effect on the learning outcomes of learners. These conditions consider the cognitive load of learners and try

to avoid overloading. Therefore this challenge require instructional designers to provide instructional design with the best practices.

4.2 Practical

In the experiment, it was observed that on-screen text far from the images, oftentimes learners fail to pay attention to the text and concentrate on the images only, causing split attention. Split attention occurs learners are presented with animation and read on-screen text (Hughes et al., 2019).

Also on the practical side, there was a limitation of resources available that can better support e-learning at school. One major one is the inadequate number of computers available at the library. It is advisable to have a good quantity of computers to at least cover the number of students in each class. Sharing of computers during a lesson might hinder the student's ability to be more engaged and understand the content.

Novices to informal logic participants are most likely to be faced with a heavy cognitive burden. It is unclear whether participants with prior knowledge would have a greater or lesser benefit of better retention and transfer of knowledge (Bednall, 2009).

5. Limitations of the study

The first limitation of this study is that there is no previous work on the conditions of narration for the modality principle. This presented a challenge as literature review findings are the foundation to achieve set aims or specific objectives. The study reviewed existing studies on the other conditions of the modality principle. Therefore the study compared and constructed with previous studies concerning the cognitive load at the discussion part. The second limitation of this study is that the sample size was young primary school students, therefore the conclusion about the effect of narration for the modality principle on this study could apply to this age group only and be different in other age groups. A third limitation is that the amount of time required for gathering data, data entry, and data analysis was not considered by the study hence the study took a longer period than scheduled.

The fourth limitation of this study is that it focused on analysing the learning outcomes of the participants on short-term performance instead of focusing on both short-term and long-term retention and transfer of knowledge. The results of this study should therefore be categorised

as short-term learning performances. The fifth limitation of this study is that using a paper-based as a method of data collection when working with primary school participants was expensive and time-consuming. Other participants returned the papers used for data collection dirty or with playful drawings, therefore, forcing the author to reprint some papers and reschedule when the participants are not busy with the school programs. The sixth limitation is that the effect size ($n=37$) was a small number on which the finding of the study was based on. Results from the analyses of cognitive load should be conscientiously interpreted (Ye, 2018).

6. Recommendations and Further Research Directions

The issue of measuring cognitive load has been widely discussed by other researchers (Van Gog and Paas, 2008, Sweller, 2010, Sweller et al., 2011c) and has also presented a challenge in this current study. Over many years, research has found it challenging to prove the question of how best to measure the cognitive load. However corresponding to the cognitive load theory, the cognitive load consists of three different loads; the extraneous load, the germane load, and the intrinsic load which are not measured individually. Usually, the reported cognitive load by the learner is viewed as an overall report of the three different cognitive loads. Future research should establish techniques that might attempt to differentiate between all three cognitive loads and determine the precise type of cognitive load the learner reports.

The original self-rating scale initiated by Paas (1992) has been demonstrated to be an effective way of reporting cognitive load and has been used in much research. In the previous studies (Pollock et al., 2002, Mayer and Chandler, 2001) participants managed to report the level of difficulty of the test. Showing that other studies have modified the original scale. Therefore, further research is required to determine the most effective and reliable measurement of cognitive load.

In quantitative research, it is often advised that the larger number, the better the data, but unfortunately the sample used in the current study was small, with 74 participants. That was because, most standard six pupils in other primary schools had already covered the experimental topic of lightning, and the experiment was targeting no prior knowledge participants about the topic. Future research should target a larger number and also consider looking at how different genders would perform.

Future research is recommended to replicate this study and investigate whether system-paced would result into a different conclusion about the identified conditions of narration for the modality principle. Due to the lack of a correlation between overall performance and the reported cognitive load on this study, further research is recommended to find the correlations between each of the different tests scores with the rated cognitive load.

Future research should also address how on-screen text should best be used in the modality principle to enhance learners' retention and transfer of knowledge. The on-screen text content in the current study experiment might have been longer causing distraction and split attention among learners. The modality principle needs further research to identify the most effective instructional designs to produce better learning outcomes in learners during e-learning.

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APPENDIX A

Pilot study questionnaire

1. Which narration voice would you prefer to be used during e-learning lessons?
 - a. A male voice
 - b. A female voice
 - c. My teachers voice
2. How would you describe the way narration was presented?
 - a. Not interesting
 - b. Interesting
 - c. Straightforward
3. The English grammar used in the narration was....
 - a. Simple to understand
 - b. Difficult to understand
 - c. Neither simple nor difficult to understand
4. How best can you describe the pace used for narrating?
 - a. Fast
 - b. Slow
 - c. Average
5. The voice used for narration was ...
 - a. Formal
 - b. Friendly
 - c. Serious
6. How did you feel while listening to the narration during the lesson?
 - a. Tense
 - b. Excited
 - c. Comfortable

APPENDIX B

Retention test questions

SECTION ONE: MULTIPLE CHOICE QUESTIONS

Please circle one correct answer. (5 marks)

