Comparing the Learning Effectiveness of Mono-sensory versus Multi-sensory Learning Environments

A Case Study

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Declaration

I hereby declare that this project is entirely my own work, and that it has not been submitted for any other academic award, or part thereof, at this or any other educational establishment.

Signed

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Andrew Tully

Date

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Student ID

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Abstract

This aim of this case study is to determine if distance learning students who collaborate within a multi-sensory learning environment can achieve better learning outcomes in terms of collaboration and retention over distance learning students who collaborated within a mono-sensory learning environment. Through the use of a case study methodology this study aimed to answer three research questions; if a multi-sensory learning environment could facilitate more effective learning, if students were more engaged with the learning process and material within a multi-sensory learning environment, and if multi-sensory collaboration could make a difference in effective learning when compared with mono-sensory collaboration?

The research took place online where participants engaged with a learning environment and collaborated with each other using a variety of software and devices. One group worked within a mono-sensory learning environment and used predominantly asynchronous communication and collaboration tools like discussion forums and emails, while the other group worked within a multi-sensory environment using a combination of asynchronous and synchronous tools like video conferencing and instant messaging. The research tools used for data collection were questionnaires, quizzes, observation and interviews.

The research findings suggested that students who worked within the multi-sensory learning environment had a better overall learning experience and had better learning outcomes than those who worked within the mono-sensory environment. There was increased engagement in terms of access among the multi-sensory group which accounted for the increased collaboration and retention. This finding was based on data collected from a variety of collection tools, both qualitative and quantitative, and supported by existing peer reviewed literature.
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<td>AOT</td>
<td>Asynchronous Online Teaching</td>
</tr>
<tr>
<td>HCI</td>
<td>Human Computer Interaction</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communications Technology</td>
</tr>
<tr>
<td>IP</td>
<td>Internet Protocol</td>
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<tr>
<td>LMS</td>
<td>Learning Management System</td>
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<tr>
<td>PDF</td>
<td>Portable Document Format</td>
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<tr>
<td>SOT</td>
<td>Synchronous Online Teaching</td>
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<tr>
<td>URL</td>
<td>Uniform Resource Locator</td>
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<tr>
<td>S-R</td>
<td>Stimulus-Response</td>
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Chapter 1  Introduction

Section 1.1  Background

From primitive stone tablets to modern touch screen digital tablets, technological advancements have always influenced education whether in the classroom or distant. While course material can be easily delivered to those who study online as with those who attend traditional classroom courses, there are certain elements considered helpful to the learning experience that cannot be easily replicated online. Among them is multi-sensory communication and collaboration where students have the ability to simultaneously see, hear and interact with their tutors and peers.

We live in a multi-sensory world and we are multi-sensory beings. It is therefore likely that our brains have evolved to learn most efficiently in a multi-sensory environment. Mono-sensory communication, common in low bandwidth distance learning environments, frequently omits a speakers’ nonverbal communication that can often support the message. Multi-sensory learning environments, on the other hand, are more likely to simulate the real “multi-sensory” world and therefore may be more effective for learning.

Collaboration is an important factor in a good learning experience where a student can acquire new knowledge and skills through discussion and analysis with their peers and tutors. Multi-sensory collaboration may help to provide a channel for dynamic and organic communication with tutors and peers, and widen the scope of multiple learning style support. By providing a channel that could facilitate inter-student communication, multi-sensory collaboration could help to develop relationships between geographically distant peers and tutors, encourage trust and enable effective collaboration. Provided the learner possesses the ability and previous knowledge base, and the learning environment is capable and reliable, multisensory collaboration can foster productive learning environments.

However, online multi-sensory communication and collaboration is inherently challenging, can be expensive and faces many technological and sociological
This raises questions about the justification of this mode of teaching and learning, are the learning benefits worth it?

This study is concerned with effective learning within online learning environments and a review of asynchronous and synchronous learning environments suggested the latter may be more conducive for dynamic multi-sensory collaboration which could be supportive of optimum moments of flow. Initial research reviewed literature on learning, learning styles, learning environments, an overview of and the justifications and limitations of distance learning, collaboration and the technology that is designed to deliver it. The research methodology involved two groups of students each working within an online learning environment designed to facilitate either mono-sensory or multi-sensory collaborative learning. The data collected from that research was analysed and, with the support of previously researched literature, helped to form conclusions and recommendations.

Section 1.2 Research aims

This study intends to determine if distance learning students who collaborated within a multi-sensory learning environment achieved better learning outcomes than distance learning students who collaborated within a mono-sensory learning environment. The primary aim was to determine if there was a difference in effective learning between the two groups of students. The secondary aim was to compare the level of engagement and enjoyment experienced by students using each learning environments.

Section 1.3 Research question

The study aimed to answer the following questions:

1. Does a multi-sensory learning environment facilitate more effective learning when compared with a mono-sensory learning environment?
2. Are students more engaged with the learning process and material within a multi-sensory learning environment when compared with a mono-sensory learning environment?

3. Does multi-sensory collaboration make a difference in effective learning when compared with mono-sensory collaboration?

Section 1.4 Research Approach

A case study approach was chosen to utilise both quantitative and qualitative research methods and data collection, this approach resulted in a balanced and accurate evaluation of research data. By retaining a holistic view of the online learning experience, this case study has the benefit of reflecting some of the complexity of the real-world. Additionally, using a case study approach provided an opportunity of intense observation, and to record and analyse data relating to the social relationships in the learning environment. The research tools used for data collection were questionnaires, quizzes, observation and interviews.

Section 1.5 Scope and limitations

The research was limited to two groups of 7 students, 14 students in total. Participants were selected from software development companies and each satisfied the selection criteria of computer literacy, knowledge baseline, access to required computer equipment and ability to fully participate in the study. Both groups worked within the same learning environment and used the same learning materials, but differed in the method of communication and collaboration; one group used mono-sensory methods and the other used a multi-sensory methods.

There were a number of limitations with the research. Both groups are very different in terms of ability; the mono-sensory group were made up of 15% Expert and 85% Intermediate users while the multi-sensory group were made up of 60% Expert and 40% Intermediate users. Due to unavoidable work/life events some participants found it difficult to commit to temporally fixed interactive sessions.
which affected some of the larger multi-sensory collaboration sessions by reducing the possible number of participants.

The length of learning the learning period was seven calendar days which proved to be shorter some participants needed due to time constraints and unavoidable work/life events. The number of participants was lower than the originally anticipated 4 groups or 10 participants each. Having two groups of two would have provided addition comparative evidence, increasing confidence in data reliability and validity. The small number of participants means that this research is not generalizable to other groups. The research tools and questions provided a simple rating of each participant’s experience which only gave an indication of whether the learning environment in this study had the potential for fostering moments of optimal flow and not definitive proof.

Section 1.6 Thesis outline

Chapter 1 provides an overview of this study and the background for the research. It discusses the aims, objectives, and the research methodology. The scope and limitations of the research were outlined and the chapter concludes with an outline of the thesis structure.

Chapter 2 concentrated on existing peer reviewed research into learning, collaboration and technology in education. Literature relating to learning theories, multimedia and multisensory learning, learning styles and multiple intelligences and blended learning were reviewed to obtain a broad understanding on the learning process. Two primary distance learning modes of asynchronous and synchronous online learning were examined followed by an analysis of the justifications and limitations of distance learning. This chapter concluded with a review of literature relating to collaboration and technology in education.

Chapter 3 focused on the process of determining the most appropriate research methodology for this study that led to the choice of a case study approach that combined qualitative and quantitative data collection methods. This chapter outlines the research questions, approach and setting, and the data collection tools
and methods of data analysis to ensure data validity and reliability are discussed in detail.

Chapter 4 presented data from the collection tools used during the study. These research findings were presented in narrative format for discussion and, where appropriate, displayed in bar chart format.

Chapter 5 compared earlier reviewed literature with the data obtained during the course of the study using the data collection tools. This chapter is organised in three sections, each focused on one research question. These sections discuss the learning effectiveness of learning environments, student engagement within learning environments, and collaborative learning within learning environments.

Chapter 6 draws together all the research and findings to formulate conclusions and set of recommendations for multi-sensory enabled distance learning environments.
Chapter 2 Literature Review

Section 2.1 Introduction

This chapter outlines literature reviewed within the context of the research question as outlined in chapter 1. The first section investigates learning and begins with exploring conditions required for optimal moments of flow and learning theories, namely behaviourism, cognitivism and constructivism, and how learning theories are utilised in distance learning programs. There follows a review of multisensory learning and the use of multimedia in education which leads into an overview of learning styles and multiple intelligences. A review of blended learning concludes the learning section.

The next section concentrates on distance learning and explores both asynchronous and synchronous online learning modes. We continue with a review of how humans interact with computers and explore the justifications and limitations of distance learning.

The third section focuses on collaboration and explores how collaboration can assist learning. It discusses online collaboration from multiple perspectives and explores advantages and limitations of implementing and maintaining collaborative environments. This section concludes with an analysis of both mono-sensory and multi-sensory collaboration.

The final section in this chapter reviews technology used in distance learning and how technology is used within online collaborative environments.

Section 2.2 Learning

The Oxford dictionary defines learning as an activity where one can gain knowledge of or skills in by study, experience or being taught (Allen, 1990). It could be argued that learning can occur anywhere and at any time but are there certain conditions that can improve the quality of that learning particularly in a distance learning scenario.
2.2.1 Optimum moments of flow

Psychologist Mihaly Csikszentmihalyi suggests that we can have periods of focused learning or moments of “optimum flow” (Csikszentmihalyi, 1990). According to Csikszentmihalyi, flow is a state of optimal experience that occurs when there is an appropriate balance between skill and challenge. Moments of “optimum flow” should require skill, be challenging and give learners clear and immediate feedback that would serve to involve the learner, thus helping create and reinforce a sense of control. Csikszentmihalyi recognised that sustaining optimum flow is a dynamic balance between excessively difficult and excessive simple activities, and he identified the ideal optimal learning environment as one where learners enjoy the process, are involved, have a feeling of control, and have a clear sense of self.

2.2.1.1 Computer assisted optimum moments of flow

Computer based learning can provide an opportunity for the learner to control their learning experience and in doing so can create a greater sense of involvement. Badrul Khan recognised that well-designed software can give distance learning applications the ability to manage the dynamic balance to deliver appropriately challenging content necessary for optimum moments of flow by monitoring performance in real time (Khan, 1997). He pointed out that “web-based teaching offers a better opportunity to provide more individualized instruction, with immediate and direct feedback on performance, than can be offered by a conventional teaching”.

Having a sense of involvement and ownership are important factors for moments of flow identified by Csikszentmihalyi that can be created using software. El-Tigi and Branch identified one major feature of web-based teaching as the possibility it offers to end linearity in the learning process by passing control of learning sequences from the program designer to the learner (El-Tigi & Branch, 1997).

By improving the learning environment it is hoped that we could enable more effective learning moments leading to more valuable optimum moments of flow.
In 1998 Forrester & Jantzie recognised that computers offered real potential to replicate Csikszentmihalyi’s optimum moments of flow by helping to manage the dynamic balance to deliver appropriately challenging content (Forrester & Jantzie, 1998). They also recognised that while software alone cannot deliver human interaction and collaboration it could gather data, provide immediate feedback, report performance, and other essential ingredients required for optimum flow as identified by Csikszentmihalyi.

Csikszentmihalyi’s notion of optimum flow focuses on creating environments best suited for optimising learning moments and how to sustain those moments but it does not help us understand how we learn. Garrison (2000) tells us that learning at a distance is a complex process and an examination of learning theories provides us with the understanding necessary to take effective action (Garrison R., 2000).

### 2.2.2 Learning theories

According to Garrison (2000), a theory is a “coherent and systematic ordering of ideas, concepts, and models with the purpose of constructing meaning to explain, interpret and shape practice”. It provides us with framework to try to make sense of complex processes and can provide a perspective that reduces that complexity while suggesting generalizability (Garrison R., 2000).

A learning theory tries to understand and explain how people learn, how they absorb, process and retain information. Learning theories can be split up into three categories: behaviourism, cognitivism, and constructivism:

- **Behaviourists** believe that the learning process is achieved by reacting to external stimuli.

- **Cognitivism** tries to look beyond behaviour and focuses on inner mental activities where learning occurs through the acquisition and retention of information.
• **Constructivists** believe the learner actively constructs knowledge where it is a function of how the learner creates meaning from their experiences.

2.2.2.1 **Behaviourism**

Behaviourism is a learning theory that assumes the learner is essentially passive, and their behaviour is based on reinforcement where an association is made between behaviour and a consequence for that behaviour. Essentially it is the study of the relationship between a student’s environment and their behaviour, without considering events that may occur within their minds (Carlson, 2000).

Edward Thorndike (1874 - 1949) is credited with pioneering work on learning theory that led to the development of operand conditioning (Thorndike, The Elements Of Psychology, 1905). Through this work, Thorndike proposed the following laws of effect, exercise and readiness that formed the building blocks of behaviourism:

- A positive response strengthens reinforcement, while negative response weakens reinforcement.
- The more responses to the stimulus, the longer they will last.
- Learning depends on the learner's readiness to act.

Thorndike’s stimulus-response (S-R) theory is known as classical conditioning (Thorndike, The Fundamentals of Learning, 1932).

Burrhus Skinner proposed a stimulus-response-reinforcement (S-R-R) theory known as operant conditioning and was based on the work of Edward Thorndike (Skinner, The behavior of Organisms: An Experimental Analysis, 1938). In it, Skinner said that learning occurs as a result of rewards and punishments for behaviour where the student makes an association between a behaviour and a consequence for that behaviour (Chomsky, 1959).
2.2.2.2 Cognitivism

In the late 1950’s a shift occurred towards learning theories from the cognitive sciences and throughout the 1960’s cognitivism dominated behaviourism. Unlike behaviourism, where no consideration is given to events that may occur within the mind of a student, cognitivism focuses on mental processes and is concerned with the storage, organisation and reception of information by the mind. The learning process is influenced by the learner’s values and beliefs are thought to be influential to the learning process (Butler & Winne, 1995). In cognitivism, the concern is what the student knows and how they have come to acquire that knowledge rather than what they do (Ertmer & Newby, 1993). Cognitivism emphases the learning of intellectual skills by combining learned principles and procedures in new ways to, for example, solve complex problems.

Cognitivists believe that students require active participation in order to learn. Ertmer and Newbie (1993) believed that the learner should be involving in the learning process, that information should be organised to facilitate optimal processing, and that the learning environment should be fashioned to provide students with the ability to connect with existing knowledge. According to Ertmer and Newbie “the real focus of the cognitive approach is on changing learner by encouraging him/her to use appropriate learning strategies”.

2.2.2.3 Constructivism

Constructivists believe that learning is actively generated by the user and is a function of how the learner creates meaning from their experiences. These experiences or perceptions are used to construct knowledge which results in understanding.

Merlin C. Wittrock (1974) said that knowledge is a generative learning process where learners actively participate in the learning process and actively construct knowledge by forming mental connections between concepts (Wittrock, 1974). Richard E. Mayer (1992) described the process of knowing as an adaptive one which organises the student’s own reality (Mayer R. E., Cognition and instruction: Their historic meeting within educational psychology, 1992). David H. Jonassen
(1991) connected a student’s own reality and knowledge construction to their environment when he said:

“How one constructs knowledge is a function of the prior experiences, mental structures, and beliefs that one uses to interpret objects and events. Constructivism does not preclude the existence of an external reality; it merely claims that each of us constructs our own reality through interpreting perceptual experiences of the external world.” (Jonassen D. H., 1991).

Constructivist learning depends largely on the students existing knowledge and experience and the structure of each of these in the mind, essentially the learner builds their own knowledge rather than the teacher supplying it. Jonassen (1991) believed that students did not share the same experience and knowledge as teachers therefore should not be obliged to share the teacher’s perception.

2.2.2.4 Distance learning and learning theories

It could be argued that the behaviourist approach is an appropriate model for a distance learning tool where students would learn through observation and content as argued by Thorndike (1932) and Skinner (1938). Positive reinforcement could result in advancing onto a higher level or score points and negative reinforcement could result in additional questioning or tasks. Computers are ideal platforms for the classic behaviourist method of drill & practice and since the S-R and S-R-R techniques are mainly reactive behaviours, they are well suited for online learning where content can be provided in linear sequential chunks and students must pass a prior subject before moving onto the next subject.

Cognitivism recognises that the acquisition of knowledge is a mental activity that involves internal organising by the student. For cognitivists, a successful learning experience is not only reliant on learning material and its delivery, but also on the students’ internal processes that that input, store and retrieve relative information that is organised in memory. Cognitive style is an important factor of individual
differences and it is important to factor in the students’ cognitive styles when designing distance education (Liu & Ginther, 1999).

Effective on-line learning can be supported by the constructivist approach where the students’ focus can be maintained on practical approaches to finding solutions for real-world problems and on knowledge construction with the aid of well-designed software. Real-world, case-based learning environments can be constructed using software that could foster collaborative construction of knowledge through social networks. In addition to re-creating real-world environments, software can also create multiple representations of reality that describe the natural complexity of the real world which can help students interpret multiple perspectives of the world which support the connection Jonassen (1991) made of individual knowledge construction and individual realities. However, as Akerlind and Trevitt point out, the use of technology in constructivist learning where students have more independence as learners can conflict with previous educational experiences that mean they must alter their understanding of the roles of students and teachers, which may result in resistance irrespective of the learning benefits of using technology (Akerlind & Trevitt, 1999). MacDonald et al also voiced concern about the use of technology in distance learning where it was seen to be more time-consuming but it overall it did seem to promote deeper understanding and better retention of new concepts (Macdonald, Bullen, & Kozak, 2007).

