Experiences of learners when a computer simulation is used to aid teaching the photoelectric effect

by

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Abstract

This study explores the use of computer simulations to supplement learning in Science lessons, specifically the photoelectric effect. This study uses the Felder and Silverman Learning Style Model (FSLSM) as a theoretical framework to investigate the use of simulations as it provides a useful lens through which to explore the consistent way in which a person learns regardless of the teaching method or content learnt. Using this theoretical framework, this research investigates the experiences of learners with different learning styles when an interactive computer simulation is used to aid teaching the photoelectric effect in Physical Science. This case study used qualitative data collected from 17 computer literate Grade 12 learners in three different classes at a secondary school in Nelspruit, Mpumalanga. Analysis of the data collected in this study shows that when the simulation is used in Science, the learning experience of the learners is enhanced. Positive experiences for all four the Dimensions in the FSLSM could be indentified when the ICS was used and this could be linked to specific learning styles. Sensory and Intuitive learners enjoyed conducting the experiment that would normally require unsafe conditions and that the experiment could be set up quickly and with ease. The different dimension brought about by using the ICS was enjoyed by Intuitive learners. The visualisation of the abstract physical systems enhanced the learning for Visual and Verbal learners, whilst Global and Sequential learners felt that they gained a deeper understanding of the photoelectric phenomenon by using the ICS. Reflective learners enjoyed the precision of their pseudo-experimental data, but the Active learners felt that they did not understand the graphs given in the ICS. The interactive control variables and the fact that the learners had an option to work in either a group or on their own, benefitted both Active and Reflective learners.

Keywords: Interactive Computer Simulations, photoelectric effect, experiential learning, Felder and Silverman Learning Style Model (FSLSM) theoretical framework, different learning styles; sensory and intuitive learners; visual and verbal learners; global and sequential learners; active and reflective learners.

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List of acronyms

FSLSM	Felder-Silverman Learning Style Model
GEM	generate-evaluate-modify technique
HBDI	Herrmann Brain Dominance Instrument
ICS	Interactive Computer Simulation
ICT	Integrated Computer Technologies
ILS	Index of Learning Styles
LSI	Learning Style Indicator
MBTI	Myers-Briggs Type Indicator
PCK	Pedagogical Content Knowledge
PhET	Physics Education Technology project
STEM	Science, Technology, Engineering and Mathematics
T-GEM	Teaching simulation Technology using generate-evaluate-modify technique

Key for learning styles

A	Active
G	Global
I	Intuitive
R	Reflective
S	Sensory/Sensitive
Q	Sequential

Ve	Verbal
Vi	Visual

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CHAPTER ONE

An overview of the study

1.1 Introduction

This study seeks to investigate how the use of an Interactive Computer Simulation (ICS) would aid the understanding and learning of the photoelectric effect in Science. Results from a study conducted by Finkelstein et al. (2005) indicate that "properly designed simulations used in the right contexts can be more effective educational tools than real laboratory equipment, both in developing learner facility with real equipment and at fostering learner conceptual understanding." The advantages of using an ICS have been proven repeatedly (Papadouris & Constantinou, 2009; Lindgren & Schwartz, 2009; Eskrootchi & Oskrochi, 2010) but I wanted to know specifically how learners with different learning styles would (or would not) benefit from using the ICS. In the introduction to this research study I discuss some views on Learning Styles and ICS to situate my research.

"Learning styles are characteristic cognitive, affective, and psychological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment" (Keefe, 1979). The concept of learning styles has been applied to a wide variety of learner characteristics and diversities. Some learners are at ease with facts and observable phenomena when they learn; others feel much more at home with theories and abstractions; some prefer visual presentation of information and others prefer verbal explanations whilst some would rather use active learning and others lean toward introspection. "One learning style is neither preferable nor inferior to another, but is simply different, with different characteristic strengths and weaknesses. A goal of instruction should be to equip learners with the skills associated with every learning style category, regardless of the learners' personal preferences, since they will need all of those skills to function effectively as professionals" (Felder & Brent, 2005). The Felder-Silverman Learning Style Model (FSLSM) is used as a conceptual framework in this study. In this model, learners are divided into four different dimensions namely the: Perception Dimension, Input Dimension, Processing Dimension and the Understanding Dimension. Each dimension is subdivided into two different learning styles each: The Perception Dimension (how the learner perceives the world) is divided into Sensory/Sensitive (S) and Intuitive (I) learners; the Input Dimension (how the learner receives information) is divided into Visual (Vi) and Verbal (Ve) learners; the Processing Dimension (how the information is comprehended and converted into knowledge) is divided into Active (A) and Reflective (R) learners and the Understanding Dimension (how the learner grasps the concept) is divided into Global (G) and Sequential (Q) learners (Felder & Silverman, 1988). A full discussion of this learning style model follows in Chapter Two.

Attempts to use computers and other technologies (Integrated Computer Technologies or ICT) to improve learner learning at school began many years ago (Bransford, Brown, & Cocking, 1999). Since the early days, the presence of computers in schools has increased dramatically, mostly in classrooms in developed countries. It is now widely accepted that computers and other ICTs play a significant role in providing interconnectivity in a globalised world (Pelgrum & Plomp 1993 cited in Draper 2010, p. 33). Therefore, we should move beyond teaching *about* computers and how to use them (computer literacy), to teaching and learning *with* computers (Draper, 2010). But what is the reason for using ICT in Science education? Recent decades have seen increasing calls for fundamental change in the teaching of Science, Technology, Engineering and Mathematics (STEM), not only in South Africa, but globally as well. Research has not been able to provide conclusive evidence of a positive impact on learner achievement (Balanskat, Blamire, & Kefala, 2006) when making use of ICT's in Science. Some promising findings of positive impact come from the use of home language in primary education and Science (Balanskat et al., 2006), although there are still conflicting findings on improved attainment in Science (Webb, 2008). "To aid the change in Science teaching, computer technologies are becoming increasingly powerful components of Science learning" (Papadouris & Constantinou, 2009). According to Papadouris and Constantinou (2009) "Computer technologies can perform complex processes which make it possible to expand the range of questions that can be investigated; they have the ability to store and rapidly process large amounts of information; the types of data that can be collected to examine these questions and the representation forms that can be used to communicate these findings' change variables." ICT can also enhance the teaching by letting the learners visualise concepts which are difficult to understand. Historically, visual encoding of teaching material was ignored in favour of verbal presentation by teachers. However, Paivio's research (1971, 1991) illustrates that "a combined visual and verbal presentation of material was more effective at increasing a learner's recall and retention because the material was dual coded by the brain." Furthermore, Goia and Brass (1985) claim that "modern learners are more visual in their approach as a result of television and video game experiences." Paivio's Dual Coding Theory predicts that "successful instruction results when learners build representational connections for verbal and visual depictions" (Clary and Wandersee, 2010) as well as "referential connections between the verbal and visual representations" (Mayer & Anderson, 1991). In the past, this would have been illustrated by using a moving picture (as in a video) but in our modern day we have the opportunity to use ICT in the classroom.

The tool around which this research is focused is Interactive Computer Simulations (ICS), which is a growing part of the global endeavour to improve Science education (Lindgren & Schwartz, 2009). The reason for this is because it can provide the learners "with the ability to observe how a simulated physical system or phenomenon behaves" and how this can change when different variables are manipulated (Papadouris & Constantinou, 2009). Therefore, by using ICS in a Physical Science classroom, learners are better able to construct a specific mental model to understand any abstract model which had previously been presented to them verbally or as abstract graphic models or pictures. ICS is one component of computer technologies which is increasingly entering mainstream education. It is a powerful tool for scientific thinking and it can be an effective learning tool but only if carefully designed, researched and implemented (Adams et al. 2005 cited in Lindgren & Schwartz, 2009). The benefits that ICS bring to school Science are that they enable learners to explore and investigate phenomena in ways which would not be possible in the classroom: for example, investigations which are too difficult or too dangerous (using toxic chemicals), too large or small (cosmic or molecular reactions), or too fast or slow for direct observation (Webb, 2008). These simulations are "dynamic; they can be highly interactive; they can scaffold enquiry; they can provide multiple representation; and they can be readily disseminated and incorporated into industry and classroom settings" (Lindgren & Schwartz, 2009), all adding to meaningful learning. There are many reasons for the usefulness of ICS in the Science learning environment: "Simulation software tools can be used to provide learners with the ability to observe how the simulated physical system or phenomenon behaves and how it changes as a result of manipulating affecting variables" (Papadouris & Constantinou, 2009). Thus, it becomes possible for learners to visualise and "understand abstract concepts and the function of complex mechanisms" (White & Frederickson, 1998). At the same time, learners are "able to build mental models to represent abstract and inferred concepts and mechanisms". ICS are a "growing part of the scientific enterprise" (Lindgren & Schwartz, 2009).

The purpose of this study is therefore to investigate what the learning experiences of learners with different learning styles will be when ICS is used in Science to scaffold these learners' understanding of the photoelectric effect.

1.2 Rationale for this study

According to the Report on the National Senior Certificate Examination results for 2010 in South Africa, in the overall analysis of selected subjects "the performance in Mathematics and Physical Science are the lowest at 47.7% and 47.8% respectively" (National Department of Educational Statistics, 2011, p. 55), whereas subjects such as Geography and History were 69.2% and 74.8% (National Department of Educational Statistics, 2011, p. 55). Over a three year period (2008 - 2010) this poor performance has not improved (National Department of Educational Statistics, 2011, p. 58) and Mathematics and Physical Science remain at a very low base (National Department of Educational Statistics, 2011). Evidence of the poor performance of South African learners in Science can be gleaned from the international comparative study of learner's achievement, in the "Third International Mathematics and Science Study" (TIMSS). "Forty-five countries took part in the 1995 cross-national survey of learner achievement in Mathematics and Science that was conducted at three levels of educational systems" (Liu, 2006). All learners' performances reflect "only the Science curricula used in the country at that time, in addition to learners' developmental progression on conceptual understanding of Science concepts" (Liu, 2006). The international average for Science in Grade 8 was 516 and South Africa's score was the lowest in the study, with an average of 326 (TIMSS 1995, p. 5). The same result was found in the Grade 12 study, where the international average was 500 and South Africa's average was 356 (TIMSS, 1995). This study was repeated in 2003 and renamed the Trends in International Mathematics and Science Study (TIMSS, 2003). Forty-four countries took part in the study and a useful comparison could then be made between the 1999 and 2003 results (TIMSS 2003, p. 16-17). In the 2003 study, the international average for Science in Grade 8 was 473, and again South Africa's score of 244 was the lowest in the study (TIMSS, 2003). This study is repeated every four years, but South Africa did not participate in the 2007 study.

There is an increasing demand from governments to improve the teaching of Science worldwide (Harvey, Ling & Shehab, 2011). This is not an easy task, since Science is a conceptually difficult subject, where most of the subject matter deals with concepts that are invisible in a normal class. To aid meaningful learning in Science, effective presentation of Science content (Clary & Wandersee, 2010) has become important. Paivio's research (1971, 1991) illustrates "that a combined visual and verbal presentation of material" is a very effective way to teach any subject, because "the material is then dual coded in the brain" (Clary & Wandersee, 2010). So, to follow this advice, I want to make use of modern day technology to improve teaching and learning in a Science classroom.

1.3 Research problem and statement of purpose

To help learners to understand and learn Science in the twentieth century, it seems appropriate to encourage them to make use of the available and useful Integrated Computer Technologies. There is, however, growing research evidence to support the view that learning will not necessarily be enhanced spontaneously if a classroom is simply equipped with computers (Brown, 1992; Howard, 2002; Chen et al., 2008; Papadouris & Constantinou, 2009;). "The difficulty of integrating computer-based tools with learning in a productive manner that can improve the quality of learning is far from trivial" (Ainsworth, Bibby & Wood, 1998) and, "despite the growing presence of Information Technology in the Science learning environment, there is a general lack of frameworks to guide the effective transition to computer-enhanced curricula" (Papadouris & Constantinou, 2009). The incorporation of computer-based technologies is a "complex matter and special care should be taken to ensure productive integration with curriculum materials in a manner that demonstrably enhances learning" (Papadouris & Constantinou, 2009). This speculates "determining what constitutes effective use of available computer-based tools" (Papadouris & Constantinou, 2009) and if one strives to achieve this goal it would be best not to depend on intuition; the effective use of available computer-based tools should rather "emerge as a result of a systematic and analytic approach" (Papadouris & Constantinou, 2009).

It is now widely accepted that computers and other integrated computer technologies (ICT) play a significant role in providing interconnectivity in a globalised world (Pelgrum & Plomp 1993 cited in Draper, 2010). There is a growing appreciation for the role that ICT can play in changing the way people learn, not only in preparing school leavers for an information society, but also in the teaching and learning processes (Kozma, 2003). Gibson (2001, p. 48) mentions that "*technology in itself does not improve learner achievement, but research is helping educators to understand how technology creates circumstances and opportunities for improving learning.*" Research focused around ICT in Science education centres predominantly around the use of technology to support practical work (Becta, 2004). In particular, the use of interactive computer simulations (ICS) and data-loggers as tools to assist in the practical investigations unique to Science (Draper, 2010). The use of digital ICS as a specific application of ICT has received much attention in Science education, as the benefits to school Science are that they enable learners to explore and investigate phenomena not possible in the classroom (Draper, 2010). The advantages of using ICS will be discussed in section 2.5.1.1, and the motivation for my choice of this tool for my research is that some of these advantages are only applicable when using ICS to help understand a difficult concept in Science. (For example, ICS enables a learner to see a microscopic view of atoms reacting, not visible to the naked eye).

1.4 Research question

What are the experiences of learners with different learning styles when an Interactive Computer Simulation (ICS) is used to aid teaching the photoelectric effect in a Science classroom?

1.5 Research methodology

The research methodology is purely qualitative and based on the preceding, prevailing characteristics. My theoretical perspectives are located within a constructivist-pragmatist paradigm (Mackenzie & Knipe, 2006). The research design is a single case study as it observed "*effects in real contexts, recognising that context is a powerful determinant of both cause and effect*" (Cohen, Manion & Morrison, 2001, p. 181). I construct an understanding of learners' experience through the interpretation of their interactions with the computer simulation. My understanding of the educational phenomenon is partial (Ernest, 1997), subjective (Nieuwenhuis, 2007 a), context bound (Koro-Ljungberg, 2007) and dependent on my experience (Maxwell, 2005). To answer the research questions a qualitative research approach is used as it concerns "*specific meanings, emotions and practices that emerge through the interactions and interdependencies between people*" (Hogan, Dolan & Donnelly, 2009, p. 4) and is essentially constructivist (Maree & Van der Westhuizen, 2007; Nieuwenhuis, 2007 a). The research focus is on understanding and interpreting the experiences of students with different learning styles when a computer simulation is used to aid teaching Science. Observations and interviews serve as data collection techniques which enable me to interpret the reality by becoming part of the lives of the learners. The data is analysed according to the categories identified in the conceptual framework. Meaning is, at least to some extent, inductively attributed to the data (Henning, 2005). The sample was conveniently selected and consisted of a group of three grade 12 Science classes. The learning styles of each of these forty-nine learners were determined and then the focus group was selected. This focus group consists of seventeen grade 12 Science learners, and was specifically selected to represent of all eight learning styles identified in the Felder-Silverman Learning Style Model (FSLSM). The interactive strategies for data collection are semi-structured interviews, classroom observations and document analysis, supported by supplementary data collection techniques of digital voice-recordings. I continually returned to the research site to ensure continuity.

The structure of the dissertation

The dissertation consists of five chapters. The research problem of investigating the experiences of learners with different learning styles is introduced in Chapter One. The statement of purpose and the research question pertaining to this study are delineated and the rationale for conducting the research is also presented in this chapter. Overviews of the literature review and the research methodology are given.

Chapter Two provides an in-depth analysis of the findings in the relevant literature and explains the conceptual framework on which the study is based. In Chapter Three details regarding the methodology of the study are given. The data analysis strategies are discussed as well as the trustworthiness and ethical considerations of the study. Chapter Four includes the presentation of findings from the data obtained through class observations and interviews conducted with the Science learners. The findings are also analysed and discussed according to the research question based on the conceptual framework and the literature and trends are identified and explained. Chapter Five contains the conclusion and implications and comprises a chapter summary, verification of the research question, a reflection on the study, the conclusions, recommendations and limitations of the study.

CHAPTER TWO

Literature review and conceptual framework

The purpose of this chapter is to present the literature review appropriate for the investigation. Prior to synthesizing the review, I conducted a critical, investigative exploration of the research literature. The development of perceptive and critical research question is one of the objectives of conducting a literature review (Yin, 2008). Jointly, the organisational structure of the literature review emerged from the research question that evolved. Chapter Two is concluded with an illuminative discussion of the generation and the application of the conceptual framework relevant to the study.

For the purposes of investigating the interaction of Science learners with a computer simulation, the delineation of this literature review is presented according to the following structure:

- Introduction
- Meaningful learning
- Learning styles
- Interactive Computer Simulations
- Teaching Science with ICS
- Accommodating different learning styles when using ICS

2.1 Introduction

The recent changes in teaching and learning practices have had their roots in two broad theoretical developments, namely the behaviourist (or positivist) view and the cognitive view. Dalgarno (2001) mentions that the "first development, in the field of psychology, has been the demise of the *behaviourist* view in favour of the cognitive view of learning. A behaviourist view of learning emphasises teaching strategies that involve repetitive conditioning of learner responses". According to Felder (2012) "the traditional philosophical view of knowledge is *positivism*, which holds that objective reality exists and becomes known through scientific examination of evidence of the senses. The positivist researcher's goal is to carry out objective and unbiased studies to arrive at the truth". The positivist educator's duty is to present material, the learners' responsibility is to take it in and understand it, "and their failure to do so indicates either their lack of aptitude or diligence or the instructor's lack of teaching skill" (Felder, 2012).

The alternative view of knowledge is *constructivism (or cognitivism)*, which claims that "whether or not there is such a thing as objective reality, human beings can never know what it is" (Felder, 2012). A *cognitive* view places importance on the learners' cognitive activity and the mental models they form (Leahy & Harris, 1993). It is the constructivist view that underpins this study. The philosophical shift, as described by Dalgarno (2001) is the gradual rejection of the assumption, held by many cognitivists, that there is some objectively correct knowledge representation. *Constructivists/Constructivism* speculates that, "within a domain of knowledge, there may be a number of individually constructed knowledge representations that are equally valid. The focus of teaching then becomes one of guiding the learners as they build on and modify their existing mental models, that is, a focus on knowledge construction rather than knowledge transmission" (McIerney & McIerney, 1994; Slavin, 1994). According to Dalgarno (2001) there are "three broad principles that are combined to define the constructivist view of learning. The fundamental principle, attributed to Kant and later adopted by Dewey, is that each person forms his/her own representation of knowledge, building on his/her individual experiences and consequently, there is no single correct version of knowledge" (Von Glaserfeld, 1984). The second principle, normally attributed to Piaget, is that "people learn through active exploration, and that learning occurs when the learners' exploration uncovers an inconsistency between their current knowledge representation and their experience" (McIerney & McIerney, 1994; Slavin, 1994). The third principle, normally attributed to Vygotsky, is that "learning occurs within a social context, and that interaction between learners and their peers is a necessary part of the learning process" (Vygotsky, 1978). Although there is general agreement on the basic views of constructivism, the results for learning and teaching are not as simple.

Learning is a complex concept and there are many and varied ways to understand it. Dalgarno (2001) mentions that it is "generally agreed that learning involves building on prior experiences, which differ from learner to learner". As a result, each individual learner must "be catered for and information must be presented within a context to give learners the opportunity to relate it to prior experience. It is also generally agreed that the process of learning is an active one, so the emphasis should be on learner activity rather than teacher instruction" (Dalgarno, 2001). There is significant disagreement about the details of how to put these broad details into practice. Radical constructivists feel that "learners should be placed within the environment they are learning about and construct their own mental model, with limited support provided by a teacher". More moderate constructivists claim that "formal instruction is still suitable, but that the learners should engage in thought orientated activities to allow them to apply and generalise the information and concepts provided in order to construct their own model of the knowledge" (Perkins 1991 cited in Dalgarno, 2001). A third dimension can be added with the view that "knowledge construction occurs best within an environment that allows collaboration between learners, their peers, experts in the field and teachers" (Dalgarno, 2001). For the purpose of this study, learning is understood as the process whereby knowledge is created through the transformation of experience, an understanding drawn from the work of Bransford et al. (1999).

2.2 Conducting a scientific practical by using a computer versus real equipment

In the laboratory, "computers have served as minor additions to collect or display data, as means of modifying laboratory experience or as complete virtual worlds in which learners embed themselves" (Finkelstein et al., 2005). Turkle (1997) questions the motives and justification for the use of computers in education, by asking questions such as: "Why should eighteen-year olds pour virtual chemicals into virtual beakers? Why should eighteen-year olds do virtual experiments in virtual physics laboratories?" The answer to these questions is often: "Because simulations are less expensive; because there are not enough science teachers" (Finkelstein et al., 2005).

It would be appropriate to address these questions by asking whether and in what fashion computers might be the most effective educational option for our learners. "Computers are commonly used as an integral part of laboratories, for real or virtual investigations in introductory physics courses" (Trumper, 2003). These applications "include using computers to facilitate data in the acquisition, to provide real-time data display, to analyze these data, and to simulate complex phenomena" (Finkelstein et al. 2005). Such efforts are "as effective as or more effective than their non-computer based counterparts, be they traditional" (Trumper, 2003) or "physics-education-research-based activities" (Steinberg, Oberem & McDermott, 1996).

There are not many studies available to compare the impact of the use of computer simulations instead of real equipment in physics laboratories. Zacharia and Anderson (2003) found that, "in a small study on university students' use of computers to prepare for laboratories, that students made greater conceptual gains when using the computer to prepare for laboratory than those who used the textbook and solved additional problems on the topic." Linn et al. (2004) demonstrate that "using the computer as a learning partner to substitute for laboratory equipment, that is: to collect and display data, and to serve as a medium of communication and coordination of learners and teachers, supports the learners' mastery of concepts and the ability to integrate knowledge." Triona and Klahr (2003) demonstrated that by comparing the effects of substituting hands-on equipment with a computer simulation and a video in an elementary school class that "computer simulations can be as productive a learning tool as hands-on equipment, given the same curricula and educational setting." Finkelstein et al. (2005) conducted a study to examine the value of completely replacing "traditional equipment with computer-based simulations." The discovered that, "if properly designed simulations are used in the right contexts they can be more effective educational tools than real laboratory equipment, both in developing learners' facility with real equipment and at fostering learners' conceptual understanding."

Baser and Durmus (2010) conducted a study "to compare changes in conceptual understanding of Direct Current Electricity (DCE) in a Virtual Laboratory Environment (VLE) and a Real Laboratory Environment (RLE) among pre-service elementary school teachers". The study investigated "the change the school teachers' (now seen as learners of new knowledge in this context) understanding of electric concepts in a technology-rich inquiry-learning environment." The authors found that male learners perform worse than females in a "technology-rich environment and the study discloses that conceptual change is durable when an inquiry-learning environment is implemented by both real and virtual learning environments". The importance of this study for this dissertation is that they found that "both groups tested (VLE and RLE) showed the same effects on the acquisition of scientific concepts" (Baser & Durmus, 2010 p. 48). This confirms that "inquiry-based learning can be facilitated effectively through the use of real laboratory experiments and/or the use of virtual laboratory experiments", as suggested by Zacharia (2007) and Finkelstein et al. (2005). The criticism against the use of a computer which mentions that a learner needs prior knowledge and computer literacy is also addressed in a study by Wecker et al. (2007). These authors confirm that are "no significant relations between procedural computer-related knowledge and self-confidence in using the computer for the acquisition of knowledge." This study also shows that "learners who are more literate in computers acquire significantly less knowledge" (Wecker, Kohnle & Fischer, 2007). According to Wecker et al. (2007, p. 141) *"the person with higher familiarity with computers spent less time on the single elements for receptive use, which gave them little opportunity to elaborate on the information provided in these elements."* Contrary to general assumptions that manipulation of physical practical equipment improves learning, Triona and Klahr (2003), and Finkelstein et al. (2005) prefer virtual manipulation to real manipulation. Baser and Durmus (2010) conclude that both physical manipulation and computer simulations improve learners' conceptual understanding.

2.3 Interactive Computer Simulations

Alessi and Trollip (2001) define simulations as an illustration of *"some phenomenon or activity that users learn about through interaction with the simulation"* (p. 213). According to this definition the word interaction means that the learner and the ICS communicate interactively in some way. This dissertation will examine an ICS that allow learners to change some of the factors in the computer program and make an observation of the result. This type of simulation is sometimes referred to in the research literature as "interactive simulation" (Blake & Scanlon, 2007). Clary and Wandersee (2010) point out that "the learning tool should complement learning goals and instructors should seek to incorporate teaching strategies in their classrooms that facilitate learners' constructions of more advanced and better integrated conceptual frameworks." ICS can provide multi-layered complex, rich and multi-textured tool to use to aid learning in Science.

"With the re-emergence of experiential learning as a dominant model of learning in education" (Eskrootchi & Oskrochi, 2010) and the "recent research on infusing information technologies into classrooms" (Papadouris & Constantinou, 2009; Eskrootchi & Oskrochi, 2010), it is appropriate to examine the experiences of learners using ICS. "Although theory supports using technology to engage learners in project-based learning, and the literature provides descriptions of suitable classroom technology to engage learners" (Blake & Scanlon, 2007), there are case studies where teachers describe their own "development and effective use of simulation in educational learning" (Blake & Scanlon, 2007). So, it would also be relevant to find out how the teacher experiences the use of interactive simulations in a classroom. These studies were conducted in Canada and the United Kingdom and, since there are very few relevant studies of this nature in South Africa, the need arises for finding out what the experience of a South African teacher will be, when interactive-computer simulations are used in a Science classroom. However, the experiences of the teacher when ICS is used to teach Science fall beyond the scope of this study and can potentially be explored in future studies.

In studying Chemistry learners are expected to understand the nature of chemical reactions which involve atoms and molecules which are invisible to the naked eye. This makes it difficult for some learners to understand the mechanics of chemical reactions at the level of atoms and molecules. ICS have the unique property of visibly showing the learners what actually happens on a molecular level. In addition the learner is able to manipulate variables involved in the change of these reactants involved in a reaction (Lindgren & Schwartz, 2009) and in so doing, predict what such changes will have on the mechanics of the reaction. This explanation of the concept would be limited without the use of an ICS.