1. What is lightning??
 - a. Raindrops very high in the sky
 - b. A bright flash of electricity produced by a thunderstorm
 - c. Very hot air in the sky
 - d. A bright flash produced by rainfall
2. Lightning strikes when charges in the clouds connect with..... on the ground.
 - a. The highest points
 - b. Rainfall drops
 - c. Metal objects
 - d. Electrical charges
3. When water and ice particles bump around into each other, they create.....
 - a. Positive charges
 - b. Negative charges
 - c. Electronic charges
 - d. Lightning charges
4. The negative charges concentrate on the of the cloud.
 - a. Bottom
 - b. Side
 - c. Middle
 - d. Top
5. Lightning comes from.....
 - a. The clouds to the ground
 - b. Frozen ices cubes
 - c. Rainfall droplets
 - d. The ground to the ground then cloud

SECTION TWO: TRUE OR FALSE QUESTIONS

Please circle the correct answer. (5 marks)

1. Thunder is the noise lightning makes. TRUE / FALSE
2. Sound travels much faster than light. TRUE / FALSE
3. Telephone lines and tall trees are extremely dangerous during a lightning storm.
TRUE / FALSE
4. Lightning is an electric current. TRUE / FALSE
5. The clouds are filled with negative charges only. TRUE / FALSE

APPENDIX C

Transfer test questions

ANSWER ALL QUESTIONS

Question One

List four objects that can be strike by lightning. (4 marks)

1).....

2).....

3).....

4).....

Question two

Describe how lightning is formed. (6 marks)

.....

.....

.....

.....

.....

.....

.....

.....

APPENDIX D

Cognitive load Self rating scale

Full name:

Date:

Please tick the number that indicate how much effort you invested into understanding the information presented during the e-learning lesson.

Very, very low mental effort	Very low mental effort	Low mental effort	Rather low mental effort	Neither low nor high mental effort	Rather high mental effort	High mental effort	Very high mental effort	Very, very high mental effort
1	2	3	4	5	6	7	8	9

APPENDIX E

Consent form

**TITLE OF RESEARCH STUDY: THE EFFECT OF THE APPLICATION OF THE
MODALITY PRINCIPLE IN E-LEARNING ON LEARNING OUTCOMES AMONG
BOTSWANA PRIMARY PUPILS' EDUCATION**

- ❖ I voluntarily agree to participate in this research study.
 - ❖ I have had the purpose and nature of the study explained to me and I have had the opportunity to ask questions about the study.
 - ❖ My questions about the study have been answered to my satisfaction and I understand that I may ask further questions at any point.
 - ❖ I understand that I am free to withdraw at any stage by advising the researcher, without having to give a reason.
 - ❖ I understand that all information I provide for this study will be treated confidentially.
 - ❖ I understand that I will not benefit directly from participating in this research.
 - ❖ I consent to the information collected for the purposes of this research study, once anonymised (so that I cannot be identified), to be used for any other research purposes.
- Signature of research participant

Signature of participant

Date

Signature of researcher

I believe the participant is giving informed consent to participate in this study

Signature of researcher

Date

APPENDIX F

Information sheet

1. Research project title:

**THE EFFECT OF THE APPLICATION OF THE MODALITY PRINCIPLE IN E-
LEARNING ON LEARNING OUTCOMES AMONG BOTSWANA PRIMARY
PUPILS' EDUCATION**

2. Invitation

You are invited to participate in this research study. Before you decide to do so, it is important you understand why the research is being done and what it will involve. Please take time to read the following information carefully. Ask questions if anything you read is not clear or if you would like more information. Thank you for reading this.

3. What is the project's purpose?

Develop instructional materials including the conditions of narration for the modality principle in order to reduce the cognitive load and promote effectively learning on students during e-learning

4. Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be able to keep a copy of this information sheet and you should indicate your agreement on a consent form. You can withdraw at any time and you do not have to give a reason to why you withdrawing from the research project

5. What will happen to me if I take part?

You will be asked to complete two tests, the first one with multiple choice and true or false questions and the second test you will be requested to complete it a week from the previous first test and it involves structured questions.

6. What are the possible disadvantages and risks of taking part?

Participating in this research project is not anticipated to cause you any disadvantages or discomfort. The potential physical and psychological harm or distress will be the same as any experienced in everyday life.

7. What are the possible benefits of taking part?

It is hoped that this work will have a beneficial impact on you can effectively learn during e-learning. Results will be shared with the participants in order to inform their professional work.

8. Will my taking part in this research be kept confidential?

All the information collected about you during the course of the research will be kept strictly confidential, you will not be identified or identifiable in any reports or publications. Data collected may be shared in an anonymised form to allow reuse by other third parties.

9. What will happen to the results of the research project?

The results of the research will be published. You will not be identified in any report or publication. Please request well in time to put you on the circulation list if you wish to be given a copy of any reports resulting from the research.

10. Contacts for further information

Any questions concerning the research and procedures will be welcomed and answered to by the researcher. For further discussion of the research, please contact Dr Malatsi Galani at +267 4931106, galanim@biust.ac.bw.

Thank you for taking part in this research

APPENDIX G

Criteria for Measuring Content Validity

1.Relevance

1 = not relevant

2 = item need some revision

3 = relevant but need minor revision

4 = very relevant

2.Clarity

1 = not clear

2 = item need some revision

3 = clear but need minor revision

4 = very clear

3.Simplicity

1 = not simple

2 = item need some revision

3 = simple but need minor revision

4 = very simple

4.Ambiguity

1 = doubtful

2 = item need some revision

3 = no doubt but need minor revision

4 = meaning is clear