While it is clear the adoption of constructivism has significant advantages for online learning designers it is not suggested that this is the only theory that should be considered (Tam, 2000). Behaviourism, Cognitivism and Constructivism can each play a role in distance education. When designing distance learning programs the learning task should determine which learning theory should take priority (Khan, 1997). This is particularly important when considering an online learning environment that facilities multiple communication and collaboration avenues, and where learning material and learning tools are placed together. The variety of learning modes would require the consideration of individual or multiple learning theories to best suit individual tasks within the environment.
According to Ertmer and Newby (1993), Jonassen (1991) believed that students would be better supported using behaviourist and cognitivist approaches when acquiring introductory knowledge. He goes on to say that as students master more complex problems and acquire higher-level thinking skills a transition to a constructivist approach is required (Ertmer & Newby, 1993). The notion of utilising multiple theories for designing instructional material is supported by the Dick and Carey systems approach model (Dick, Carey, & Carey, 2009). In it they incorporate a variety of tools used in each of these three learning theories to produce a framework for designing pedagogical processes, and very relevant when considering an online learning environment that supports multisensory collaboration.

2.2.3 Multimedia and Multisensory Learning

The Oxford dictionary define learning as an activity where one can gain knowledge of or skills in by study, experience or being taught (Allen, 1990). Mayer suggests that learning is a change in knowledge attributed to experience and learning is dependent upon cognitive processing during the learning experience (Mayer R. E., 2008). According to Mayer during the learning experience a student uses three important cognitive processes; selecting, organising, and integrating. The selecting process is applied to relevant incoming material to yield a text and/or image base. The organising process is applied to the selected incoming material and sorted into coherent mental representation. The integrating process connects the organised incoming material with existing knowledge from long-term memory.

Mayer defines multimedia learning as learning from words and pictures, where the learner uses both auditory and visual stimuli (Mayer R. E., Multimedia learning, 2001). The words can be either printed or spoken text and the pictures can be either static (illustrations, photos, or diagrams), or dynamic (animation or video). Interacting with an educational video game or viewing an instructional video are all examples of multimedia learning. Mayer highlights three elements that are most relevant to multimedia learning; dual channels, limited capacity and active processing. Dual channelling allows learners to process visual and verbal
material at the same time. However, each channel possesses a limited capacity and can only process a limited quantity of material at any one time. Active processing recognises that deep learning is dependent upon cognitive processing during learning (e.g., selecting, organizing, and integrating).

![Diagram of Mayer's Cognitive Theory of Multimedia Learning](Figure_1.png)

Mayer suggests that multimedia learning can be more effective when content is presented in a way that observes research-based principles and is complimentary to the way the human mind functions. Using the following seven multimedia principles, learning and understanding can be encouraged by means of interactive multimedia that communicates using words and pictures (Mayer R. E., Multimedia learning, 2001):

- **Multimedia Principle**: Students learn better from words and pictures than from words alone. Practical applications include on-screen animations, slide shows and narratives that include both written and oral text, and static or dynamic images.

- **Spatial Contiguity Principle**: Students learn better when corresponding words and pictures are presented near rather than far from each other on the page or screen. Where text and images are coupled the text should be close to or embedded within the image.
- **Temporary Contiguity Principle**: Students learn better when corresponding words and pictures are presented simultaneously rather than successively.

- **Coherence Principle**: Students learn better when extraneous words, pictures and sounds are excluded rather than included. Multimedia presentations should focus on clear and concise presentations. Presentations that add extraneous content could impede learning.

- **Modality Principle**: Students learn more deeply from a multimedia message when the words are spoken rather than printed.

- **Redundancy Principle**: Students learn better from animation and narration than from animation, narration and on-screen text.

- **Individual Differences Principle**: Design effects are stronger for low-knowledge learners than for high-knowledge learners and for high-spatial learners rather than low-spatial learners

While Mayer’s principles of multimedia offer a comprehensive guide to designing multimedia instructional material, Lor and Gall point out that Mayer’s research does not take into consideration video and non-narrative audio (Lohr & Gall, 2004).

Seitz, Kim and Shams (2006) investigated the use of audio to facilitated visual learning and they found that multi-sensory audio-visual training resulted in significantly faster learning when compared to mono-sensory visual only training, suggesting that multisensory learning programs would be better suited to that task (Seitz, Kim, & Shams, 2006). Shams and Seitz (2008) suggest that this is a likely result of the evolution of the human brain to operate more efficiently within multisensory environments. They argue that mono-sensory training processes could create an unnatural setting that may not utilise evolved multi-sensory learning processes that produce more efficient behaviour in the real-world multisensory environment (Shams & Seitz, 2008). While investigating the
effectiveness of animated pedagogical agents over less expressive agents Johnson, Rickel, & Lester (2000) concluded that there may be significant learning benefits from utilising animated content with audio and video capability (Johnson, Rickel, & Lester, 2000). The effectiveness of multi-sensory learning environments could be gauged by creating two learning environments (one that supports synchronous communication and mono-sensory collaboration and another that supports asynchronous communication and multi-sensory collaboration) and measuring the effectiveness of learning between the two.

2.2.4 Learning styles and multiple intelligences

James and Gardner define a learning style as “the complex manner in which, and conditions under which, learners most efficiently and most effectively perceive, process, store, and recall what they are attempting to learn” (James & Gardner, 1995). Felder considered a learning style to be a combination of “characteristic strengths and preferences in the way they take in and process information” (Felder, 1996). Fleming identified Visual, Auditory, or Kinaesthetic (movement) sensory types as the three main sensory receivers to categorise learning styles (Fleming, 1995).

Felder noted that some students prefer visual content, like pictures and diagrams, while others responded positively to verbal content, like text and audio. Some students have a preference for active learning while others prefer a more introspective approach. Howard Gardner suggested that each of these preferences actually represented a different type of intelligence (Gardner, Frames of Mind: The Theory of Multiple Intelligences, 1983). He concluded that each individual is capable of seven ways of processing information:

- Words and language (Linguistic)
- Logical thinking and numbers (Logical)
- Pictures, shapes, images and 3D space (Spatial)
• Music, sounds and rhythm (Musical)

• Physical experience, movement, touch and feel (Bodily)

• Human contact, communication and teams (Interpersonal)

• Self-discovery and self-reflection (Intrapersonal)

Gardner suggested that “intelligence is a set of talents, skills, or potentials for finding solutions” that have a dependence on an individual’s culture and that intelligences are unique to an individual (Gardner, Intelligence reframed: multiple intelligences for the 21st century, 1999). Gardeners’ definition goes on to state that intelligence is:

“... an ability to solve problems or to create products, that are valued within one or more cultural settings.” (Gardner, Multiple intelligences: The theory in practice, 1993).

Intelligences are developed through interaction with an individual’s environment and may be cultivated, strengthened or weakened. Gardner's theory acknowledges that learning is a holistic experience and that cognition is not a linear process. This is significant when considering the use of technology to manage a distance learning environment which can accommodate all students learning styles by the use of multimedia like audio and video, text and images, etc. (Khan, 1997). Online learning environments can provide students with the ability and facility to access remote resources like museums and libraries at any time. Computers have a vast array of software applications and multimedia capabilities that can be used to target each of the intelligences, for example:

• **Linguistic**: Word processing, Desktop publishing, Presentation tools, Audio & video recording, Email, Discussion forums and blogs, Social networking
Logical: Organisational tools (databases, calendars), Calculation tool (spread sheets), Programming

Spatial: Animation tools, Computer Aided Design, Graphics, imaging and illustration tools, Presentation tools

Musical: Video and Audio recording, Music composition and playback tools, Animation tools, Interactive books

Bodily: Animation tools, Virtual reality, Photography, Robotics

Interpersonal: Blogs, Chat and Social Media, Video and Audio conferencing, Forums and discussions, Presentations

Intrapersonal: Blogs, Websites, Internet research, Portfolios and CV’s, Word processing (brainstorming, journals, diaries)

However, there may be significant limitations to accessing rich media online if the students’ bandwidth is insufficient or unreliable, or where bigger file sizes may adversely affect the access to multimedia elements (Khan, 1997). The infrastructure delivering learning material could also be a limiting factor if it suffers from insufficient bandwidth or is unreliable. Appropriate and sufficient client-side hardware and software is another potential limiting factor to the effective use of multimedia for distance learning.

2.2.5 Blended Learning

According to Garrison and Vaughan (2008) blended learning is the “thoughtful fusion of face to face and online learning experiences” (Garrison & Vaughan, 2008). Essentially in-classroom methods are blended with activities facilitated by computers to create an integrated approach that supports the intended educational purpose.
Blended learning aims to utilise the benefits of both classroom and online learning environments by using the most appropriate environment for each task. For example students could listen to a lecture or review content on their own time, and the limited classroom time can be better utilised for asking and answering questions, clarifying information, and participating in collaborative activities (Imbriale, 2013).

The portion of the course delivered online could provide students with a variety of media content that can be accessed at any time and from anywhere the student has access to the web.

Osguthorpe & Graham (2003) identified six goals of a blended learning approach (Osguthorpe & Graham, 2003):

1. **Pedagogical richness** – valuable classroom time can be better utilised for interactive activities and other non-interactive activities can be accessed online.

2. **Access to knowledge** – online resources are virtually limitless and students would have the ability to explore a lot more options than a text book could provide.

3. **Social interaction** – since blended learning environments mix classroom with online learning, students have the benefit of in-person interaction, something that a purely online learning environment cannot provide.

4. **Personal agency** – a blended learning environment can increase the range of personal choice for learners and can offer the learner some control in directing their own learning.

5. **Cost effectiveness** – financial savings may be made through reduced classroom time.

6. **Ease of revision** – online digital content can be easily and quickly revised.
Imbriale (2013) pointed out that students would still need guidance from teachers to maintain their focus on essential learning and that learning materials should be continually updated and evaluated to ensure that the content is accurate and relevant. Blended learning relies on student-centred learning and teachers would need upfront professional development in that area. Also, the online learning environment would need to work on multiple platforms and devices to as accessible and flexible as possible.

When compared with some other forms of distance learning, the blended approach to instruction and the fact the students were collocated dramatically improves isolation and collaboration problems experienced by some students (Locatis, et al., 2006).

Section 2.3 Distance learning

Finding a definitive statement that describes distance learning has proven to be difficult but Mood (1995) has identified three key characteristics of distance learning that researchers and practitioners agree on (Mood, 1995). They are:

- Separation of instructor and learner
- Use of media
- Two-way communication between instructor and learner.

Distance learning encompasses all forms of learning and teaching in which students and teachers are for all or most of the time in different locations (Moore & Anderson, 2003). It consists of instruction through print or electronic media to students engaged in learning in a place of time different from that of their instructor(s) or peers (Moore, Cookson, & Donaldson, 1990). The spatial separation between teachers and students removes the necessity for them to meet in a fixed place which can greatly enhance the flexibility of course delivery. While spatial separation is a key component of distance education, this may also
be combined with temporal separation where students and teachers are not sharing the same time and interact asynchronously.

Recently there has been a significant increase in distance learning interest and offerings and, according to Moore, the emergence and spread of new computer-based communications technologies is one of the principle reasons but he points out that distance learning should not be identified with communications technology and those who believe distance learning is merely adding such technologies to existing tools and procedures of the classroom are misinformed. According to Moore distance learning offers opportunity and equality for students, and perhaps introduces the notion of democratisation of education by redirecting some of the control and authority that would traditionally lie with the teacher towards the student. Distance learning is often associated with a lack of learner interaction but the capabilities that the internet provides make active learning in distance learning environments possible (Khan, 1997). Well-designed distance learning systems can allow students interact with each other, with instructors, and online resources. Instructors and experts can act like facilitators and can provide support, feedback, and guidance both synchronously and asynchronously.

Distance learning has the potential of offering more effective teaching and quality of learning. In addition it could provide a better return on investment for institutions (Moore & Anderson, 2003). However, these advantages are dependent upon good planning, clear policies, and good leadership. There is a danger that over enthusiasm of technology could lead to poorly designed and managed programs which runs the risk of eroding the satisfaction students may have with their learning experiences. This could have potentially negative effects since satisfaction ultimately leads to motivation, learning and successful outcomes (Mahle, 2007).

Distance learning environments are often referred to as virtual schools which rely on both asynchronous online teaching (AOT) and synchronous online teaching (SOT) but the tutor is still key to the process as a facilitator of the process (Murphy, Rodriguez-Manzanares, & Barbour, 2011).
2.3.1 Asynchronous Online Learning (AOL)

AOL abandons the classroom metaphor by designing virtual learning environments without real-time interaction between student and teacher. In an AOL scenario students (and teachers) are geographically and temporally independent and may experience delays of hours or days between questions or comments and responses to them from the teacher or other students. The communications limitations created by AOL require the use of a medium to connect teachers and students. In the past postal mail was used in correspondence courses (Mood, 1995). However, technology can now provide AOL with new ways and methods of communication, such as email, blogs, discussion boards and wikis.

In recent years, there has been a significant increase in the number of educational institutions offering their courses and even entire degree programs asynchronously via the web (Carswell & Venkatesh, 2002). Because AOL unitises communication via web pages, email and message boards they are inherently low band-width and therefore less likely to be negatively impacted by network issues (Locatis, et al., 2006). Bernard et al (2004) characterised AOL as ‘individually-based’ (Bernard, Abram, Lou, Borokhovski, Wade, & Wozney, 2004).

2.3.2 Synchronous Online Learning (SOL)

In some respects SOL extends the classroom walls where, although in different locations, students and teachers can interact in real-time. This can be achieved using technology like videoconferencing, teleconferencing, chat rooms, and instant messaging (Bernard, Abram, Lou, Borokhovski, Wade, & Wozney, 2004). Teachers and students are geographically diverse and independent but they can be temporally dependant when real-time interaction occurs.

An online learning environment that supports SOL would include tools like instant messaging, video conferencing, audio conferencing, whiteboards and application sharing. Some SOL software has a built-in recording functionality to
capture synchronous interactions and communication for asynchronous playback at a later date (Murphy, Rodríguez-Manzanares, & Barbour, 2011).

Studies have shown that interaction that SOL can provide on distance learning courses can lead to improved outcomes. Davie conducted a study involving two graduate level distance courses at the University of Toronto and reported high levels of satisfaction with the courses were due primarily to the levels of interactivity (Davie, 1988). Gao and Lehnam’s (2003) study found that students who participated in courses with higher levels of interactivity outperformed those who participated in less interactive courses (Gao & Lehman, 2003).

2.3.3 Human Computer Interaction

When considering the design of a distance learning environment that requires students and teachers interact with computer technology the application of human computer interaction (HCI) principles should be observed. Dix (2004) compiled a list of three USE words that must be true for a product to be successful (Dix, 2004), it must be:

- **Useful** – accomplish what is required: play music, cook dinner, format a document

- **Usable** – do it easily and naturally, without danger of error

- **Used** – make people want to use it, be attractive, engaging, fun

There is a need to recognise diversity where designers must take into account the type of user interacting with the software, ranging from novice user, knowledgeable but intermittent user and expert frequent user (Shneiderman, 1998). Each individual user type has an expectation that the interface can accommodate their needs. Novices may require extensive help whereas experts may want to progress quickly and facilitating both user types within the same interface can be challenging.
Shneiderman compiled a list of eight rules of interface design which should be observed when designing distance learning environments, they are:

- Strive for Consistency
- Enable Frequent User Shortcuts
- Offer Informative Feedback
- Design Dialogue to Yield Closure
- Offer Simple Error Handling
- Permit Easy Reversal of Actions
- Support Internal Locus of Control
- Reduce Short Term Memory Load

Organisation of content should enhance the users’ learning experience. In First Principles of Instruction, Merrill tells us that, “when learners think that they already know some of the material to be taught, then their existing experience can be activated by an appropriate opportunity to demonstrate what they already know. This activity can be used to help direct students to the yet-to-be-learned new material and thus result in more efficient instruction” (Merrill, 2002).

2.3.4 Justification for distance learning

Mather (1998) said that online learning brings education into the home allowing everyone in the family to participate, whereas traditional classroom based learning limits the experience to students and their peers. Providing students with the flexibility of a virtual classroom 24 hours a day allows students to work at their own pace and at a time of their choosing. This shift from static to dynamic
learning environments gives students more control over their learning experience (Mather, 1998).

While supporting the notion that online learning environments were useful Guthrie (2010) also pointed out that some students had difficult replacing face to face tuition (Guthrie, 2010). This difficulty did not mean a choice between online and classroom learning but rather how we can build online learning environments that are supportive of project-based learning. This would explain the popularity of a blended approach or the need for the process to be distance but tutor facilitated.

2.3.4.1 Access to Education

Distance learning can provide additional options for access to education for those who would ordinarily have little or no opportunity to participate in classroom based learning due to work, family or geographical challenges. It can help to equalise access to education (Bouhnik & Marcus, 2006).

2.3.4.2 Flexibility

Students can participate from multiple locations (provided technology and environment permits), for example home, office, library, etc. Students can participate at times of their choosing (Bouhnik & Marcus, 2006).

2.3.4.3 Cost effective

There can be little doubt that distance learning can be considerably cheaper than traditional learning for governments, students and institutions (Simpson, 2012). Governments that subsidise higher education benefit from the intrinsically lower cost of distance education and the fact that distance students are often economically active while studying. In many cases distance students benefit from lower fees, when compared to comparable classroom based courses, and can continue to earn. Institutions may receive reduced fees from distance students but there can be saving made in real-estate, maintenance, administration, and course production.
A well designed distance learning environment can facilitate a much greater number of students that a traditional classroom environment. The cost for a student hour of learning should take into consideration all the costs associated with development and delivery, even those sometimes hidden. While expensive developments cannot guarantee quality learning, good learning material is costly. A delivery system that is inexpensive with a large numbers of users can mean high quality learning material at low costs per hour (Bork & Gunnarsdottir, 2001).

2.3.4.4 Self-directed learning

Distance learning allows flexible pacing where student background and needs rather than class timetables determine how long each student can take to complete each learning module (Bork & Gunnarsdottir, 2001). A blended learning approach that combines the best aspects of classroom and online learning environments gives students flexibility within a structured learning environment where students could review content on their own time and use the limited classroom time for asking and answering questions, clarifying information, and participating in collaborative activities (Imbriale, 2013).

2.3.4.5 Subject variety

Online courses require little or no real-estate and significantly less real-time tutor involvement making it easier for institutions to offer a wider variety of subjects to students. The location of an institution is not a limiting factor for distance learning so courses unavailable in one institution may be available in another, anywhere in the world (Shih, Liu, & Sanchez, 2013).