"Simulations include models explicitly designed to simulate particular physical phenomena, systems, or processes. Unlike modelling tools, simulation models are pre-designed and they cannot be changed. During the design and development of a simulation, the scientific laws that pertain to the phenomenon to be represented are taken into account to simulate its behaviour as accurately as possible" (Papadouris & Constantinou, 2009). Simulations offer an easy way of "controlling experimental variables, opening up the possibility of exploration and hypothesising." Simulations are "valuable in presenting many types of representational formats including diagrams, graphics, animations, sound and video that can facilitate understanding" (Eskrootchi & Oskrochi, 2010). Simulation modelling generally takes two forms in which learners are "(a) required to develop their own models of scientific phenomena, or (b) given existing models and are asked to alter particular parameters to examine the subsequent effects on the entire system. These two approaches to modelling are likely to produce different cognitive outcomes in terms of content knowledge and general problem-solving skills" (Eskrootchi & Oskrochi, 2010). It is therefore important to keep in mind what learning outcome is intended, before deciding on which simulation model to use.

2.3.1 The Physics Education Technology simulations

The Physics Education Technology (PhET) project at the University of Colorado developed a range of "physics simulations that take advantage of the opportunities of computers while addressing some of the limiting concerns of these tools" (Perkins et al., 2006). The PhET range of simulations developed more than 60 ICS which covers the curriculum of basic Science and these are freely available online. "These simulations are designed to be highly interactive and engaging, and to open learning environments that provide animated feedback to the user. The simulations model physically accurate, highly visual, dynamic representations of Physics principles" (University of Colorado, 2011). At the same time, the ICS are "designed to build explicit bridges between learners' everyday understanding of the world and its underlying physical principles, often by making these physical models (such as current flow or electric field lines) visible" (University of Colorado, 2011). An example will help to illustrate this point: a learner learning about electromagnetic radiation starts with a radio station transmitter and antenna at a nearby house. Learners can then move an electron to oscillate at the transmission station, and then observe the formation of the electric field and the resulting motion of an electron at the receiving antenna. "A variety of virtual observation and measurement tools are provided to encourage learners to explore properties of this micro world" (University of Colorado, 2011). Figure 1 shows the simplicity of the above-mentioned simulation.

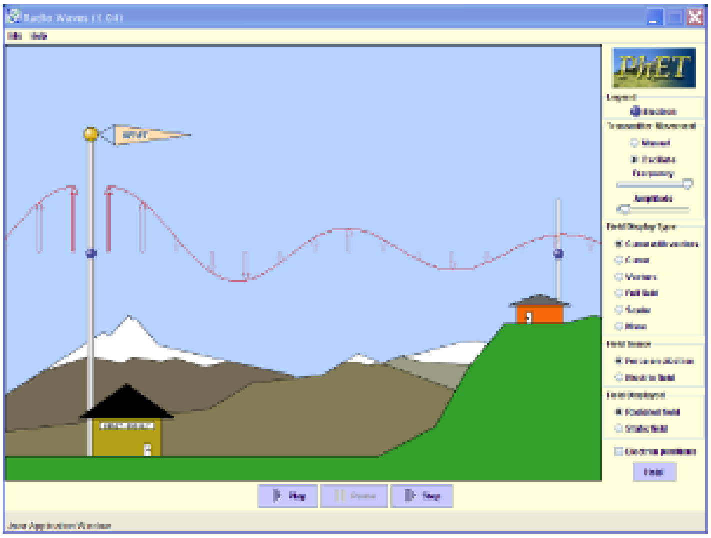

Figure 1: Radio waves and Electromagnetic Motion (PhET)

Each ICS is subjected to multiple trials and learner interviews before being user tested in class and out of class. "Knowledge gained from these evaluations is continuously used to improve the next generation of simulations" (Finkelstein et al., 2005).

2.3.1.1 Advantages of Interactive Computer Simulations

Several studies mention the advantages of ICS (Finkelstein et al., 2005; Lindgren & Schwartz, 2009; Limon, 2001; Hennesy, Twigger, Driver, O'Shea, & O'Malley, 1995), but Papadouris and Constantinou (2009) summarise these as capabilities of ICS. A combination of the capabilities identified by these authors and PhET simulations will draw attention to the advantages of using ICS in Science. Table 1 is a summary of the capabilities provided by computer-based simulations. The potential contribution to the Science learning environment is taken from a study by Papadouris and Constantinou (2009, p. 528):

Table 1: Capabilities provided by modelling software and potential contribution to the Science learning environment

Capabilities provided	Potential contribution to the Science learning environment
1.1 Creating animated or dynamic models of physical phenomena	• "Making comparisons between the model and corresponding physical phenomena in order to: (a) effectively test hypotheses, theories and predictions; (b) refine the model gradually, aiming for closer alignment with the physical system • Develop systems thinking"
1.2 Engaging in the "construction, validation and deployment of models"	Appreciating "Science as a process of model construction"
1.3 Engaging learners in the process of: • selecting "appropriate objects to be included in the model" • identifying "variable quantities" • exploring "interactions between objects"	Identifying causal relationships and irrelevant parameters
1.4 Facilitating synthesising diverse representations	Developing the ability to: • "translate information across different representation formats; • communicate ideas through the use of multiple representations; and • choose optimal representations for specific ideas" "Identifying the benefits that emerge as a result of synthesising representations to convey ideas"
1.5 Providing generic routines and procedures for model construction	Developing awareness with respect to the "fact that Science is characterized by only a small number of fundamental principles" Constructing "understanding with respect to the coherence that characterise physics"
1.6 Carrying out the calculations relevant to the model	Identifying Science "learning with the development of conceptual understanding rather than memorisation of facts and formulae Shifting the focus to qualitative conceptual reasoning"

The University of Colorado started an initiative by creating a website called the PhET (Physics Education Technology) website, which provides fun, interactive, research-based simulations of physical phenomena free of charge. They have a "research-based approach by incorporating findings from prior research and also conducting their own testing which enables learners to make connections between real-life phenomena and the underlying science, deepening their understanding and appreciation of the physical world" (University of Colorado, 2011). This website provided the ICS for this dissertation as well as access to research done on the use(s) of ICS in different topics.

The capabilities mentioned in Table 1 can be illustrated by using a few of the PhET simulations as examples in the discussion which follows.

2.3.1.1.1 Creating animated/dynamic models of physical phenomena

For any practical activity or model used in Science to be successful, it is vital that the learner is able to link the model to a real life phenomenon. This includes the value of making use of dynamic models, as opposed to a static visual. The following (Figure 2) is an example of a PhET- physics simulation used to illustrate the induction of magnetic current.

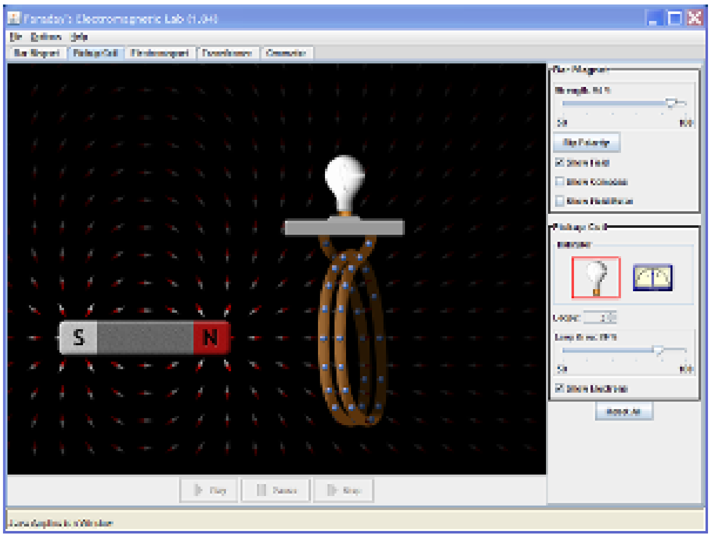

Figure 2: Faraday's Electromagnetic laboratory (PhET)

When the magnet is moved into the solenoid, (by using the mouse), the light bulb connected to the solenoid lights up, indicating that current is induced in the solenoid. This demonstrates that movement is necessary before the light bulb is switched on. It is possible to move either the magnet or the solenoid, showing that moving either one would induce current. Once learners understand this concept, it would be possible to move on to aligning this with physical systems in the real world. This also makes it possible to discuss electromagnetism as part of an entire system, such as the generation of electricity for the National Grid.

2.3.1.1.2 Engaging in the construction, validation and deployment of models

The following PhET physics simulation (Figure 3) shows how the simulation can be used to construct a model. It provides the learner with a virtual kit to construct a direct or alternating current circuit.

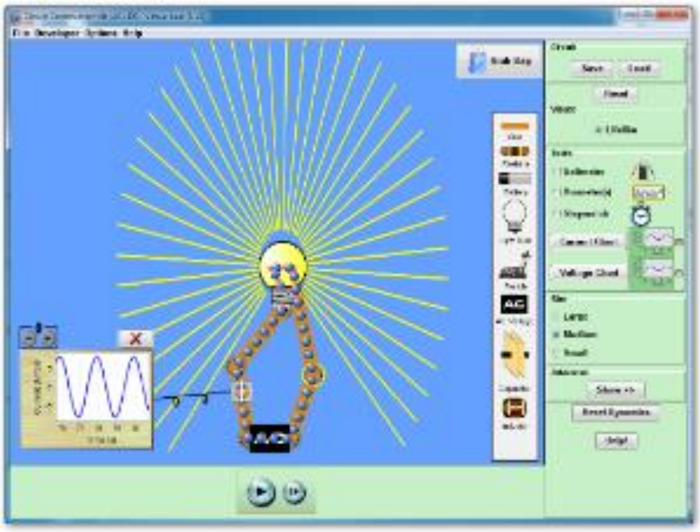

Figure 3: Circuit construction kit (PhET)

This simulation provides the learner with a virtual kit enabling the learner to build an electric circuit. It is possible to start the process by building a very simple circuit, making use of direct current. This can then progress into building an alternating current kit and eventually use capacitors and inductors, also allowing the learner to inspect the circuit by using voltmeters and ammeters, giving different readings. This allows for the "appreciation of Science by a process of model construction."

2.3.1.1.3 Engaging learners in the process of selecting appropriate objects to be included in the model, identifying variable quantities and exploring interactions between objects

The PhET simulation which follows is used to build a capacitor. The learners can investigate how a capacitor functions. They can add a dielectric to see how it affects the capacitance or they can change the size of the plates of the capacitor. They can see how the charges build up on the plates if they change the potential difference. The simulation shows the electric field in the capacitor, and measures the electric field and the potential difference. All of these add to the identification of fundamental relationships and unrelated limitations in Science. Figure 4 shows an image of the simulation and indicates how the learners will engage with the simulation.

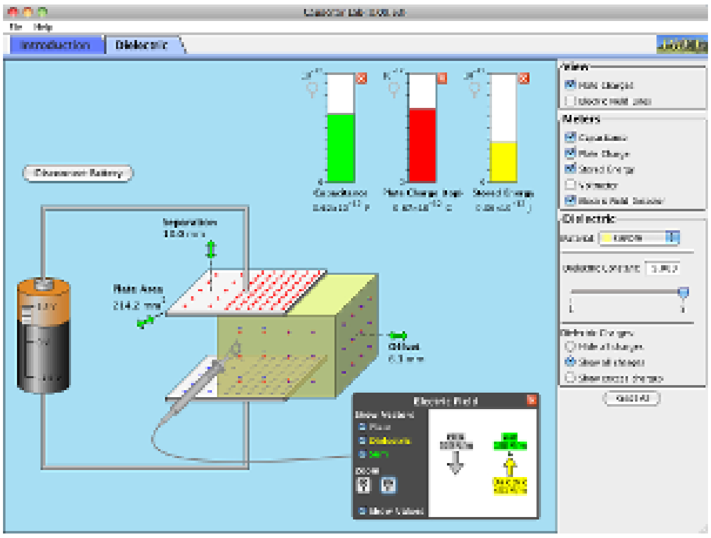

Figure 4: Capacitor lab (PhET)

2.3.1.1.4 Facilitating synthesis of diverse representations

The PhET simulation titled "Blackbody spectrum" enables the learners to develop the "ability to translate information across different representation formats; communicate ideas through the use of multiple representations; and choose optimal representations for specific ideas" (University of Colorado, 2011).

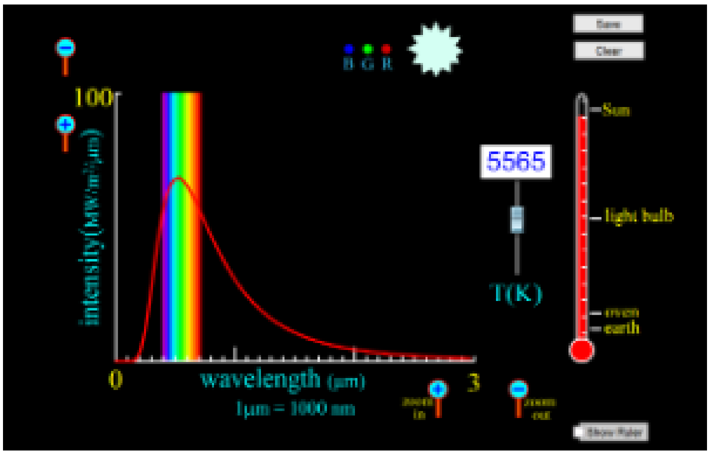

Figure 5: Blackbody Spectrum (PhET)

Figure 5 shows how the learner gets the opportunity in this simulation to see how the Blackbody spectrum of the sun compares to visible light. "They learn about the Blackbody spectrum of the sun, a light bulb, an oven and the earth. Learners can adjust the temperature to see the wavelength and intensity of the spectrum change and also to view the colour of the peak of the spectral curve"

(University of Colorado, 2011). This allows the learner to identify the benefits that emerge as a result of synthesizing representations to convey ideas.

2.3.1.1.5 Provision of generic routines and procedures for model construction

The simulation Davisson-Germer (Figure 6): In this ICS electron diffraction can be used to develop awareness with respect to the fact that “Science is characterized by only a small number of fundamental principles amongst learners” (University of Colorado, 2011). The original experiment which proved that electrons behave as waves is simulated, as shown in Figure 6.

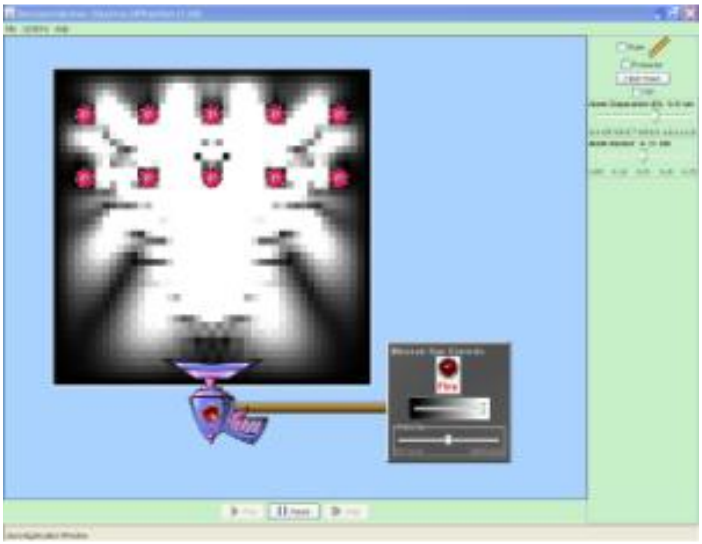

Figure 6: Davisson-Germer: electron diffraction (PhET)

The learner watches electrons diffract off a crystal of atoms interfere with themselves to create peaks and troughs of probability and thereby see that all waves have the same properties, whether it is a water; sound or electromagnetic wave. Construction of understanding with respect to the coherence that characterises physics then follows.

2.3.1.1.6 Carrying out the calculations relevant to the model

A game of ice hockey is used to demonstrate the principles of electric fields in the simulation: Electric Field Hockey. The learners can play ice hockey with “electric charges, by placing the charges on the ice and then hitting “start” to try to get the puck into the goal. They can see the electric field and trace the puck’s motion. They can make the game harder by placing walls in front of the goal” (University of Colorado, 2011). Figure 7 shows how the learner would be able to score in the ice hockey game, by calculating the correct angles and forces.

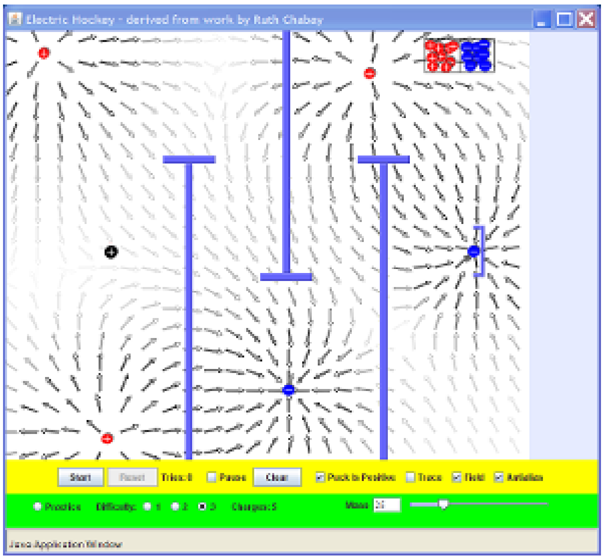

Figure 7: Electric Field Hockey (PhET)

By combining Physics principles of electric fields and ice hockey rules, it is possible for the learner to identify with Science learning and the development of conceptual understanding rather than memorisation of facts and formulae. The focus then shifts to qualitative conceptual reasoning.

In general:

Table 1 is useful narrowing down the “learning experiences” of the learners involved in this research (as stated in the research question). It was possible to look for specific outcomes in the simulation used in the research, as which capability of the simulation, would enable a certain learning outcome in Science could be determined beforehand.

Several other studies also mention advantages of using ICS as a learning tool (Finkelstein et al., 2005; Limon, 2001; Hennesy et al., 1995; Lindgren & Schwartz, 2009). Learners can use “virtual experiments in which they can easily collect pseudo-experimental data. Experiments can be conducted quickly and can be repeated several times. In this way, learners can test their models against real phenomena, evaluate their validity, and identify aspects that need to be refined. This, in turn, may support the process of gradually moving their mental models to bring” them in line with corresponding phenomena (Raghavan, Sartoris & Glaser, 1998). “Providing learners with the ability to experience, explore, and manipulate a physical system as well as to observe immediately the consequences of their actions may serve to induce cognitive conflicts” (Hennesy et al., 1995). Cognitive conflict arises when learners come across experimental cases which differ from their own predictions and expectations. “However, even though cognitive conflict has been widely recognised as an important stage in the course of conceptual change" (Posner et al., 1982), "rendering it meaningful to learners" (Limon, 2001) and framing it with appropriate activities, it still presents a major challenge to Science educators.

ICS can also provide learners with "the opportunity to conduct experiments that cannot be carried out easily in real settings." A good example of being able to carry out an experiment in dangerous circumstances would be the following simulation, titled "Alpha-decay":

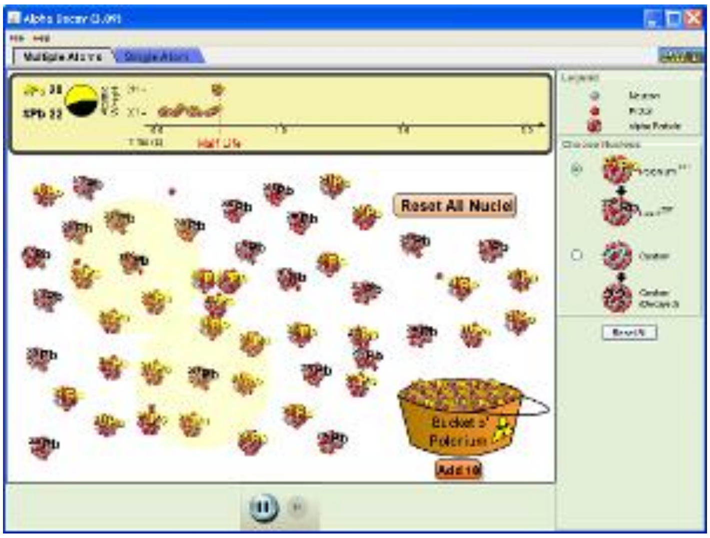

Figure 8: Alpha-Decay (PhET)

Figure 8 shows how this simulation enables a learner to "watch alpha particles escape from a polonium nucleus, causing radioactive decay" (University of Colorado, 2011). The learner can then see how the radioactive decay relates to the half-life of the particle. This would never be possible in a school laboratory given the radioactive nature of the experiment. In addition, the learner is given a macroscopic view of the microscopic behaviour of the particles – which is normally not possible in a school laboratory.

Another factor to consider is that "experiments requiring ideal conditions, such as non-frictional surfaces and the absence of air resistance or gravity, can be very expensive or impractical to conduct in real settings" (Papadouris & Constantinou, 2009). The PhET simulation shown in Figure 9 on projectile motion demonstrates the effects of adding or reducing air resistance specifically:

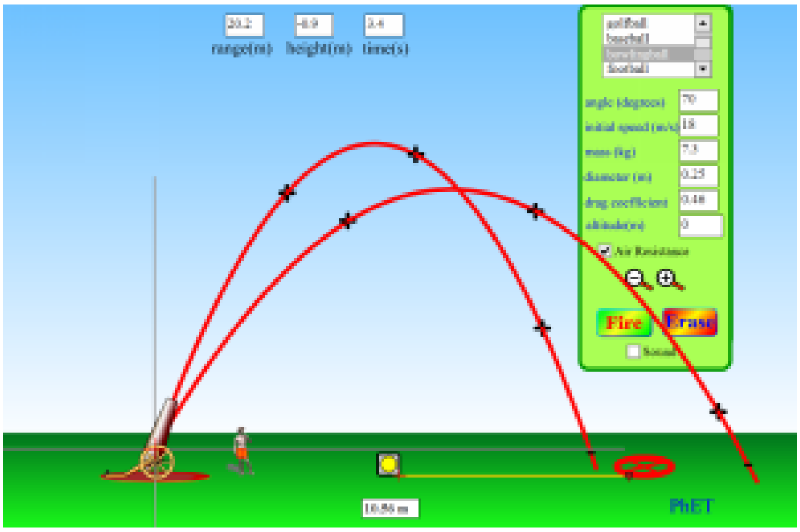

Figure 9: Projectile Motion (PhET)

Conducting an experiment of this nature in a school laboratory, would require very expensive equipment to demonstrate frictionless conditions, and might not be possible. However, by using the ICS, the learner can see the effects of frictionless conditions on the trajectory of a projectile. "Similarly, studying physical processes that last for very long or very short periods of time or are invisible presents practical difficulties" (Hennesy et al., 1995). ICS can also be used to improve such limitations and also to set up ideal conditions for an experiment.

ICS can also represent phenomena through "multiple representational formats, such as images, sounds, animations and graphs, which are combined to describe more effectively a phenomenon of interest. This can contribute to Science learning in multiple ways. Learners are likely to visualise abstract and complex processes of the natural world and gain a deeper understanding of the simulated phenomena" (Papadouris & Constantinou, 2009). These learners will be able to guess the usefulness of "alternative representation formats in conveying certain information in given situations". They may also be able to develop skills needed to transform ideas from one representational form to another. Finally, they may "develop communication skills and awareness of what constitutes effective communication. In particular, they may recognise that conveying complex information and ideas may be greatly enhanced when multiple representational formats are combined, and also that specific types of information are best communicated in specific representational formats" (Papadouris & Constantinou, 2009).

2.3.2 Spatial learning and computer simulations

Most studies of ICS have measured how to ease the process of verbal problem solving, which is suitable given the prominence of the investigation. It is important to keep the inquiry-driven problem-solving as the focal point. However, as pointed out by Lindgren and Schwartz (2009) other features of simulations and learning are also important. It is essential to take into consideration the perceptive learning properties of the simulation when a simulation is chosen to be used.

2.3.2.1 The picture superiority effect

To explain the picture superiority effect, Paivio's (1971) dual coding hypotheses is mentioned again: "people encode both a picture and its verbal interpretation." Therefore, people construct two recovery paths which enhance the probability of recollection. The "permeability and mutual reinforcement of visual and verbal processes is important for Science education. Simply remembering striking visual information runs the risk of excellent memory for irrelevant superficial features and little understanding. Verbal processes can help make sense of visual images in useful ways. At the same time, visual presentation supports subsequent memory, so learners can reconstruct their original understanding" (Lindgren & Schwartz, 2009). "Science education simulations could be enhanced by selecting visual elements that improve memory and evoke elaborative processing. Ideal visual elements are vivid or distinctive, provide grounding, and invite interpretive effort" (Lindgren & Schwartz, 2009). The ICS to be used in this study meets the requirement, as the picture of the equipment, the electrons, photons and light are vivid and easy to identify.

2.3.2.2 The noticing effect

Learning is often considered as "the development of abstract knowledge that permits inferences that go beyond the information given" (Bruner 1957 cited in Lindgren & Schwartz, 2009). Lindgren & Schwartz (2009) also refers to the work of Gibson & Gibson (1955) who said that "learning moves one progressively further from the world through abstraction". On the other hand for those who study perceptual learning, the consequence of learning is that one gets closer to the world, not further. A good example of this would be that a wine expert would be able to detect flavours in a certain wine that a beginner would not be able to. Suitable "experience enables people to extract more information from the stimulus array and appropriate instruction can support perceptual learning" (Lindgren & Schwartz, 2009). In the PhET ICS used in this study, it is easy for the learners to notice several differences, as it is possible to vary the options used in the ICS, for example the incident light can be seen as photons or as a ray of light.

The advantages of perceptual learning do not stop with observation. The ability to notice differences prepare learners "to understand conceptual treatments that depend on and explain these differences." To encourage perceptual learning, "people need exposure to appropriate variability." Frequently "instructions strip out all the variability so that learners can focus on an abstraction such as a formula" (Lindgren & Schwartz, 2009). Inconsistency is important for "learning to notice what is important and what is not important". Lindgren & Schwartz (2009) referred to the work of Posner & Keele (1968) who found that "greater variability led to slower learning in the short term, but resulted in a more potent learning that could be applied to a set of transfer problems". The "controlled and replicable nature of ICS makes them ideal for delivering optimal variability for perceptual learning." An important characteristic of ICS is the repetitive method of constructing and testing. This constructs two possible distinctions for learning. "One contrast is the difference between the expected and the observed, which help learners align their mental model with the perceptual phenomena" (Monaghan & Clement, 1999). The "second contrast, more in line with perceptual learning, is the difference between two runs of the simulation" (Lindgren & Schwartz, 2009). The noticing effect is "particularly useful in the context of assessment, because it provides convenient ways to measure learners learning from a simulation." One simple method which can be used is to show learners a visual presentation and ask them to write down what they notice. "This is often an illuminating assessment" (Lindgren & Schwartz, 2009).

2.3.2.3 The structuring effect

"Human perception extracts form from the confusion of sensory data" (Lindgren & Schwartz, 2009). This process is unforced for us humans, but computers battle to divide pixels into objects and sound waves into words. "Evolution has afforded human perception the ability to make rapid and cumulative assessments of structure" (Lindgren & Schwartz, 2009). Controlling the construction capabilities of perception is a great way to help learners see the forest and not just the trees. Scientific visualisation apparatus help scientists see patterns that might have been overlooked in a stream of numbers. More generally, "changing concepts to space have been an important scientific tool for the discovery of structure" (Lindgren & Schwartz, 2009).

ICS can be used to support the positive reception of three types of structure: unseen, sequential and ideas. Science education ICS can highlight the deep configuration underneath surface changes. ICS of molecules, for example, can explain the surface contraction of an elastic band. In some cases, ICS filter phenomena, so that "it is easier to see the deep structure without the noise of incidental variation" (Lindgren & Schwartz, 2009). On a more general level, ICS could help a learner "develop an intuitive spatial understanding of many Science phenomena, such as quantum mechanics, that otherwise depend on advanced Mathematics for conveying structure" (McKagan, Handley, Perkins & Wieman, 2009). Sequential construction is another important place for spatial representation and ICS. Simple examples "involve spatial displacement over time", as in the case of projectile motion (Lindgren & Schwartz, 2009). It is important for learners to appreciate the structure in scientific thought about those phenomena and not only to see the structure in phenomena, for example using a simulation explaining how one might reason about a domain by making thinking visible (Schwartz, Blair, Biswas, Leewalong & Davis, 2007). By "using simple artificial intelligence techniques", the character in the simulation can "animate a path of reasoning when asked inference questions." This "helps the learner to develop better abilities to reason through" fundamental chains that is omnipresent in Science (Lindgren & Schwartz, 2009). It is possible for learners to deduce and understand the particle nature of light associated with the use of this PhET ICS on the photoelectric effect.

2.3.2.4 The tuning effect

The power of human interception lies in its ability to entertain and facilitate possible actions. Perception and action are so tightly linked that action influences perception. Humans are "quicker to perceive a revealed object if their hand is positioned at the right orientation for grasping" (Craighero, Fadiga, Rizzolatti & Umilta, 1999). Humans are also better at "predicting the destination of an object moving behind an occluder if they had previously controlled the object's movement. Perception helps guide action, and action helps shape the predictions of perception" (Lindgren & Schwartz, 2009). Perception-action links are important for understanding as well as for performance. The literature on "embodied cognition, in direct response to amodal brands of information processing, argues that all thought is an evolved simulation of perceptual-motor activity" (Barsalou, 1999).

"Much everyday perceptual learning involves tuning perception and action through a process called recalibration" (Redding & Wallace, 2006). A good example to demonstrate recalibration is taken from prism alteration studies. Kohler (1964) conducted a study in which he "wore prism glasses that made the world appear upside down." In the beginning it was very "difficult for him to interact with the world, but after a few days, the world "flipped" upright as his motor and visual system recalibrated" (Lindgren & Schwartz, 2009). The human ability "for quick recalibration suggests the utility of supporting spatial interactions that engage the perceptual-motor system." Studies of "recalibration in a virtual milieu" (e.g., Richardson & Waller, 2007) show that even conventional "3D software run on a desktop computer is capable of achieving this effect". The impact of "using virtual worlds for tuning perception-action links has not yet been fully explored, but the relevance of recalibration to learning seems to be opening up for investigation, especially in light of rapidly advancing media technologies" (Lindgren & Schwartz, 2009).

The most noticeable ICS significant to tuning are "embodied, immersive learning environments," which is clearly demonstrated by the keen reception of the Nintendo Wii®. From this it seems to be a sign that people like embodied ICS. Input devices in embodied ICS can "have a direct mapping to the real-world input devices, as in the use of a brake pedal. Training ICS do not need to copy the input devices from the real world, unless the goal is immediate high proficiency at the real task. Most pedagogical ICS simply need to map the structural correspondences between input and output" (Lindgren & Schwartz, 2009).

One goal of ICS design can be "to help learners tune motor movements to perception, so they can recruit the motor system to help develop intuitive inferences". Much like "researchers in the area of communication have demonstrated that people treat their computers like real people" (Reeves & Nash, 1998), the hope is that learners will "treat virtual phenomena like real physical objects and events so that they facilitate powerful and authentic learning experiences" (Lindgren & Schwartz, 2009).

The design of an ICS should be clear about the types of learning that it hopes to bring forth. Instead of only elicit improved problem solving, there could also be for example, "effective memory of spatial structure and the ability to notice the relevant information is a prerequisite to problem solving." Assessment can be a very important guideline when thinking about desired learning outcomes in ICS design. "While most current assessments use problem solving, the four spatial learning effects mentioned (namely the picture superiority effect, the noticing effect, the structuring effect and the tuning effect) provide natural ways to measure specific types of learning that do not exclusively rely on verbal problem solving" (Lindgren & Schwartz, 2009). The interactive nature of the PhET ICS used in this study met this requirement.

2.3.3 Critique on using an ICS in Science

Advocates for the use of ICS in Science teaching and learning have encountered adversity. Although several previous studies have shown that learners who go through active-engagement computer based activities do better than learners who go through traditional instruction, Cummings et al. (1999 cited in Steinberg, 2000) found that "using the computer in the classroom, even if the learners are actively engaged, does not guarantee success." As mentioned before, ICS makes "it possible to explore physical situations where conducting the real experiment is impractical or impossible." On the other hand, when using ICS, "instructors are asking their learners to learn in a fundamentally different way compared to when scientists originally learnt the material" (Steinberg, 2000). A very good example of this is when using an ICS of an ideal gas. The learners are, obviously, not going to conduct a physical experiment. In fact, what they are watching is not directly observable in any lab, as an ideal gas does not really exist and is only a theoretical concept. The series of experiments that led to a detailed understanding of the particulate nature of gases is complex and exceedingly inferential. The same argument can be made about ICS of "planetary motion or physical optics" (Steinberg, 2000). Steinberg (2000) made it clear that "the impact of using an ICS in a classroom depends on the details of the programme and the way in which it is implemented." He argues that it is important to help learners "understand what Science is and what it means to do an experiment." Steinberg (2000, p. 40) states that: *"Running a computer simulation is very different to doing a physical experiment"* and asks: *"Are we encouraging learners to think that the process of doing Science consists only of extracting the right answer from some all-knowing source?"* He feels that this would "support a narrow perspective of what it means to do Science." It is important for any Science educator to ensure that the learners understand and work according to the scientific method. If this method is followed and understood, the learners will know that the ICS would only be a small part in helping the learner to understand the entire concept(s) involved.

"Learners should know that ICS makes it possible to explore new domains, make predictions, design experiments and interpret results. Unfortunately many ICS models used in physics are only demonstrations of the end product of Physics. There is little opportunity for the learner to use the computer as a tool while participating in the scientific process. ICS and other applications of the computer in the classroom will appropriately continue to be an integral part of teaching Physics. As part of the process involving classroom instruction, the physics education community will hopefully continue to try to make sense of what and how learners learn" (Steinberg 2000, p. 40-41). Finkelstein et al. (2005) conducted a study where some learners used an ICS to conduct an experiment on electrical current while other learners used real equipment. They found that learners "who used ICS in lieu of real equipment performed better on conceptual questions related to simple circuits." These learners developed an improved ability at manipulating real apparatus. However, the authors state that ICS does not "necessarily promote conceptual learning, nor does it ensure facility with real equipment." These authors answer Steinberg's question: "To simulate or not to simulate?" (2000)

with the following answer*: "Yes, providing that the ICS are properly designed and applied in the appropriate contexts"* (Finkelstein et al., 2005). This answer was used in formulating this study.

2.4 Teaching Science with ICS

The use of ICS has become more common in Science classrooms as Science teachers "gain access to the World Wide Web (www) from home and at school." As mentioned before, ICS is largely defined as "a computer program that attempts to simulate a model of a particular system." Any user of the ICS can "manipulate the model to view how it would behave under various conditions, and these manipulations are made visible or reported as a measurement by the program itself" (Khan, 2011). Some ICS models are predominantly valuable for Science teachers because they "help learners visualise aspects of Science that are either too large or too small for them to view, afford rapid testing of ideas, reveal trends via graphs or other representations, and provide extreme situations to support thought experiments and "what if" scenarios" (Khan, 2011). Additionally, ICS that assists learners' visualisation of "scientific phenomena have been associated with gains in conceptual understanding among Science learners in areas such as: protein synthesis, electrical circuits, predator-prey relationships, intermolecular forces, mechanics and spread of disease" (Finkelstein et al., 2005). ICS programs are quickly becoming accepted as effective educational tools in this regard. Because ICS programs contain "a model of a real system, a learner can design experiments by changing values of input variables in these programs and, subsequently, observe the resulting changes in values of output variables. When experiments are conducted, "relations between input and output variables can be inferred or induced" (De Jong & Van Joolingen, 1998). "Therefore this kind of learning is often referred to as inductive learning" (Holland, 1986) or, "because of the resemblance to scientific teaching, scientific discovery learning" (De Jong & Van Joolingen, 1998). This was also supported by Kurtz dos Santos and Ogborn (1994), who argue that learners "learn more about system behaviour with a dynamic computer model than when they create static depictions of system relationships. They also make the claim that with interactive virtual environments learners engage in an authentic scientific practice of using models as tools of observation, exploration, synthesis and prediction, thereby learning about the nature of Science."

ICS technology has unambiguous opportunities for teaching Science. ICS technology appears to provide T-GEM (teaching simulation Technology using generate-evaluate-modify technique) "teachers and learners with the capacity to: compile information between variables in order to generate initial relationships, push values to extremes or in increments to assess the scope of the relationship, and provide an environment to make comparisons between data and visually draw attention to patterns and contrasts using graphs and animations" (Khan, 2011). Learners are also able to "test assumptions, dynamically regenerate graphs, and view graphics at the molecular level with ICS" (Khan, 2011). ICS technology may also "afford teachers the capacity to engage learners in multiple GEM (generate-evaluate-modify) cycles in one classroom period, beyond what could be accomplished in the scientific laboratory." Learners report that ICS assisted them to analyse a "problem critically, make unobservable processes more explicit, and contribute to their Science learning in ways that go beyond textbooks" (Khan, 2011).

2.5 Teaching the Photoelectric Effect with an ICS

"Understanding the photoelectric effect is a crucial step in understanding the particle nature of light, one of the foundations of quantum mechanics. It is a powerful tool to help learners build an understanding of the photon model of light, and to probe their understanding of the photon model" (McKagan et al., 2009). This statement highlights the importance of ensuring that learners understand the concept of the photoelectric effect properly when it is introduced for the first time. Unfortunately, the topic is only covered briefly in modern physics and quantum mechanics at tertiary level and even less time is spent on it at secondary level. Although educators agree on the importance of the photoelectric effect, many acknowledge that they do not spend enough time teaching it. The two main goals set out at tertiary level are that university students should be able to:

1. Predict the results of experiments of the photoelectric effect correctly, and
2. Describe how the results of this experiment lead to the photon model of light.

According to Steinberg et al. (1996) learners have "serious difficulties understanding even the most basic aspects of the photoelectric effect, such as the experimental set-up, experimental results, and implications about the nature of light". The authors summarised specific difficulties as follows:

1. "A belief that V= IR applies to the photoelectric experiment."
2. "An inability to differentiate between intensity of light (and hence photon flux) and frequency of light (and hence photon energy)."
3. "A belief that a photon is a charged object."
4. "An inability to make a prediction of an I-V graph for the photoelectric experiment."
5. "An inability to give any explanation relating photons to the photoelectric effect." (Steinberg et al., 1996)

2.5.1 The Photoelectric Effect Simulation

The results of this research were used to justify the use of this specific ICS for the research for this dissertation. The following discussion illustrates why the previous research involving this specific simulation allowed me to look for something different relating to this simulation. Figure 10 shows a screenshot of the Photoelectric Effect simulation, after the tertiary students involved in this study by McKagan et al., (2009) were introduced to the photoelectric concept in lectures similar to any typical modern Physics course at tertiary level. These tertiary students from the mentioned study are now referred to as learners in the discussion which follows, as the underlying concept in this dissertation deals with all humans obtaining new information as learners.

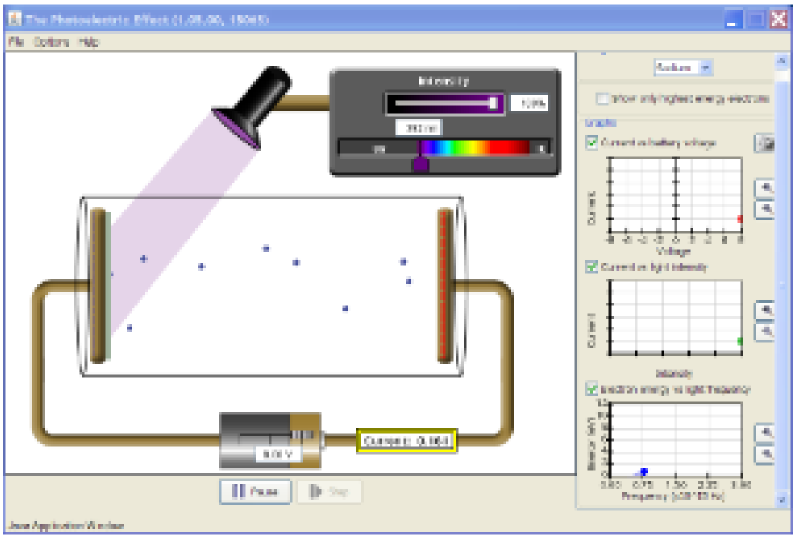

Figure 10: Photoelectric effect (PhET)

The ICS allows learners “to control inputs such as light intensity, wavelength, and voltage, and to receive immediate feedback on the results of changes to the experimental set-up” (University of Colorado, 2011). With assistance from an educator learners can create a mental model of the experiment. The ICS allows learners “to construct the graphs commonly found in textbooks interactively, such as current vs. voltage, current vs. intensity, and electron energy vs. frequency. By seeing these graphs created in real time as they change the controls in the experiment, learners are able to see the relationship between the graphs and the experiment more clearly than when viewing static images” (McKagan et al., 2009). Learners “have trouble understanding the circuit diagrams generally used in textbooks to represent the photoelectric effect and therefore the circuit diagram in the computer program was replaced with a cartoon-like picture of an actual experiment” (University of Colorado, 2011). Research shows that learners learn best when the cognitive load is reduced by eliminating unnecessary details and therefore the variable voltage supply was replaced with a simple battery with a slider to change the potential difference (McKagan et al., 2009). One aspect of the ICS is that the electrons moving from one plate to another are shown, a feature that would be

impossible in a real experiment. This aspect helps learners to see the effect of changing the potential difference; by noticing that increasing the potential difference the electrons are accelerated and by making the potential difference negative, the electrons are decelerated. Learners have "difficulty understanding the relationship between current and electron speed" (McKagan et al., 2009). The ICS is an important tool to show the learners that "increasing the speed of the electrons does not increase the number of electrons arriving per second at the plate, and therefore does not increase the current" (University of Colorado, 2011). Another concept which learners find extremely difficult is stopping potential. In the ICS when the potential difference in the cell "is tuned to exactly the stopping potential", learners can see the electrons "just reach the opposite plate and then turn around". This image of the electrons just not reaching the opposite plate seems to be a powerful one.
Criticism from some teachers was that by showing the learners how the electrons come off the plate prevents the learner from inferring the model of electron flow from observed results. However, when this ICS is used, it is assumed that the learners already understand the model of current flow and that "seeing a phenomenon on a computer screen is different from having an internal model of the phenomenon" (McKagan et al., 2009). Passively viewing an animation is not sufficient for building a mental model, and learners must interact with an ICS to learn from it (Adams 2008 cited in McKagan et al., 2009). "*Even with the animation of electrons, learners must still spend considerable mental effort to formulate a useful mental model"* (McKagan et al., 2009).

The current versus potential difference graph provides a helpful image of the most important features of the photoelectric effect. The shape of this graph depends on the assumptions made and this shape can also vary from textbook to textbook. In order to draw this graph correctly, it is important to understand that "the electrons leave the plate at a range of energies and a range of angles." This is hardly ever mentioned in textbooks, but some learners have asked about this possibility. To accommodate this, there is an option on the simulation to select which only shows the electrons leaving the plate perpendicularly and with the highest possible energies. Another simplification made possible in the ICS and not in a real experiment is to define intensity as a function of frequency. It would not be possible in a real experiment to change the "frequency of light while keeping the intensity constant," but it is possible in the ICS (McKagan et al., 2009). This research and its conclusion led to the conviction that this particular ICS was the correct tool to use for this study, namely to aid the understanding of the photoelectric effect in a Science class.

2.6 Learning styles

For some time now educational research exploring the issue of academic achievement or success has extended beyond "simple" issues of intelligence and previous academic achievement. There are a number of learning-related concepts, such as "perception of academic control and achievement motivation which have been a focus of attention when attempting to identify factors affecting learning-related performance" (Cassidy & Eachus 2000 in Cassidy, 2004). The concept of learning style has provided some valuable insights into learning in both academic and other settings. It is generally agreed upon that the "manner in which individuals choose to or are inclined to approach a learning situation has an impact on performance and achievement of learning outcomes. Whilst learning styles has been the focus of such a vast number of research and practitioner-based studies in the area, there exist a variety of definitions, theoretical positions, models, interpretations and measure of the construct" (Cassidy, 2004).

The terms *learning style*, *cognitive style* and *learning strategy* are often used incorrectly in theoretical and empirical discussions of the topic. Cassidy (2004) mentions that the terms *learning style* and *cognitive style* are used "interchangeably", but they could also be considered as separate ideas and are given separate definitions (Cassidy, 2004). *Cognitive style* is described as "an individual's typical or habitual mode of problem solving, thinking, perceiving and remembering, while the term learning style is adopted to reflect a concern with the application of cognitive style in a learning situation" (Riding & Cheema, 1991). These authors continue to describe *cognitive style* in terms of a holistic-analytic dimension, while *learning style* is seen as encompassing a number of components which are not mutually exclusive. It is also likely that *cognitive style* can be regarded as one component of *learning style*. Three key terms are indentified by Hartley (1998): "*Cognitive styles* are the ways in which different individuals characteristically approach different cognitive tasks; *learning styles* are the ways in which individual characteristically approach different learning tasks and *learning strategies* are the strategies which learners adopt when studying". The word *learning preferences* should also be mentioned here. This is understood as preferring one method of teaching over another for example such as group work over independent study. These preferred choices are usually included within a number of the models discussed and are often dealt with "explicitly by the elaborate models of learning styles" (Cassidy, 2004).

The same definitions are mentioned by Brown et al., (2009) "Individuals use learning to adapt to and manage everyday situations, which then gives rise to different styles of learning". Huston and Cohen

(1995 cited in Brown et al., 2009) mention that *learning styles* refer to the way individuals prefer to process new information and the strategies they adopt for effective learning. "The concept of learning styles has received considerable attention in the empirical literature and many theories have been proposed in order to understand the dynamic process of learning better" (Arthurs, 2007). Evaluating learners' learning styles provides "knowledge about their particular preferences. This awareness can be used to develop, design, format, and deliver educational programmes and resources that will motivate and stimulate learners' acquisition, integration, and application of information and professional knowledge in an attempt to individualise instruction" (Brown et al., 2009). *"Understanding learning styles can improve the planning, producing, and implementing of educational experiences, so they are more appropriately compatible with learners' desires, in order to enhance their learning, retention and retrieval"* (Federico, 2000, p. 367). Research indicates that people differ in their approach to learning and that no one strategy or approach will result in an optimal learning circumstance for all individuals (Brown et al., 2009). It seems that researchers use these terminologies without paying attention to the nuances that existed.

Felder and Silverman (1988) state that learning "in a structured educational setting may be thought of as a two-step process involving the reception and processing of information. In the reception step, external information (observable through the senses) and internal information (arising introspectively) become available to learners, who select the material they will process and ignore the rest". The processing step may "involve simple memorization or inductive or deductive reasoning, reflection or action, and introspection or interaction with others". The outcome is that "the material is either learned in one sense or another or the material is not learned at all" (Felder & Silverman, 1988). Humans normally absorb information by using their sensory organs and then either discard the information or they add it to their existing mental structures. This means that humans "construct their own reality, either individually (*cognitive constructivism*) or collectively with others (*social constructivism*)" (Felder, 2012). A positivist educator has an easier task than a constructivist educator. Simple factual knowledge can be learned by most learners by using rote memorization, but learners cannot transmit information directly which they have absorbed and understood. "Whether or not difficult concepts, structures and mechanisms are learned and understood does not just depend on how accurately and clearly the instructor explains them and on how intelligent learners are and how hard they work (although those factors are still important), but also on such things as the learners' prior knowledge, conceptions, and misconceptions about the course content; the level of their interest in the subject and their view of its relevance to their needs; and the degree of compatibility between their learning style (the way they characteristically take in and process information) and the instructor's teaching style" (Felder, 2012). Learner-centred teaching (Constructivist education) attempts to "take these factors into account when designing instruction, presenting new information in the context of what learners already know and helping them to develop understanding and skills through activity and reflection rather than making them passive recipients of information" (Felder, 2012). Paul Cobb (1990, p. 88) mentions that

> the views of learners as environmentally driven systems and of teachers as people who manipulate learners' environments in order to control their behaviour is rather dehumanising. By comparison, a characterisation of learners as active participants in classroom communities and of teachers as initiators and guides of negotiation processes might seem positively enlightened.... the time is ripe for cognitive science... education to question and transcend its behaviourist origins.

This confirms the need, for me as a researcher and constructivist, to take a learner's learning style into account, when reporting on learning in a Science classroom.

The concept of learning styles is not universally accepted. The mere mention of the term provokes "strong emotional reactions in many members of the academic community (notably but not exclusively the psychologists), who argue that learning style models have no sound theoretical basis and that the instruments used to assess learning styles have not been appropriately validated" (Felder & Brent, 2005). But, on the other hand, there are a number of studies which show that there is a consistent link between different learning styles and the effects of these on learner performance and attitudes (Felder & Brent, 2005). In addition to this, when instruction was designed to address a broad spectrum of learning styles it has "consistently proved to be more effective than traditional instruction, which focuses on a narrow range of styles" (Felder & Brent, 2005). I will take a scientific approach to learning styles, regarding them as a useful examining tool to understand learners and to design an effective instruction. A *learning-style model* is used to classify learners according to "where they fit on a number of scales pertaining to the ways they receive and process information" (Felder & Silverman, 1988). "A variety of learning style theories and frameworks has been developed along with accompanying instruments that operationalise their learning style constructs" (Dunn & Griggs, 2003). Hickcox (1995) classifies learning style instruments into three groups: "1) instructional and environmental learning preferences; 2) information processing learning processes; and 3) personality related preferences."

2.7 Learning style models

Science, Technology, Engineering and Mathematics (STEM) fields are collectively considered core technological foundations of an advanced society. The characteristics and requirements of learners play an important role in the educational domain and therefore the concept of learning styles are treated with immense value. A good start to improve STEM education is to look at the learning styles of learners in STEM disciplines (Harvey, Ling & Shehab, 2011). According to Özpalat & Akar, (2009) there are "five main learning style models, which are the subject of studies in STEM literature." These learning style models are namely "Myers-Briggs type indicator (MBTI); Kolb's model; Felder and Silverman learning style model (FSLSM); Herrmann Brain Dominance Instrument (HBDI) and Dunn and Dunn model" (Özpalat & Akar, 2009). The best known of these models is Jung's Theory of Psychological Type as used by the Myers-Briggs Type Indicator (MBTI). "Strictly speaking, the MBTI assesses personality types, but MBTI profiles are known to have strong learning style implications" (Felder, 1996). The MBTI was used in a "multi campus study of STEM learners in the 1970s and 1980s and a number of other STEM-related studies since then" (Felder, Felder & Dietz, 2002). Kolb (Felder, 1996), and Felder and Silverman (1996) are other models that have been used at length to STEM studies. Another two models that have been used in STEM studies are those of "Herrmann" (Felder, 1996), and "Dunn and Dunn" (Dunn, Beaudry & Klavas, 1989). Not much assessment has been performed on the "applicability of the Herrmann and Dunn models to instructional design in STEM studies" (Felder & Brent, 2005).

To summarise the concept of learning style, I concur with Keefe's definition which states that "a learning style is defined as a characteristic cognitive, affective and physiological behaviour that serves as a stable indicator of how people perceive, interact with and respond to the learning environment" (Keefe, 1987). The learning style is a consistent way in which a person learns and that persists regardless of the teaching method or the content learnt (Harvey et al., 2011). There are three dimensions that affect a learner's learning style: "the cognitive dimension, the affective dimension and the physiological dimension". "Cognitive styles are information-processing habits; affective styles are motivationally-based processes and physiological styles are biologically-based responses. Since a learning style is composed of characteristic cognitive, affective, and physiological traits, the learning style is assessed under each of these three dimensions" (Keefe, 1987).

2.7.1 The Myers-Briggs Type Indicator (MBTI)

The theory behind the MBTI is Carl Jung's theory of psychological types, that part of Jung's theory which was specifically concerned with the way that people consciously use their minds. The MBTI was developed by Isabel Myers-Briggs in 1977, by applying Jung's framework "for looking at individual differences in their relationships with others, their work and their inner lives" (Watkins & Campbell, 1999 p. 100). The MBTI is used by educators in conjunction with teachers and learners to work with "type differences in teaching styles, learning styles, academic aptitude, achievement and motivation, dropout from college and college roommate matching" (Watkins & Campbell, 1999). Other organisations that make use of the MBTI include companies involved in industry, government or business to deal with "type differences in communication, teamwork, management styles, leadership development and lifelong career planning". Translation of the MBTI into many languages makes it possible to be used world-wide. The core of the MBTI theory is that apparent unsystematic differences in behaviour is "actually quite orderly and consistent, being due to basic differences in the way individuals use their preferences on four scales" (Watkins & Campbell, 1999).

People are classified on the Myers-Briggs Type Indicator® (MBTI) according to their "preferences on four scales derived from Jung's Theory of Psychological Types" (Lawrence, 1993):

- *extroverts "*(try things out, focus on the outer world of people) or *introverts* (think things through, focus on the inner world of ideas)" (Lawrence, 1993).
- *sensors "*(practical, detail-oriented, focus on facts and procedures) or *intuitors* (imaginative, concept-oriented, focus on meanings and possibilities)" (Lawrence, 1993).
- *thinkers "*(sceptical, tend to make decisions based on logic and rules) or *feelers* (appreciative, tend to make decisions based on personal and humanistic considerations)" (Lawrence, 1993).
- *judgers "*(set and follow agendas, seek closure even with incomplete data) or *perceivers* (adapt to changing circumstances, postpone reaching closure to obtain more data)" (Lawrence, 1993).