2.3.4.6 Access to resources

Distance learning provides 24/7 access to online resources and expertise. Resources are not limited to what the institution can offer and can include 3rd party academic and professional partnerships and any other online resources available on the internet (Bouhnik & Marcus, 2006).
2.3.4.7 Learner type

Distance learning can be adapted to suit more learner types than classroom based environments by having multiple steams of learning material, the use of multimedia and multiple collaboration and communication options (Dimitrova, Sadler, Hatzipanagos, & Murphy, 2003), (Shih, Liu, & Sanchez, 2013)

2.3.5 Limitations of distance learning

When learning online, students tend to work in isolation which can make online learning more difficult than the classroom. Students may have less control of their learning environment if working from home where they are surrounded by the normal distractions of everyday family life. Some students may experience a lack of intrinsic motivation, particularly where the content or course does not meet their needs or interests.

Distance learners could find it more difficult to ask questions and confirm understanding if their interaction with peers and/or tutors was limited to static text-based modes like forums or email. It would also be harder to share ideas with their peers if their communication method was predominantly text based. Kay (2001) noted that learners can have at least negative control of any learning situation, where they can ‘turn off’ and not pay attention (Kay, 2001). In a distance learning environment where tutor supervision can be limited this could have a significant negative impact for the student.

2.3.5.1 Discipline

Students require more self-discipline and focus when working in isolation (Bouhnik & Marcus, 2006).

2.3.5.2 Technology dependence

Many distance learning environments require access to internet and an ability to use technology required to access the learning environment. Technology dependence can be a limiting factor both within and beyond the students’ control.
Students would need to possess a level of computer competence to fully enable access to both their own computer equipment and the online learning environment. Students who are uncomfortable with computer technology find studying and interacting online difficult.

Limiting factors often beyond the students control include unreliable or slow broadband speeds that would hamper high bandwidth activities, unreliable or poorly designed learning environments, power outages and unreliable computer equipment (Panagiotakopoulos, Tsiatsos, Lionarakis, & Tzanakos, 2013).

2.3.5.3 Personal interaction

Distance learning lacks the ability to provide students with constant and immediate personal interaction with peers and tutors. While online communication is possible there is a dependency on technology operating normally and without interruption to provide satisfactory online communication channels with peers and tutors (Bouhnik & Marcus, 2006).

2.3.5.4 Real time feedback

Students may experience a lack of real time feedback to queries, comments and questions, resulting in delays and unnatural breaks in study flows (Bouhnik & Marcus, 2006).

Section 2.4 Collaboration

The Oxford English dictionary gives a broad definition of collaboration as the action of working with someone to produce something (Allen, 1990). Dillenbourg (1999) narrowed his focused on learning when he provided a definition of 'collaborative learning' as a situation in which two or more people learn or attempt to learn something together (Dillenbourg, 1999). Student collaboration is very important to both learning and teaching effectiveness regardless of their physical location, whether students are collaborating in person within a classroom or remotely within an online learning environment (Hay, Hodgkinson, Peltier, & Drago, 2004).
2.4.1 Collaborative Learning

Khan (1997) recognised that people often work well in small groups, sharing knowledge and collaborating to perform complex tasks. They often performed best when their learning was practical, situated, and context-dependant. Within an online learning environment where learning is self-paced, provided students are motivated and the learning environment is of sufficient quality, students are able to pause and reflect on what they have learnt. In this scenario Khan argues that an ideal online learning environment should maintain the substance of traditional, structured instruction, while achieving some of the flexibility and informality of learning experiences out of school (Khan, 1997). Initially, online learning environments were a little more than information repositories but over time they evolved, in part by applying constructivist principles, to include capabilities for tutor-student and student-student, synchronous and asynchronous communication (Lambropoulos, Faulkner, & Culwin, 2012).

Collaboration is more than just putting two or more individuals in the same physical or virtual space and giving them the same task. For true collaboration, members of the group need to actively communicate and interact with each other, establishing a common focus to achieving a common goal (Kirschner, Paas, & Kirschner, 2009).

Online learning environments designed to foster collaborative learning can benefit students both instructionally and socially, and they may accomplish more than an isolated student because the interactions between the students may be just as important for learning as the interactions between the students and the online learning material (Khan, 1997). By designing online learning environments with collaboration tools that assist the development, testing and evaluation of new ideas could enable students to build new and modify existing knowledge structures (Jonassen, Davidson, Collins, Campbell, & Haag, 1995). This, as Seaton (1993) points out, clearly suggests that collaborative learning is the focus of constructivist, distance learning activities (Seaton, 1993).
Collaboration is an important factor in a good learning experience where a student can acquire new knowledge and skills, and critically examine assumptions and beliefs (Eastmond & Ziegahn, 1995). From an online learning perspective, technology should facilitate these good learning experiences in an extended classroom model rather than broadcast teacher-centred lectures and demonstrations (Burge & Roberts, 1993).

There is little doubt that collaboration improves the learning experience as research shows the benefits of working in collaboration rather than in more traditional individual learning environments (Kirschner, Paas, & Kirschner, 2009). However frequent real-time interaction with tutors and interactivity between teachers and students as well as cooperation among students is difficult at a distance (Hentea, Shea, & Pennington, 2003). Periodic or occasional face to face interaction is also needed. Hentea, Shea and Pennington point out that this type of blended distance learning is more promising than traditional methods. Using high bandwidth online audio visual communication tools and if organised correctly this face to face interaction could occur online and successfully integrate multisensory elements. Khan (1997) points out that, if used effectively, technology can allow students and tutors to interact in ways that the designers of the system did not plan, and well-designed interactive multimedia materials make it unnecessary to structure materials in advance for the user. The sharing of knowledge and resources that an online learning environment facilities engages students in higher level thinking skills, which promote active and interactive learning from multiple perspectives, a cooperative learning which extends beyond the classroom to potentially every classroom that is connected to the internet (Khan, 1997).

2.4.1.1 Mono-sensory collaboration

A mono-sensory learning environment limits communication channels by interfacing with single sense, for example auditory communication via speech or visually via text. Mono-sensory environments often employ asynchronous communication methods where typically participants do not see each other unless through pre-recoded video or if images are made available (Murphy, Rodriguez-Manzanares, & Barbour, 2011). Since mono-sensory learning environments
would typically have very low bandwidth requirements they would, from a
technical perspective, be likely to perform well in areas where broadband was
unavailable or unreliable.

Typical collaboration tools used in a mono-sensory learning environment are
discussion forums, email, blogs and wikis. These tools lack immediate responses
and the time delay could be conducive to reflection but they can also form barriers
to learning since they are not dynamic and they could to limit the flow of
thoughts, ideas and result in static conversations. With forums and emails,
thoughts are generally edited and not spontaneous and some students may
concentrate more on spelling, grammar and flow rather than content. This
staggered communication approach could result in distant, delayed and static
collaboration, and provide a two-dimensional representation of a students’
collaborators.

We live in a naturally multi-sensory environment and therefore a mono-sensory
learning environment could provide an unnatural setting that would fail to tap into
our multisensory learning mechanisms (Shams & Seitz, 2008). A view shared my
Miller (2012) who argued that mono-sensory learning does not make use of the
natural abilities of our cognitive structure (Miller, 2012).

2.4.1.2 Multi-sensory collaboration

A multi-sensory learning environment is one that facilities simultaneous multi-
channel, synchronous communication. Information can be communicated is many
ways. For example, verbal communication involves the production of words and
sentences to convey a message, but a speaker also produces nonverbal cues like
facial expressions and hand gestures that can reinforce and even carry part of their
meaning (Hostetter & Alibali, 2011). In a mono-sensory learning environment
where users are limited to engaging using a single sense, in this case auditory, the
listener would hear the speaker but without seeing the speaker they would be
unaware of the speakers’ visual cues and may lose some meaning.
Shams and Seitz (2008) point out that during the process of localising and tracking visual objects we integrate visual and auditory information. It is therefore likely that the human brain has evolved to function more efficiently in multi-sensory environments and that multi-sensory learning environments are more likely to simulate natural settings and therefore more effective for learning (Shams & Seitz, 2008). A point echoed by Carp (1995) who reminds us that “people are not mono-sensory beings, nor do we operate our senses one at a time. We are simultaneous and synaesthetic, and it is the operation of our senses (of our bodies) wholly and at once that brings us our experience of the world” (Carp, 1995).

Multi-sensory collaboration may help to provide a channel for dynamic and organic communication with tutors and peers, and widen the scope of multiple learning style support. By providing a channel that could facilitate inter-student communication, multi-sensory collaboration could help to develop relationships between geographically distant peers and tutors, encourage trust and enable effective collaboration. Provided the learner possesses the ability and previous knowledge base, and the learning environment is capable and reliable, multisensory collaboration can foster productive learning environments.

Section 2.5 Technology

From stone tablets to touch screen digital tablets, technological advancements have always influenced education (Sherman, 2000). With the rapid development of online technologies that facilitate multichannel communication, collaboration and interaction, educators have the ability to exploit the social nature of learners regardless of their physical location (Lambropoulos, Faulkner, & Culwin, 2012). Windschitl (2000) argues that there is an important role for technology in education for the creation of effective learning provided advantage is taken of the rapid evolution of telecommunication and multimedia strategies (Windschitl, 2000). Sherman (2000) reminds us that we live in a technologically advanced society and that technologically sophisticated communication skills are now a necessary component of the new global economy (Sherman, 2000).
2.5.1 Technology and Distance Learning

Today’s distance learning exists because of technology and, when designed and managed well, online learning programs have the ability to provide rich learning environments in a global, democratic and interactive manner (Khan, 1997). The benefits of using computer technology to deliver well designed distance learning programs include efficient information management, geographical, temporal and platform independence, and, combined with user ability and motivation, increased communications, collaboration and learner control (McCormack & Jones, 1998). McCormack and Jones pointed out that successful delivery of technology based distance learning systems depended upon a number of factors including reliable infrastructure, support and administration on the institutions side and sufficient broadband speeds, hardware quality and compatible software on the students’ side. Other issues like copyright, privacy, security and authentication may present as limiting factors (McCormack & Jones, 1998).

While technology can provide the infrastructure that enables distance learning the overall quality of a learning environment also relies on other factors like general features and functionality, content, media quality, interface design, support tools, management, technical infrastructure and maintenance, (Yildirim , Temur, Kocaman, & Goktas, 2004). Locatis et al. point out that all students in their study indicated that presenter personality, interactivity and teaching style were more important that the point of origin (Locatis, et al., 2006).

2.5.2 Technology and Collaboration

Moore (1992) saw the distance between student and teacher in an online learning scenario as both psychological and physical, and emphasised that this so called “transactional distance” needed to be bridged (Moore D. S., 1992). Martin (2005) argues that by bringing teachers and learners face to face in a virtual but real-time environment, video conferencing could not only bridge the transactional distance, it could also enrich the distance learning process (Martin, 2005). Martin maintains that video conferencing can cater for a range of intelligences and learning styles and, as Gardner points out learner learn best when different learning styles are
addressed (Gardner, Frames of Mind: The Theory of Multiple Intelligences, 1983). Martin also highlights one of the significant advantages of a classroom environment that is difficult to replicate in a distance learning environment, which is the ability of a teacher to gauge student interest through body language. She cites video conferencing as the only technology which allows the distant teacher to observe these vital clues (Martin, 2005).

Martin highlights a number of issues with video conferencing, including difficulties in sustaining remote learners’ interest, issues surrounding specific training and guidance for teachers, and there were concerns about the robustness and cost of the technology (Martin, 2005). While Khan (1997) noted that conferences became exciting events while utilising video conferencing technology, that student projects improved because of the conference interaction, and the teacher was supported in making sense of the students’ efforts and accomplishments, they also raised concerns about difficulties and frustration experienced by both teachers and learners when using internet based video conferencing with low bandwidth connections and without technical support (Khan, 1997). In order to create a personal and dynamic interactive experience there needs to be enough bandwidth and the technology needs to be as dependable as the everyday office software that has become commonplace.

Video conferencing was the preferred technology by participants of the Dissolving Boundaries project, a cross-national collaboration through Information and Communications Technology (ICT) between 10 special schools in Northern Ireland and the Republic of Ireland. Reasons cited for this reference were the ability to see one another and the immediacy of the medium which made discussion easier, improved listening skills and let to a greater tolerance of perspectives. Sixty per cent of participants found that collaborative work was more interesting when using video conferencing. It was also noted that video conferencing significantly improved communication skills (Abbott, Austin, Mulkeen, & Metcalfe, 2004).
Section 2.6 Conclusion

This analysis of literature related to learning theories gives an understanding of the advantages and disadvantages of each learning theory so when designing a learning environment they can be optimised to support the behaviourist, cognitivist and constructivist theories. Mayers’ seven principles of multimedia should be observed when designing a learning environment to provide the best possible combination of media types to enhance the learning experience and it should also be tailored to focus on some or, if possible, all intelligences as identified by Gardner.

In theory, designing a learning environment that supported asynchronous communication and multi-sensory collaboration would improve the likelihood that students experience Csikszentmihalyi’s optimum moments of flow where learners are given clear and immediate feedback that serves to involve the learner, thus helping create and reinforce a sense of control (Csikszentmihalyi, 1990).

Collaborative environments facilitate the sharing of knowledge and resources that engages students in higher level thinking skills, which promotes active and interactive learning from multiple perspectives (Khan, 1997). These environments should help to sustain moments of optimum flow, consequently students should experience a higher level of sustained attention, enjoyment and engagement, resulting in more effective learning taking place.

The focus of this study is to examine differences between mono-sensory and multi-sensory distance learning environments with a view to determining if there are potential advantages with either environment in terms of effective learning. These two environments provide differing capabilities for collaboration and this research aims to investigate if these collaboration platforms can provide better learning outcomes for distance learning students. Online learning environments seem to be more challenged when it comes to creating and maintaining optimum moments of flow and this study aims to identify models which are better suited to that task.
Chapter 3  Methodology

This chapter outlines the aims and objectives of the study. It discusses the methodology used and explains the rationale for choosing the research approach and data collection instruments. It outlines the background to the study, piloting, timeframes, and demonstrates how the study conforms to the principles of validity and reliability.

Section 3.1  Background

The literature review examined technology in distance learning and explored the significance of sensory communication to the learning process. It suggested that effective learning requires a variety of conditions that can result in what Csikszentmihalyi calls optimum moments of flow (Csikszentmihalyi, 1990). These conditions could be environmental, social, technological or psychological, and may vary within student populations with diverse learning styles. This study is concerned with effective learning within online learning environments and a review of asynchronous and synchronous learning environments suggested the latter may be more conducive for dynamic multi-sensory collaboration which could be supportive of optimum moments of flow. Online learning environments seem to be more challenged when it comes to creating and maintaining optimum moments of flow and this study aims to identify models which are better suited to that task.

Section 3.2  Research Questions

This study intends to determine if distance learning students who collaborated within a multi-sensory learning environment achieved better learning outcomes than distance learning students who collaborated within a mono-sensory learning environment. The primary aim was to determine if there was a difference in effective learning between the two groups of students. The secondary aim was to compare the level of engagement and enjoyment experienced by students using each learning environments.
The study aimed to answer three questions. Does a multi-sensory learning environment facilitate more effective learning when compared with a mono-sensory learning environment? Are students more engaged with the learning process and material within a multi-sensory learning environment when compared with a mono-sensory learning environment? Does multi-sensory collaboration make a difference in effective learning when compared with mono-sensory collaboration?

Section 3.3 Research Approach

The process of deciding a research approach began with an understanding of two leading and, in many ways, divergent research approached, namely positivism and interpretivism.

Positivism is the view that research can and should use natural sciences (physics, chemistry, mathematics, etc.) processes and techniques, and that researchers should use quantitative methods to undertake their research and data analysis. Interpretivism is the view that scientific methods are inappropriate for the study of human activity since we think and reflect and can, if we know we are being observed, change our behaviour (Roth & Mehta, 2002). Interpretivism contends that in order to understand a human activity we have to explore reasons and meanings behind that activity rather than take the positivist approach and use quantitative methods to measure changes and identify patterns. The following table provides a summarized version of methodological differences of each approach (from Carson et al, 2001, p. 6).

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Positivist</th>
<th>Interpretivist</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focus of research</strong></td>
<td>Concentrates on description and explanation</td>
<td>Concentrates on understanding and interpretation</td>
</tr>
<tr>
<td><strong>Role of the researcher</strong></td>
<td>Detached, external observer</td>
<td>Researchers want to experience what they are studying</td>
</tr>
<tr>
<td></td>
<td>Clear distinction between</td>
<td>Allow feeling and reason to</td>
</tr>
</tbody>
</table>
reason and feeling govern actions

Aim to discover external reality rather than creating the object of study

Partially create what is studied, the meaning of phenomena

Strive to use rational, consistent, verbal, logical approach

Use of pre-understanding is important

Seek to maintain clear distinction between facts and value judgements

Distinction between facts and value judgements less clear

Distinction between science and personal experience

Accept influence from both science and personal experience

<table>
<thead>
<tr>
<th>Techniques used by researcher</th>
<th>Formalized statistical and mathematical methods predominant</th>
</tr>
</thead>
</table>

(Roth & Mehta, 2002) contend that interpretive analysis and positivist analysis are each important in their own right but since each approach can be used together to inform one another combining the two has even greater analytic value (Roth & Mehta, 2002). Cohen et al (2011) echoes this view and believes both qualitative and quantitative data are both important forms of research and while they may be traditionally used independently, the two paradigms can be combined (Cohen, Manion, & Morrison, 2011). The following table provides a summary of positivist and interpretivist approaches.
Table 2: Summary of Positivism and Interpretivism

<table>
<thead>
<tr>
<th></th>
<th>Positivism</th>
<th>Interpretivism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causation</td>
<td>Seeks to understand the causal explanation for a phenomenon or event</td>
<td>Interpretation-Seeks to understand how people interpret a phenomenon or event</td>
</tr>
<tr>
<td>Objective reality</td>
<td>Presumes the “existence of facts”</td>
<td>Subjective reality-Recognizes the “construction of facts”; facts are seen as interpreted and subjective</td>
</tr>
<tr>
<td>Generality</td>
<td>Analysis seeks a “law” that extends beyond specific instances studied</td>
<td>Specificity-Analysis is context specific and based only on the subjective understanding of individuals within a specific context</td>
</tr>
<tr>
<td>Replicability</td>
<td>Analyses can be tested and verified empirically against other cases</td>
<td>Self-validation- Analyses can only be self-validating, through the consistency and coherence of “thick description” (Roth &amp; Mehta, 2002)</td>
</tr>
</tbody>
</table>

By utilising both quantitative and qualitative research methods in this case study it is expected that a balanced and accurate evaluation of research data has been achieved. A case study is a written account that gives detailed information about a person, group, or thing and their development over a period of time (Collins English Dictionary, 2011). One of the benefits of using a case study approach is that it provides an opportunity of intense observation, and to record and analyse data relating to social relationships in a relevant social setting (Shang, Fisher, & Xie, 2011). Cox (2009) points out that a case study can “reflect some of the complexity of the real-world be retaining a holistic view of a situation” which benefits both tutors and students by adding interest to the learning experience (Cox, 2009).
Section 3.4 Research Setting

The research took place online where participants engaged with the learning environment and collaborated with each other using a variety of software and devices.

3.4.1 Online Learning Environment

The primary learning environment was created using the open source Learning Management System (LMS) Moodle which was hosted using a dedicated URL (www.learningglue.com). The Moodle environment hosted the learning material, module quizzes, pre and post course questionnaires, pre and post course knowledge quizzes, discussions forums, email and a calendar. The entire learning environment included a number of other platforms used for communication and collaboration that were linked to the Moodle environment, these were Google Hangouts for video conferencing and instant messaging, Skype for video conferencing, and 3rd party email clients. Social media was used provide additional avenues of communication and collaboration with the creation of a Facebook and Twitter account. Social media can be described as socialising online through a variety of media types including text, graphics and video (Reuben, 2008). Student activities in these accounts were monitored for the duration of the course and their usefulness was discussed during the post-course interviews. Students accessed the entire learning environment from the learningglue web site.

3.4.2 Piloting

The function of piloting is to ensure reliability, validity and practicability of the research tools and environment (Cohen, Manion, & Morrison, 2011). Prior to commencement of the study, the learning environment and all tools within it and linked to it were the subject of a pilot to ensure they operated as expected and identify any user. The data collection tools involved in the piloting period included the pre-course questionnaire, the pre-course quiz, the post-course questionnaire and the post-course quiz. The pilot ran over a period of a week and involved 2 reviewers that satisfied the requirements for participation in the study.
but would not take part in the study itself. The pilot did reveal a number of usability issues with the learning environment, questionnaire and the learning material which were addressed.

### 3.4.3 Participant Selection

Participants were selected from similar educational backgrounds and underwent a subject knowledge assessment to ensure that selected participants had similar knowledge bases. Since the study was conducted entirely online it was essential to ensure that all participants were comfortable using technology for communication and computer literate. Each participant was required to ensure that their computer equipment and internet connection was free of any technical and connectivity issues that may prevent them from participating in either study group.

There were a total of 14 participants involved in the research and were assigned to either the mono-sensory group (group A) or the multi-sensory group (Group B). Each group contained 7 students.

#### 3.4.4 Mono-sensory group

Group A, the mono-sensory group, used a range of synchronous communication and collaboration tools like email and discussion forums where they were encouraged to post questions and comments related to the learning material, and reply to other participants’ comments and questions. This group with be collaborating within a mono-sensory learning environment.

#### 3.4.5 Multi-sensory group

Group B, multi-sensory group, had access to the same tools as group A with additional access to a range of tools that enabled asynchronous communication and collaboration like video conferencing, telephone conferencing, and instant messaging where they can collaborate in real time. Participants in this group were required to follow a group twitter account that was broadcast relevant snippets of information related to the learning material. Participants were encouraged to join a Facebook group that will have regular updates relevant to the learning material,
however it is recognised that some participants may not have or want a Twitter account or a Facebook page. It is also recognised that to fully participate in these processes students in this group will have to have a certain amount of intrinsic motivation. This group would be collaborating within multi-sensory environment.

3.4.6 Learning material

The research data was gathered from two groups of adult learners who took part in a 7 calendar day online course on the operation of a microwave oven. The learning subject was chosen after a survey revealed that while many people own and frequently operate a microwave oven most respondents did not understand how they heated food but were very interested in learning how they worked.

The course consisted of four modules. Each module delivered learning material in the form of static PDFs within the learning environment. Each module also contained a knowledge quiz that generated random questions relevant to that module from a data bank and students were encouraged, but not obliged, to score 100% before moving onto the next module. Both groups used the same learning material within the same learning environment and had the same time to complete the course. The only difference between the groups was the way they communicated and collaborated.

Upon first entering the learning environment, students were required to complete an "About You" questionnaire. In it participants provided details on their computer literacy and how often they use computers in their personal and working life. It also asked participants to discuss any issues they may have with using technology and how comfortable are they using technology for communication through text, voice and video. Participants were also asked to provide details of any previous online learning experience they may have had and to discuss their feelings on the experience.

Each participant was then required to take the pre-course test on the course subject matter. This was designed to give a baseline of their current level of subject. The
quantitative results of that test were compared to another test at the end of the course to measure new knowledge acquired during the course.

An introductory session with each group then followed where each participant was guided around the learning environment, the structure of the course, their communication tools and collaboration platforms. Participants were then allowed to begin with the first module, “Atoms, Elements and Molecules” and encouraged to score 100% on each module quiz before moving onto the next module. Throughout the learning period participants were encouraged to engage with each other using the tools at their disposal to share thoughts and ideas, and to ask and answer questions.

Upon concluding the fourth and final module participants were required to take a post course knowledge quiz. This quiz asked exactly the same questions as the pre-course quiz and was used to quantitatively measure each participant’s learning during the duration of the course.

Participants were also required to complete a post course questionnaire that aimed to collect a combination of qualitative and quantitative data on user experience, learning time and experience, likes, dislikes, recommended improvements, identification of learner type any issues (technical or otherwise) that they may have experienced.

**Section 3.5 Data Collection Tools**

As discussed above, a combination of qualitative and quantitative data collection tools were used during the study. The questionnaire is widely used in research and useful for collecting survey information without the presence of the researcher (Cohen, Manion, & Morrison, 2011). Questionnaires are an important tool in this study and are used to record each participant’s thoughts and feelings about their ability, preparedness, and confidence as well as more quantitative data like usability and experience ratings. Quizzes are used throughout the learning process within this study and are useful for measuring knowledge, diagnose strengths and weaknesses, and assess performance and abilities (Cohen, Manion, & Morrison,
Observation is a very useful research tool and was used throughout the learning period to provide ways to check for nonverbal expression of feelings, identify collaboration patterns, determine how participants communicate with each other, and measure time spent on various activities (Kawulich, 2006). During this study, participants were directly observed through their communication and collaboration activity within the discussion forum, during video and audio conferences, and indirectly through the learning environment logs. Interviews are a way of collecting data from individuals through conversations where the researcher or the interviewer often uses open questions and data is collected from the interviewee (Kajornboon, 2004).

3.5.1 Pre-course Questionnaire

All participants were required to complete a pre-course questionnaire to establish a baseline for each participant’s level of technical ability, online experience and any real or perceived issues. To ensure participants shared a similar technical ability they were asked to describe their level of computer literacy and rank it expert, proficient, intermediate, beginner or novice. They were also asked to state how often they use computers, and if they feature in their personal and/or working life to help get a more holistic view of their relationship with technology.

Communication and collaboration is a critical part of this study and the participants were asked to describe their level of comfort in using technology for communication. If they were familiar with video and audio conferencing using computers and if they were familiar with text-based communication like instant messaging, forums, and email.

It was important to understand each participant’s feelings on distance learning, and if they had any experience of learning online. To that end, they were asked if they had participated in an online course before and if so they were asked to state how many courses they had participated in and how long did they run for, were some or all of those courses mandatory, did they enjoy the experience, did they think the experience was worthwhile, did they think they may have learnt as much
or more when compared to a classroom based course and what did they like or dislike about the experience.

Finally to determine each participant’s technical ability to attend the course and contribute using their respective communication tools they were asked if they own or have unlimited access to a webcam, speakers/headphones, and have a good broadband service (capable of supporting video conferencing).

3.5.2 Pre-course Knowledge Quiz

All participants were required to take an online exam on the course content before they could access the course material. The quantitative data that this exam could provide would be used as the knowledge baseline for each student and would be used to determine how much each student learned during the course. This data also ensured that all participants had similar knowledge bases.

3.5.3 Observation

To understand how often students were interacting with the learning environment and each other the LMS access logs, collaboration platforms and social media sites were observed throughout the duration of the course. The LMS logs were automatically and continuously updated each time any part of the system was accessed. Activity on the asynchronous collaboration platforms was observed and recorded daily. Activity on the synchronous collaboration platforms were observed in real time which required the researcher taking part in any observed session. The social media sites were reviewed daily for any user activity.

3.5.4 Post-course Knowledge Quiz

All participants were required to take a knowledge quiz to determine how much learning had occurred when compared with the pre-course quiz. Both the pre-course and post-course quizzes were identical so a direct comparison would yield accurate quantitative data to assist that determination.
3.5.5 Post-course questionnaire

All participants were required to complete a post-course questionnaire. The learning material was a common feature between the two groups of students and it was important to understand how the material was received and if it improved or diminished the experience. To achieve this students were asked to rate their overall experience of the learning material in terms of usability, intuitiveness, colour scheme, layout, accessibility, legibility and design by the grades bad, poor, average, good or excellent.

Time spend reading the learning material could be useful data for triangulation purposes when validating other data like knowledge acquisition or learning experience, and students were asked to state how much time they spent reading each PDF.

Delivering learning material and providing collaboration platforms online have a significant dependency on technology and broadband infrastructure operating as expected. To gauge if there were any connectivity issues students were asked to discuss any technical difficulties they may have encountered at any time during the duration of the course.

We all learn in different ways and understanding how each student in the study learns most effectively would be extremely valuable qualitative data. Gardner identified seven distinct learning styles, or “multiple intelligences”, and each student was asked to identify and prioritise which styles they felt related to them (Gardner, Frames of Mind: The Theory of Multiple Intelligences, 1983). The options were:

- Visual (spatial): You prefer using pictures, images, and spatial understanding
- Aural (auditory-musical): You prefer using sound and music
- Verbal (linguistic): You prefer using words, both in speech and writing
- Physical (kinesthetic): You prefer using your body, hands and sense of touch
- Logical (mathematical): You prefer using logic, reasoning and systems
- Social (interpersonal): You prefer to learn in groups or with other people
- Solitary (intrapersonal): You prefer to work alone and use self-study

Optimum flow describes a period of focused learning that Psychologist Mihaly Csikszentmihalyi suggests can occur when learning environments enable learners to enjoy the process, are involved, have a feeling of control, and have a clear sense of self (Csikszentmihalyi, 1990). To determine if the learning environment in this study had the potential for fostering moments of optimal flow each student was asked to rate their learning experience using the categories enjoyment, sustained learning, learning pace, presentation and understanding by grades of bad, poor, average, good or excellent.

In the pre-course questionnaire participants were asked if they had any issues or anxieties with distance learning or communication and collaboration in an online environment. This was revisited in the post-course questionnaire and participants were asked if their thoughts about online learning had changed as a result of taking the course and to discuss in detail.

The final questions on the post-course questionnaire invited students to discuss any aspects of the experience that they liked and disliked, and any suggestions that they may have for improvements.

3.5.6 Post-course interview

Each participant was contacted after the course had concluded for a discussion about their experience. Most of these discussions were conducted in person with a small number via telephone and videoconferencing. The data collected during these interviews was used to gain a deeper insight into aspects of each student's experience.
learning experience, and for the triangulation of findings acquired by other data collection tools.

**Section 3.6 Triangulation, validation and reliability**

According to Cohen et al. (2011), triangulation is the use of two or more methods of data collection, contributing to data validity and reliability (Cohen, Manion, & Morrison, 2011). By using multiple forms of diverse evidence we can positively impact the validity and reliability of research data had we used a single form of evidence.

Triangulation can be used to compare both quantitative and qualitative research methods and is therefore a particularly useful technique for analysing data in case studies. This study yielded quantitative and qualitative data from quizzes, questionnaires, observations, interviews and system logs, and by triangulating this data we can have confidence in our findings (Cohen, Manion, & Morrison, 2011).

Validity and reliability are important concepts when considering data collection instruments. Reliability’s aim is to minimise errors and biases in a study by producing stable and consistent results, and it suggests that if another researcher were to repeat the studies procedures the same results would be obtained (Yin, 2003). Validity is how successful a test measure is at actually measuring what it is supposed to measure.

**Section 3.7 Limitations of the research**

All of the participants in the study work full time in the software industry and due to unavoidable work/life events some found it difficult to commit to temporally fixed interaction sessions. While this affected some of the larger multi-sensory collaboration sessions by reducing the possible number of participants, everyone in that group did get involved albeit in smaller groups.
The length of learning the learning period was seven calendar days but due to time constraints and unavoidable work/life events, some participants would have welcomed a longer learning period.

The number of participants was lower than originally anticipated and the researcher would have liked enough participants to create four groups, two multi-sensory and two mono-sensory. Having two groups of two would have provided addition comparative evidence, increasing confidence in data reliability and validity. The small number of participants means that this research is not generalizable to other groups.

The research tools and questions provided a simple rating of each participant’s experience, and it should be noted that this only gives an indication of whether the learning environment in this study had the potential for fostering moments of optimal flow and not definitive proof.

Measuring student engagement beyond their level of access and activity as recorded in the LMS logs, the collaboration platforms and social media platforms was inconclusive and could only provide an indication.
Chapter 4  Research Findings

The overall aim of this study is to determine if distance learning students who collaborated within a multi-sensory learning environment can achieve better learning outcomes than distance learning students who collaborated within a mono-sensory learning environment. The primary aim is to determine if there is a difference in effective learning between the two groups of students. The secondary aim is to compare the level of engagement and enjoyment experienced by students using each learning environment. There were a total of 14 participants involved in the research and were assigned to either the mono-sensory group (group A) or the multi-sensory group (Group B). Each group contained 7 students. This chapter will review the results and findings from the seven data collection tools used during this study.

The study aims to answer the following questions:

1. Does a multi-sensory learning environment facilitate more effective learning when compared with a mono-sensory learning environment?

2. Are students more engaged with the learning process and material within a multi-sensory learning environment when compared with a mono-sensory learning environment?

3. Does multi-sensory collaboration make a difference in effective learning when compared with mono-sensory collaboration?

Section 4.1  Data from collection tools

There were a total of seven data collection tools that captured a variety of data types. Data collected from each one will be examined in detail.
4.1.1 Participants Profile

4.1.1.1 Participant profile

Participants were selected from a pool of professionals who were employed by software development companies in various positions. Each participant was education to at least degree level and had an intermediate or above level of computer literacy. All participants used computer technology to communicate during their working day and they were very familiar with audio and video conferencing, email, instant messaging and discussion forms.

4.1.1.2 Pre-course questionnaire

The pre-course questionnaire focused on establishing a series of baselines for each user. First, levels of computer literacy were established. Both groups contained intermediate level users or higher, the ratios were:

- Group A - mono-sensory: 15% Expert, 85% Intermediate
- Group B – multi-sensory: 60% Expert, 40% Intermediate

All participants indicated that they used computers on a daily basis, that they were comfortable using technology for communication (email, video conferencing, instant messaging, etc.), and had access to the required equipment and infrastructure to fully participate in this study.

Previous experience of online learning was mirrored between groups with 60% of group A (Mono) and 40% of group B (multi) indicating that they have enrolled on a distance learning course in the past. Most of these courses were related to the workplace, organised by employers, and frequently mandatory which indicates that most participants did not make a choice to learn online. Those that had previous experienced said that they liked the convenience, flexibility and the control over their own learning pace.
On the other hand some respondents said that online learning required more discipline than a classroom based course and many disliked the delay in feedback, the lack of the personal touch and easy peer collaboration that they would have experienced in the classroom. Also, some respondents felt that online learning would only suit certain course types, specifically one that did not have theoretical or abstract subject matter.

One student was concerned that answers given are not totally correct which appeared to be result of an inability to question and validate answers in person as one would in a classroom. Some felt that too much time was spent working out systems and technology unlike a classroom where the student literally walks in and sits down to begin. This view was shared by a number of students and suggests that past experience of online learning may have been poorly designed and managed.

4.1.2 Pre-course knowledge quiz

The pre-course knowledge quiz gave a baseline for each student’s current knowledge on the subject matter of the course. This data was measured against data obtained from an identical quiz to be taken at the end of the course and would establish how much each student had learnt during the course and is discussed in detail below.

4.1.3 Observation

Throughout the learning period all visible student activity within the learning environment was observed. The kind of activity that was observed included forum discussions, video and audio conferencing that included the participation of the researcher, social media usage and learning environment logs.

There were some limitations to this data collection method since any communication and collaboration that occurred outside the learning environment and did not include the participation of the researcher (like email, instant
messaging, phone calls, video conferencing, etc.) were unobservable. However, these would be reviewed during the post course interview with each student.

4.1.3.1 Social media

There was very little interest is using the social media options provided for participants. While the course Facebook page received numerous visits it only received two “likes” and no direct contributions like comments or links. The Twitter account suffered a similar lack of interest from participants. Both options were available for the duration of the course and were advertised on the LMS homepage each time a participant logged in so lack of visibility and awareness could be ruled out as a course for lack of usage.

4.1.3.2 Forum discussions

There was no significant difference in the rate of activity between group A (mono-sensory) and group B (multi-sensory) within the forums. This is noteworthy because group B had, and used, a lot more options for communication and collaboration.

Some participants in group B used the forum as an extension to conversations that had already taken place in an earlier video conferencing session. In that case the temporal dependence of asynchronous forms of collaboration clearly benefited from the temporal independence of forums by allowing participants of the video conference to follow-up with questions and comments long after the video conference had concluded. The forum also allowed students who did not participate in the in the video conference to participate in, or at least observe, the conversation.