The MBTI is widely used but has nonetheless been subjected to considerable criticism. For example it has been noted that "the measure and the results it provides can be quite unclear and confusing; in addition, it only provides vague type descriptions" (Bayne, 1997) and the validity and reliability of the MBTI has also been queried. For example, Pittenger (1993 cited in Johnsson, 2009) argues that "the MBTI has a low reliability as people who have completed the inventory twice often get different types". Bayne (1997) however, "argues that the MBTI is reliable with an average of over 80%". Inconsistent evidence for the measure's validity has also been provided: Pittenger (1993 cited in Johnsson, 2009) suggests that "although it has been widely used for a substantial period of time, its validity has only recently been demonstrated," whereas Quenk (2000) and Bayne (1997) argues that "substantial evidence supports the validity of the MBTI." For example, Bayne (1997) argues that "the MBTI is related to other personality measures, especially the Big Five". Despite its criticisms, "the MBTI is still a commonly used instrument for assessing personality" (Quenk, 2000).

2.7.2 Kolb's Experiential Learning Model (ELT)

Experiential Learning Theory (ELT) provides a "holistic model of the learning process and a multi-linear model of adult development, both of which are consistent with what we know about how people learn, grow, and develop. The theory is called "Experiential Learning" to emphasize the central role that experience plays in the learning process, an emphasis that distinguishes ELT from other learning theories" (Kolb, Boyatzis & Mainemelis, 2001). The term "experiential" is then used to distinguish ELT both from "cognitive learning theories, which tend to emphasise cognition over affect and behavioural learning theories that deny any role for subjective experience in the learning process" (Kolb, Boyatzis & Mainemelis, 2001. The intellectual origins of the experiential works of Dewey, Lewin and Piaget supply another reason why the theory is being called "experiential". Jointly, Dewey's "philosophical pragmatism, Lewin's social psychology and Piaget's cognitive-developmental genetic epistemology form a unique perspective on learning and development" (Kolb 1984 cited in Kolb et al., 2001). Experiential learning theory defines learning as *"the process whereby knowledge is created through the transformation of experience. Knowledge result from the combination of grasping and transforming experience"* (Kolb 1984 cited in Kolb et al., 2001 p. 41). The ELT model "portrays two dialectically related modes of grasping experience -- Concrete Experience (CE) and Abstract Conceptualization (AC) -- and two dialectically related modes of transforming experience -- Reflective Observation (RO) and Active Experimentation (AE). According to the four-stage learning cycle immediate or concrete experiences are the basis for observations and reflections. These reflections are assimilated and distilled into abstract concepts from which new implications for action can be drawn. These implications can be actively tested and serve as guides in creating new experiences" (Kolb et al., 2001).

"A closer examination of the ELT learning model suggests that learning requires abilities that are polar opposites, and that the learner must continually choose which set of learning abilities he or she will use in a specific learning situation. In grasping experience some of us perceive new information through experiencing the concrete, tangible qualities of the world, relying on our senses and immersing ourselves in concrete reality. Others tend to perceive, grasp, or take hold of new information through symbolic representation or abstract conceptualisation – thinking about, analyzing, or systematically planning, rather than using sensation as a guide" (Kolb et al., 2001). Some people prefer careful observation of others involved in an experience and reflect on the outcome, while other people choose immediate active participation. We are given a choice with each dimension of the learning process. A good example of this would be, for example, if a person is asked to take off in an aeroplane (Concrete Experience) and at the same time read a manual about the aeroplane's functioning (Abstract Conceptualisation), that person would solve the conflict by choosing. Because of "our hereditary equipment, our particular past life experiences, and the demands of our present environment, we develop a preferred way of choosing. We resolve the conflict between concrete experience or abstract conceptualisation and between active experimentation or reflective observation in some patterned, characteristic ways. We call these patterned ways learning styles" (Kolb et al., 2001).

To summarise Kolb's experiential learning style model (ELS): learners are classified as "having a preference for (a) *concrete experience or abstract conceptualisation* (how they absorb information) and (b) a*ctive experimentation or reflective observation* (how they process information)" (Felder, Felder & Dietz, 2002).
The four types of learners in this classification scheme are:

- *Type 1* (concrete, reflective)—*the diverger*. "Type 1 learners respond well to explanations of how course material relates to their experience, interests, and future careers. Their characteristic question is "*Why*?" To be effective with Type 1 learners, the instructor should function as a *motivator"* (Felder, Felder & Dietz, 2002).
- *Type 2* (abstract, reflective)—the *assimilator*. "Type 2 learners respond to information presented in an organised, logical fashion and benefit if they are given time for reflection. Their characteristic question is "*What*?" To be effective, the instructor should function as an expert" (Felder, Felder & Dietz, 2002).
- *Type 3* (abstract, active)—the *converger*. "Type 3 learners respond to having opportunities to work actively on well defined tasks and to learn by trial-and-error in an environment that allows them to fail safely. Their characteristic question is "*How?*" To be effective, the instructor should function as a *coach*, providing guided practice and feedback in the methods being taught" (Felder, Felder & Dietz, 2002).
- *Type 4* (concrete, active)—the *accommodator*. "Type 4 learners like applying course material in new situations to solve real problems. Their characteristic question is "*What if?*" To be effective, the instructor should pose open-ended questions and then get out of the way, maximizing opportunities for the learners to discover things for themselves. Problem-based learning is an ideal pedagogical strategy for these learners" (Felder, Felder & Dietz, 2002).

Allegations that the styles outlined by Kolb will be "associated with learner performance have been borne out in a number of studies where, for example, convergers perform better in conventional examinations involving concrete answers" (Lynch et al. 1998 cited in Cassidy, 2004). The instrument used by Kolb supporters to identify the learning style of learners is called the Learning Style Index (LSI) and the revised version is a 12-item self-report questionnaire (Kolb, 1984). "Despite the support, studies examining the psychometric properties of the LSI have raised concerns regarding its reliability and validity" (Newstead, 1992). Kolb's emphasis on "experiential learning and the developmental nature of learning suggests a potential for change in style" (Rayner & Riding, 1997). A mixed picture is sketched by previous studies where the LSI was used to examine stability and change. "Low test-retest reliability statistics and changes in style classification reported by Sims et al.," (1986 cited in Cassidy, 2004) are "countered by reports of exceptionally high test-retest reliability of 0.99 found by Veres, Simms & Locklear," (1991 cited in Cassidy, 2004). Although also reporting high test-retest reliability statistics, Loo (1997) is "cautious about them, believing that inappropriate statistical techniques may be masking individual changes in styles in favour of group effects."

2.7.3 The Felder-Silverman Model (FSLSM)

The third model is the Felder–Silverman Learning or Teaching Style Model (Felder & Silverman, 1988). "*This model, originating in the engineering sciences, defines learning style as the characteristic strengths and preferences in the ways individuals take in and process information"* (Felder & Silverman, 1988 p. 674). This model emphasizes that "individuals have preferences along five bipolar continua: the Active-Reflective, the Sensing-Intuitive, the Verbal-Visual, the Sequential-Global, and the Intuitive-Deductive" (Hawk, 2007).

The Felder and Silverman Learning Style Model (FSLSM) is more suitable for applications (Özpalat & Akar, 2009) and will be used as a conceptual framework for this study. The FSLSM model considers two steps of receiving and processing new information as the main steps in learning. Under the first step the model distinguishes between the perception of knowledge and secondly the reception of knowledge. The second step in the FSLSM deals with the processing of knowledge where the model distinguishes between the understanding and the processing of new information. The four dimensions that the learning style focuses on are: the Perception Dimension, the Input Dimension, the Understanding Dimension and the Processing Dimension (Felder, 1993).

- The perception dimension (How the learner perceives the world) makes up the sensing/intuitive dimension. Sensing learners gather data through their five physical senses and obvious facts, whereas intuitive learners use their intuition, in other words, they gather data by using theoretical abstract approaches like principles, theories and memories.

- The input dimension (How the learner receives information) is also known as the visual/verbal dimension. Visual learners receive information by what they see, e.g. visual materials or illustrations and verbal learners by what they hear (listening) and then say (verbal).
- The understanding dimension (How the information is presented to the learner or how the learner grasps the concept) is also called the sequential/ global dimension. Sequential learners learn step by step in a logically ordered fashion, but global learners learn in leaps, starting with an overall picture of the concept at hand and then only going into detail.
- The processing dimension or the active/reflective dimension refers to information that is comprehended and is converted into knowledge by active experimentation facilitated by working in groups, or reflective observation, or by the learner observing and reflecting on the information, mostly by themselves.

Figure 11 was created to illustrate the four dimensions identified in the Felder-Silverman Learning Style Model.

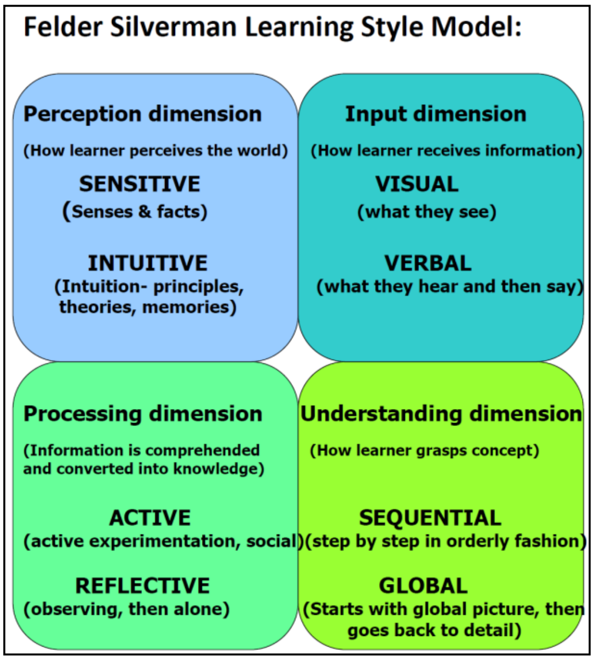

Figure 11: Four learning dimensions according to the Felder-Silverman Learning Style Model

(Adapted from Felder & Silverman 1988, p. 676; Felder 1993, p. 286; Felder et al., 2002, p. 1)

According to Felder and Silverman (1988), a learner's learning style may be defined by the answers to four questions:

1. "What type of information does the learner preferentially perceive: *sensory* (sights, sounds, physical sensations) or *intuitive* (memories, thoughts, insights)? Sensory learners tend to be concrete, practical, methodical, and oriented toward facts and hands-on procedures. Intuitive learners are more comfortable with abstractions (theories, mathematical models) and are more likely to be rapid and innovative problem solvers" (Felder, 1989). This scale is identical to the sensing-intuitive scale of the Myers-Briggs Type Indicator.
2. "What type of sensory information is most effectively perceived: *visual* (pictures, diagrams, flow charts, demonstrations) or *verbal* (written and spoken explanations)" (Felder, 1989).
3. "How does the learner prefer to process information: *actively* (through engagement in physical activity or discussion) or *reflectively* (through introspection)? This scale is identical to the active-reflective scale of the Kolb model and is related to the extravert-introvert scale of the MBTI" (Felder, 1989).
4. "How does the learner characteristically progress toward understanding: *sequentially* (in a logical progression of incremental steps) or *globally* (in large "big picture" jumps)? Sequential learners tend to think in a linear manner and are able to function with only partial understanding of material they have been taught. Global learners think in a systems-oriented manner, and may have trouble applying new material until they fully understand it and see how it relates to material they already know about and understand. Once they grasp the big picture, however, their holistic perspective enables them to see innovative solutions to problems that sequential learners might take much longer to reach, if they get there at all" (Felder, 1990).

In the 1988 version of the FSLSM five learning dimensions formed part of the learning style model. The fifth dimension was known as the inductive/deductive dimension. Felder has removed this dimension for the current FSLSM and motivates this with the following statement: "I have come to believe that while induction and deduction are indeed different learning preferences and different teaching approaches, the "best" method of teaching—at least below the graduate school level—is induction, whether it be called problem-based learning, discovery learning, inquiry learning, or some variation on those themes" (Felder et al., 2002).

The second or visual/verbal dimension was initially known as the visual/auditory dimension, but Felder explains the reason for changing this dimension's name:

> "Visual" information clearly includes pictures, diagrams, charts, plots, animations, etc., and "auditory" information clearly includes spoken words and other sounds. The one medium of information transmission that is not clear is written prose. It is perceived visually and so obviously cannot be categorised as auditory, but it is also

> a mistake to lump it into the visual category as though it were equivalent to a picture in transmitting information. Cognitive scientists have established that our brains generally convert written words into their spoken equivalents and process them in the same way that they process spoken words. Written words are therefore not equivalent to real visual information: to a visual learner, a picture is truly worth a thousand words, whether they are spoken or written. Making the learning style pair visual and verbal solves this problem by permitting spoken and written words to be included in the same category (verbal) (Felder et al., 2002).

The FSLSM is constructed from experiences in engineering education. The reason therefore to select the "FSLSM is that it is more suitable for applications covering basic Science issues. Also, in adaptive educational systems, which incorporate learning styles, the FSLSM is one of the models that has been used most often in recent times (especially in STEM studies) and some researchers even argue that it is the most appropriate model, since it describes learning style in more detail" (Carver, Howard & Lane 1999 cited in Özpalat & Akar, 2009).

2.8 Accommodating different learning styles through the use of simulations

In recent years, educational researchers have focused increasingly on "various aspects of learning styles and how they can be considered in educational technology." "Investigations into learning styles in technology-enhanced learning were conducted and several adaptive systems were developed that aim at incorporating learning styles and providing courses that fit to the individual learning styles of the learners" (Graf, Viola & Leo, 2007). The investigations into "learning styles and the development of adaptive systems are motivated by learning style models which state that learners have different ways in which they prefer to learn. Incorporating learning styles in teaching plans may make learning easier and leads to better achievement" (Graf, Viola & Leo, 2007). "Learners with a strong preference for a specific learning style may experience difficulties if the teaching style does not match their preferred learning styles" (Felder & Silverman, 1988). Several studies have found that learners with different learning styles (tested by different types of assessments) "respond differently to specific forms of instruction, and that these differences were consistent with the learning style model upon which those assessments were based" (Felder, 2010). It was also found that "instruction that matches a learner's learning style leads to greater learning than mismatched instruction" (Felder, 2010) and therefore instruction can be improved if learning styles could be taken into account.

The art of education is changed by the latest "technology in information systems." There is a "trend towards e-learning to access the information worldwide. It is important to use "adaptivity and personalisation of e-learning systems to support the learner's diversity and individual needs" (Özpalat & Akar, 2009) in order to obtain the most from these e-learning systems. Most of the existing studies achieve adaptive personalisation using learner/user modelling. As mentioned before, "a learner model can be described as a combination of personality factors, behavioural factors and knowledge factors" (Gu & Sumner, 2006). Additionally, as a part of personality factors, "learners have different learning styles; i.e. they learn in different ways" (Özpalat & Akar, 2009). It is generally agreed then that "learning involves building on prior experiences, which differ from learner to learner" (Dalgarno, 2001). Learners preferentially absorb and "process information in different ways: by seeing and hearing, reflecting and acting, reasoning logically and intuitively, analysing and visualising, steadily and in fits and starts. Teaching methods also vary. Some instructors lecture, others demonstrate or lead learners to self-discovery; some focus on principles and others on applications; some emphasise memory and others understanding" (Felder, 2007). Subsequently, "each learner should have a say in what they are to learn, different learning styles must be catered for and information must be presented within a context to give learners the opportunity to relate it to prior experience. It is generally agreed that the process of learning is an active one, so the emphasis should be on learner activity rather than on teacher instruction" (Dalgarno, 2001).

It is important for teachers to make every effort to balance of instructional methods, as opposed to trying to teach each learner exclusively according to his or her preferences. If the balance is achieved, "all learners will be taught partly in a manner they prefer, which leads to an increased comfort level and willingness to learn, and partly in a less preferred manner, which provides practice and feedback in ways of thinking and solving problems which they may not initially be comfortable with but which they will have to use to be fully effective professionals" (Felder, 2007). The ideal lesson, using the frameworks of teaching and learning presented here, would contain theory and its underlying meanings and frameworks to address the needs of intuitive learners, but also anchor this lesson to the real world, the physical, the concrete to accommodate the sensory learners in a class. It will be impossible for any teacher to teach according to the specific needs of every learner in the class. The most important thing for any teacher to remember is to have balance in his/her lessons, in other words, to develop him/herself to be able to address the needs of the different learners in the class. When a classroom practice is changed, it is important to assess this change by keeping the different learning styles in mind.

The use of ICS in Science teaching and learning could provide the learners with learning opportunities needed to improve their ability to learn Science and, at the same time, aid teachers in supplying the balance mentioned in the previous paragraph. For this reason, the use of ICS is the focus of this study. An ICS programme may "provide a realistic context in which learners can explore and experiment, with these explorations allowing the learners to construct their own mental model of the environment," (Rieber, 1992) thus accommodating the intuitive learners. At the same time the interactivity allows learners to see immediate results as they try out their theories about the concepts modelled thus accommodating the sensory learners. Some studies on the use of ICT in Science simulations have focused on the most difficult aspect of Science teaching, namely developing learners' conceptual understanding of difficult Science topics. McFarlane and Sakellariou (2002) argue that using ICT either as a tool or as a substitute for the laboratory-based elements of an investigation can aid theoretical conceptual understanding in some topics in the Science curriculum. Some experimental studies have shown that ICS can be as effective as the real activity in teaching Science concepts and improving scientific understanding across a variety of topics (Baxter & Preece, 2000; Huppert, Lomask & Lazarowitz, 2002; Trindade, Fiolhais & Almeida, 2002). Learners in ICT-supported Science classrooms also benefit from the instant feedback from experiments, as well as from the chance for more independent and self-directed learning (Baggott La Velle, McFarlane & Brawn, 2003).

Developing simulation pedagogies that maximise learner learning is another meaningful goal for Science education. Thus far, ICS research in Science education has been "informed largely by the information processing literature, and more recently by the socio-cultural literature" (Lindgren & Schwartz, 2009). By using interactive computer simulations, it not only changes the way knowledge is delivered to the learners, but also the way they absorb and retain the knowledge. Learners will become more active and they will be more creative participants in the educational process (Zajac, 2009). This implies that if the teacher then uses an interactive computer simulation as part of their Science teaching method, by connecting "prior knowledge and experiences", and new concepts in a "substantive non-verbatim way, this may lead to cognitive restructuring" as mentioned by Bransford et al. (1999) and meaningful learning in Science is more likely to take place.

This study considers an ICS that allows learners to "change some of the parameters in the computer program and observations are made of the results" (Blake & Scanlon, 2007), a strategy in line with the second form of simulation modelling mentioned previously. ICS's do not just serve as "mere animations to help learners visualise complex ideas; they are always interactive in that learners are presented with the ability to intervene in their execution by altering certain variables of the model, in run-time, and observe how they affect the behaviour of the simulated system" (Papadouris & Constantinou, 2009). In this way, learners become "acquainted with virtual experiments, which are in sharp contrast to passive observation of the execution of demonstrated experiments, and are a powerful tool for exploring, investigating, and interpreting natural phenomena" (Papadouris & Constantinou, 2009). Although research suggests a positive association between successful use of ICS and learner achievement, and a few studies reported on teaching practices with ICS, the topic remains virtually under-reported. For example, at the time of this research, in review of the Eric database for articles with the search terms "computer simulations", "physical science", "secondary" and "learning styles", the one article found was one where the topic dealt with "The different ways in which learners in lower secondary school (14-16 year olds) experience compound random events, presented to them in the form of combined junctions..."

In summary, there is evidence that "focusing on specific areas of difficulty in Science and addressing those with carefully designed ICT-based simulations can lead to productive learning" (Webb, 2008). However, sacrificing the hands-on aspect of learning Science is not without criticism. ICS as a tool for practical work completely remove any mechanical manipulation of equipment, thus eliminating experimental error. Sanitised data produced by simulations may serve to reinforce misconceptions (Osborne & Hennessy, 2003).

2.9 Conceptual Framework

The focus of this study is to find out *"What are the experiences of learners with different learning styles when an Interactive Computer Simulation (ICS) is used to aid teaching the photoelectric effect in a Science classroom?"* The FSLSM was chosen as a conceptual framework for this study, as it is a learning style model that is often used in technology-enhanced learning (Graf, Viola & Leo, 2007). According to Keefe (1979 cited in Felder & Spurlin, 2005) "learning styles are characteristic cognitive, affective and psychological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment." Felder and Spurlin (2005) feel strongly that while Keefe's definition can be used to characterise the learning style preferences that the Felder-Silverman model expresses and the ILS assesses, there are several "qualifying statements that are needed to clarify the intended use of the instrument and to guard against possible misuse."

- Learning style dimensions- such as the four dimensions of the Felder-Silverman model- are continuous and not either/or categories. "A learner's preference for one or the other pole of a given dimension may be mild, moderate or strong" (Felder & Spurlin, 2005).
- Learning style profiles suggest behavioural tendencies rather than being infallible predictors of behaviour. An example would be that "while the characteristics of sensors and intuitors are commonly presented as distinct and contradictory traits and behaviours, neither pure sensors

not pure intuitors can be found in nature: all sensors behave like intuitors in some situations and all intuitors sometimes behave like sensors" (Felder & Spurlin, 2005).

- Learning style preferences are not reliable indicators of learning strengths and weaknesses. For example: "The fact that a learner prefers sensing provides no sure measure of his or her skill at tasks with either sensing or intuition. However, the stronger the preference for a strength, the greater the likelihood" (Felder & Spurlin, 2005).
- Learning styles preferences can be exaggerated by a learner's educational experiences. If, for example, "a learner with a strong preference for sensing takes a well-taught course that provides guided practise in intuitive skills, the learner's comfort level with abstract conceptualisation might increase and the strength of his/her preference for sensing might decrease accordingly" (Felder & Spurlin, 2005).
- The point of identifying learning styles is not to label individual learners and modify instruction to fit their labels. "Some studies have shown that greater learning may occur when teaching styles match learning styles than when they are mismatched, but a strong case can be made against teaching exclusively to accommodate learning styles. To function effectively as professionals, learners will need skills associated with both categories of each learning style dimension. If they are never given practise in their less preferred categories, they will never develop the skills that correspond to those categories" (Felder & Spurlin, 2005).

2.9.1. The Felder-Silverman Learning Style Model (FSLSM)

The FSLSM identified four dimensions, namely the Perception Dimension; the Input Dimension; the Understanding Dimension and the Processing Dimension. These dimensions are subdivided into two learning styles per dimension: In the Perception Dimension we can distinguish between Sensing and Intuitive learners; in the Input Dimension we can distinguish between Visual and Verbal learners; in the Understanding Dimension we can distinguish between Global and Sequential learners and in the Processing Dimension we can distinguish between Active and Reflective learners (Felder & Silverman, 1988). The following is a description of the characteristics of each learning style in an identified dimension, to provide the framework needed to analyse the data.

The ***First Dimension*** identified in the FSLSM is the ***Perception Dimension*** (see Figure 12). This dimension focuses mainly on the question: What type of information does the learner *preferentially perceive?* Figure 12 highlights the most important characteristics of learners in the perception dimension and indicates the differences in the types of information absorbed by either sensory or intuitive learners:

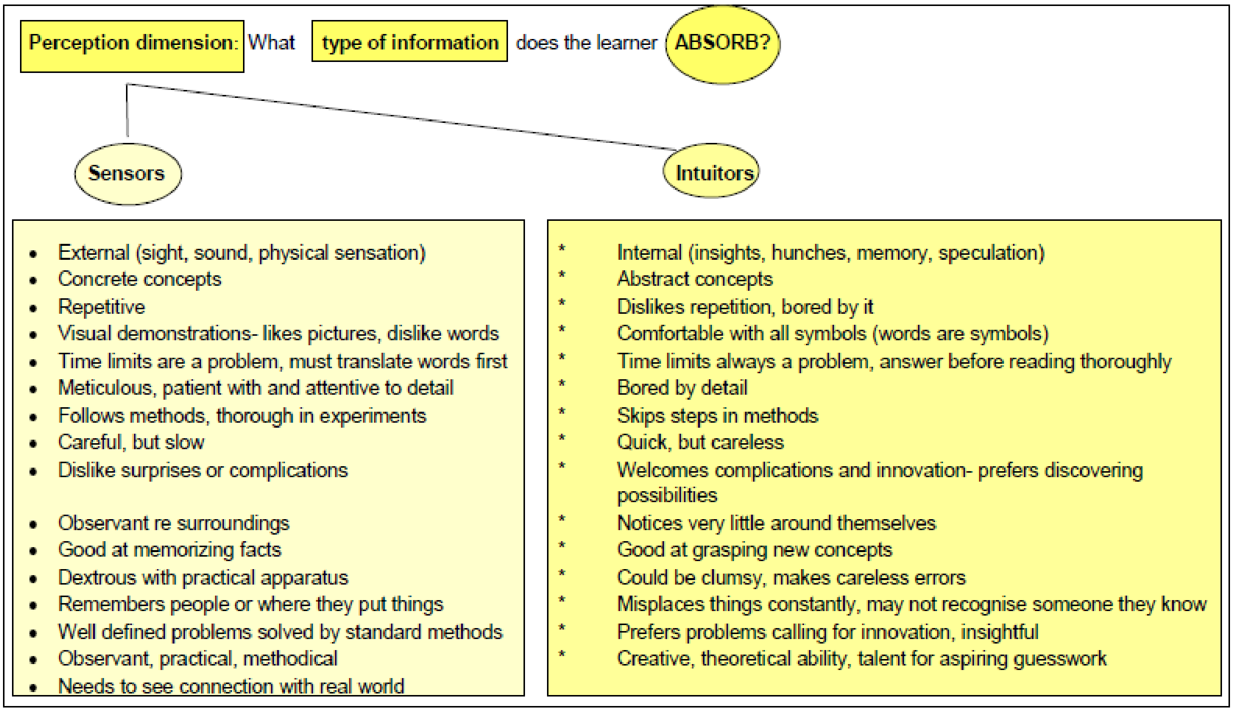

Figure 12: Summary of the most important features of learners in the Perception Dimension

(Adapted from Felder & Silverman, 1988, p. 676; Felder, 1993, p. 286; Felder et al., 2002, p. 1)

Figure 12 summarises the properties of sensing (S) and intuitive learners (I) (Felder & Silverman, 1988, p. 676; Felder, 1993, p. 286; Felder et al., 2002, p. 1). It also shows the possible comparison of the FSLSM with the MBTI: Sensory learners as indicated in FSLSM can be compared to Sensors as identified by using the MBTI and Intuitive learners as indicated in FSLSM can be compared to Intuitors as identified by using the MBTI. It is also a close relative of the Concrete versus Abstract dimension of Kolb's experiential model (Felder, 2010). This serves to indicate that there are overlaps possible between different models of learning styles.

Several features in Figure 12 can be related to the use of the PhET photoelectric ICS. The repetitive feature of the PhET ICS should appeal to sensory learners, as they would be able to replay the ICS as many times as they needed to, but an intuitive learner would find this boring. The visual aspect of the ICS is another feature of value to a sensory learner, because they prefer to see visual demonstrations of information which they need to take in. This visual feature also ties in with the detail visible in an ICS, as sensors need to see details. The microscopic view of the photoelectric effect will only be visible when using an ICS, as it is a diagram showing the learners the behaviour of photons and electrons. Sensory learners like solving problems by well-established methods and by following the instructions given to the learners when they are using the ICS, the information is effectively taken in by the learners (Litzinger et al., 2007).

Intuitive learners prefer to discover possibilities and relationships which means they would relate well to the use of the ICS. With the improved versions of this particular ICS, there are different options of the variables available in the task bars. A specific example of this from the ICS used in the study on the photoelectric effect is that the incident light can be seen as photons or as a beam of light. This feature would excite an innovative intuitive learner, but a cautious sensory learner would dislike the different option and see it as a "complication" (Litzinger et al., 2007).

The ***Second Dimension*** identified in the FSLSM is the ***Input Dimension*** and this dimension focuses mainly on the question: Through which *sensory organ* does the learner *receive external information* most effectively*?* Figure 13 is used to highlight characteristics of learners in the Input Dimension:

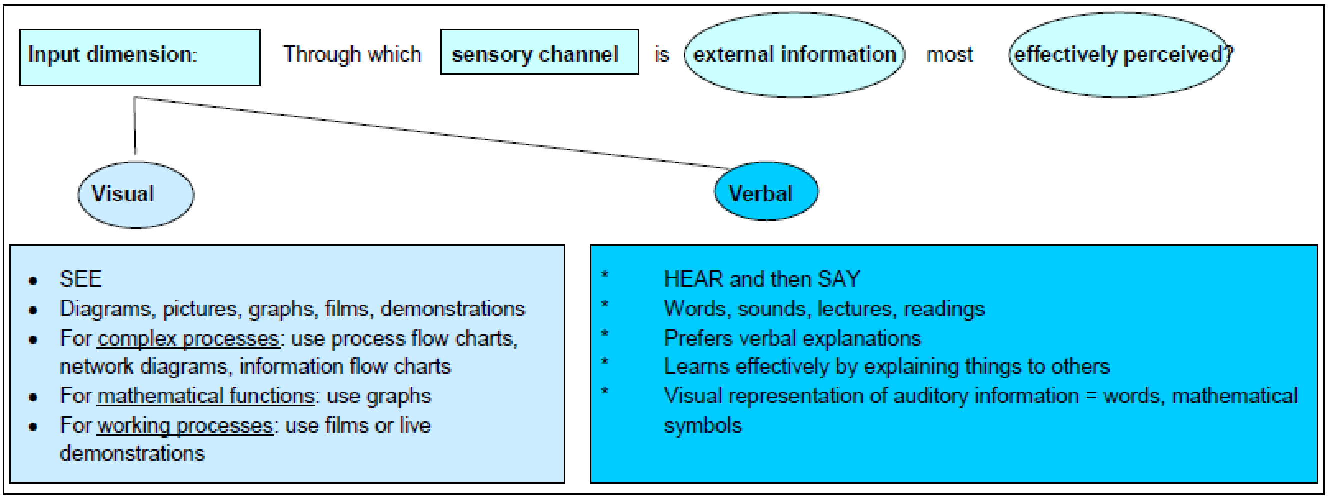

Figure 13: Summary of the most important features of learners in the Input Dimension

(Adapted from Felder & Silverman, 1988, p. 676; Felder, 1993, p. 286; Felder et al., 2002, p. 1)

Figure 13 depicts the properties of learners in the Second Dimension of the FSLSM, namely Visual (Vi) and Verbal (Ve) learners (Felder & Silverman, 1988, p. 676; Felder, 1993, p. 286; Felder et al., 2002, p. 1). This dimension deals with the sensory channel used most effectively to perceive external information, namely the eyes (visual) or the ears and mouth (auditory and verbal). Visual learners remember best what they see (diagrams, films and demonstrations). The PhET ICS on the photoelectric effect show moving particles which is visible when any specific variable is changed by the learner. The photoelectric effect is visually illustrated when the learner uses the ICS as a flow chart to explain the effect of changing the frequency of the incident light on a specific metal. The

ICS illustrates how the use of a different colour light on different types of metals changes the number of electrons released from the metal. The microscopically small photons and electrons (never visible in any macroscopic class experiment) are also visible. The visual learner can also identify the frequency of the light, by comparing the colour of the light used by him/her, to the frequency of light supplied in a chart given on the ICS. Visual learners could however form misconceptions when a clear image is presented to them, for example the electron and photon size could be confusing.

Verbal learners prefer to hear new information in the form of verbal explanations, readings or lectures. The words and sounds make sense to them when they hear it and then they will reinforce that information by explaining it to others. They prefer visual representation of auditory information in the words or mathematical symbol format. While verbal learners will enjoy explaining the ICS to aloud to themselves or a friend, they could become irritated with the noise level of other learners if they are working in the same area.

The ***Third Dimension*** identified in the FSLSM is the ***Understanding Dimension*** and this dimension focuses mainly on the question: How does the learner progress towards understanding*?* Figure 14 is used to highlight the most important characteristics of learners in the Understanding Dimension:

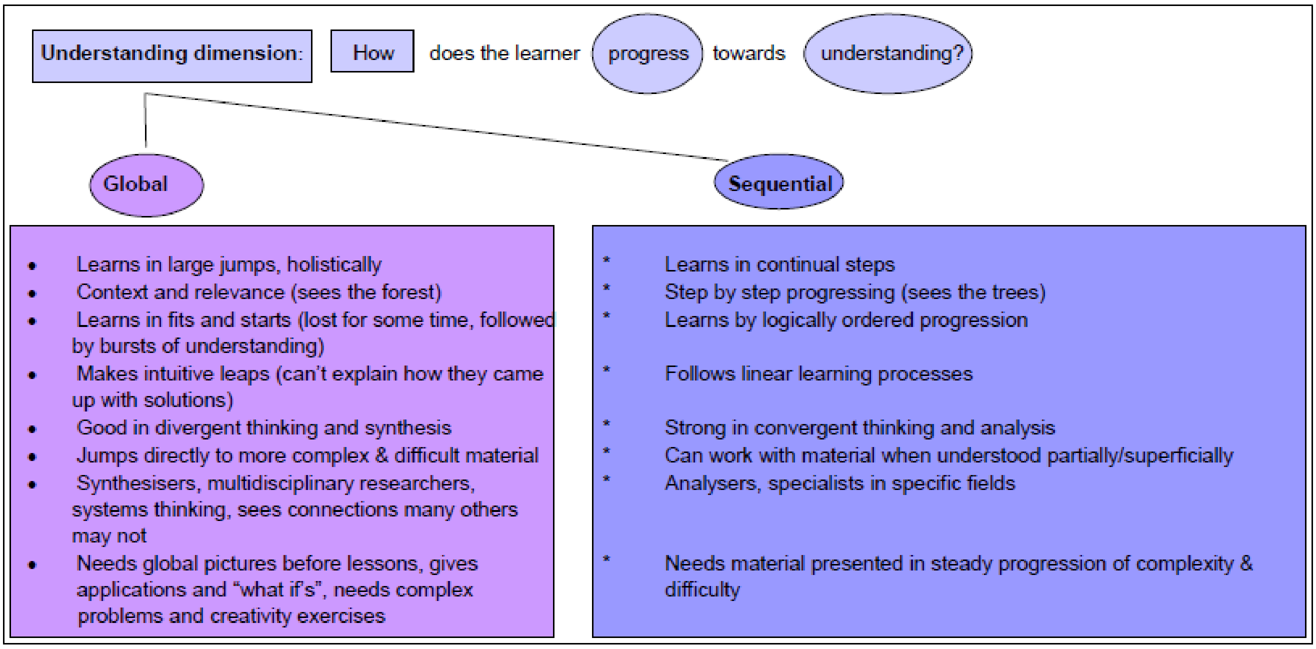

Figure 14: Summary of the most important features of learners in the Understanding Dimension.
(Adapted from Felder & Silverman, 1988, p. 676; Felder, 1993, p. 286; Felder et al., 2002, p. 1)

The Department of Education prescribes education in South Africa by curriculum documents and these are structured in a logically ordered progression. The "pace of learning is dictated by the clock and the calendar" (Felder & Silverman, 1988). Sequential learners (Q) can work with material when they "understand it superficially" and because they are "strong in convergent thinking and analysis", they will understand the new material as they follow the linear reasoning process. Sequential learners "learn best when material is presented in a steady progression of complexity and difficulty" (Felder & Silverman, 1988). Global learners (G) make intuitive leaps when they learn and they are good at divergent thinking. The ICS on the photoelectric effect could enable a global learner to learn in fits and starts, as they could restart or forward the process at any given time. Global learners could make intuitive leaps to understand the concept of the photoelectric effect, without having to go through the logical steps of the ICS as needed by a sequential learner. The global learners are the ones who would see the connections in the ICS which the sequential learners would not be able to.

The ***Fourth Dimension*** identified in the FSLSM is the ***Processing Dimension*** and this dimension focuses mainly on the question: How is information comprehended and converted into knowledge? Figure 15 is used to highlight the most important characteristics of learners in the Processing Dimension:

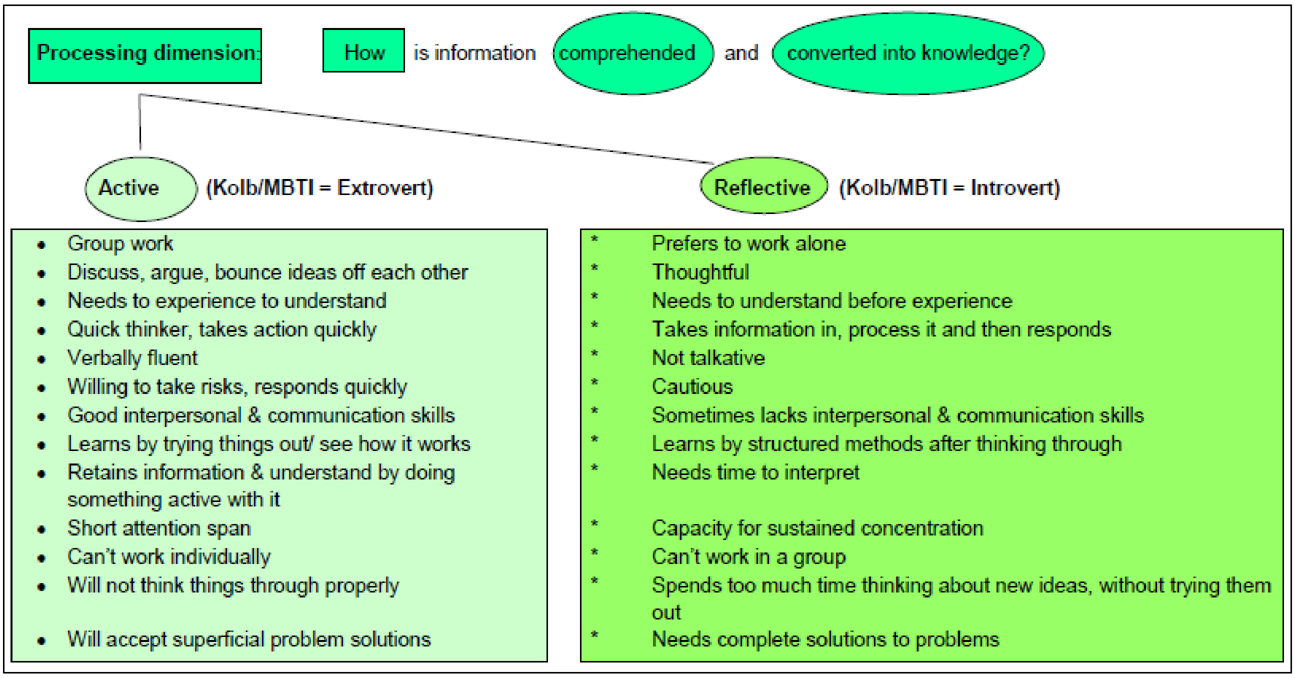

Figure 15: Summary of the most important features of learners in the Processing Dimension

(Adapted from Felder & Silverman, 1988, p. 676; Felder, 1993, p. 286; Felder et al., 2002, p. 1)

Figure 15 summarises the properties of active and reflective learners (Felder & Silverman, 1988, p. 676; Felder, 1993, p. 286; Felder et al., 2002, p. 1). It also compares the FSLSM with the MBTI: Active learners, as indicated in FSLSM, can be compared to Extrovert learners as identified by using the MBTI. Reflective learners, as indicated in FSLSM, can be compared to Introvert learners as identified by using the MBTI. Active learners learn the most in situations where they are actively involved and reflective learners "learn best in situations that provide them with an opportunity to think about the information" (Felder & Silverman, 1988). In an ICS environment active learners can change the variables of the ICS interactively. They can change these variables beyond the "safe" measures which would be expected in a normal class practical, as no harmful consequences are possible.

The characteristics indicated in Figures 12 to 15 were used as a conceptual framework for this study. The conceptual framework enables the comparison of the experiences of learners with different learning styles when an Interactive Computer Simulation (ICS) is used to aid teaching the photoelectric effect in a Science classroom. Once the different learning styles are identified, it is important to accommodate the diverse learning types. Potential learning style/teaching style mismatches in the classroom must be addressed. To help sensing and intuitive learners, instructors need to balance the teaching of concrete and conceptual information. To accommodate visual and verbal learners, "process flow charts, network diagrams and logic flow diagrams should be used to" (Harvey et al., 2011) accompany oral and written explanations. To help active and reflective learners, instructors should enable them both to participate and to think about material being presented. Finally, to help sequential and global learners, instructors should demonstrate a logical flow of individual course topics and point out connections between current material and other relevant material (Harvey et al., 2011).

The "optimal teaching style is a balanced one in which all learners are sometimes taught in a manner their learning style preferences, so that they are not too uncomfortable to learn effectively, and sometimes in the opposite manner, so they are forced to stretch and grow in directions they might be inclined to avoid if given the option" (Felder & Spurlin, 2005). It is important to keep in mind, as pointed out earlier in this chapter, that "learning styles (as measured with the ILS or any other instrument) should not be used to predict academic performance or draw inferences about what learners are or are not capable of doing. Learning styles reflect preferences and tendencies; they are not infallible indicators of strengths or weaknesses in either the preferred or the less preferred categories of a dimension" (Felder & Spurlin, 2005). There is a specific need then to identify how the different learning types experience computer simulations because, as pointed out earlier (Section 2.8, p. 41), there are several capabilities from simulations that cannot be demonstrated or used to learn from when using traditional teaching methods.

CHAPTER 3

Research Methodology

3.1 Introduction

This chapter provides a description of the methodology used in this study. A considerable degree of inconsistency regarding research terminology exists in the literature (Mackenzie & Knipe, 2006). I will use Kothari's (2006) definition of *research methodology* as the multi-dimensional science of research that encompasses the philosophical assumptions underpinning the research, the rationale for conducting the research, the statement of purpose, the research questions pertaining to the study, the sampling and collection of the data, the nature of the data, data analysis and the ultimate research report. In my attempt to understand the phenomena being studied, I will firstly discuss my research paradigm and assumptions as the lenses through which I view the world. Certain aspects which is included in Kothari's definition has already been discussed in the following sections: The rationale for conducting the research (see Section 1.2, p. 4) the statement of purpose (see Section 1.3, p.5) and the research question (see Section 1.4, p.6) relevant to this study are discussed in Chapter 1, while the conceptual framework is presented in Chapter 2 (see Section 2.9, p.44). The *research design*, as described in this chapter includes the sampling criteria and process, the collection and the nature of the data, the approach to data analysis, the quality criteria, the ethical considerations, the scope and delimitations of the study.

3.2 Research paradigm

Personal philosophical assumptions influence a researcher's stance towards the "nature of reality, how a researcher knows what s/he knows, the role of values in the research, the language of the research, and the methods chosen in the research process" (Creswell, 2005). Mackenzie and Knipe (2006) explain that it is important to start off by discussing the research paradigm as a start to the rest of this chapter: "Without nominating a paradigm as the first step, there is no basis for subsequent choices regarding methodology, methods, literature or research design". Nieuwenhuis (2007 a, p. 47-48) defines a paradigm as: "A set of assumptions or beliefs about fundamental aspects of reality which gives rise to a particular "worldview" – it addresses fundamental assumptions taken on faith, such as beliefs about the nature of reality (ontology), the relationship between knower and known (epistemology) and assumptions about methodologies". Creswell (2009) adopted the term "worldview" rather than paradigm to define the basic set of beliefs that guide the research. It defines the general orientation of the researcher towards worldviews and the nature of the research that the author of the research holds. Creswell also suggests four possible worldviews: positivism, constructivism, advocacy and (particularly) pragmatism.

I came to this study with a set of beliefs, assumptions, and perspectives about the nature of teaching and learning, particularly of Science, and the use in Science teaching of computer simulations, all of which influenced what I chose to study, the research design, and data collection methods. My perspectives on teaching and learning and Science education developed through many years of teaching. These perspectives were sharpened by following debates in the literature on learning from the works of Bransford et al (1999). My selection of research methods for data collection and data analysis springs from my worldview. A worldview includes certain categories of assumptions. The first assumption is ontological assumptions which concern "the very nature or essence of the social phenomena being investigated" (Cohen et al., 2007). Secondly, epistemological assumptions are those which are "related to the nature, the acquisition and the transferral of knowledge and the relationship between the knower and what can be known" (Nieuwenhuis, 2007 a).

3.2.1 Ontology

Qualitative researchers tend to follow the constructivist cue that reality is a social construction. It accepts that the researcher cannot be separated from the research and it asserts that research findings are created rather than discovered. Truth is therefore not an "objective phenomenon that exists independently of the researcher" (Nieuwenhuis, 2007 a). During the periods of fieldwork, I observed the participating learners' constructions of reality, how they understood their worlds. Their realities were independent from mine, as researcher or observer. I constructed knowledge, which could only be partial, relevant to the participants' realities through the subjective interpretation of their discourses and actions. The internal and subjective experiences and realities of the participants is central to this study. The nature of my study is subjective as I was personally involved in the process of making sense of the uniqueness of the situation being studied. I hold the nominalist position as ontological assumption where I created reality in my mind and regard reality as the product of individual consciousness.

3.2.2 Epistemology

Whereas "ontological assumptions concern the nature of reality, epistemology relates to how things can be known- how truths or facts or physical laws, if they do exist, can be discovered and disclosed" or, (Nieuwenhuis, 2007 a) - in other words, it refers to a set of questions about knowledge. It "looks at how one knows the reality, the method for knowing the nature of reality, or how one comes to know reality- it assumes a relationship between the knower and the known" (Nieuwenhuis, 2007 a). The involvement and the collaboration of the participating learners were instrumental in this investigative process of constructing knowledge. The construction of partial and subjective knowledge, through discussion and compromise, was an attempt to explore the experiences of the learners with different learning styles. My epistemological assumptions concerning the nature of knowledge are that knowledge is constructed socially and are therefore subjective. There was an interactive "relationship between me (the researcher) and the participants, as well as between the participants and their own experiences and how they constructed reality based on those experiences" (Ernest, 1997). These experiences were biased and subjective, but qualitative research accepts them for those who have lived through the experiences. These experiences of the respondents were the medium through which I could explore and understand reality. My understanding of the educational phenomenon was subjective and was gained through the perspectives of the participating learners who were involved in the phenomenon. Such knowledge is incomplete and tentative.

3.2.3 Research methodology

Cohen et al. (2007) says that "methods are a range of approaches used in educational research to gather data which are to be used as a basis for inference and interpretation." This study is a qualitative case study. As a qualitative researcher I seek "to gain better understanding of intentionality (from the speech response of the respondent) and meaning (why did this person/group say something and what did it mean to them?)" … "to describe and to understand, rather than to explain and predict" (Babbie & Mouton, 2001 p. 49). Hogan et al. (2009 p. 4) points out that "qualitative research is about researching specific meanings, emotions and practices that emerge through the interactions and interdependencies between people." Similarly White (2005) emphasises that "qualitative research is concerned with conditions or relationships that exist, beliefs and attitudes that are held, effects that are being felt and trends that are developed." Qualitative research also provides "opportunities for marginalised groups to voice their opinions on matters that are of concern to them and which may have been overlooked in conventional research."

3.3 Background

The research site was a secondary school in Mpumalanga and the research took place during the third quarter (July and August) of 2011. The section of school content covered for the purposes of collecting the research data was the photoelectric effect as described by the grade 12 Subject Assessment Guidelines for Physical Sciences (DoE, 2011, p.15). Table 2 shows an excerpt from the Subject Assessment Guidelines (SAGS) (DoE, 2012, p. 26-29). This document is used as a guideline by all teachers in schools who write the Independent Examination Board (IEB) Grade 12 exams; and states the learning outcomes and goals expected from the learners, once this section of their syllabus is covered. The section preceding this was on the electromagnetic spectrum and served as an introduction to the photoelectric effect.

Table 2: Excerpt from Subject Assessment Guidelines for Physical Sciences (DoE, 2012, p. 26)

MATTER AND MATERIALS	
Optical phenomena and properties of materials:	Learners must be able to:
Photoelectric effect.	• Describe the photoelectric effect as the process that occurs when light shines on the surface of a metal and electrons are emitted. • Explain that monochromatic light is made up of photons, each of energy $E = hf$. • Explain why electrons are not emitted from a metal when the monochromatic light is below the threshold frequency (work function) for that metal. • Use the relationship: Work function $W_\ell = hf_{threshold}$ to predict whether electrons will be emitted from a metal. • Explain why the intensity of light does not affect the maximum kinetic energy of the emitted electrons (photoelectrons). • Make use of Einstein's equation: $hf = W_\ell + ½ mv^2$. • Relate the intensity of light to the number of photoelectrons emitted per second. • State and explain the significance of the photo-electric effect: - it establishes the quantum theory - it illustrates the particle nature of light

The interactive simulation used in this study was a PhET simulation that was developed by the University of Colorado. This simulation about the photoelectric effect involves the movement of electrons and photons of light, which is not visible with the naked eye. However, these particles are visible in the PhET simulation. The simulation is interactive, as the learner controls the frequency and the intensity of the light, and can then record the effect caused by the photoelectric effect itself.

The teacher introduced the photoelectric effect as stated in the SAGS document as *"the process that occurs when light of a particular frequency shines on the surface of a metal and electrons are emitted"* (DoE, 2012) and illustrated this process with a macroscopic experiment, as in Figure 16.

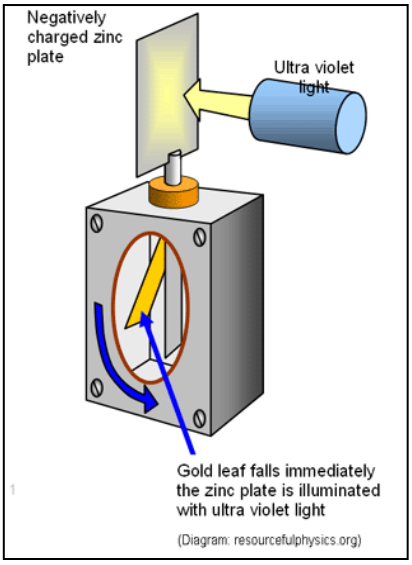

Figure 16: Example of equipment used to demonstrate photoelectric effect macroscopically

As shown in Figure 16, the teacher used the macroscopic experiment to demonstrate the photoelectric effect to the learners by using an ultraviolet light and a filament tube white light (not visible in the figure). A negatively charged zinc plate is attached to the electroscope and the learners can see that the gold leaf will only drop when the UV light strikes the zinc plate, not when the white light is shone on the zinc plate (Institute of Physics, 2012). This demonstration was then supplemented by allowing the learners to do the PhET ICS. Instructions on how to use the ICS were then handed out to each learner (see appendix E). The learners were given some time to familiarise themselves with the ICS and the variables involved, as shown in Figure 17:

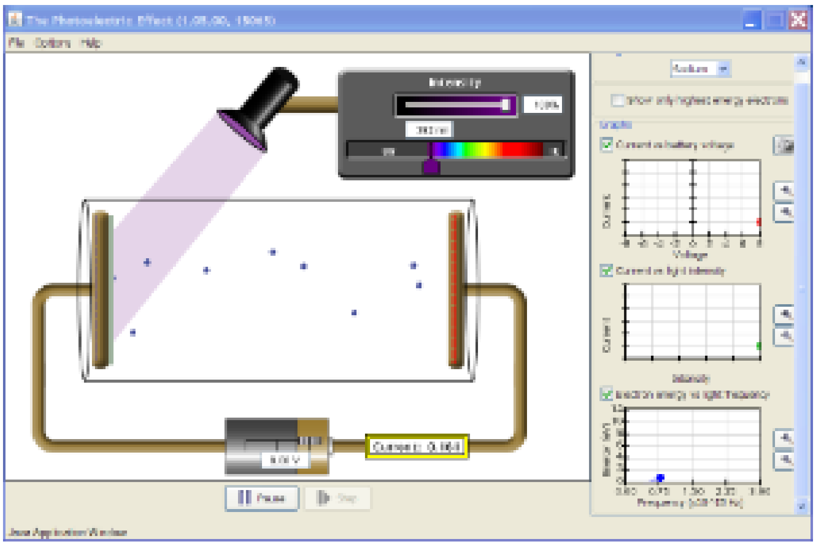

Figure 17: Photoelectric effect (PhET)

The simulation shows a light shining on a metal plate, (on the left hand side of the sketch) which forms one half of a cell. The other half of the cell is indicated with another metal plate (on the right hand side of the sketch). The circuit is complete as soon as electrons leave the illuminated plate and move to the other side of the cell (University of Colorado, 2011). The first instruction on the worksheet (Appendix E) told the learners to select sodium as a metal. Figure 18 illustrates the next instruction for the learners which was to set the intensity of the light at 10%: As soon as the violet light intensity is increased above 0, electrons leave the illuminated plate.