4.1.3.3 Video conferencing

This platform was limited to group B (multi-sensory) and while a direct comparison with group A was not possible there was a lot of evidence students were engaged and enthusiastic to communicate in real time. During off topic conversations many students heighted the ability to ask questions, get immediate
feedback and ask follow up questions as one factor that appealed to them and a good reason to make the time for a video conference. Some students also noted that they liked seeing each other for a variety of reasons, one student pointed out that he trusted answers to their questions more since they could see the person giving the answer, being able to observe the body language of their peers made this student more at ease with the information being imparted.

"Seeing [the tutor] during a Google Hangout video conference helped me better understand his answers to my questions about the materials. I think seeing him explain--rather than hearing him explain--helped me absorb the information better."

Another student was keen to point out that her experience within these video conference sessions differed greatly from her experience in the workplace where video conferencing is a common mode of communication between geographically distant offices. When questioned she suggested it may be down to her level of interest was higher with this new subject, that she felt comfortable knowing that everyone else on the call was in the same place and just as interested as her, and that she didn’t feel pressure to perform and be heard as she would in the workplace.

It was noted that off topic conversations were common and without steering video conferences could easily be diverted off the subject.

"I really enjoyed reading the material on my own, formulating my questions, then engaging with someone else to explore the answers. Even when our conversation went off-topic (yet still related to the material), that helped me relate the subject matter in my own way, thereby, increasing my enjoyment. And the fact that I can use the word "enjoyment" in this is a testament given I'm not at all into the sciences."

While on topic, students appeared to enjoy the ability to discuss with two or more peers especially as the technology (Google Hangouts) supported multiple participants and for the most part worked as expected. There were occasional
breaks in the connection but more often than not they were a result of bandwidth fluctuations are the software handled those issues gracefully, reconnecting when possible.

4.1.3.4 Audio conferencing

This mode of communication turned out to be less popular than video conferencing. Audio conferencing appeared to have similar positive effects on peer collaboration. It enabled group discussion and facilitated immediate feedback but the lack of visual presence did de-personalise the experience for some students, but only when compared to video conferencing. Once students tried video conferencing they all but abandoned audio conferencing, even though audio conferencing required less technology and was more likely to maintain a good connection throughout the entire conversation.

When questioned, students highlighted a number of significant benefits that audio conferencing has over video conferencing including the reduced demand for bandwidth if performed online, flexibility since you can audio conference on any telephone, and you need less equipment.

4.1.3.5 Learning environment logs

Every time a student accessed a page within the online learning environment it was logged with date, time, username, IP address, and details of the page and section accessed. This data gave a detailed view of each user’s access behaviour over time.

**Unique Page Visits**

The unique page visit log provided details of how often an individual student viewed a single page on the learning environment. This data gives an indication of the level of interaction with the content over time. The data received indicated that group B (multi-sensory) were more active and visited more pages more often than group A (mono-sensory). The number of page visits varied within each group but
on average there were over 121 pages visits per student in group B compared with a little over 82 per student in group A.

Table 3: Average unique page visits

<table>
<thead>
<tr>
<th></th>
<th>Multi</th>
<th>Mono</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique page visits</td>
<td>121.86</td>
<td>82.57</td>
</tr>
</tbody>
</table>

**Online access time**

Number of unique days students interacted with the learning environment was recorded and displayed below in Table 4: Online access time. It was noted that some students did not access the learning environment every day so for completeness the range of days between first and last access was also recorded and displayed below.
Table 4: Online access time

<table>
<thead>
<tr>
<th></th>
<th>Multi</th>
<th>Mono</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of days</td>
<td>3.00</td>
<td>2.71</td>
</tr>
<tr>
<td>Range of days</td>
<td>4.00</td>
<td>3.71</td>
</tr>
</tbody>
</table>

**Online access time**

Quiz attempts

Each of the four modules within the learning environment had a quiz attached to it for students to test their knowledge before moving onto the next module. Students were encouraged to not only take the quiz but also repeat the quiz if they failed to achieve 100%. The number of quiz attempts per student was recorded in the logs and is displayed in Table 5: Quiz attempts below.

The data indicates that students in group B (multi-sensory) consistently attempted the quiz more often than students in group A (mono-sensory) and there were two students in group A that failed to attempt any of the quizzes. The average attempt rate for group A was only 3.29 attempts, while group B achieved a slightly higher rate of 4.43 attempts.
Unique IP addresses

IP stands for Internet Protocol and an IP address is a set of four numbers separated by a single dot that unique to a single computer or networked device at any one moment in time. Each number in an IP address can have between one to three digits and can have a value ranging from 0 to 255.

An IP address can be either static or dynamic. Static IP addresses never change but dynamic IP addresses can change over time and the frequency of that change depends largely on the network that the device is connected to. Dynamic IP addresses are effectively borrowed from a pool of IP addresses that a network or service provider has reserved and these numbers often have similar numerical structures. Each time a computer connects to a new network it is given a new IP address.

The learning environment logs capture the users IP address with each and every page visit. If a user has a high number of unique IP addresses associated with their access record it could indicate high mobility or multiple device usage. The captured data is displayed on Table 6: Unique IP addresses per student where on average group B (multi-sensory) recorded more instances of unique IP addresses per user than group A (mono-sensory).
Table 6: Unique IP addresses per student

### Unique IP addresses per student

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>9</td>
<td>3</td>
<td>3.29</td>
</tr>
<tr>
<td>Mono</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2.57</td>
</tr>
</tbody>
</table>

4.1.4 Post-course knowledge quiz

The data collected from the post-course knowledge quiz was directly compared with the data collected from the pre-course knowledge quiz, and the difference between the two would indicate how much each student had learned during the course. Students were asked nine questions in each knowledge quiz. Their answers were graded in both and the difference between the two quizzes is displayed in Table 7: Learning.
Table 7: Learning

We can see that group B (multi-sensory) consistently performed better than group A (mono-sensory). This clearly demonstrates that group B learnt more than group A.

4.1.5 Post-course questionnaire

The post-course questionnaire focused on the learning environment and experience. First, students were asked to rate their overall experience of the learning environment using seven categories; Usability, Intuitiveness, Colour Scheme, Layout, Accessibility, Legibility, and Design. Each category offered a rating from 1 to 5 where 1 is bad and 5 is excellent. A summary of the results is displayed in Table 8: Learning
Table 8: Learning environment

Group B rated their multi-sensory learning environment higher in every category when compared with the mono-sensory learning environment that group A worked within.

Reading Time
Students were then asked how long they spent reading the learning material. Times varied within each group and on average the multisensory group spent 54.6 minutes reading the learning material, which is just over ten minutes longer than the mono-sensory group average of 44 minutes.

Technical Issues
Both group reported some minor technical difficulties that affected their learning experience. Some students in Group A had some initial difficulties navigating within the learning environment and there were some minor usability issues with the PDF’s when viewed within certain browsers and on very small screens. Group B reported no usability issues but some students did experience connectivity issues while video conferencing, specifically audio break ups and occasional disconnections. It is likely that issues were due to low bandwidth availability at the time and students indicated while annoying and they did interrupt the flow of conversation, the issues were temporary and infrequent.
Learning Style

Students were asked to identify their preferred mode or modes of learning and they were given the seven categories as defined by Gardner (Gardner, Frames of Mind: The Theory of Multiple Intelligences, 1983). 40% of students in the monosensory group A considered themselves primarily visual learners and another 30% put themselves in the verbal learning style category. Many students included additional styles and of those 60% included solitary as their second or third preference, and some of those students noted that online learning was particularly enjoyable to them because of that. Every student in the multi-sensory group B considered visual as their primary learning style, and 40% considered verbal as their secondary learning style.

Learning Experience

Students were asked to rate their experience using five categories; Enjoyment, Sustained Interest, Learning Pace, Presentation, and Understanding. Each category offered a rating from 1 to 5 where 1 is bad and 5 is excellent. The summaries results of their responses are displayed in Table 9: Learning experience.

Table 9: Learning experience

<table>
<thead>
<tr>
<th></th>
<th>Enjoyment</th>
<th>Sustained Interest</th>
<th>Learning Pace</th>
<th>Presentation</th>
<th>Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi</td>
<td>4.43</td>
<td>4.00</td>
<td>4.43</td>
<td>4.14</td>
<td>4.43</td>
</tr>
<tr>
<td>Mono</td>
<td>3.71</td>
<td>4.00</td>
<td>4.43</td>
<td>3.57</td>
<td>4.14</td>
</tr>
</tbody>
</table>
Enjoyment

Enjoying the learning process is one of Csikszentmihalyi’s key criteria for creating and sustaining moments of “optimum flow” (Csikszentmihalyi, 1990). The participants in this study indicate that they did enjoy the process very much but there was a sizable difference between the multi-sensory group B and the mono-sensory group A, with the multi-sensory group finding more enjoyment than the mono-sensory group.

Sustained Interest

Csikszentmihalyi recognised the importance of a dynamic balance between excessively difficult and excessive simple activities to sustain optimum flow and to measure this students were asked to rate their level of sustained interest throughout the course. The data revealed that there were no differences between students in either group.

Learning Pace

One of the benefits of online learning is that it facilitates a variety of learning paces, and this view was reinforced during this study when students indicated that they were highly satisfied with the learning pace they experienced during this course. Both groups’ ratings were identical.

Presentation

Both groups indicated that they were happy with the presentation of learning material and other aspects of the learning environment, with the multi-sensory group giving a slightly higher rating than the mono-sensory group.

Understanding

Knowledge represents facts whereas understanding represents the meaning of those facts. According to Wiggins and McTighe, “an understanding is a mental construct, an abstraction made by the human mind to make sense of many distinct pieces of knowledge” (Wiggins & McTighe, 2005). Both groups were asked to rate the level of understanding of the subject matter that they believe they achieved throughout the course. While both groups responded with very high
rating, the multi-sensory group rated their understanding higher than the mono-
sensory group.

**Thoughts on online learning**

In the pre-course questionnaire students were asked to consider any issues or
anxieties they may have had with online learning. In this post-course
questionnaire the students were asked to reflect on their experience and consider if
their views have changed as a result of taking the course. The results show that
40% of students in the mono-sensory group had a more positive view of online
learning. The figure for students in the multi-sensory group was a lot higher where
over 70% indicated that they now have a more positive view of learning online:

“Yes I would be much more open to online study after this
course as I found it very manageable.”

**Likes and Dislikes**

When asked what they like about the experience most students from both groups
highlighted the preciseness, engaging tone and clarity of the learning material
content, the use of images and module quizzes. In relation to quizzes, a number of
students noted that they really liked that they gave immediate feedback:

“I loved the quiz after each section so I could test out my
knowledge and it got me thinking”

Students in the multi-sensory group highlighted video discussions and quizzes as
elements they particularly enjoyed adding that served to aid knowledge retention
and understanding.

Students from both groups would like to have seen more graphics, diagrams and
real world stories to aid understanding of the occasionally complex learning
material. Some students from the mono-sensory group highlighted the lack of
human contact as a serious disadvantage:

“I am most definitely a visual learner and enjoy the human
interaction when learning and discussing. I missed the
"human" element of this medium but can certainly see the benefit of using this type of learning for people who are located in remote areas and cannot access a physical classroom”

Some students from the multisensory group disliked asynchronous collaboration tools, like the forums and email, due to the lack of feedback.

Suggestions
When asked what could be done to improve the learning material or environment there was a general consensus that more images, diagrams and animated graphics would help. Mono-sensory students wanted more and easier interaction channels:

“I would have liked to interact with the other students via video conference.”

Some multisensory students really liked the video conferencing experience and wanted more, particularly with their peers. Within the forums there was evidence of users sharing their anxiety of forgetting their high school science and mutual support, this provided a bonding platform for many users and encouraged a more open discussion and greater desire for video conferencing.

4.1.6 Post-course interviews

Once the course had concluded each student was contacted for a post-course interview. Most of these interviews were conducted in person Post-course interviews with a small number via telephone and videoconferencing. These interviews were generally informal conversations using a student’s questionnaire responses and quiz results as talking points. In most cases the interviewee confirmed and reiterated points made in the questionnaires. However, the analysis of the learning environment logs did raise some questions which were included in the interview talking points, they were:

- The number of time students took quizzes at the end of modules was lower than expected, why was that?
• For some students there were gaps of some days between accessing the learning environment, why was that?

• Some students may very little use of the collaboration tools made available to them, why was that?

• Students had a variety of page access counts and some had particular access patterns, was there any reason for this?

• The logs of unique IP’s suggested that some students were accessing the learning environments from different location and possibly different computers, was this actually the case?

• There was very little interest in using social media to communicate and collaborate, why was that?

Most students felt that one attempt was sufficient, even though some students did not answer all answers correctly. Some students did not realise that the questions in each quiz were picked at random from a pool of questions relevant to that module and therefore felt that once they had seen the questions once there was little point in repeating the quiz.

There was no real explanation for a gap between accessing the learning environment other than it was inconvenient on those particular days. Most students did access from a variety of locations, and usually on the same laptop computer. The most popular locations were home and office but some did access from cafes and friends’ homes. Students who made little use of the collaboration tools felt that they didn’t have much to contribute whenever they access those tools. Some felt that any questions they may have asked had already been asked and answered and others felt that they simply had no questions at that time.

For many students access to the learning environment was only possible when certain conditions were true:
I enjoyed the flexibility of the learning experience, being a busy mom and also working part time, I liked that I could study at my own pace and was not tied to a strict schedule.

Some felt they could not access during working hours, others could not access until late in the evening when they literally had a quiet moment. Some students accessed at random times whenever they both had some free time and could remember. Others had a favourite time of day, usually early in the morning or very late at night.

The social media tools used within this study, Facebook and Twitter, failed to attract participant interest in using them to communication and collaborate with their peers or tutor. Both of these social media sites require users to either create an account or link their existing account before students can access them. Students who did not have accounts for either of these sites did not want to create one just for this course. Students who did have social media accounts already considered them a personal space for their friends and family only, and did not consider their peers on this course part of that “personal” group.
Chapter 5 Discussion

This study compares the learning effectiveness of a mono-sensory learning environment versus a multi-sensory learning environment. This was achieved by creating two learning environments; one that supports synchronous communication and mono-sensory collaboration and one that supports asynchronous communication and multi-sensory collaboration, and measuring the effectiveness of learning between the two. This chapter discusses the findings and presents them in a sequential structure in relation to the research questions:

1. Does a multi-sensory learning environment facilitate more effective learning when compared with a mono-sensory learning environment?

2. Are students more engaged with the learning process and material within a multi-sensory learning environment when compared with a mono-sensory learning environment?

3. Does multi-sensory collaboration make a difference in effective learning when compared with mono-sensory collaboration?

Section 5.1 Learning effectiveness of learning environments

To answer the question of whether a multi-sensory learning environment can facilitate more effective learning than a mono-sensory learning environment a comparison of the learning environments and the participants was conducted which led to an analysis of effective learning by those participants within both environments.

5.1.1 Comparison of learning environments

Both environments were built using the same learning management software so from usability, look and feel perspectives they were similar. Both environments used the same learning material and it was delivered in the same way, and they both used the same module structure and modules quizzes. There are no discernible differences between the environments other than additional
asynchronous communication tools within the multisensory environment. These similarities were designed to level the playing field and allow for a fair comparison for all participants and equalise the effort of using the environments for all participants.

The mono-sensory learning environment contained communication and collaboration tools that would typically suit a low bandwidth distance learning scenario that offered almost exclusively asynchronous methods of communication. Low bandwidth distance learning, as Locatis et al (2006) point out, is less likely to be negatively impacted by network issues (Locatis, et al., 2006). In it students used text base tools like email, discussion forums and instant messaging to communicate with their peers and tutor. It is, as Bernard et al describe it, an ‘individually-based’ learning mode (Bernard, Abram, Lou, Borokhovski, Wade, & Wozney, 2004).

The multi-sensory learning environment utilised tools that would suit a higher bandwidth distance learning scenario and offered synchronous methods of communication in addition to the tools available to the mono-sensory environment. In this environment students used text based tools with the addition of synchronous tools like audio and video conferencing facilities (Bernard, Abram, Lou, Borokhovski, Wade, & Wozney, 2004).

5.1.2 Comparison of participants

Participants were selected with similar bases in education, ability and subject knowledge to ensure the groups were as similar as possible before the study commenced. Both groups showed no significant differences in how often they use computers and both were comfortable using technology to communicate online. However, there was dissimilarity between groups when it came to computer literacy. The mono-sensory group contained 15% expert users and 85% intermediate users, while the multi-sensory group contained 60% expert users and 40% intermediate users. This gave the multi-sensory group a potential advantage in so far as more members of that group had advanced computer skills and, as
Shneiderman (1998) points out, was less likely to require assistance or experience user related issues (Shneiderman, 1998).

On the other hand 60% the mono-sensory group have participated in an online course in the past, and when compared with 40% of the multi-sensory group having some previous online learning experience the mono-sensory group have the advantage of more experience. Some of these students felt that too much time was spent understanding how to use the software they were to work with this may have lowered expectations for this course, although it should be noted that this feeling was common in both groups. It is likely that those students who may have had negative previous experiences were using software that failed to observe good HCI principles, like the three USE words as defined by Dix (2004) where the software where should be Useful and be able to accomplish what it is designed to do, that it is Usable and perform its functions with ease, and that it is Used by being engaging, fun and encourage people want it to use it (Dix, 2004).

Looking at user experience, both groups indicated that they liked using the learning environment and found it easy to use, intuitive and well designed, but the multisensory group consistently rated their experience of the learning environment higher than the mono-sensory group. This could be partly due to some usability issues experienced by some mono-sensory students and partly a reflection on previous experience where the majority of multi-sensory students had no reference to compare.

Both groups contained participants with different learning styles which was consistent with the thinking of Gardner (1999) where he said no two people have exactly the same intelligences in the same combinations (Gardner, Intelligence reframed: multiple intelligences for the 21st century, 1999). Gardner’s view on learning style is supported by Felder (1996) who considered them a combination of characteristic strengths and preferences in the way they take in and process information (Felder, 1996). Gardner's theory acknowledges that learning is a holistic experience and both environments in this study were designed with that in mind and offered different opportunities and channels for learning.
40% of the mono-sensory group were primarily visual learners preferring pictures, images, and spatial understanding. 30% preferred the verbal learning style of using words, both in speech and writing. These students worked within a low-bandwidth learning environment with predominantly text based asynchronous communication tools, static text with supporting graphic learning material and interactive quizzes with immediate feedback capabilities. This environment may have been an advantage for the 30% of learners who preferred a verbal learning style but less so for the 40% of visual learners as there was little opportunity to exercise that mode of learning.