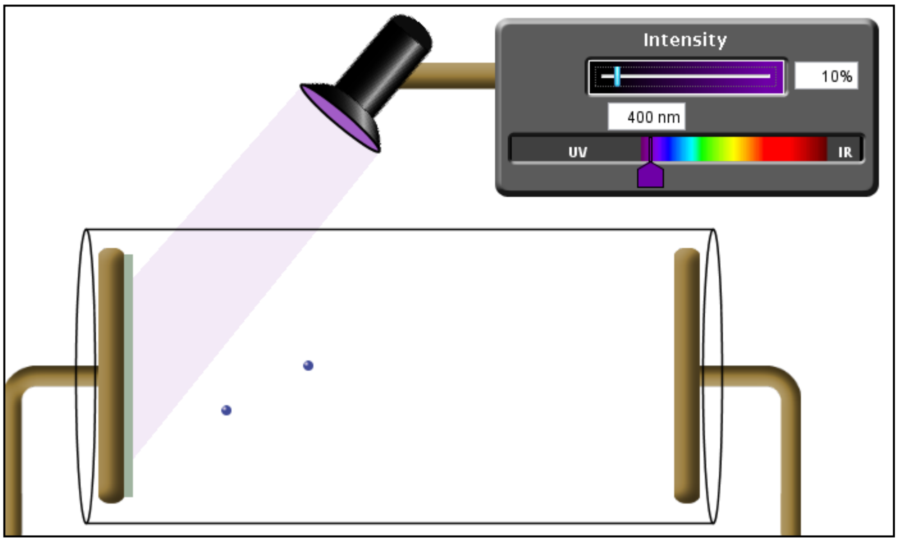

Figure 18: Setting the light intensity on 10%

The learners were then instructed to move the wavelength bar slowly towards lower wavelengths in increments of 50 nm and write down everything that they observed. Other helpful hints were given in computer task bar, but it was not specifically pointed out to the learners to use the drop-down menus. This was done on purpose so that some of the learners could experience "discovering" something "new" in the ICS. Research has shown that learners rarely look in the options menu (Adams 2008 cited in McKagan et al., 2009). In this option menu the light released could take the form of ordinary light rays or the actual photons in the beam of light could be made visible, depending on what the learner selected in the options drop-down menu.

3.4 Research design

A research design is a "plan or strategy which moves from the underlying philosophical assumptions to specifying the selection of respondent, the data gathering techniques to be used and the data analysis to be done" (Cohen et al., 2007). This design was influenced by the main research question:

"What are the experiences of learners with different learning styles when an Interactive Computer Simulation (ICS) is used to aid teaching the photoelectric effect in a Science classroom?"

This is an exploratory case study where the focus of the study has already been decided on and explained in the conceptual framework. A case study can be defined as a unit of analysis such as an individual or work team, where each case studied has a set of inter-relationships within it which both bind it together and shape it, but also relationships which interact with the world (Edwards & Talbot, 1999). According to Nisbet and Watt (1984 cited in Cohen et al., 2007) "a case study can enable readers to understand how ideas and abstract principles can fit together and it can penetrate situations in ways that are not always susceptible to numerical analysis." Sturman (1999 cited in Cohen et al., 2007) argues that "a distinguishing feature of case studies is that human systems have a wholeness or integrity to them rather than being a loose connection of traits, necessitating in-depth investigation." The focus is the case itself and its own very particular features, which was then used to examine complex phenomena (Edwards & Talbot, 1999 p. 53). The Science learners with different learning styles are regarded as the 'unit' that is studied in order to explore their experiences when a computer simulation is used. The research was done in two phases. In the first phase the learners completed the Index of Learning Styles (ILS) online questionnaire to find the learning styles of the learners involved in the study. The online data from the ILS was used to contribute to a landscape view of each learner's learning styles. The second phase involved in-depth exploration of each learner's experiences of the PhET photoelectric ICS. I visited the classrooms; spoke to the learners and listened to their stories about how they have experienced the use of the ICS. It is important to mention that I helped the teacher to understand and use the PhET photoelectric effect ICS beforehand. The teacher showed the learners a PowerPoint presentation (designed by the researcher - Appendix C) on the electromagnetic spectrum, followed by a worksheet (designed by the researcher Appendix D) to test prior knowledge of the learners. In the next lesson, the learners received feedback on their worksheet answers and the teacher continued with the next part of the PowerPoint presentation which introduced the photoelectric effect.

Phase 1: Identification of Learning Styles

The aim of the first phase was to describe the learning style of each learner and to identify "characteristics of each of the four dimensions of the FSLSM in order to make a distinction within the learning style dimensions. I also analysed how representative each trait is for each learning style dimension" (Graf, Viola & Leo, 2007). Such detail is useful in many ways. In general, "a more detailed description of learning styles leads to a more precise model of the learner," (Graf, Viola & Leo, 2007). This allows for a thorough research about learning styles, but at the same time also helps to give more appropriate adaptivity. If, for example, the ICS only partially supports a learning style, "this has to be considered when analysing the output of the system and when drawing conclusions. When using information about learning styles to provide adaptivity, a detailed description of learning styles can improve the adaptation process". If a system supports only some of the characteristics of a learning style, "then a learner model that includes information about exactly these characteristics is needed to provide suitable adaptivity rather than using information about the overall learning style" (Graf, Viola & Leo, 2007). Another example for the use of such detailed information about learning styles is the derivation of learning styles from the behaviour of learners during an online activity, such as using the ICS. It should be noted that "not all characteristic behaviour described in a learning style model can be plotted as well identified from the behaviour in a specific learning system" (Graf, Viola & Leo, 2007). This means that "the patterns which identify specific preferences for learning styles are adapted to the features of the systems. When identifying the learning style, it is important to know which characteristics can be plotted and identified, and which cannot. Being aware of the characteristics and their relevance for the learning style leads to a better estimation of the results of the approach and hence, to a more meaningful application of the identified information" (Graf, Viola & Leo, 2007).

Phase 2: In-depth exploration of the learner's experiences

In the second phase, during the data collection period, I was on a sabbatical period of three months and the learners were exposed to a substitute teacher. I attended the contact sessions as an observer; I immersed myself in the research situation created in the classroom and became part of the observation. My role as interviewer was an interactive one during the process of knowledge construction. My central character and personal history were important elements in the research process. Although personal bias was a concern as I was also teaching these learners prior to my data collection period, these personal experiences were contributing to the uniqueness of this research account. Nieuwenhuis (2007 a) mentions that "the researcher's involvement and immersion in the changing, real world situation is essential since the qualitative researcher needs to record those changes in the real-life context (sometimes before, during and after the change occurs)", which is exactly what I have done.

3.4.1 Sample

Qualitative research is "based on non-probability and purposive sampling" (Nieuwenhuis, 2007 a). Purposive sampling means that "participants are selected because of some defining characteristics that made them the holders of the data needed for the study" (Nieuwenhuis, 2007 a). There were forty nine initial participants (Grade 12 Science learners who completed the ILS questionnaire), but this was narrowed down to seventeen participants to be purposively selected and then interviewed. The seventeen participants were selected because they were representative on all the scales of all the different dimensions of the FSLSM. The criteria used to select these seventeen learners included: different learning styles with high readings on the scale to indicate a strong preference for that learning style; different learning styles with low readings on the scale to indicate a weak preference for that learning style; different genders; different races; different ages; different home languages; different computer proficiency abilities and learners that would not be influenced in my personal capacity. The "sampling decisions were therefore made for the explicit purpose of obtaining the richest possible source of information to answer the research question" (Nieuwenhuis, 2007 a). My rationale for using the Grade 12 learners in my study is that I was familiar with the content of the PhET simulation and that the photoelectric section formed part of their syllabus. My study did not therefore interfere with their grade 12 year at all.

3.4.2 Data Collection Strategies

The data collection took place in different phases. The first phase was to collect data to describe the learning style of each learner and the second phase involved interviews, observations, and document analyses to gain a better understanding of the learner's experiences. I observed three Grade 12 Science lessons on the photoelectric effect. An interview was conducted with each of the seventeen participants prior to using the simulation and this was followed by an interview soon after they used the simulation. The duration of the interview prior to the observations was approximately half an hour each and was conducted during the period or break before the specific lesson (and in some cases the afternoon before). The first interviews were based on the general feeling of the learners about Science, what they thought the photoelectric effect was and to establish what they knew (or thought they knew) in general about Computer Simulations.

ILS (Index of Learning Styles) questionnaire

To assess the learning style with the Felder-Silverman model, the Index of Learning Styles (ILS) was used as an instrument. This is a "forty-four item, force-choice questionnaire developed in 1991 by Richard Felder and Barbara Solomon to assess preferences on the four dimensions of the FSLSM" (Őzpalat & Akar, 2009). The Index of Learning Styles (ILS) provides "metrics for all but the Intuitive-Deductive dimension, with scores showing the strength of an individual's preference for the indicated continuum. Individual learners have relative preferences along each of the four choices but can learn to function in the other direction" (Őzpalat & Akar, 2009). The completion of the ILS questionnaire was done electronically in the computer centre of the school, by following the link from the website. The ILS is available "at no cost to learners and faculty at educational institutions to use for non-commercial purposes. The commercial rights are held by North Carolina State University which has decided to provide open access to the web-based instrument and so have voluntarily relinquished control over its use. When the learners checked answers to all 44 items on the questionnaire and clicked on "Submit," their learning style profile was immediately returned with scores on all four dimensions, brief explanations of their meaning, and links to references that provide more detail about how the scores should or should not be interpreted." (Felder, 1988). This learning style profile was then used to identify the different types of learners, so that the researcher would know how that specific learner absorbs and process information, how that learner will respond to instruction and what his/her experiences would be when the interactive simulation is used.

Interviews

Interview schedules were used to interview the seventeen learners (Appendix H) before using the simulation. Open ended and semi-structured interviews were conducted as this gave direct indications of the experiences of the respondents and the semi-structured interviews were used to probe the initial responses. These questions were mainly to obtain background information on their prior experiences with computers in general, how they experienced Physical Science in general, what their concerns were about using the simulation and any suggestions that they might have **before** the simulation was used. The group was then interviewed directly **after** the simulation was used (see Appendix I for interview schedule). These questions focused mainly on their experiences by using the simulation itself, for example: did the simulation help them to understand the concept and which part of the simulation did they enjoy most. All interviews were audio-taped or digitally recorded and these recordings were transcribed verbatim and coded afterwards by me. The challenge was to integrate the findings from the observations and interviews to make sense of the reality and the complexity of the phenomenon, in other words to determine the relationship between learners' learning style and their experiences when using the computer simulation.

Observations

Classroom observations are essential since lesson preparations can provide direction to a lesson, but can never predict exactly what will happen in class, as learners' participation, contribution and interaction with the content, teacher and peers allow for that dynamic aspect in class from which valuable data can be collected (Nieuwenhuis, 2007 a). Observation data was used by the researcher to enrich the interview data obtained. The use of observations and interviews as data collection techniques improve the quality of this study's data and increase the trustworthiness of the study. The main focus of the observation data was to determine whether all the learners were actively engaged in the use of the ICS and how they reacted with the ICS and with each other. Cohen et al. (2005, p. 185) believe that

> ...case studies are typified by observations as the purpose of observations is to probe deeply and to analyse intensively the multifarious phenomena that constitute the life cycle of the unit with a view to establishing generalisations about the wider population to which that unit belongs...

The type of observation I used was that of the observer as participant, "not directly influencing the teaching process in the class situation" (Nieuwenhuis, 2007 a). I was seated in the classroom before the class arrived, so that I could observe everything that happened from start to finish for the duration of the lessons in the three different classes. The learners were observed for a period of one week, or 7 teaching periods per class; when the teacher tested their pre-knowledge, when she introduced the new topic, when the teacher explained the reason for using the ILS and gave instructions to the learners on how to use the ILS and find their results, when she explains how and where to find the simulation on the World Wide Web (www), during the use of the simulation and the discussion with the three classes after using the simulation. I used an observation schedule (see Appendix G) and field notes to record my observations. This gave me an understanding of the verbal and non-verbal communication involved, as well as giving an overall impression of the situation. Field notes were made regarding any unexpected valuable data that had emerged.

Worksheets

Existing worksheets from the PhET website were adapted and used to test the learners' knowledge and understanding of the photoelectric effect. The learners' written assessment tasks were useful and important as a source of data to the researcher. By looking at these sources, I could alter the questions in the semi-structured interviews. Data collected from documentation were used to substantiate the results obtained from data obtained from other sources. The first worksheet (Appendix E) explains how to use and access the PhET photoelectric effect simulation and make provision for answering questions whilst manipulating the simulation. This worksheet was mostly content-based and consisted of tables where the learner had to fill in values which changed as the learner manipulated various variables in the ICS. In the next lesson, this worksheet was marked by the learners themselves and discussed by the teacher and the learners. Another worksheet (Appendix F) was used to test their knowledge after using the simulation. This worksheet was used to see if the learners could *apply* their knowledge of the photoelectric effect. This worksheet contained summative types of questions where the learner had to calculate certain values by applying their knowledge.

3.4.3 Data Analysis

The Index of Learning Styles (ILS) is a 44-question instrument designed to assess preferences on the four dimensions of the Felder-Silverman model. "When someone submits a completed ILS questionnaire on-line, a profile is immediately returned with scores on all four dimensions, brief explanations of their meaning, and links to references that provide more detail about how the scores should and should not be interpreted" (Felder & Spurlin, 2005). Appendix B has an example of the results received by a learner. Several tables containing these results were drawn up and relevant graphs of the results drawn. "Scoring is 1, 3, 5, 7, 9, and 11, with 1 and 3 showing a balance along the continuum, 5 and 7 showing a moderate preference for one end of the continuum, and 9 and 11 a strong preference for one end or the other" (Felder & Spurlin, 2005).

The document data which I collected gave me and the learners an indication of the level of understanding about the topic by each learner. This was then compared to the experiences of the learner as identified during the interviews (before and after using the simulation). The interviews were tape-and digitally recorded and then transcribed. According to Cohen et al. (2005) data analysis "*involves organising, accounting for, and explaining the data; in short, making sense of the data..., noting patterns, themes, categories and regularities"* (p. 147). They further suggest that early analysis will reduce the problem of data overload as huge volumes of data rapidly accumulate in qualitative research. It is important in qualitative analysis to be able to reduce copious amounts of written data to manageable and comprehensive proportions (Cohen et al., 2007). Therefore it was important to reduce the data in such a way that the quality of the data will not be lost. This process is known as content analysis (summarising and reporting the written data). I made use of ATLAS.ti software to assist me in this process. Inductive analysis was done where I studied the organised data in order to explore undiscovered patterns and emergent understandings. Through inductive analysis I "*allowed research findings to emerge from the frequent, dominant or significant themes inherent in the raw data"* (Nieuwenhuis, 2007 a). New patterns, themes and categories in the data were discovered which contributed towards possible implications for teacher training and theory building. The inductive approach allows for correlating the study's purpose with the findings. I therefore classified the many words in the text into fewer categories. Some of these categories were derived from areas of interest in advance of the analysis (rather than developed from the material itself) and others emerged from the data during the analysis. For this purpose I have been guided by Cohen et al.'s (2007, p. 148) seven-step analytic strategy. The purpose is to move from thematically describing the cases to explaining the phenomena to eventually generating theory:

- **Step 1**: Establish units of analysis of the data, indicating how they are similar and different- ascribing codes to the data. The units of analysis were defined as different levels of analysis and this raised different issues of reliability: the coding unit defined the smallest element of material that could be analysed; the contextual unit defined the largest textual unit that could have appeared in a single category. There are three kinds of units namely: "sampling units which are units of selection" (Cohen et al., 2007), recording /coding units which are units of description and "context units which are units of textual matter that set limits on the information to be considered in the description of the recording units" (Cohen et al., 2007). I then decided on the codes to be used in the analysis "(codes should be kept as discrete as possible- read and reread the data to become familiar with them, noting interesting patterns)" (Cohen et al., 2007) and then constructed the categories for analysis which are key features of the text, showing links between units of analysis (Cohen et al., 2007). The coding was then conducted, this "means the translation of question responses and respondent information to specific categories for the purpose of analysis" (Cohen et al., 2007) and the data was categorised.
- **Step 2**: *Create a domain analysis* – dividing my data into groups, patterns and themes according to my conceptual framework. The data analysis was then conducted by making use of ATLAS.ti software. In the data analysis the frequency of each code in the text was counted and this provided an indication of the significance of the code. By writing a summary of the main features to identify key factors, key issues/key concepts and key areas for subsequent investigation were the preliminary stage of theory generation (Cohen et al., 2007).
- **Step 3**: *Writing a case study narrative* – giving a description of each case, thus providing the reader with *all the information needed to understand the case in all its uniqueness* (Patton 2002, p. 450).
- **Step 4**: *Establish relationships and linkages between the domains.* The data were put in context by establishing relationships and links between the domains and also between the sets of data from the observations and interviews. This was done by *identifying confirming cases, by seeking 'underlying associations' and connections between data subsets.*
- **Step 5**: *Making speculative inferences.* From the analysis I could draw certain conclusions and could consider the implications of those findings for teacher training. Speculative

inferences means the researcher posits some explanation for the situation, some key elements and possibly even their causes (Cohen et al., 2007).

- **Step 6**: *Summarising* – reporting on the main features of the research so far indicating the major themes, issues and problems that have arisen from the data, also identifying negative cases and cases with discrepancies.
- **Step 7**: *Theory generation.* Generating a theory that is grounded in the data and that emerges from it. All audio data was transcribed verbatim to text data immediately after the data was collected. Following the transcribing process, I coded the transcriptions by using ATLAS.ti 6 which allows for codes to be easily accessed, sorted and merged. My transcripts are synchronised with associated files in order to jump from a particular part in the transcript to the original recording.

The generation of the themes was partly inductive, arising from groups of codes that I as the researcher was able to anticipate as a result of the review of the literature, and part deductive, arising from groups of codes that I was unable to anticipate. Together, these themes formed the basis for my interpretation of the interview data to answer the research question. I have used my written field notes to add to my themes which emerged from the interviews, which confirmed (or dispelled) what the interviews have revealed.

3.4.4 Quality Criteria

To conform to the quality assurance criteria for qualitative research, I considered aspects such as the trustworthiness, validity and reliability of my study and the ISL instrument used and also bore in mind the Hawthorne and Halo effect. Nieuwenhuis (2007 a) uses the term trustworthiness and states that “when qualitative researchers speak of research ‘validity and reliability’ they are usually referring to research that is credible and trustworthy” (p. 80). Being aware of the use of different terminology (trustworthiness, validity and reliability) by different researchers, I use the terms interchangeably as all these terms are referring to valuable aspects of quality assurance applicable to my qualitative study.

An inquiry of this nature should guard against presenting a one-sided view of a particular phenomenon. This was avoided by ensuring triangulation in data collection. Triangulation, a term originally drawn from naval military science, is now applied to research and “allows researchers to improve their inquiries by collecting and integrating different kinds of data which have bearing on the same phenomenon” (Creswell 2002 cited in Draper, 2010). Collecting survey interview, observation, field notes, and documenting data allowed me to combine the strengths of one kind of data collection method to counterbalance the weaknesses of another. By using multiple data collection strategies such as multiple observations and interviews, the researcher as data gathering instrument, enhances the trustworthiness of the study. I also acquired the services of a peer researcher with ten years of experience to assist me with the coding and interpretation of the data to further enhance trustworthiness.

Reliability refers to the "*consistency and re-applicability over time, over instruments and over groups of respondents; it is concerned with precision and accuracy"* (Cohen et al. 2005, p. 117). I made use of the ISL questionnaire to determine the learning style of my respondents. The validity of the ILS questionnaire is discussed in a paper published in 2005 by Felder and Spurlin with the title *"Applications, Reliability and Validity of the Index of Learning Styles".* A brief discussion of the history of the development of the current ILS as discussed in this paper follows*:*

An initial version of The Index of Learning Styles (ILS) (p. 60) was created in 1991to be used to identify the preferences of learners on the four dimensions of the Felder-Silverman model. However, in 1994 a factor analysis was conducted on hundreds of sets of responses to Version I which were collected. Items that did not load significantly on single factors were discarded and replaced by new items to create the current version. A hard copy version of the ILS was put on the World Wide Web (www) in 1996 and in 1997 an on-line interactive version was added (Felder & Spurlin, 2005). This is the present version used. Response data for the ILS have been collected in a number of studies (Felder & Spurlin, 2005 p. 105-106) and have been analysed statistically.

The following results are results from above mentioned studies to prove that the ILS is a valid and reliable instrument: "Test-retest correlation coefficients for all four scales of the instrument varied between 0,7 and 0,9 for an interval of four weeks between test administrations and between 0,5 and 0,8 for intervals of 7 months and 8 months." "*All coefficients were significant at the 0,05 level or better"* (Felder & Spurlin, 2005 p. 110). "Cronbach alpha coefficients were all greater than the criterion value of 0,5 for attitude surveys in three of four studies, and were greater than that value for all but the sequential-global dimension in the fourth study. The values of the coefficients for each dimension in all but the last study were remarkably consistent with one another. Pearson correlation coefficient-relating preferences on the different dimensions of the ILS were calculated in all four studies." "*The values were consistently 0,2 or less except for those relating the sensing intuitive and the sequential-global dimensions, which ranged from 0,32 to 0,48"* (Felder & Spurlin, 2005 p. 110). In 2007 Litzinger et al: published a paper titled "A Psychometric study of the Index of Learning Styles." This paper was conducted "to assess reliability, factor structure, and construct validity as well to determine whether changing its dichotomous response-scale to a five-option response-scale would improve reliability and validity. Data collected from this study had internal consistency reliability ranging from 0,55 to 0,77 across the four learning style scales of the ILS. Factor analysis revealed that multiple factors were present within three of the learning style scales, which correspond to known aspects of scale definitions. The factor analysis and direct feedback from learners on whether they felt their scores accurately represented their learning preferences provide evidence of construct validity for the ILS. Changing the response scale improved reliability, but it did not change the factor structure substantially nor did it affect the strength of the evidence for construct validity based on learner feedback" (Litzinger et al., 2007). Zywno (2003 cited in Felder & Spurlin, 2005) and Livesay et al. (2002 cited in Felder & Spurlin, 2005) concluded that "their reliability and validity data justified a claim that the ILS is a suitable instrument for assessing learning styles." Van Zwaneberg et al. (2000 cited in Felder & Spurlin, 2005) "concluded that the ILS is best used to allow individuals to compare the strengths of their relative learning preferences rather than offering comparisons with other individuals. They based this assertion on their lack of success in predicting academic performance from ILS scores." The mentioned results enabled me to use the ILS as an instrument for assessing the learning styles of the Science learners in my study.

The Hawthorne effect

The credibility of my data may be influenced due to my presence in class which possibly influenced the Science learners' behaviour during observations. To reduce this effect, the first observation was done without a prior interview or discussion. I emphasised the fact that I was interested in the uniqueness of each learner and my purpose was only to observe their actions and interactions with each other, in an objective way. To enhance the trustworthiness of the interviews, it was important that the interviewees be honest and open in their responses. The data from the interview prior to the lessons were compared with the classroom observations. The same interview schedules, including the same questions and in the same sequence were used for all interviewees. The questions were short and concise in order to avoid confusion or misunderstanding. I allowed each learner to make an appointment with me for the interviews at a time that would suit them so that they might have feel less threatened or pressured. This allowed for more time to think about the questions and to provide valuable responses.

The Halo effect

To enhance the trustworthiness of the interviews, I avoided the tendency to seek answers that would have supported my preconceived ideas. The researcher who assisted me with the coding and transcribing of the data pre-empted this problem. The interviewees were asked exactly the same questions and after each interview I gave a summary of my interpretation of the interview for them to verify or modify.

3.4.5 Ethical Considerations

I obtained ethical clearance from the Ethics Committee in the Faculty of Education at the University of Pretoria prior to the commencement of my systematic investigation. A designated form, explaining the purpose and the nature of the research, was completed and submitted to the Ethics Committee with the relevant documentation. These applications were submitted after the proposal was successfully defended at faculty level and before fieldwork was conducted. Issues addressed in the application involve the sensitivity level of the research activities, the research approach, design and methodology, voluntary participation, informed consent, confidentiality, anonymity and risk. As researcher, I had to obtain written permission from the Head of Council and the school principal, after the purpose and the nature of the research had been explained to them. A relevant form was then completed prior to applying for ethical clearance. Written informed consent was obtained from the voluntary participants. During individual meetings with each participant, the purpose and the nature of the research were explained to him or her. They were presented with letters of informed consent (see Appendix J a) for learners older that 18; letters of consent for minors' parents (see Appendix J b) and letters of informed consent for the minors (see Appendix J c) explaining the research and emphasising the fact that participation was voluntary. Before the start of the interviews participants were reminded again of the voluntary nature of participation (McMillan & Schumacher, 2001). All participants had the opportunity to read the letters of informed consent and to ask clarifying questions prior to signing the consent forms.

As researcher, I had the responsibility to protect the participants from physical, psychological, or any harm. I remained conscious of possible means in which the participating teachers could be harmed. I guaranteed the participants of my truthfulness. I guaranteed the participants privacy, confidentiality and anonymity by not disclosing their names, or the school where the research was conducted. Pseudonyms were used for the participants. Audio recordings were not made publicly accessible. The sole purpose of the recordings was for personal reference, to validate my field notes and to enrich descriptions of the contexts.

3.5 Limitations

ICS have been criticised for their tendency "to over-simplify reality or de-emphasize some aspects of the phenomena in order to focus on some others" (Scaife & Wellington, 1993). Therefore special care should be taken to safeguard against formulating invalid over-generalisations from simplistic depictions of complex phenomena and "against formulating over-simplified ideas, e.g. controlling variables in the real world constitutes an unproblematic task. In any attempt to design a valid experiment, the decision on what variables to control, in practice, has to be partly subjective and is almost always constrained by such practical factors as what variables are accessible for measuring" (Papadouris & Constantinou, 2009).

The case study, like any other research method, has its weaknesses. In this study a limitation is that the primary data are gathered from a relatively small number of learners who are observed on three different occasions and interviewed twice. Cohen et al. (2005, p. 184) mentioned that "*results may not be generalisable except where other readers/researchers see their application."* It will therefore not be possible to generalise the findings, but one may still acknowledge the value of the findings obtained from rich in-depth involvement in specific cases as "*they provide insights into other, similar situations and cases"*. My presence during learning periods might have had an influence on the dynamics of the classroom situation, although I made a conscious and deliberate attempt to avoid that. Possible bias on my part could exist due to my prior experiences of Science education and my exposure to scholarly literature.

CHAPTER FOUR

Presentation and discussion of the results

4.1 Introduction

The research question is: *What are the experiences of learners with different learning styles when an Interactive Computer Simulation (ICS) is used to aid teaching the photoelectric effect in a Science classroom?* Based on my conceptual framework (Figure 11, p. 40) I thematically present and discuss the results from participants of similar learning styles, relate the findings to the literature and explain the identified trends. After the learning styles of the Science learners were identified I divided them into their respective learning style groups for each of the four dimensions mentioned in my conceptual framework (Figure 11, p. 40) and the following themes emerged: 1) Positive experiences and 2) Negative experiences of Science learners using an ICS in Science 3) Learning styles and motivation of learners.