100% of the multi-sensory group were primarily visual learners with 40% considered verbal as their secondary learning style. These students worked within a high-bandwidth learning environment with a variety of text, voice and video based synchronous and asynchronous communication tools, static text with supporting graphic learning material and interactive quizzes with immediate feedback capabilities. Since this environment provides multiple learning channels it can be more inclusive of multiple learning styles. The entire group would have benefitted from the visual capabilities of this learning environment, and as with the mono-sensory group, the 40% with verbal as their secondary learning style would have benefitted the presentation of the learning material and verbal communication channels.

5.1.3 Effective Learning

To answer the question of whether the multi-sensory learning environment facilitated more effective learning when compared with the mono-sensory learning environment it would be prudent to measure this using both qualitative and quantitative data by analysing both the learning experience and the quiz results that measured learning.

5.1.3.1 Learning experience

Overall the multi-sensory group had a more positive view of the experience than the mono-sensory group. This view is backed up with empirical evidence from
student questionnaires, performance, engagement, and interviews. When asked to rate their learning experience both groups gave high ratings for all categories but the multi-sensory group have a higher rating to presentation, understanding and particularly enjoyment, a key criteria of Csikszentmihalyi’s “optimum flow” (Csikszentmihalyi, 1990). Both groups had similar high ratings for sustained interest and learning pace which demonstrates that both environments engaged and guided students but it also indicated that one environment was not more successful that the other in that regard. Student performance and levels of engagement within both groups were generally good, but data relating to the multi-sensory group from the questionnaires, performance, engagement, and interviews indicated that they recorded a consistently rating.

5.1.3.2 Measurement of learning

An analysis of quiz scores shown in Table 7: Learning clearly shows that the multisensory group learnt more. Table 10: Difference in learning, below, charts the percentage difference in learning that the multi-sensory group achieved over the mono-sensory group, clearly indicating significant knowledge gains by the multi-sensory group. Since the only significant difference between the two groups was their learning environment, specifically the method in which they communicated and collaborated, this increase in learning must be related to the environment in which the multi-sensory students worked within.
The evidence suggests that distance learning students who engage in a multi-sensory learning environment can experience more effective learning than students engaged in a mono-sensory learning environment. This aligns with thinking of Forrester & Jantzie (1998), that while computers offer real potential to replicate Csikszentmihalyi’s optimum moments of flow they noted that software alone cannot deliver human interaction, collaboration and other essential ingredients required for optimum flow as identified by Csikszentmihalyi (Forrester & Jantzie, 1998). But, as we have seen, software can provide an environment that enables the replication of those ingredients in a virtual sense. However, as Imbriale (2013) points out, that environment must include tutors and enable them to guide students to maintain their focus and ensure that learning materials are continually updated and evaluated ensuring the content is accurate and relevant (Imbriale, 2013).

These findings also align with the investigations into the use of audio to facilitate visual learning undertaken by Seitz, Kim and Shams (2006) where they found that multi-sensory audio-visual training resulted in significantly faster learning when compared to mono-sensory visual only training (Seitz, Kim, & Shams, 2006). These measurements must be viewed in terms of the limitations of the study.

Table 10: Difference in learning

<table>
<thead>
<tr>
<th>Difference %</th>
<th>56</th>
<th>24</th>
<th>1</th>
<th>20</th>
<th>9</th>
<th>16</th>
<th>36</th>
<th>47</th>
<th>44</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

Difference in learning: multi-sensory gains over mono-sensory
Section 5.2  Student engagement within learning environments

To answer the question of whether students are more engaged with the learning process and material in a multi-sensory distance learning environment or in a mono-sensory distance learning environment a range of data types, both qualitative and quantitative, had to be analysed. This approach is supported by Roth and Mehta (2002) who argued that the use of both interpretivist and positivist analyses may each help achieve each other’s goals (Roth & Mehta, 2002). The learning environment logs provided quantitative data on student access and usage over time. Discussion forum, collaboration platform and social media participation provide additional indicators of engagements as well as data collected during the post-course interviews.

5.2.1 Analysis of access logs

The online learning environment access logs provided a number of alternative views on student interaction with the various parts of the system. While this quantitative data alone did not accurately determine how engaged the student was, it did provide supporting evidence by giving a clear indication of how often each student visited the environment, which pages they accessed, the frequency and length of each visit, etc. Combining this quantitative data with qualitative data from other data collectors will, as Cohen et al (2011) tell us, result in more balanced and accurate research data (Cohen, Manion, & Morrison, 2011).

The course was available for seven calendar days. On average, students in the mono-sensory group accessed their learning environment for 2.7 days whereas students from the multi-sensory group accessed their learning environment for a slightly longer period of 3 days. This trend is mirrored in the average range of days accessed by each group, which is the number of days between the first login date to the last login date, where the mono-sensory group range was 3.7 days and the multi-sensory group ranged a slight longer period of 4 days.

This evidence suggests that student in the multi-sensory group spent longer within the learning environment and over a longer period of time. This theory is
supported by the actual page views where the mono-sensory group averaged 82 page views per student but the multi-sensory group averaged 47% more page views of 121 per student.

5.2.2 Analysis of questionnaires

The questionnaires revealed some data that is relevant to this question. When questioned about the time taken to read the learning material students in the mono-sensory group said that, on average, they spend 44 minutes. When asked the same question, students in the multi-sensory group spent on average 54 minutes reading the learning material, that’s 22% longer that the mono-sensory group. Considering the participants has similar bases in education it seems likely that the multi-sensory group spend more time reading the learning material because they found the content more interesting and choose to engage with it for longer.

This theory is supported by comments in the post-course questionnaire where the majority of multi-sensory students appeared to be excited about what they had learnt and demonstrated their understanding when asked what they liked about the course, typical comments were:

“I enjoyed learning so much about an appliance I use every day, and knew almost nothing about! I enjoyed taking the quiz at the end of each tutorial and how it cemented the learning for me.”

“I also really enjoyed the interesting facts - last night I put my hand on what I perceived as 'cold' metal and chuckled to myself as I thought about the heat being conducted away from my hand!!”

Mono-sensory students also indicated that they enjoyed the subject and learning material but appeared less enthusiastic and were less descriptive in their account than the multi-sensory students, typical responses to the question of what they liked about the course were:
“I enjoy learning detailed information about microwaves”

“Learning fully how a microwave oven works”

Spending more time reading learning material could indicate that these students were experiencing longer periods of focused learning or, as Csikszentmihalyi (1990) calls them, moments of “optimum flow” (Csikszentmihalyi, 1990). Through their dynamic and interactive learning environment the multi-sensory students would have a heightened sense of involvement and ownership which are important factors for moments of flow.

The course in this study contained four modules and at the end of each module the students were asked to attempt a quiz to test their knowledge on each module before moving onto the next. Each quiz contained random questions that were drawn from a pool relative to that modules content. Once the student submitted their answers they would receive immediate feedback and a grade for each of their answers. Giving the students clear and immediate feedback is another important factor for the creation and maintenance of Csikszentmihalyi’s moments of optimum flow. If there were any incorrect answers the student was encouraged to try again and only proceed to the next module when they achieved a 100% pass rate.

The number of quiz attempts was recorded in the learning environment logs and show that the, on average, each multi-sensory students attempted the quizzes 4.4 times. Considering there were 4 quizzes that number is not very high and suggests that the majority of these students attempted each quiz once. The mono-sensory students attempted fewer times, only 3.2 attempts on average per student. Also, some mono-sensory students did not attempt any quizzes at all. Although the multi-sensory group attempted more quizzes, the difference between the groups was too small to call it a significant measure of engagement.
5.2.3 Analysis of observation

Observation of the discussion forums and social media tools provided additional insights into student engagement levels. There were no significant differences in student activity within the discussion forums between either group which is interesting in so far as the multi-sensory group had additional communication and collaboration platforms to use yet their rate of engagement on the forums equally that mono-sensory group. This finding relates to Csikszentmihalyi’s notion of optimal flow because there is evidence that students, particularly within the multisensory group, enjoyed the process and were very involved which Csikszentmihalyi highlights as important factors for an ideal optimal learning environment (Csikszentmihalyi, 1990).

The social media tools used within this study, Facebook and Twitter, were not popular with students and few made any attempt to utilise them. Post-course interviews revealed that many students who already had social media accounts considered them a personal space for their friends and family only. Others who did not ordinarily use social media did not see any reason to change their opinion and refrained for creating an account for this course alone.

The evidence presented here suggests that students using a multi-sensory distance learning environment are more engaged with the learning process and material than students using a mono-sensory environment. This conclusion supports the argument that Shams and Seitz (2008) made that mono-sensory training processes could create an unnatural setting that may not utilise multi-sensory learning mechanisms that have evolved to produce optimal behaviour in the naturally multisensory environment (Shams & Seitz, 2008).

Khan (1997) said that distance learning is often associated with a lack of learner interaction but the capabilities that the internet provides make active learning in distance learning environments possible (Khan, 1997). This is largely dependent on distance learning systems that are well-designed to allow students interact with each other, with tutors, and online resources and it would appear from this study
that there is a correlation between multi-sensory communication and student engagement.

Section 5.3  Collaborative learning within learning environments

Collaboration is when members of a group actively communicate and interact with each other to establish a common focus to achieving a common goal (Kirschner, Paas, & Kirschner, 2009). In this study there were two group using two different collaboration environments:

- A mono-sensory environment that used predominantly asynchronous collaboration tools like email and discussion forums
- A multi-sensory environment that used predominantly synchronous collaboration tools like video conferencing, instant messaging and social media

Kirschner et al (2009) make the point that collaboration is more than just putting two or more individuals in the same physical or virtual space and assigning them the same task so just because the students in this study are communication it doesn’t necessarily mean that they are collaborating. Each group had the common goal of understanding the operation of a microwave oven by progressing through four modules and collaborating with their peers and tutor during each module.

To answer the question of whether multi-sensory collaboration can make a difference in effective learning when compared with mono-sensory collaboration a comparison of collaboration platforms and an analysis of effective learning had to be analysed.

5.3.1  Comparison of collaboration platforms

A collaboration platform is a set of tools within an environment that enables collaboration between individuals within a group with a common focus working towards a common goal (Havlíček, Šilerová, & Halbich, 2008). The methods of
collaboration differed between groups. The mono-sensory group utilised collaboration tools that used text based asynchronous methods of communication, like discussion forums, email and instant messaging, which are typically found within low bandwidth distance learning environments. The multi-sensory group utilised collaboration tools that used high bandwidth multi-channel methods of communication, like video or audio conferencing, which supported synchronous communication. The multi-sensory group also utilised the collaboration tools available to the mono-sensory group giving their platform a wider choice of tools.

5.3.1.1 Mono-sensory collaboration platforms

The collaboration platform used by the mono-sensory group was largely text based and included the following tools:

**Discussion forum:** This was the primary tool used for collaborative learning within this group and was fully integrated into the learning environment. Group members could start and contribute to threaded conversations at any time during the lifetime of the course. Many students found the forums beneficial and helped to maintain interest in the course:

"I talked with a few participants in the forum. Hard to say that those were real 'conversations.' But it was good to have a place to interact. I think it raised my interest in the topic because I got to know a little bit more about the others taking the course."

Mayer (2001) pointed out that messages communicated using both words and pictures can promote learning and understanding, and to utilise this the discussion forums supported multiple media formats allowing students to add images, sound and video to their contributions should they choose to do so (Mayer R. E., Multimedia learning, 2001).

Discussion forums are an asynchronous form of communication so once a student submitted a post they would have to wait for one of their peers or tutor to view and respond to it. Kay (2001) highlighted the risk of learners having at least negative control of their learning situation, where they can ‘turn off’ and not pay
attention (Kay, 2001). This may have been a factor in this study were the time taken for students to receive a response was one of the primary dislikes for this collaboration method, for example:

“I found it too one dimensional. I enjoy the lecture experience and the interaction between students. This was lacking in this environment, even with the forum and discussion options, it is not immediate enough for me to have waited several days for a response to a question that you might have after a tutorial.”

Despite the asynchronous nature of communicating via discussion forums, some students did point that there were benefits in having unlimited access to this tool and its temporal independence was welcomed by some members whose access was limited to random moments of availability to participate. This flexibility ensures that student needs rather than timetables determine how long each student can take to complete each learning module (Bork & Gunnarsdottir, 2001). Also, having the discussions recorded in written format limited misunderstandings and enabled all other group members access to every conversations thus enabling true group-wide collaboration.

There were, however, some students who wanted to simply learn the material and considered the forum an additional effort that held little value for them:

"I simply liked reading the materials and taking the quizzes. I was more interested in my own learning than in how others were doing. The forum was of no interest."

**Email:** This form of communication was conducted outside the learning environment and was therefore difficult to observe. Students did say that the majority of email communication between peers was on a one to one basis and only a small number of group emails were send to multiple recipients. Some students felt isolated and would have preferred to physically in the same pace as their peers:
"At first glance, learning about how microwaves work seemed easy. But I think because I haven't been exposed to chemistry in a while, it was more challenging than I thought it would be! Maybe I'm 'old school.' I wish I had been able to be with the other students. Emailing just wasn't enough to help me understand better. Inevitably, I felt it was just me and the materials."

Based on that feedback this communication method does not encourage group collaboration as it can limit the visibility of ideas and discussion points to the group.

Since this was an external mode of communication it not accessible through the learning environment and was therefore unsearchable and difficult to observe. However, students did access their email using already familiar software using their own email accounts and were likely to have access on multiple devices, including mobile devices. This flexibility of easy access to email on multiple devices is enhanced since email is inherently low band-width and therefore less likely to be negatively impacted by network issues (Locatis, et al., 2006).

5.3.1.2 Multi-sensory collaboration platforms

The collaboration platform used by the multi-sensory group was a combination of text, audio and video based and included the following tools:

**Video conferencing:** This was the most popular communication tool within the multi-sensory group. Google Hangouts was used to facilitate video conferencing during the study and apart from some minor setup issues and infrequent disconnections due to bandwidth limitations the conferences were successful. Students liked the immediate feedback that this form of real-time communication gave and many believed that it helped to establish and re-enforce relationships that would have been less likely to form through other communication methods. When asked to compare video conferencing with other forms of collaboration available to them most students commented on the fact that they felt they were more focused on speakers and were more engaged in the conversation. A view
supported by Abbot et al (2004) who found that video conferencing significantly improved communication skills (Abbott, Austin, Mulkeen, & Metcalfe, 2004).

Some students also pointed out that since video conferencing had a temporal dependence they found it difficult to schedule time and therefore did not participate as often as they would have like:

"I wish I had had more opportunities to video conference with the other participants. Scheduling mutually convenient times was simply too difficult given we all have jobs and responsibilities."

An important aspect of seeing and hearing a speaker at the same time is the non-verbal communication that is expressed in addition to the spoken communication. As Hostetter and Alibali (2011) point out facial expressions and hand gestures can reinforce and even carry part of the speakers meaning (Hostetter & Alibali, 2011). This noted by some students who commented on benefits of seeing and hearing their peers:

"Interacting with a few other students helped me feel less...inadequate. It was good to see other people's confusion about how microwaves work. I don't think just hearing them would have given me the same sense of community."

Discussion forum: Like the mono-sensory group, the multi-sensory group highlighted the benefits of having unlimited access to this tool and its temporal independence. In addition the benefits of having the discussions recorded in written format were raised. Students in the multi-sensory group tended to use the discussion forum as an extension of video conference conversations where follow up questions were posted or answers to questions that were not available during a video conference. However, not all students agreed that discussion forums were beneficial:

"I didn't find the forum that interesting. People tend to go off-topic in that kind of environment. It would have been better for me to interact more directly with the others. Like over the
Audio conferencing: Audio conferencing is often used to supplement distance learning (Shahmohammadi, 2012). However, in this study it was not a popular option as most students in the multi-sensory group preferred to collaborate via video conferencing. However, one student did point out that technical issues related to video conferencing that she experience made audio conferencing appear like a very attractive alternative:

"Not everyone is technologically savvy when it comes to video conferencing. One could spend a good chunk of time just trying to connect. In those moments, a simple telephone conference would have been more efficient.”

Instant messaging: Instant messaging is one of many tools that effectively bridge what Moore (1992) called the “transactional distance” between distance learning students and their tutors (Moore D. S., 1992). The instant messaging capability of Google Hangouts facilitated for this mode of communication was generally used as a supplementary mode of communication during video conferences. Students who used this method generally did so for one to one messaging during conversations to check understanding or for reassurance that they were in the same place, essentially is was the digital version of whispering to your classmate during a lecture. Instant messaging was also used to continue communication when the video connection failed enabling a continuation of asynchronous communication until the video connection was restored.

Email: As with the mono-sensory group, this mode of communication was conducted outside the learning environment and was therefore difficult to observe. Some students who used email to communicate did so only because they had difficulty with the temporal dependence of asynchronous modes of communication:
"Emailing is kind of impersonal. I would rather have talked to others more, there just wasn't time. I think I would have learned more that way."

Other students welcomed the option to use email as an alternative when they could not use other modes:

"I'm really busy, so taking this course was a bit challenging. But being able to e-mail was great because I could do it on my own schedule. I think doing anything more would have hindered me from finishing the course because I'd have to rely on other peoples' schedules."

**Social Media:** Facebook and Twitter were two social media applications utilised during this research however use of social media as a communication and collaboration platform failed to gain traction. Of those participants who considered using social media viewed it as a personal space and they were concerned about inadvertently sharing personal information with their peers on this course. This uncertainty about information control was a barrier, and the other options for collaboration and communication within the learning environment were considered adequate for their needs. Selwyn (2012) recognised the potential of social media applications for collaboration but conceded that they are most often use for the one-way passive consumption of content (Selwyn, 2012).