The first step in the data collection process was then to identify the learning styles of the Science learners by using the ILS (see section 3.5). Pseudonyms are used to protect the identity of the learners. I kept to the planned data collection process of three observations during the lessons prior to the simulation, during and after the learners had used the computer simulation. I observed the Grade 12 Science lessons on the photoelectric effect. An interview was conducted prior to the lesson using the simulation and this was followed by an interview directly after they used the simulation. The duration of the interview prior to the observations was approximately 30 minutes each and was conducted either shortly before the specific lesson or the afternoon before the lesson. The first interviews explored the general feeling of the learners about Science, what they thought the photoelectric effect was and to establish what they knew (or thought they knew) in general about Computer Simulations. By then they knew what their own learning style was because they had completed the ILS questionnaire.

The duration of the final in-depth interview was approximately 50 minutes per interview. In this interview I asked questions related to what they had experienced by using the Computer Simulation (see Appendix I). I attempted to structure my interview and related questions so that I would be able to see if learners with different learning styles experienced the use of the Computer Simulation differently.

4.2 The learning styles of the seventeen respondents

The ILS was used (see Section 3.5) to determine what the learning style of each learner was and Table 3 shows the results of each of the respondents after they had used the ILS to identify their own learning style in each of the four dimensions indicated in the FSLSM.

Table 3: Numerical values obtained by every learner in each of the four different dimensions indicated in the FSLSM

Name	Perception dimension	Numerical value on scale Perception Dimension	Input dimension	Numerical value on scale Input Dimension	Under-standing dimension	Numerical value on scale Under-standing Dimension	Processing dimension	Numerical value on scale Processing Dimension
Bill	Intuitive	7	Visual	7	Sequential	1	Reflective	7
Charmaine	Sensory	3	Visual	5	Global	5	Active	5
Desmond	Sensory	1	Visual	3	Sequential	9	Reflective	5
Faiza	Intuitive	5	Verbal	11	Global	3	Reflective	3
Fundile	Sensory	5	Visual	7	Sequential	3	Active	5
Jacques	Sensory	11	Visual	7	Sequential	7	Active	7
Jimmy	Intuitive	5	Visual	5	Sequential	3	Active	5
Johan	Sensory	9	Visual	11	Global	1	Active	5
Kirsten	Sensory	9	Visual	9	Sequential	5	Active	11
Lee	Sensory	1	Verbal	1	Sequential	9	Active	7
Lelo	Intuitive	1	Visual	11	Global	11	Reflective	5
Leroy	Sensory	7	Visual	1	Sequential	3	Reflective	1
Mojo	Intuitive	9	Visual	11	Global	1	Active	5
Monty	Sensory	3	Visual	11	Global	11	Active	7
Rina	Intuitive	7	Visual	3	Global	5	Active	9
Stuart	Sensory	7	Verbal	1	Sequential	5	Reflective	5
Victor	Sensory	5	Visual	7	Sequential	3	Active	7

The numerical value obtained when the ILS is applied is an indication of the following: If the learner's style is on a scale of 1 - 3, he/she is fairly well balanced on the two dimensions of that scale. If the learner's style is on a scale of 5 - 7, he/she has a moderate preference for one dimension of the scale and will learn more easily in a teaching environment which favours that dimension. If the learner's style is on a scale of 9 - 11, he/she has a strong preference for one dimension of the scale and may have real difficulty learning in an environment which does not support that preference. The data obtained for the learning style is descriptive therefore a bar graph or pie chart should be used to represent the information graphically. I have decided to make use of a bar graph, as it allows for comparisons between the different categories. All the graphs are stacked bar graphs: the subparts show the numerical value of the specific subparts of each dimension while the whole bar shows the cumulative effect (the learner's learning style in all four dimensions). Table 3 and Figure 19 represent and summarise the learning styles.

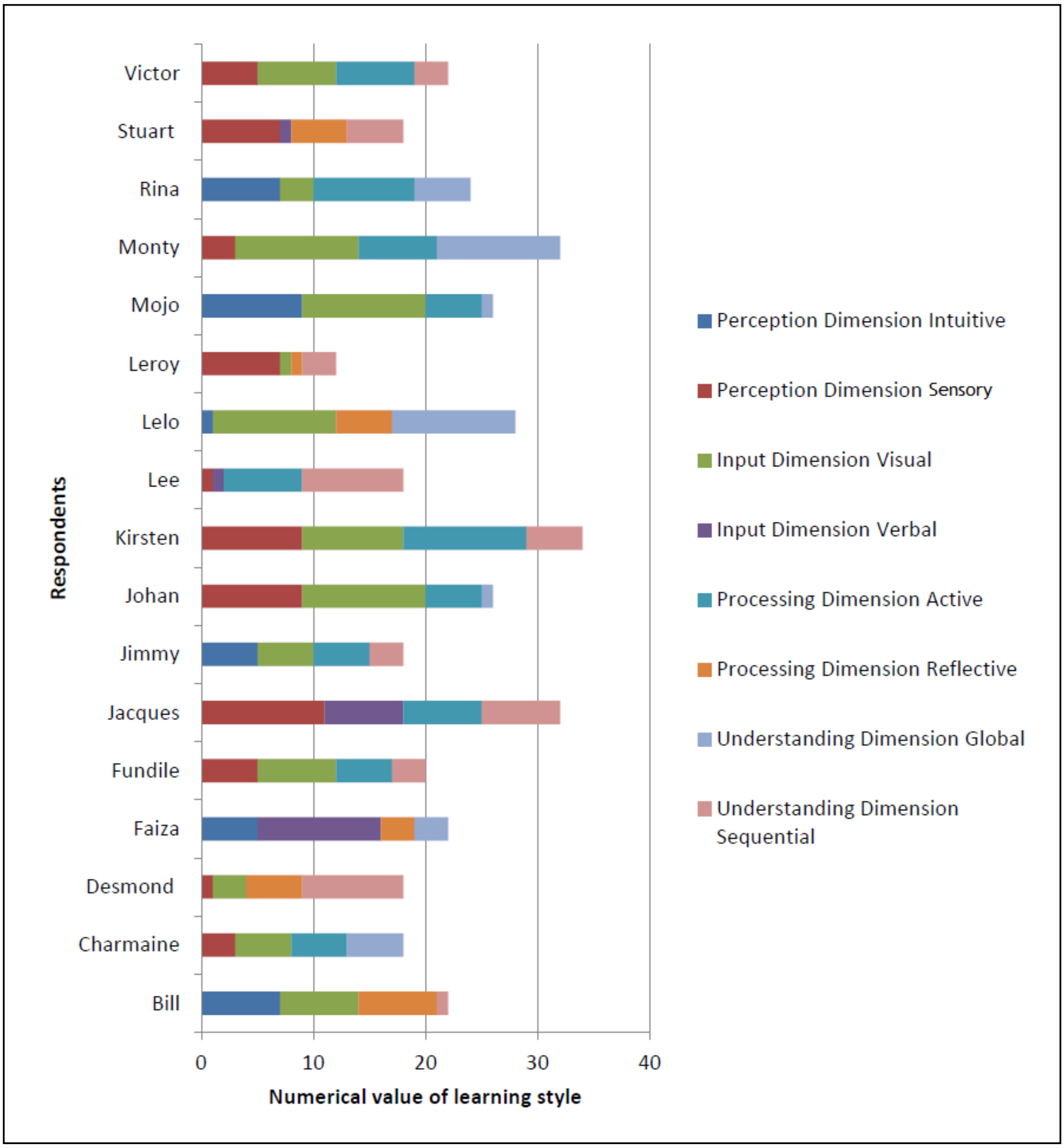

Figure 19: Respondent's learning styles in each of the four possible dimensions indicated in the FSLSM

The information given in Figure 19 is useful in showing the four learning styles of each learner. The numerical value is an indication of the strength of that specific learner in that learning style. This enabled me to make comparisons between the learners since it was an indication of a learner's preference in a specific dimension. For example, the low numerical value that Monty has obtained (3) indicates that he is fairly balanced in the perception dimension between sensitive and intuitive, but he has a high numerical value in the Input Dimension for Visual Information (11) and in the Understanding Dimension for the Global process (11). This shows that Monty will experience great difficulty learning in an environment which does not support the Visual or Global learning style. He has a moderate score in the Processing Dimension for Active learning (7) and will learn more easily in an environment supporting Active learning.

Table 4 is a simplified version of the information obtained in Table 3. This gives a picture of the learning style in the four dimensions for that learner and a key is identified to summarise the learning style for each respondent. This information can be used to compare results of different learners.

Table 4: Learning styles of each learner indicated in the FSLSM

Name	Perception dimension	Input dimension	Understanding dimension	Processing dimension	Key
Bill	Intuitive (I)	Visual (Vi)	Sequential (Q)	Reflective (R)	**IViQR**
Charmaine	Sensory (S)	Visual (Vi)	Global (G)	Active (A)	**SViGA**
Desmond	Sensory (S)	Visual (Vi)	Sequential (Q)	Reflective (R)	**SViQR**
Faiza	Intuitive (I)	Verbal (Ve)	Global (G)	Reflective (R)	**IVeGR**
Fundile	Sensory (S)	Visual (Vi)	Sequential (Q)	Active (A)	**SViQA**
Jacques	Sensory (S)	Visual (Vi)	Sequential (Q)	Active (A)	**SViQA**
Jimmy	Intuitive (I)	Visual (Vi)	Sequential (Q)	Active (A)	**IViQA**
Johan	Sensory (S)	Visual (Vi)	Global (G)	Active (A)	**SViGA**
Kirsten	Sensory (S)	Visual (Vi)	Sequential (Q)	Active (A)	**SViQA**
Lee	Sensory (S)	Verbal (Ve)	Sequential (Q)	Active (A)	**SVeQA**
Lelo	Intuitive (I)	Visual (Vi)	Global (G)	Reflective (R)	**IViGR**
Leroy	Sensory (S)	Visual (Vi)	Sequential (Q)	Reflective (R)	**SViQR**
Mojo	Intuitive (I)	Visual (Vi)	Global (G)	Active (A)	**IViGA**
Monty	Sensory (S)	Visual (Vi)	Global (G)	Active (A)	**SViGA**
Rina	Intuitive (I)	Visual (Vi)	Global (G)	Active (A)	**IViGA**
Stuart	Sensory (S)	Verbal (Ve)	Sequential (Q)	Reflective (R)	**SVeQR**
Victor	Sensory (S)	Visual (Vi)	Sequential (Q)	Active (A)	**SViQA**

Another bar graph could then be drawn by combining the information in Tables 3 and 4. This time, the numerical values for each respondent is compared to each of the subdivisions in the dimension. Figure 20 thus enabled me to compare the learning styles of the respondents numerically and find the learning styles most common amongst the respondents.

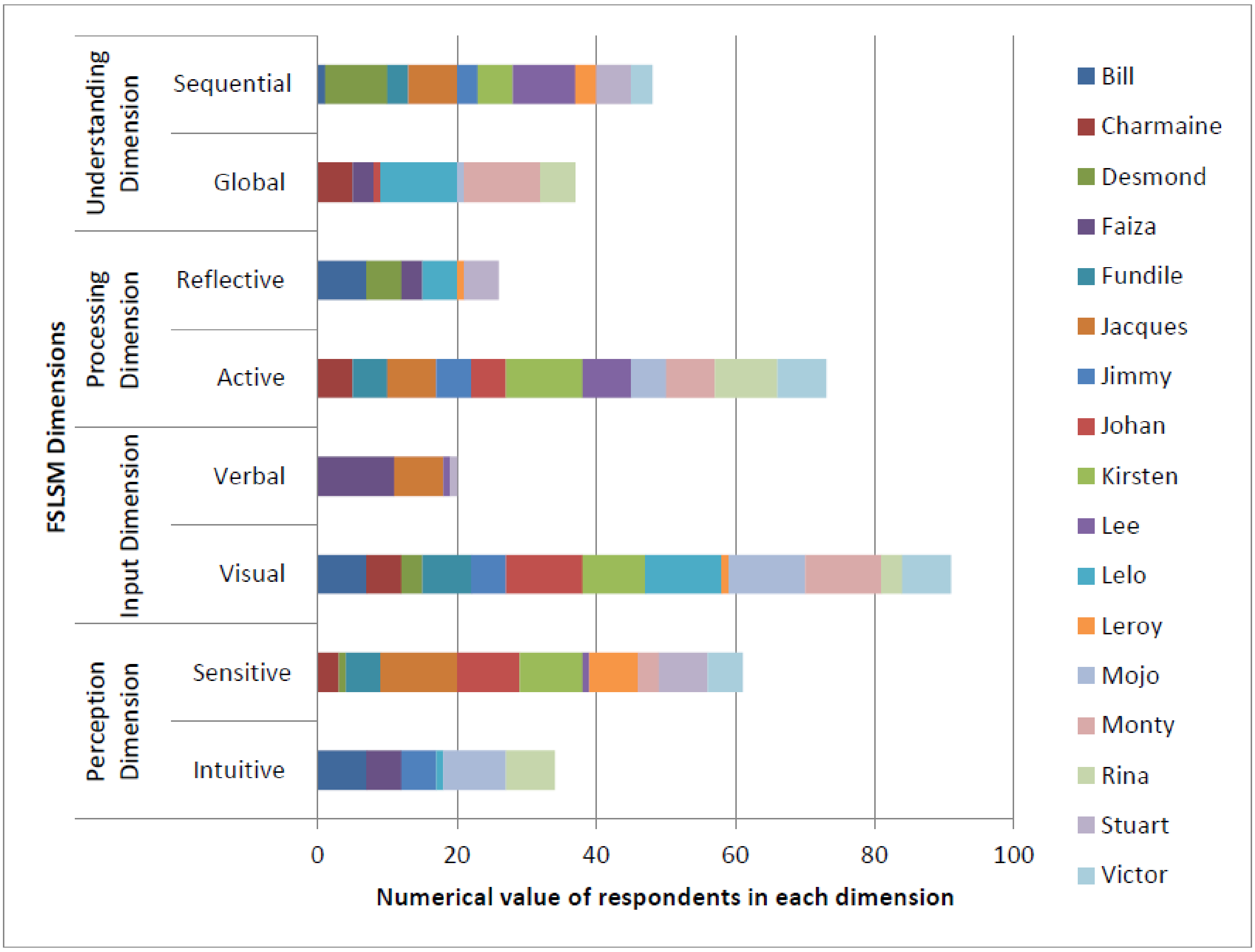

Figure 20: Summative comparison of all the learning styles of the respondents as indicated in the FSLSM

Colour coding is used to distinguish between the four different dimensions mentioned in the FSLSM. If this information is simplified by only indicating the number of respondents in each dimension, an even clearer picture emerges. “Most STEM students (at university) are visual, sensitive, active and sequential” (Felder, 1996; Felder & Brent, 2005) and this trend is supported by the outcome of my study (for the learners). Figure 21 shows a stacked bar graph representing the numbers of learners in each dimension. The bars represent the learning styles which are divided into subparts to show the cumulative effect in each dimension.

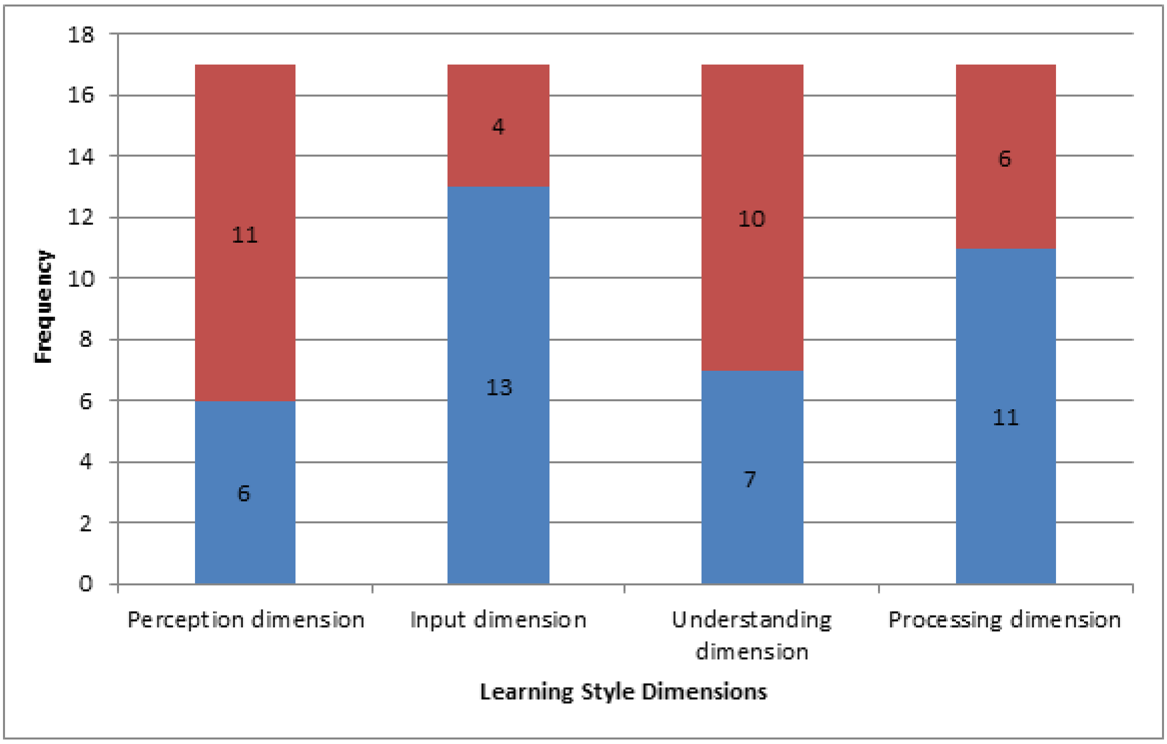

Figure 21: A stacked bar graph to show the distribution of the learning styles amongst the seventeen respondents

Figure 21 shows how the results supported the statement that most Science learners in this study (like STEM students at University) are: In the First Dimension, which is the Perception Dimension, most learners were Sensory; in the Second Dimension which is the Input Dimension, most learners were Visual; in the Third Dimension (Understanding Dimension) most learners were Sequential and lastly, in the Fourth Dimension (Processing Dimension) most learners were Active.

The data obtained from the ILS supplied me with descriptive statistics, which then enabled me to purposively select the learners to be used in the qualitative case study. The learners who were selected were representative of all the different dimensions in the FSLSM.

4.3 Results from interviews

The study's inductive approach and analytic strategies used in analysing the data are discussed in Chapter 3. In this section I only discuss the transcribing and coding of the data. The inclusion and exclusion criteria for coding the data are also discussed and presented.

I transcribed my digital and audio-taped data verbatim to text data immediately after the data had been collected. Care was taken not to interpret the data during the transcribing phase. After each observation all hand-written field notes made during the observations as well as insights gained were typed on a template form. Uncertainties that emerged were cleared up by listening to the audio-tapes or digital recordings again. Transcripts were read afterwards to ensure the transcripts were true accounts of the actual observations and interviews. In coding the data, I used an inductive approach based on my conceptual framework. According to the conceptual framework learners were classified into four different learning styles, namely 1) the perception dimension; 2) the input dimension; 3) the processing dimension and 4) the understanding dimension. Codes can be allocated in several ways (Archer, 2009) but for the purpose of this research I used open coding (codes are created for a specific piece of text) and coding by list (assigning a code to a piece of text from a list of already existing codes). Codes have been ascribed to the different experiences as dimension indicators of each sub-theme according to which the raw data were analysed. By using the software programme ATLAS.ti 6, I coded the transcripts. Annexure L shows a list of all the codes used and their definitions. The ATLAS.ti 6 software enabled me to use a code manager where it was possible to find the groundedness of each code. This is a number indicated next to any code when using the code manager of the software to analyse the data which is a number indicating how many quotations have been associated with the specific code. The higher the number, the more "grounded" the code and this was an indication of how true each code was.

After the data were coded I created *coding families* which are clusters comprising codes related to one other. Families were created by selecting from the comprehensive list all those codes that were related to one another. A specific code could belong to more than one family and families were therefore not exclusive. Several themes could be identified from the data, namely: positive and negative experiences with Science as a subject; the content knowledge of the learners with the photoelectric effect; how familiar the learners were with the use of computer simulations; learning styles as "now discovered" and experienced by the learners; positive and negative experiences of the learners when using the computer simulation and suggestions of the learners on how to change (to improve) the computer simulation. Networks for these sub-themes were created afterwards where the connections between the different codes assigned to the families were indicated. Graphical representations of these code families will precede the discussion of each theme identified.

4.3.1 Results from interviews after using the ICS

The research question was*: What are the experiences of learners with different learning styles when an Interactive Computer Simulation (ICS) is used to aid teaching the photoelectric effect in a Science classroom?*, and therefore I have decided that five themes will be analysed, namely 1) Experiences of learners in the Perception Dimension of the FSLSM; 2) Experiences of learners in the Input

Dimension of the FSLSM; 3) Experiences of learners in the Understanding Dimension of the FSLSM; and 4) Experiences of learners in the Processing Dimension of the FSLSM. For the sake of clarity each of the themes were arranged into sub-themes of the relevant learning styles of that dimension. Sub-themes for each of the themes were created using ATLAS.ti 6, namely a) Positive experiences of learners using the ICS and b) Negative experiences of learners using the ICS, by using an inductive approach when the data is discussed. Theme 5 deals with the motivation or lack of thereof of the learners, as a result of learners knowing what their learning style is. All quotes used are verbatim.

4.3.1.1 Theme 1: Perception Dimension- Sensory learners(S)

The first theme identified in this study is the first dimension identified in the FSLSM, namely the Perception Dimension, which is subdivided into Sensory (or Sensitive) and Intuitive learners. The first subtheme is then the positive experiences of **sensory** learners using the ICS in Science. A code family was created for each of these subthemes. The data for the *code families* was collected inductively from the transcripts of the interviews.

4.3.1.1.1 Sub-theme 1: Positive experiences of Sensory learners when ICS was used

Keeping the conceptual framework in mind, I looked for codes inductively in the data corresponding to Figure 12 (p. 47), which is a summary of the properties associated with sensory learners**.** Sensory learners perceive information externally: sight, sound and by physical sensation, in other words they observe and gather data through their senses. The following codes, as summarised in Table 5, were identified inductively from the data, as applicable to the criteria of this dimension, when the interviews were transcribed.

Table 5: Descriptions of each code used in the Sensory learner's code family- Positive

Code	**Description**
Cheap	The learner's opinion on what is not expensive, a low-priced, low cost, affordable way to do experiments
Macroscopic level	Large enough to be observed with the naked eye
Microscopic level	Not visible with the naked eye,- referring to motion of, or minute changes to atomic particles
Moving	Refers to active state of particles moving about while the simulation is played
Own pace	Working at their own pace; not being rushed or pushed for time
Time constraints	Limited amount of time available, pushed for time when they work
Pictures/diagrams	A visible image
Repeat	The learner will be able to say or try the action again, until understanding is reached
Sees effects	The effects of changing any variable during the ICS are clearly visible to the learner
Unlimited repeats	It is possible to repeat the experiment an unlimited amount of times, not restricted by time or apparatus or quantities involved

Use senses	The learner uses one of more of the five human senses to perceive information
Visual	The learner receives information by seeing the information e.g. a picture or diagram of the concept

The *code family (CF)* created for the first sub-theme **Positive experiences of learners in the First Dimension of the FSLSM: Perception Dimension- Sensory learners** appear in Figure 22. The red solid line arrows indicate the different codes (indicators) being linked to the code family. A full description of each code is provided in Table 5 above. The data linked to these codes were collected from the interviews conducted with the learners. In the network view there are several branches which can be identified. The first code of the branch is linked to the code family, but then other codes, which were also obtained inductively from the data are either associated with each other, or which form part of each other. These are indicated on the network view, by black solid lines linking the codes to one another.

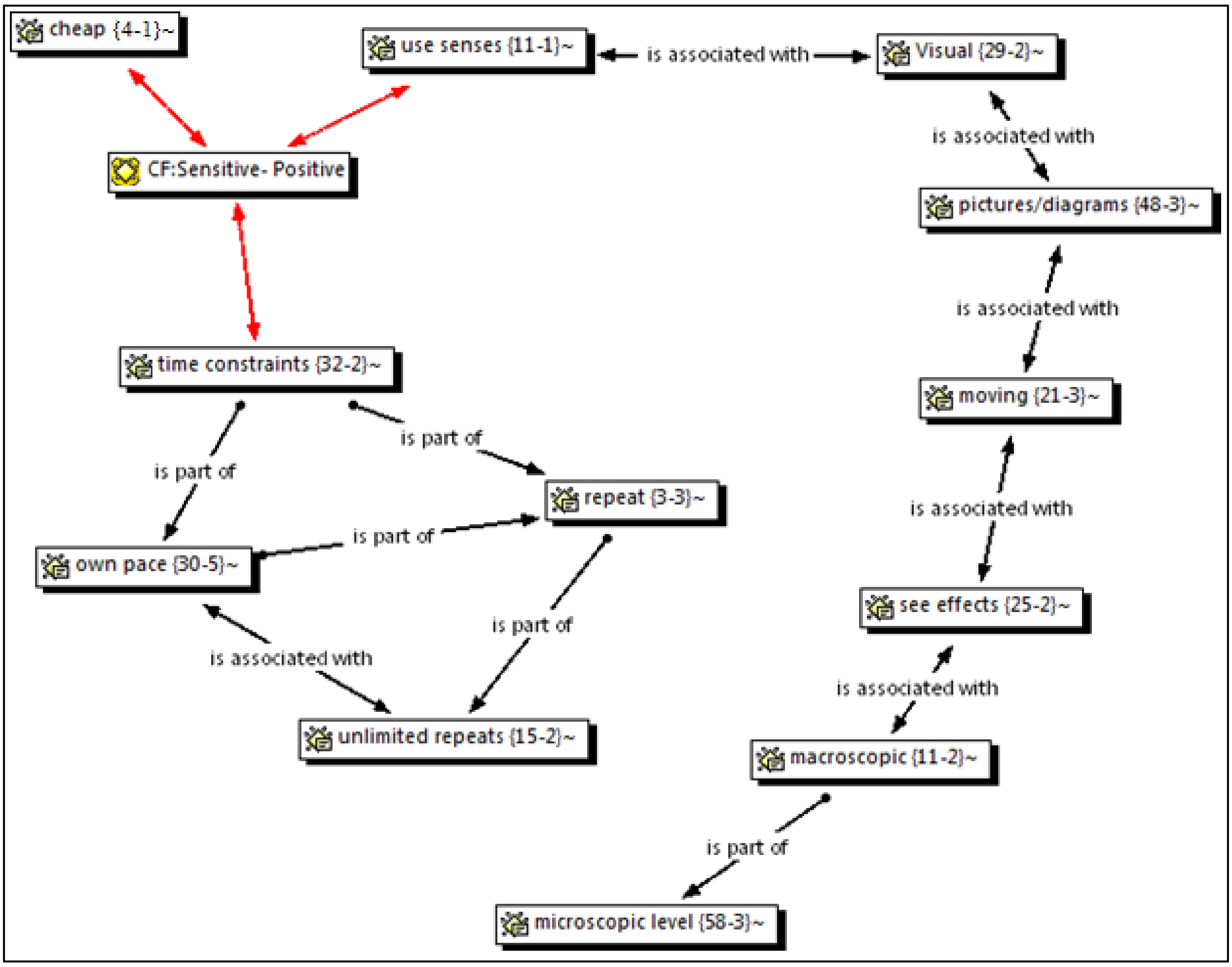

Figure 22: Network view of positive experiences of Sensory learners when using the ICS

ATLAS.ti 6 uses solid red line arrows to indicate the codes *associated with the positive experiences of the sensory learners* (which is the code family). For example codes such as "uses senses and simulated practical" are linked with **Sensory learners (S)**, while codes such as "prefer practical" and "doing things practically" are associated with each other. At the end of each code, for example macroscopic level, there is a pair of numbers in parentheses e.g. {11-2} where the **11** refers to the groundedness of the macro level, in other words the frequency with which the code was attached to quotations in the interview transcripts. This means that there were eleven incidents during the seventeen interviews where there was evidence of the learners mentioning the macroscopic level of diagrams. The number **2** is the density, indicating the number of times a code has been linked to codes in all the networks that were created. In this example it means the code for the macroscopic level was linked to two networks (Positive experiences of Sensory or Sensing learners and Visual learners). ATLAS.ti uses solid black lines with double arrows to indicate codes *that are associated with each other* as seen between repeat and unlimited repeats and a solid black line with a single arrow to indicate codes which are *part of each other such as* microscopic level and macroscopic level. Each learner's learning style (as indicated in the key column of Table 4) will be indicated next to his/her name when a learner is quoted.