As concluded earlier, evidence from this study suggests that distance learning students who engage in a multi-sensory learning environment can experience more effective learning than students engaged in a mono-sensory learning environment. But this doesn’t answer the question of whether multi-sensory collaboration has contributed to that increase in effective learning when compared with mono-sensory collaboration.

Based on observation and student feedback multi-sensory collaboration was more effective at engaging students in collaborative activities and maintaining their interest in the subject than mono-sensory collaboration. Eastmond & Ziegahn (1995) agree that collaboration is an important factor in a good learning
experience and this study has shown that multi-sensory collaboration enhanced that collaboration experience for students (Eastmond & Ziegahn, 1995).

The primary mode of multisensory collaboration in this study was video conferencing and, as Martin (2005) argues it could not only bridge the transactional distance, it could also enrich the distance learning process and the findings of this study support that argument (Martin, 2005).

Section 5.4 Conclusion

This study compares the learning effectiveness of a mono-sensory learning environment versus a multi-sensory learning environment and asked the following questions:

1. Does a multi-sensory learning environment facilitate more effective learning when compared with a mono-sensory learning environment?

2. Are students more engaged with the learning process and material within a multi-sensory learning environment when compared with a mono-sensory learning environment?

3. Does multi-sensory collaboration make a difference in effective learning when compared with mono-sensory collaboration?

The analysis of findings combined with supporting evidence for the literature review indicates that a multi-sensory environment can facilitate more effective learning and result in increased student engagement with the learning process and learning material when compared to a mono-sensory environment. This study concludes that multi-sensory collaboration can result in more effective learning when compared to a mono-sensory collaboration. This conclusion aligns with conclusions arrived at by Seitz, Kim and Shams (2006) where they found that multi-sensory audio-visual training resulted in significantly faster learning when compared to mono-sensory visual only training (Seitz, Kim, & Shams, 2006). This view is further supported by Kirschner et al (2009) who argue that
collaboration improves the learning experience (Kirschner, Paas, & Kirschner, 2009). Forrester & Jantzie (1998) shared this view when they recognised that Csikszentmihalyi’s optimum moments of flow had the potential to be replicated using technology they reminded us that software alone cannot deliver the collaborative activity required for optimum flow (Forrester & Jantzie, 1998). The human element is also highlighted by Imbriale (2013) who points out that an online learning environment must include tutors to guide students (Imbriale, 2013).

The heightened levels of engagement experienced by students using a multi-sensory distance learning environment supports Shams and Seitz (2008) who argued that the naturally multisensory environment that we all live in has shaped how we learn and an online multi-sensory learning environment is better equipped to utilise the multi-sensory learning mechanisms that have (Shams & Seitz, 2008). Engaging students in collaborative activities and maintaining their interest was best achieved through multi-sensory collaboration which support the view that Eastmond & Ziegahn (1995) had that collaboration is recommended for a good learning experience (Eastmond & Ziegahn, 1995).
Chapter 6  Conclusions and Recommendations

Section 6.1  Introduction

The research findings highlighted a number of factors that indicated positive support for the research questions. It emerged that students working within the multi-sensory learning environment appeared to have a more positive learning experience than mono-sensory students. Multi-sensory students performed much better than their mono-sensory counterparts in the post-course knowledge quiz indicating that they had learnt more during the course. Furthermore, the multisensory students appeared to be more engaged with the learning process and material, which research literature indicate that this may be a result of working in a more natural “multi-sensory” environment. The research findings also indicated that those students who engaged in multi-sensory collaboration had a better learning experience and achieved better learning outcomes than those who collaborated in a mono-sensory environment.

The research and data from the findings indicates that distance learning students are more involved, more active and more engaged when learning within a multi-sensory environment. Furthermore, students who were learning within a mono-sensory environment specifically recommended that the tools that were available to the multi-sensory group be available to all students. The conclusions that can be drawn from the literature review, the research process and the data analysis are that multi-sensory learning environments are more conducive for effective learning that mono-sensory learning environments.

Section 6.2  Learning environments

Students working within the multi-sensory environment exhibited slightly elevated senses of enthusiasm and enjoyment when compared with other students. They consistently scored higher on the quizzes indicating that they had learnt more from the learning material partly as a consequence of utilising multi-sensory learning technology. However, credit for this cannot be attributed to the environment alone. The participation of peers and tutors within the learning
environment is crucial, and the fact that it is that the learning environment that enables higher levels of participation that makes the difference. It must be noted that this conclusion that a multi-sensory learning environment does facilitate more effective learning can only be realised when certain requirements are met, namely sufficient bandwidth to enable synchronous collaboration tools to operate effectively, the use and availability of the correct technology and a degree temporal dependence between those involved in the learning experience.

While student engagement was difficult to ascertain there was clear evidence of a genuine excitement and noticeably prolonged engagement with students who interacted within a multi-sensory environment, particularly during video conferences where multi-sensory experiences were maximised. Improved student engagement is largely dependent on how well the distance learning environment designed. It must facilitate student interaction with each other, with tutors, and online resources. Considering that we are multi-sensory beings that ordinarily function in a multi-sensory world it is reasonable to assume that a mono-sensory environment creates an unnatural setting for learning. This notion supports the conclusion that there is a correlation between multi-sensory communication and student engagement.

Determining if multi-sensory collaboration made a positive difference in effective learning when compared to mono-sensory collaboration was difficult to measure. Evidence from participant interviews and continuous observation indicated that collaboration and retention appeared to be enhanced within the multi-sensory environment when compared to the mono-sensory environment. This conclusion is supported by literature research on collaboration that agree it is an important factor in a good learning experience, and this study has shown that multi-sensory collaboration can enhance the collaboration experience for students.

Section 6.3 Recommendations

Recent increases in the interest and availability of online learning played a major part in the rationale for this research. Classroom learning brings inherent benefits that are difficult to replicate online, one of which is effective collaboration. This
research highlighted the importance of student collaboration for effective learning and aimed to explore online environments that fostered better collaboration. The following recommendations would, in the author’s opinion, contribute the operation of multi-sensory learning environments:

- Multisensory collaboration was a key research point in this research and the learning benefits of multisensory collaboration would improve the overall learning experience and increase effective learning for students. By integrating a multisensory collaboration platform into existing or new online learning environments students would benefit in terms of more effective learning, more control over their learning environment, reduced isolation and improved relationship and trust building with their peers and tutors.

- An effective multi-sensory learning environment requires the provision of the right network infrastructure and technology for it to operate at optimal efficiency.

- Online multi-sensory learning requires significant bandwidth to operate effectively and this is not always achievable even in the most modern first world environments. A bandwidth management system would be recommended to enable continuity of communication and collaboration if the bandwidth narrows enough to disconnect participants from a collaborative learning session.

- By its very nature, a real-time collaborative event is temporally dependant and all participants should have advanced notification and should have visibility into the availability of other participants.

- The use of social media should be an integral part of any online learning environment and efforts should be made to ensure students can safely interact using social media.
Section 6.4 Recommendation for future research

Technology in education is a fact and the continuous increase in distance learning offers more choice and more flexibility for people who would otherwise have struggled to participate in educational programs. The following recommendations look beyond immediate needs and focus on what this research can offer future learners and designers of multi-sensory learning environments:

- The replacement of or significant improvements to the configuration of the learning management system (LMS) that would enable the system to support all of the components that is required for the learning environment. This would simplify navigation and usability for participants and greatly enhance direct and indirect observation.

- The time allowed for the course should be extended to enable a wider range of participants to fully engage with the learning environment and their peers. Some participants in this research study found it difficult to find a reasonable amount of “quite” time to focus on the demands of the learning environment.

- Provide addition multimedia elements (e.g. video & audio podcasts, canned demos, interactive diagrams) to enhance the learning experience. Many participants from both groups expressed an interest in having access to video or audio podcasts of learning material that they could download onto a mobile device for viewing at a more convenient time.

- Mobile devices are becoming more and more powerful. A modern smartphone has as much computing power, more storage and a better display than a typical laptop computer had 10 years ago at a fraction of the size. Further research could investigate expanding the platform range of this research to include mobile devices and investigate the effectiveness of participants partially or entirely interacting with the learning environment from a mobile device.
• Delivering distance learning to remote and/or disadvantaged communities, particularly in developing countries, is often faced with obstacles created by the digital divide. Issues like the availability of bandwidth, basic technology, training or even a reliable electricity supply would be not uncommon. Further research could investigate the feasibility of creating multi-sensory learning environments in low bandwidth, poorly resourced environments. The use of mobile devices should be part of such a study since they are smaller, cheaper, more readily available and more likely to have a data connection since they are likely to have both cellular network and Wi-Fi connectivity.

• Social media applications are powerful communication tools that are growing in popularity across all sections of society and age groups from the classroom to the boardroom. Social media is seen by many as bridging the digital divide between generations of computer users. These tools are flexible, support multiple communication modes (text, voice, and video) and are for the most part free. Further research should utilise social media to supplement a range of communication and collaboration needs.

This study did have significant limitations and the research is not generalizable to other groups due to the small number of participants. However, the benefits of multisensory online environments in education go beyond the virtual classroom and can help to prepare students for the careers in the ever changing digital workplace. With so many companies going global, being able to pick up on social cues in the workplace is critical to building community, working with empathy, and building trust. Non-verbal cues are not just for communication but for learning too and corporations could gain from this and further research. Much can be lost in translation when just emailing, and the result can be damaging misunderstandings between people speaking different languages. But a smile is a smile in any language and can help to strengthen relationships. Companies already have the tools for instant video conferencing but many still don't do it. A change in behaviour is necessary, some convincing is needed and this research could help do that.
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Appendices

Appendix A: Pre-course Questionnaire

**Participant Questionnaire: About You**

1. What is your name?

2. Describe your level of computer literacy. For example, would you consider yourself an expert, proficient, intermediate, beginner or a novice user?

3. How often do you use computers, and do they feature in your personal and/or working life?

4. Are you comfortable using technology for communication?

   Are you familiar with video and audio conferencing using your computer?

   Do you use instant messaging, forums, email, and other text-based modes of electronic communication?
Participant Questionnaire: About You

*5. Have you ever participated in an online course before?

If so:
- How many courses have you participated in and how long did they run for?
- Were some or all of these courses mandatory?
- Did you enjoy the experience?
- Did you think it was worthwhile, did you learn as much or more when compared to a classroom based course?
- What did you like or dislike about the experience?

*6. Do you have a webcam, speakers/headphones, and a good broadband service (capable of supporting video conferencing?)
Appendix B: Pre-course Quiz

Participant Questionnaire: Current Subject Knowledge

Closed book test!!

Please complete this short quiz in one sitting without referring to any online or print references. It is important that we have a subject knowledge level for each participant so that we can accurately measure new knowledge and understanding gained by you during the course.

Please answer every question asked and if you do not know the answer to any question (or all questions) please simply state "Do not know" in the appropriate answer box. Your responses are totally confidential, it is not graded and the results are not retained, they will only be used to measure learning.

Success of this research project hinges on your participation, and your accurate and honest responses to questionnaires and tests, and I sincerely thank you for taking valuable time out to participate.

* 1. What is your Name?

* 2. Describe your understanding of an atom, a molecule and an element.

Do you think there is any relationship between these them? If so, what is it?

Generally speaking, which is bigger: an atom or a molecule?

* 3. What is your understanding of heat and temperature?

Can you list different ways heat is transferred?

Figure 4: Pre-course quiz page 1
Participant Questionnaire: Current Subject Knowledge

4. What is your understanding of Radio Waves?

What do you think Microwaves are?

Do you know what the electromagnetic spectrum is?

5. Write as much as you know about "H2O".

6. List as many different types of heat as you can.

7. What is a wavelength?

8. How does a microwave oven heat food?
Participant Questionnaire: Current Subject Knowledge

9. What are the main components of a microwave oven?

10. What does a magnetron do?
Appendix C: Post-course Questionnaire

Figure 7: Post-course questionnaire page 1
5. There are 7 main learner type categories;
- Visual (spatial): You prefer using pictures, images, and spatial understanding.
- Aural (auditory-musical): You prefer using sound and music.
- Verbal (linguistic): You prefer using words, both in speech and writing.
- Physical (kinesthetic): You prefer using your body, hands and sense of touch.
- Logical (mathematical): You prefer using logic, reasoning and systems.
- Social (interpersonal): You prefer to learn in groups or with other people.
- Solitary (intrapersonal): You prefer to work alone and use self-study.

What type of learner are you? If you feel that you identify with more than one learning style please include and prioritise all styles that are relevant to you.

Overall reaction to the learning material

These questions are aimed at your overall reaction to the tutorial sheets only.

6. How would you rate your learning experience?

Enjoyment
- Poor
- Fair
- Average
- Good
- Excellent

Sustained Interest
- Poor
- Fair
- Average
- Good
- Excellent

Learning Pace
- Slow
- Average
- Fast

Presentation
- Poor
- Fair
- Average
- Good

Understanding
- Poor
- Fair
- Average
- Good

7. Have your thoughts about online learning changed since you started this course? If you had any anxiety, doubts or dislikes about distance learning before starting this course do you feel more or less comfortable using this method of learning, or are your feelings unchanged.
8. What did you enjoy most about this course?

9. What did you enjoy least about this course?

10. Is there anything you could suggest that would improve this course?
Appendix D: Post-course Quiz

Participant Questionnaire: Post-course Subject Knowledge

Closed book test!!

Now that you have completed the course we would like to accurately measure new knowledge and understanding gained by you during the course. Please complete this short quiz in one sitting without referring to any online or print references.

Success of this research project hinges on your participation, and your accurate and honest responses to questionnaires and tests, and I sincerely thank you for taking valuable time out to participate.

*1. What is your Name?

*2. Describe your understanding of an atom, a molecule and an element.

Do you think there is any relationship between these them? If so, what is it?

Generally speaking, which is bigger: an atom or a molecule?

*3. What is your understanding of heat and temperature?

Can you list different ways heat is transferred?

*4. What is your understanding of Radio Waves?

What do you think Microwaves are?

Do you know what the electromagnetic spectrum is?
Participant Questionnaire: Post-course Subject Knowledge

*5. Write as much as you know about "H2O".

*6. List as many different types of heat as you can.

*7. What is a wavelength?

*8. How does a microwave oven heat food?

*9. What are the main components of a microwave oven?

*10. What does a magnetron do?
Appendix E: Online Learning Environment Screenshots

Figure 12: Online learning environment (learningglue.com) homepage

Figure 13: Course homepage
Figure 14: Course structure and contents
Appendix F: Module 1 Learning Material

How Microwave Ovens Work

Tutorial 1: Atoms, Elements & Molecules
To begin our journey of understanding how a microwave oven heats food let’s start at the very beginning and discuss the atoms and molecules that make up our food.

Atoms
Atoms are collections of tiny particles called protons, neutrons, and electrons. Protons and neutrons join together to form the nucleus, this is the central part of the atom. Electrons orbit the nucleus in much the same way the planets orbit the sun. Each of these three particles has different electrical properties:

- Protons carry a positive charge
- Neutrons carry no charge
- Electrons carry a negative charge.

Atoms are so small you can’t see them with the naked eye and they only become visible using a powerful microscope like an electron microscope or scanning tunneling microscope (STM). To give you an indication of how small an atom is, imagine you made a tiny dot on a piece of paper with the tip of a sharp pencil, and if the pencil lead was made entirely of carbon atoms, that little dot would have about four billion billion carbon atoms in it. Needless to say, atoms are really really small!

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Figure 15: Module 1 learning material page 1
Elements

The number of particles within atoms varies. Some atoms have more protons, neutrons, and electrons, and some have fewer, and these differences change the way an atom behaves. There are over a hundred different types of atom, and these are called elements. Each element has a unique name like carbon, oxygen and hydrogen. Gold is an element too, and a piece of pure gold contains only gold atoms, nothing else. The same goes for all other elements in their purest form.

The more protons, neutrons, and electrons an atom has, the more mass it has, and the heavier it will be in Earth’s gravity. Hydrogen and helium are very light, and people use them to inflate balloons. Gold, which has 79 protons, is very heavy, and lead, which has 82 protons, is even heavier, so people use lead to make weights. The heaviest atom that occurs naturally is uranium.

Chemical reactions join or split atoms to rearrange them. But they cannot change one element into another element, or anything simpler. A chemical reaction cannot turn lead into gold, because it can’t change the atoms into different elements.

Because protons have a positive electrical charge, the protons tend to push away from each other. This would make atoms fall apart, except that another force, the strong nuclear force, pulls them back together. It’s this balance of forces that makes atoms possible, and since everything is made out of atoms, that’s what makes everything possible.

So, we have seen that an element is made of one type of atom, like carbon, oxygen and hydrogen. Now let’s look at three ways that atoms can exist.

Single Atoms

Some elements are made up of atoms that do not join up with other atoms. Although there may be many millions of atoms that make up this type of element, that all remain as single atoms.

A good example of an element that is made up of single atoms is Helium. Helium is known as an unreactive gas because it cannot combine with, or react with, other atoms. Helium atoms do not join up with each other or any other element.

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Figure 16: Module 1 learning material page 2
Simple Molecules

When atoms of the same element join together we get a molecule of that element. Oxygen is like this. Two oxygen atoms join together to make an oxygen molecule. Most of the oxygen in the air is in this form. Hydrogen and chlorine also have molecules with two atoms.

The number of atoms within a molecule depends on the element. Some elements have molecules with more than two atoms. Sulfur atoms can make molecules of eight atoms joined together.

Interesting Info

All molecules need some way to hold their atoms together. The two main ways that atoms hold together are:

- covalent bonding (a stronger kind, like in carbon dioxide and water)
- ionic bonding (a weaker kind, like in most rocks)

Compound Molecules

Earlier we saw that a molecule is made when atoms of the same element join together. A compound is a type of molecule that is made when atoms of different elements join together by chemical bonds. This means that compounds will always exist as molecules, not separate atoms. A good example of a compound molecule is a water molecule. This is created when two Hydrogen atoms combine with one Oxygen atom.

Interesting Info

Today people can make new kinds of molecules in laboratories and factories. Some of the biggest molecules that people make are plastics, like what plastic garbage bags or plastic Legos are made of. Plastics are also hydro-carbon molecules. People also make new molecules for medicines.
Symbols
Each element has been assigned a symbol, like O for oxygen or H for Hydrogen. The use of symbols makes it easier to write out complex compound compositions and if there are more atoms of one type we use numbers after the relevant symbol to indicate how many of that particular atom is present.

Take a water molecule for example, this is created when two Hydrogen atoms combine with a single Oxygen atom. Let’s write that out in plain English:

\[
\text{Water = Two Hydrogen Atoms plus One Oxygen atom}
\]

But using the atomic symbols H for Hydrogen and O for Oxygen, and using numbers to denote how many of each atom is present, we can simplify that statement to:

\[
\text{Water = H}_2\text{O}
\]

H$_2$ tells us that there are two Hydrogen atoms, if there was only one hydrogen atom we wouldn’t need to include the number 1 after the H symbol, we only need to use numbers if two or more atoms are present. This is the case with the symbol O where there is no number present telling us that there is only one Oxygen atom in this molecule.

Interesting Info
We believe the first molecules formed about 300,000 years after the Big Bang, or just under 1.5 billion years ago. They were the smallest kind of molecule - two hydrogen atoms joined together. As time went on, and supernovas from exploding stars shot out different kinds of atoms, different kinds of molecules formed and floated around in space. Because most of the atoms in space were hydrogen atoms, many of these molecules combined hydrogen with another kind of atom. So hydrogen combined with oxygen to make water molecules. Hydrogen combined with carbon to make hydrocarbons (what living things are built out of). Even before there were any planets, water and hydrocarbons were floating around in space on their own. Other molecules were made of heavier atoms, like silicon or gold. Still out in space, some hydrocarbons got together and formed bigger molecules called amino acids.
Periodic Table of Elements

There are a lot of different types of elements. Some are gases, some solids, and others are liquids. Each element has unique properties, each with their own number of Protons, Neutrons and Electrons. The Period Table of Elements was devised to arrange the elements to make it easier to read and understand where each element fits.

Here are the basic rules for reading this table:

- The horizontal rows are called periods.
- The vertical columns are called groups.
- Elements in the same group are similar to each other.
- The metals are on the left and the non-metals are on the right.
- One non-metal, hydrogen, is often put in the middle.

The main groups are numbered from 1 to 7 going from left to right, and the last group on the right is group 0. The zigzag line in this diagram separates the metals, on the left, from non-metals, on the right. Hydrogen is a non-metal but it is often put in the middle. If you look carefully you’ll notice that most elements are metals, rather than non-metals.
Symbols are used to represent each element (remember H for Hydrogen and O for Oxygen?) and each element has its own unique symbol.

Remember that elements are made from only one type of atom and you will only find elements in the periodic table. You will never find compounds like water which is made of compounds (H₂O).

**Summary:**
- Atoms are tiny building blocks that everything in the universe is made of; they consist of Protons and Neutrons, that are contained in a Nucleus, which is surrounded by bands of orbiting electrons, just like planets orbiting the sun. There are over a hundred different types of atom, each with different ratios of Protons, Neutrons and Electrons.
- Elements are made of large quantities of a single type of atom, so there are over a hundred types of elements just like there are over a hundred types of atoms. Hydrogen, Oxygen, Gold and Lead are all types of element.
- Molecules are formed when atoms combine. Simple molecules are formed when atoms of the same type combine. Compound molecules are formed when atoms of different types combine.
- Each Element has a unique symbol made up of a letter or letters (O for Oxygen for example), and these are organized in the Periodic Table of Elements.

**What’s Next:**
In this tutorial we talked about the atoms and molecules that make up matter. In the next tutorial we will discuss a form of energy called heat or thermal energy.
Appendix G: Module 2 Learning Material

How Microwave Ovens Work

Tutorial 2: Heat

The universe is made up of matter and energy. In the previous tutorial we discussed the atoms and molecules that make up matter. In this tutorial we will discuss a form of energy called heat or thermal energy.

Atoms, Molecules and Heat

In general, energy causes atoms and molecules remain in a state of perpetual motion - either by bumping into each other or by vibrating back and forth. This motion of atoms and molecules creates heat, or thermal energy, which is present in all matter.

Types of Energy

There are many forms of energy in the universe, for example light, electrical, mechanical, chemical, nuclear, sound and thermal energy itself. Energy can change from one form to another and there are many different types of energy can be converted into heat energy. This happens when the energy causes a substance to heat up by increasing the speed of its molecules. So, put energy into a system and it heats up, take energy away and it cools. For example, if you are cold, you can rub our hands together to get warmer.

Let’s look at how a few different types of energy can be converted into thermal energy, or heat energy.

- **Mechanical energy** is converted into thermal energy whenever you bounce a ball. Each time the ball hits the ground, some of the energy of the ball’s motion is converted into heating up the ball, causing it to slow down at each bounce.

- **Thermal energy** can be transferred to other objects causing them to heat up. When you heat up a pan of water, the heat from the stove causes the molecules in the pan to vibrate faster causing the pan to heat up. The heat from the pan causes water molecules to move faster and heat up. So, when you heat something up, you are just making its molecules move faster.
• **Electrical energy** is converted into thermal energy when you pass electric current through an electrical element often found in heating pads, electrical cookers, toasters, hair dryers, or light bulbs.

• **Chemical energy** from some of the food we eat is converted into thermal energy to heat our bodies.

• **Light** from the sun is converted to heat as the sun’s rays warm the earth’s surface.

• **Energy from friction** creates heat. For example when you rub your hands or use the brakes on your car, friction generates heat.

**Heat Transfer**

So, we understand that there are different forms of energy that can be converted into thermal energy or heat. Now let’s consider how heat moves from one place to another. There are three main ways heat can be transferred from place to place: Conduction, Convection and Radiation:

• **Conduction** is where heat is transferred from one material to another without the material itself moving. Heat energy is transferred and distributed from atom to atom within a substance. For example, a spoon in a cup of hot soup becomes warmer because the heat from the soup is conducted along the spoon. Conduction is most effective in solids—but it can happen in fluids. Fun fact: Have you ever noticed that metals tend to feel cold? Believe it or not, they are not colder! They only feel colder because they conduct heat away from your hand. You perceive the heat that is leaving your hand as cold.

  **Interesting Info**

  Have you ever noticed that metals tend to feel cold? In fact it is unlikely that they are actually colder but they only feel colder because they conduct heat away from your hand. You perceive the heat that is leaving your hand as cold.

• **Convection** is where the transfer of heat occurs by the actual movement of the warmed matter. Generally convection is the transfer of heat energy in a gas or liquid by movement of currents, but it can also happen in some solids, like sand. For example, some heat will leave a hot cup of coffee as the currents of steam and air rise.
Interesting Info

*Convection* is part of the reason that wind makes you cold—heat flows away from your body more rapidly in a wind. You don’t “get” cold from the wind, you just lose heat.

- **Radiation** is where heat is transferred through electromagnetic radiation that is emitted from a hot object. A good example is sunlight that is a form of radiation that is radiated through space to our planet without the aid of fluids or solids. That energy travels through a vacuum to reach Earth, there are no atoms or molecules to assist the transfer of energy from the sun, some 93 million miles away, so convection and conduction play no part in the transfer, it is all down to radiation.

**Summary:**

- **Heat is a form of energy.** There are many types of energy, for example light, electrical, mechanical, chemical, nuclear, and sound. Many of these can be converted into heat energy by increasing the speed of molecules within a substance.
- **The motion of atoms and molecules creates heat,** or thermal energy, which is present in all matter.
- **Heat can be transferred through:**
  - **Conduction,** where heat is transferred from one material to another without the material itself moving.
  - **Convection,** where the transfer of heat occurs by the actual movement of the warmed matter.
  - **Radiation,** where heat is transferred through electromagnetic radiation that is emitted from a hot object.

**What's Next:**

In this tutorial we talked about heat. In the next tutorial we will discuss microwaves and how they can be used to generate heat within our food.
Appendix H: Module 3 Learning Material

How Microwave Ovens Work

Tutorial 3: Microwaves

In previous tutorials you were introduced to matter and energy. You saw how matter is made up of atoms, and combinations of atoms can be simple or compound molecules. You were introduced to the Periodic Table of Elements and saw how combinations of elements can make new substances, for example H2O or water. You were also introduced to a number of energy types, you saw how they could be transformed into thermal energy or heat and how heat can be transferred by three processes; conduction, convection and radiation.

In this tutorial we are going to look at a form of radiation called microwave radiation, and we will see that this type of radiation is essential for the successful operation of a microwave oven.

Electromagnetic Spectrum

Spectrum is a word that describes a broad sequence or range of related qualities. We could use that word to describe lots of different groups with related qualities, for example a lawyer can advise on a broad spectrum of legal matters or a running club can have a wide spectrum of athletes ranging from walkers to sprinters.

We are interested in microwaves, and microwaves are one of many types of electromagnetic radiation. Radiation travels in a wave formation just like a ripple on a pond or a sound wave, which is itself a form of radiation.

Each type of electromagnetic radiation has a unique wavelength which is the distance between repeating units of a wave pattern, see Figure 1: A typical wave pattern.

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Remember that spectrum is a word that describes a broad sequence or range of related qualities? Well the whole range of electromagnetic radiation is contained within the electromagnetic spectrum. The types of electromagnetic radiation are organized by their wavelengths.

At one end of the spectrum you will find radio waves that can have wavelengths from a few feet to well over a mile. At the other end of the spectrum you will find gamma ray radiation which can have a wavelength smaller than the size of an atom, so small that we do not have instruments capable of directly measuring them. Figure 2 is a detailed diagram of the electromagnetic spectrum.

![The Electromagnetic Spectrum](image)

Figure 2: The electromagnetic spectrum spans the range from radio waves at long wavelengths to gamma rays at short wavelengths. (Courtesy: Advanced Light Source)

Figure 2 gives you a lot of information about each radiation type including their atomic energies, their common names, the kinds of objects that commonly emit each type of radiation, their wave length and an visual guide of how large each wavelength is using everyday objects. The difference in wavelength can be enormous, for example x-rays can be as small as an atom while at the other end of the spectrum radio waves can be a large as a football field.
Take a moment to consider the common sources of various type of radiation. You may see a pattern as you look from left to right. Looking at the left side of the diagram first you’ll see AM and FM radio within the radio waves portion of the spectrum. We all know that radio waves are harmless; they fill the space around us carrying countless radio stations, two way radio conversations, and so on.

But not all radio waves are the same. Notice that the wavelengths for AM radio and FM radio are different. AM radio has a wavelength roughly the size of a football field whereas FM radio is much smaller, roughly the size of a house. Notice too that the atomic energies differ too; AM has a much smaller energy level than FM radio, this means that FM is more powerful than AM. Next time you are listening to a radio set try listening to an FM station and then switch to an AM station, and compare the difference between the two. The quality of the FM signal will be vastly superior to the AM signal because it is more powerful and can carry a lot more information.

Moving further to the right you will notice the pattern repeating. The wavelengths become shorter and carry more energy. Microwaves have a wavelength similar to radio waves, but they are more powerful as they have a shorter wavelength and a higher atomic energy. And the pattern continues through infrared radiation, to visible light (the light that we all see, without it we would be literally in the dark) to ultra violet, and onto very powerful x-rays and gamma-ray.

**Microwaves**

We have established that a microwave is a form of electromagnetic radiation where the microwave energy travels in the radiating wave movement. This type of energy travels in a straight line and does not require a medium to travel through. It can pass through non-metal materials like plastic and glass, but they do get reflected off metal surfaces.

In tutorial 1 we discussed how the motion of atoms and molecules creates heat, or thermal energy, as these particles move against each other. This motion results in friction which, just like rubbing your hands on a cold day, creates heat. When microwaves pass through certain materials they can have the effect of resonating molecules within that material.

Some molecules are affected in this way more than others. Molecules that have a better environment to move, like liquids, would find it easier to resonate than molecules that form more solid materials, like ceramics. Water molecules are particularly reactive to microwaves. Since our food often has a high
water content we find that water molecules within food that is subjected to microwave radiation will heat up over time. Not only will the water molecules heat up, but by conduction (remember that from tutorial 2) the food itself will heat up and begin to cook.

So, as a result of the microwave absorption, the water molecules in food begin to vibrate. This molecular movement produces heat, which cooks the food. And this is the operational principle on which microwave kitchen appliances work.

**Interesting Info**

Like many of today's great inventions, the microwave oven was a by-product of another technology. It was during a radar-related research project around 1946 that Dr. Percy Spencer, a self-taught engineer with the Raytheon Corporation, noticed something very unusual. He was testing a new vacuum tube called a magnetron (we are searching for a picture of an actual 1946 magnetron), when he discovered that the candy bar in his pocket had melted. This intrigued Dr. Spencer, so he tried another experiment. This time he placed some popcorn kernels near the tube and, perhaps standing a little farther away, he watched with an inventive sparkle in his eye as the popcorn sputtered, cracked and popped all over his lab.

**Summary:**

- The electromagnetic spectrum contains the whole range of electromagnetic radiation from radio waves at long wavelengths to gamma rays at short wavelengths.
- A wavelength is the distance between repeating units of a wave pattern.
- Microwaves are a form of electromagnetic radiation.
- Microwave radiation can cause certain molecules vibrate, for example water molecules in food.
- The vibrating molecule movement produces heat within the food.
- Given enough time this heat can cook the food.
- This is the operational principle on which microwave kitchen appliances work.

**What's Next:**

In this tutorial we talked about microwaves and how they can be used to generate heat. In the next tutorial we will learn how a microwave kitchen appliance creates microwaves which are used to heat food.

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How Microwave Ovens Work

Tutorial 4: The Microwave Oven
The last tutorial we covered what microwave radiation is and how it heats or cooks food. In this tutorial we are going to cover how a microwave oven is constructed and how it produces the microwaves required to cook your food. At the end of this tutorial you will understand how a microwave oven works!

Microwaves
Let's remind ourselves of what we have learned so far:

- The electromagnetic spectrum contains the whole range of electromagnetic radiation from radio waves at long wavelengths to gamma rays at short wavelengths.
- A wavelength is the distance between repeating units of a wave pattern.
- Microwaves are a form of electromagnetic radiation.
- Microwave radiation can cause certain molecules to vibrate, for example water molecules in food.
- The vibrating molecule movement produces heat within the food.
- Given enough time this heat can cook the food.
- This is the operational principle on which microwave kitchen appliances work.

The Microwave Oven
We are all familiar with the microwave oven kitchen appliance. Virtually every modern kitchen has one and they are one of the most utilized of all kitchen appliances yet few people understand how they actually work.

Figure 1: A Microwave Oven

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At first glance the oven appears to be a simple device with a hinged door, a cooking chamber and a control panel. But as you are now aware there is a lot more to the microwave oven than that.

The most important function of the device is the generation of microwaves, without them it’s just a metal box with a door. There are four main components required for the generation of microwaves:

- A high voltage transformer.
- An electron tube called magnetron.
- A wave guide fan.
- A cooking chamber.

**Transformer**
A standard domestic electricity supply can range from 110 volts (in the USA for example) to 220 volts (the European standard). When compared to the 3000 volts required by a microwave oven to generate microwaves there clearly needs to be a major step up in voltage from the supply. This is done by the transformer. These are found on many appliances and will take the input supply voltage and either step it up to a higher voltage or step it down to a lower voltage depending on the appliances’ requirements.

**Magnetron**
The magnetron is the component that generates the high powered microwaves that are required to cook the food. It is essentially a high-powered vacuum tube that generates microwaves using the

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interaction of a stream of electrons with a magnetic field. The magnetron requires a great deal of power to operate effectively, and this power is supplied by the transformer.

Wave Guide
The next stage in the process is the wave guide. This essentially transfers power from the magnetron, where the microwaves are formed, to the oven chamber, where the microwaves are contained and heat the food.

Oven Chamber
Like a Faraday cage (which is a metallic enclosure that prevents the entry or escape of an electromagnetic field) the oven chamber prevents micro waves from leaving the oven.

Interesting Info
Michael Faraday (1791-1867) was the son of a blacksmith and received little in the way of formal education yet contributed enormously to various scientific and engineering fields. He is especially remembered for his work with electromagnetism and he invented the electric motor. He is quoted as saying “nothing is too wonderful to be true”. Next time you’re cooking a delicious meal in a microwave oven remember how wonderful it is!

More often than not the oven door will have a window with a layer of conductive mesh some distance from the outer panel to maintain the shielding. The size of the perforations in the mesh is important, and you may need to refer back to the electromagnetic spectrum diagram in tutorial 3 to fully understand why. The size of the perforations is much less than the microwaves’ wavelength which will prevent most of the microwave radiation from passing through the door while visible light (with a much shorter wavelength) can.
Within the oven chamber the microwaves bounce back and forth off the reflective metal walls. When the microwaves come in contact with the food itself they penetrate inside the food. As they travel through it, they make the molecules inside it vibrate more quickly which generates heat and cooks the food.

The food usually sits on a turntable that spins slowly to give the microwaves a better chance of more evenly penetrating the food and therefore cooking the food more evenly.

**Control Panel**
The brains of the operation is the control panel. It is essentially a timer and power adjuster so that you can ensure that your food gets just the right amount of time and energy to cook properly, provided you read the instructions of course!

Cooking Time is important. Too little and you risk undercooked food, too much and you risk charred food and a splattered oven chamber. When you read those cooking instructions you will notice that a "cooking time" AND a "standing time" that can be just as long (where you leave the cooked food to stand without the oven on before eating it). The standing time is not to allow the food to cool or for any rogue rays to dissipate, rather it allows the food to effectively keep on cooking. The hotter parts of the food will pass heat by conduction (remember this from tutorial 2?) to the cooler parts, giving a more uniformly cooked food.

**Summary**
In this tutorial you learnt how microwave ovens are constructed and how they produce the microwaves required to heat your food. A microwave oven has the following core components:

- A high voltage transformer to step up the supply voltage.
- An electron tube called magnetron that generates the microwaves.
- A wave guide fan to channel the microwaves into the oven chamber.
- A cooking chamber that contains the microwaves and the food to be heated.
- The control panel is a timer and power regulator.

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