The network view illustrated in Figure 22 gives a picture of the positive experiences of the sensory learners when they use the ICS to understand the photoelectric effect. As stated before, sensory learners are generally more comfortable with concrete information- facts, observations and data. Sensory learners are practical, observant and attentive to detail; they are more patient with replication of calculations and experiments; slower at solving analytical problems and less inclined to think outside the box. In this network view, two different branches can be linked to the code family. I will discuss each of these branches within the family and the relationships between the codes within the branch. By studying the responses of the learners after they have used the ICS, these were characteristic positive experiences of the sensory learners when they used the ICS.

The first branch identified in the network view in Figure 22 is based on the following characteristics identified in the conceptual framework regarding sensory (S) learners: They use external information obtained by using their senses; they are observant; they need pictures to obtain information and they have a good memory. This branch then starts off by mentioning the code: **"using senses".** The description for this code in Table 5 is: "The learner uses one of more of the five human senses to perceive information". The frequency of this code is 11, which means that the number of times of that this code was used by sensory learners in the interview transcripts was high. Sensory learners were able to mention how important it is for them to use their senses to obtain information. Johan (SViGA) was aware of this as he said:

> *"I use my senses to learn... I like to see things and hear things and just interact with things making use of my senses."*

Associated with this code is the code: **"visual".** The code description is: "The learner receives information by seeing the information e.g. a picture or diagram of the concept". The frequency of the code visual is 29 and the density of the code is 2, which means that it is mentioned in two other network views. This shows the importance of the visual effect of the ICS. Sensory learners need to use their visual sense to understand new information. It is clear from the following quotes that these learners felt that the ICS gave them a picture of the photoelectric effect and it was possible for the learners to construct a mental model of the experiment due to this visual. Fundile (SViQA) mentioned:

> *"I have a clear picture of what's being taught. I didn't have to use my imagination and not be sure if I was right"... There is a clear visual of the concept you are learning. This helps with the understanding and remembering of it... I have to use pictures to memorise things."*

Associated with this code is the code: "**pictures/ diagrams"** (a visual image) with frequency 48 and a density of 3. The learners were aware of the importance of visual images of the concepts that they have to deal with, visible from the high frequency and density of the code. This is illustrated by Kirsten's (SViQA) comment:

> *"... I have to see it. I have to see a picture... I have to make a picture in my mind. Often, when I see it in my mind in a picture, which is what I do when a teacher speaks, I picture it and then it usually stays".*

When Jacques (SViQA) was asked what he enjoyed most in the ICS his answer was:

> *"The visual aspect... The moving visual, coz (sic) I've got a very good memory when things are visual. I can remember visual things very well... the simulation was good, coz (sic) it's a visual, but at the same time it also shows you what's going on. The visual is not just a visual, it's a moving visual."*

The code used in the network view is **"moving"** (which refers to active state of moving about while the simulation is played). The frequency of this code is 21 and the density 3. This illustrates how important it was for the learners to mention the advantage of the ICS's dynamic nature to show the photoelectric effect. Another link in this branch which is important is the code **"see effects"**. The description of this code is: "The effects of changing any variable during the ICS are clearly visible to the learner". Once again this code is significant because it has a frequency of 25 and density of 2. It was mentioned twenty four times in the transcripts of the interviews and is important in two of the network views. The ICS shows the learners an animated version of the microscopic process of the effect when light of the correct frequency hits the correct metal. The metal then releases electrons, which creates a current through a potential difference. Charmaine (SViGA) summarised it quite strongly:

> *"I liked how I could see what was happening and the effects of each factor that I changed in the simulation... It was like playing God. You could just mess around with anything and then see what the result was and I think it's just easier, coz (sic) you get prepared for any picture that you could get in the exam."*

Leroy (SViQR) also added to this:

> *"...you could see different frequencies and intensities so I think it does help because I think a lot of the time when you struggle in Science it's because you can't picture the concept. You can't picture that there's a force of gravity pulling it down and it actually works that way. It's...like your mind does not really register. I think with the simulation it helps because now your mind is put at rest. Your mind's like "Oh! So that's what it is..." and your mind just accepts this information and takes it from there."*

Monty (SViGA):

> *"Well in the simulation you can see the photons moving and you can see all the electrons moving, whereas with a practical you can only see the result. In a practical you only have so many variables to work with, but with the simulation, you can go on forever..."*

Two other codes which are also part of each other, whilst associated with the code "see effects" are the codes **"macroscopic"** and **"microscopic"**. "Macroscopic" has a frequency of 11 and a density of 2 whilst "microscopic" has a frequency of 58 and a density of 3. The description for the code macroscopic in Table 5 is: "large enough to be observed with the naked eye" and in this case refers to the physical macroscopic apparatus used in the physics experiment (See Figure 16, p. 57) in class. By using this apparatus, learners would see the apparatus in real life three dimensionally. The true colour of real ultraviolet light and the effect of shining this light on a piece of zinc lying on a charged electroscope are clearly visible. The gold leaf drops rapidly as soon as the piece of zinc metal loses electrons and discharges the electroscope. As mentioned before, the **effect** of the ultraviolet light on the zinc metal is visible. When the ICS is used, the microscopic view enables the learner to "see" why the gold leaf drops, because now the electrons involved in the process are "visible". The description for the code microscopic is then: "not visible with the naked eye- referring to motion of or minute changes to atomic particles". Charmaine (SViGA) explained the dilemma of macroscopic versus microscopic views:

> *"With an ordinary practical you normally see the beginning and the end and I wanna (sic) see the middle... I think in an ordinary practical, the only thing you can see is sort of the outside effect. Without the simulation, I would just have the practical and I would not have, or see the middle part you know."*

and Bill (IViRQ) commented:

> *"I saw the micro level of it when we used the simulation and that's what was important for me and that then made sense on the macro level..."*

When Kirsten (SViQA) was asked what she enjoyed most in the ICS, she explained that the ICS enabled her to understand the photoelectric effect, because of the possibility of seeing what was happening on the microscopic level when electrons were emitted from the metal by photons:

> *"It puts the theory that is not always possible to do in a practical, into practise. For example, in a physical class practical you wouldn't see the photons or the electrons moving, you would just see that the gold leaf drops, but you would not see why it drops".*

This first branch of the network view underpins the positive experiences that the learners had when they used the ICS to understand the photoelectric effect. It appealed to the sensory learners (S) in the perception dimension because they perceived information externally. These learners are observant and have a good a memory. By identifying the importance and frequency of the relative codes in the branch that relates to the use of their senses when they used the ICS, it seems the ICS enhanced their understanding of the photoelectric effect. They understood the concept much easier because the ICS provided an environment supporting sensory learning.

The second branch visible in the network view for sensory learners deals with time issues. The first code identified from the data is called "**time constraints**" and the description for this code is "Limited amount of time available, pushed for time when they work" as mentioned in Table 5. The frequency for this code is 32 and the density 2. It shows the importance for the learners in this network, to mention time constraints. In Figure 12 (p. 47) it is pointed out that time, specifically, is a problem for sensory learners when they take in new information, because they need to translate words into symbols which they can perceive. Desmond (SViQR) explained:

> *"... well I did not like the first part of the lesson, where we were given the introduction and she showed us the practical using the electroscope in class and then we rushed to the*

computer centre and I did not really know what was going on... and then luckily we did not have much time in class. So, I could go back home and then after I learnt everything, and then the simulation made sense. So I was doing the simulation with the full background that was really very nice for me."

Charmaine (SViGA) said:

"I really like the pace of the lesson as well because as soon as I could understand the work, I could move on by myself and it wasn't like we were just going, going, going."

Another code visible in this branch which is part of time constraints is "**own pace**" and its description is: "Working at their own pace, not being rushed or pushed for time." This code has a frequency of 30 and a density of 5, showing the importance of working at their own pace for these learners. The ICS allowed the learners the freedom of completing the task in the amount of time that each individual needed. Desmond (SViQR) said:

"I like the pace on the computer, it's good that you can do it at your own speed and then discover everything at your own time, no one is rushing you, whereas in class you have a limited amount of time or it's for marks or something so you don't want to mess around with all the stuff to discover something so you just work along according to the rubric."

"Repeat" and "**unlimited repeats"** are also codes associated with time constraints. Repeat refers to "The learner will be able to say or try the action again, until they can understand it" (frequency 3 and density 3) and the code "unlimited repeats" is described as "It is possible to repeat the experiment an unlimited amount of times, not restricted by time or apparatus or quantities involved" and has a code frequency of 15 and density of 2. Desmond (SViQR) admitted:

"I kind of cheated because we did the simulation but I did not have enough time, so I went back home and then I read through the notes that we were given and then it made sense after that. I mean I could see all the stuff. So the good thing was that I missed doing it in class but then I actually did not miss it coz (sic) I could go home and do it at home."

Fundile (SViQA) said:

"I can also practise the concept or work I'm learning to understand it better, which was then possible for me with the simulation".

And Jacques (SViQA) added:

"*...Or just do it again or start it again and that was really cool for me".*

This second branch on the network view demonstrates how the ICS relieved the issue of not having enough time for the sensory learners to perceive information. It allowed them to be meticulous and to be attentive to detail. They could be careful as is true to their nature, but this time around, being careful and therefore slow was not a problem time wise, as would normally be the case for sensory learners. They could be observant and methodical; they could be repetitive - the ICS compensated for most of the features of sensory learners pointed out in Figure 12 (p. 47) of the conceptual framework.

Another feature of the ICS which appealed to the cautious nature of the sensory learners is indicated in the third branch visible on the network view in Figure 22. This deals with the fact that these learners realise that it is safer and "**cheaper"** to do the practical on a computer. Kirsten (SViQA) said:

> *"So instead of doing the practical live you get to do it on the computer and you would get the same results that you would get doing the practical in real life but without the dangers of doing the practical. So you would basically be doing the same steps... and it would also be much cheaper."*

Charmaine (SViGA) added to this:

> *"It is not always possible in a prac (sic), you can't just instantly change your chemicals or if you've mixed the wrong stuff it's a mess. I really liked the fact that you could spend the whole lesson doing the prac (sic) and not waste time in actually setting up the prac (sic)or cleaning up afterwards."*

These quotes showed that the sensory learners (S) enjoyed the use of the ICS and the data indicate that the sensory learners focused on the features of the ICS that deals with their sensory abilities. They mostly mention features in the ICS which will appeal to the external information obtained from the ICS, showing that the learners felt that they had gathered data through their senses.

4.3.1.1.2 Sub-theme 2: Negative experiences of Sensory learners when ICS was used

The second sub-theme is then the negative experiences of sensory learners using the ICS in Science. The negative experiences of the sensory learners engaging with the ICS are indicated in the network view in Figure 23. It must be pointed out though, that these were not completely negative experiences as such. It was mostly comments made by the learners intended as positive criticism. According to Figure 12 (p. 47), sensory learners are dextrous with practical apparatus. In this network view, the codes simulated practical, prefer practical, doing things practically, practical equipment and practicals were identified inductively form the data. These codes all referred to dealing with the actual physical apparatus. Table 6 summarises the descriptions of the codes used.

Table 6: Descriptions of each code used in the Sensory learner's code family- Negative

Code	**Description**
Doing things practically	Learners who prefer to do hands-on experiments
Practical equipment	Refers to the physical apparatus used in a laboratory when conducting a practical investigation
Practicals	Practical experimentation in class conducted by learners themselves, learners are engaging with the physical equipment
Prefer practical	The learner still prefers the experience of doing the physical macroscopic practical, involving use of the actual physical apparatus and most of their senses
Simulated practical	The learner recognises that the ICS is a virtual representation of a practical, available on the computer and is interactive

The parenthesis of each code as given by ATLAS.ti is shown in Figure 23 and as before, the first number refers to the groundedness (frequency) of that code and the second number refers to the density of the code.

By using the Conceptual Framework (with specific reference to Figure 12 (p. 47) which indicates characteristics of sensory learners) and ATLAS.ti 6, it was possible to create another network of the *code families*. This network is now illustrated and explained. The *code family* created for the second subtheme: **Negative experiences of learners in the First Dimension of the FSLSM: Perception Dimension- Sensory learners (S)** appears in Figure 23 below. The red solid line arrows indicate the *different codes (indicators) being linked to the code family*. A full description of each code is provided in Table 6 above. The first code of the branch is linked to the code family, but then other codes, which were also obtained inductively from the data, are *associated with each other*. Examples of these are: The code "simulated practical" is linked to the code family, which indicates the negative experiences of the sensory learners while using the ICS. All the other codes in the branch are associated with each other. This means that rest of the codes in the network view in Figure 23 indicates different parts of the ICS which the sensory learners had negative experiences with while using the ICS. A discussion of the data to support these views follows.

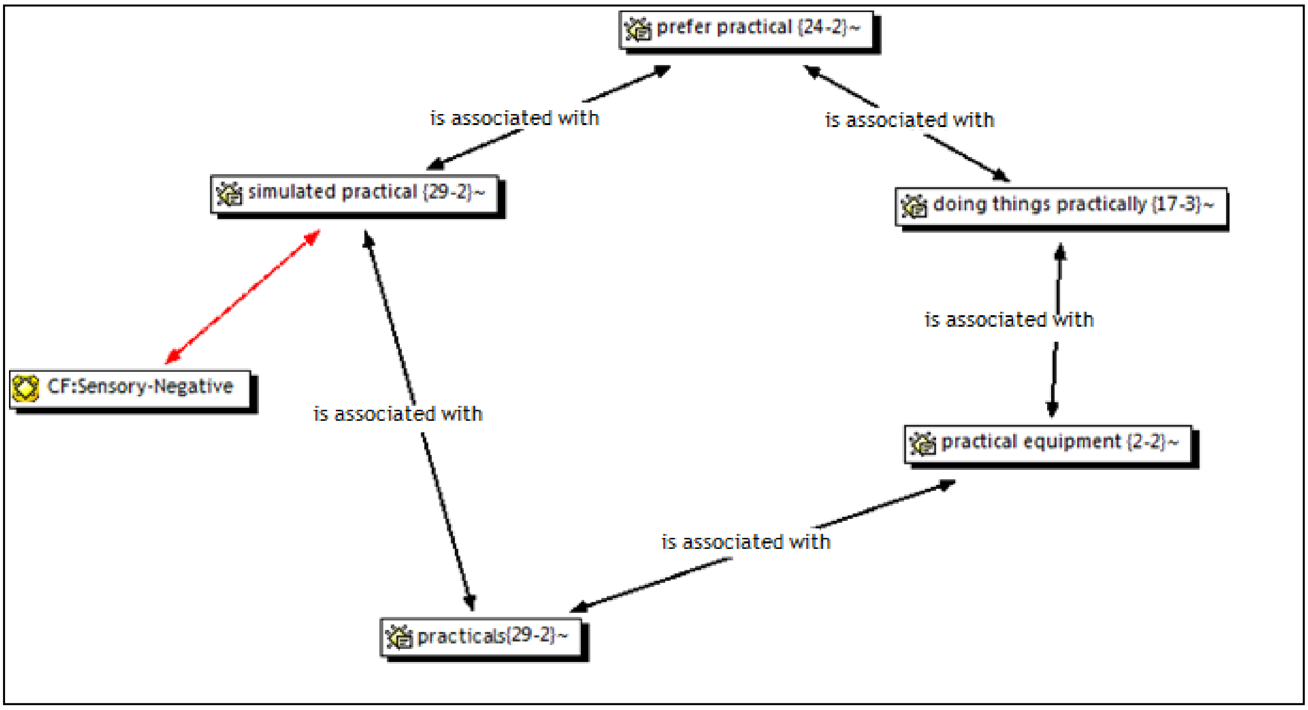

Figure 23: Network view of negative experiences of Sensory learners when using the ICS

This network deals mostly with the fact that the learners realised that it was a good thing to do the ICS, but that it would be necessary for them to do the actual physical experiment as well. Desmond (SViQR) said:

> *"You still need to do more than that but it still feels as if you are doing the real thing*."

Johan ((SViGA) pointed out:

> *"The main disadvantage of a simulation would be that you're not actively involved in setting up the apparatus and getting that first-hand experience, you're not using all your senses. It's nice to see the actual apparatus and stuff happen in practise."*

Victor (SViQA) explained why he likes doing the practicals more than just using an ICS, but then admits that he would actually like to have the opportunity to do both of them:

> *"coz (sic) I like them both (practical and simulation)... uhm... doing a practical it's like the real thing, it's not a computer thing. You know you get to use your senses, all your senses which you don't use on the computer. I really like working with the physical equipment. When the teacher showed us the practical in class, I could even relate to it in the exam, I could remember the theory, coz I've seen the practical. Seeing the practical in class, doing the practical myself in class, I think I learn a lot better like that, than with the simulation. With the simulation I was able to see how the phenomenon works and through that I understand better. But even though you see how the simulation works, and you're doing it on the*

computer, but (sic) it's not really the actual thing. I am 100% for the use of simulations, but with the physical practical as well. I would like to do both of them actually."

The data shows that negative experiences of the sensory learners are centred on the features of the ICS that would limit their collection of data externally. Most of the sensors wanted changes made to the ICS that would enhance their ability to collect the data externally, but the learners realised that it might not even be possible. A good example of this paradox is that they refer to the ease of using the ICS without having to set up the practical equipment, but then complain about not being able to experience the use of the physical practical equipment.

4.3.1.2 Theme 1: Perception Dimension- Intuitive learners (I)

The First Dimension identified in the FSLSM is the Perception Dimension which is subdivided into Sensory (S) and Intuitive learners (I). The next discussion is still part of theme 1 and deals with the experiences of **Intuitive learners (I)** using the ICS in Science.

4.3.1.2.1 Sub-theme 3: Positive experiences of Intuitive learners when ICS was used

Keeping the conceptual framework in mind I looked for codes inductively in the data corresponding to Figure 12 (p. 47), which is a summary of the properties associated with intuitive learners**.** Intuitive learners perceive information internally (insights, hunches, memory and speculation) which means they gather data indirectly, often not conscious of collecting data. The following codes, as summarised in Table 7, were identified inductively from the data, as applicable to the criteria of this dimension when the interviews were transcribed.

Table 7: Descriptions of each code used in the Intuitive learner's code family: Positive

Code	**Description**
Computer game development	The learner is involved in the development of computer games, he/she is interested in the programming side as such, applying Information Technology knowledge in the Scientific field
Different dimension	The learner enjoys the fact that the concept is looked at from a different angle, starting from a different viewpoint
Different Science lesson	Not the usual and ordinary lecturing format of a Science lesson
Dislike practicals	The learner does not like doing the practical lessons - the responsibility of working with the physical equipment and possibly breaking or damaging it is simply too much for the learner
Expands effects	Add more to the effects simulated in the simulation, either by using better graphics or sound
Imagination expanding	To picture or fabricate an idea about a concept in one's mind
Learn differently	To acquire knowledge in a different way to what the learner is used to, mostly referring to it as not as in a formal lecture
Limits to expand effects	Very creative learners understanding the limits in changing the visual effects

	of the ICS
Own pace	Working at their own pace; not being rushed or pushed for time, or able to work ahead
Prefer CS	Learners would have like to do the entire science course using ICS's
Wrong results	The results of an experiment are not what they are expected to be
Quick	Fast reaction or action
Quick to set up	The simulation does not waste time in setting up the equipment as in a lab practical, all the apparatus is immediately available, all apparatus is set up correctly and in working order
Quick results	The results of any changes done in the simulated practical are immediately visible

The *code family* created for the third subtheme: **Positive Experiences of learners in the First Dimension of the FSLSM: Perception Dimension- Intuitive learners** appear in Figure 24 below. A full description of each code is provided in Table 7 above. In the network view there are several branches which can be identified. The first code of the branch is linked to the code family, but then other codes, which were also obtained inductively from the data are *either associated with each other*, or form *part of each other*. These are indicated on the network view in Figure 24, by black solid lines linking the codes to one another.

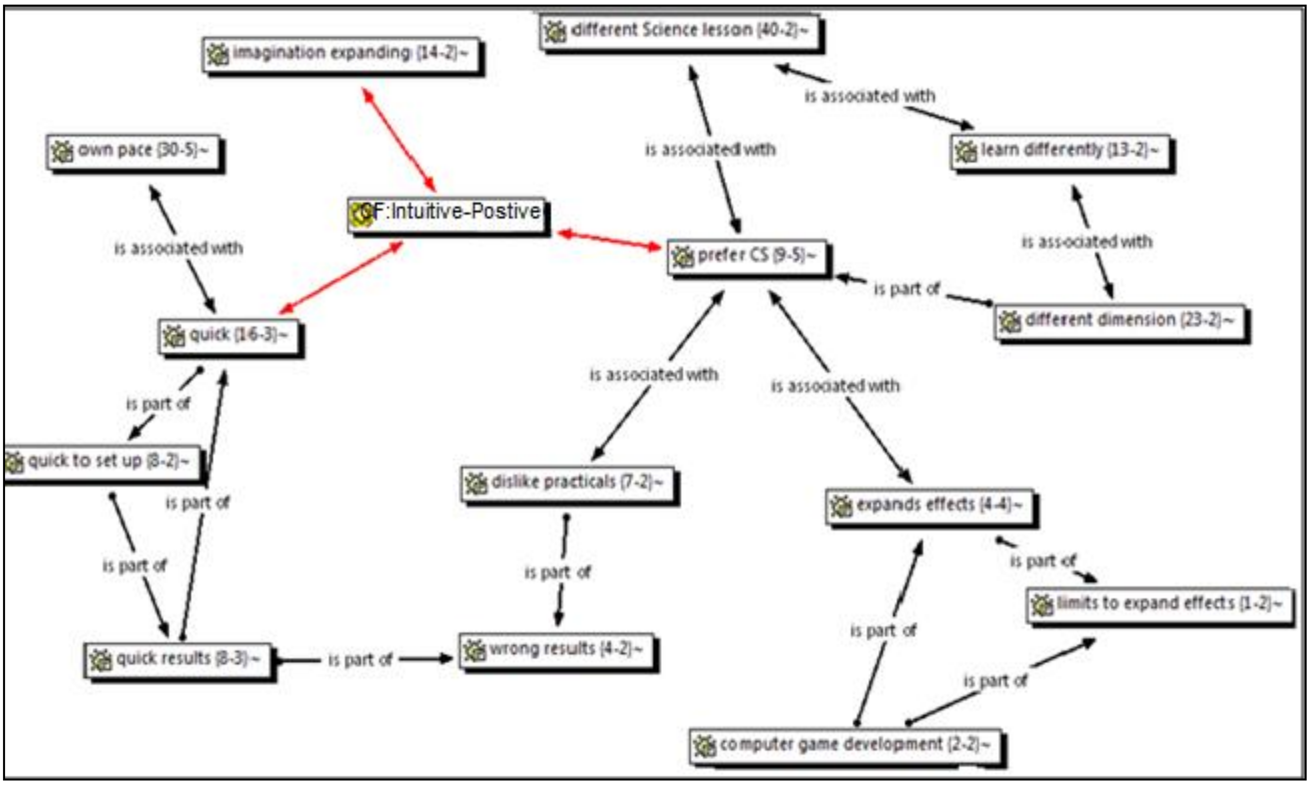

Figure 24: Network view of positive experiences of Intuitive learners with ICS

Codes such as: “quick” and “prefer CS” are linked with **Intuitive learners (I)**, while codes such as “wrong results” and “dislike practicals” are part of each other. At the end of each code, for example “own pace”, there is a pair of numbers in parentheses {30-3}. This means that there were thirty incidents during the seventeen interviews where there was evidence of the learners mentioning own pace in the interviews. In this example it means the code “own pace” was linked to three networks (Experiences of Intuitive learners, Reflective learners and Positive ICS experiences for all).

The network view illustrated in Figure 24 gives a picture of the positive experiences of the intuitive learners (I) when they used the ICS to help them understand the photoelectric effect. As stated under sub-theme 3 (p. 88), intuitive learners are generally more comfortable with abstract information-principles, theories or concepts. Intuitive learners are good at grasping new concepts. Although they work quickly it makes them careless. They are comfortable with all symbols, but find details and repetition boring. Intuitive learners (I) are creative and they prefer problems calling for innovation (see sub-theme 3, p. 88). In this network view, six different branches can be linked to the code family. I will discuss each of these branches within the family and the relationships between the codes within the branch. By studying the responses of the learners after they have used the ICS, characteristic positive experiences of the intuitive learners (I) using the ICS are illustrated.

If we follow the branches anti-clockwise in the network view, the first branch identified is based on the following characteristics identified in the conceptual framework regarding intuitive learners: They use internal information obtained by way of the unconscious- they use speculation, imagination or hunches to obtain information. The code associated with the code family, which was obtained inductively from the data during the interviews is the code **“imagination expanding”** (frequency 14 and density 2). The description for this code in Table 6 is “To picture or fabricate an idea about a concept in one's mind.” Rina (IViGA) explained what aspect of the ICS she liked most:

> *“It just opens my mind and terms of my imagination. I can make pictures in my head of all the stuff all the time.*”

Although Mojo (IViGA) knows he uses his imagination to interpret data, he stated:

> “*Because instead of imagining the concept where there is a possibility of misconceptions occurring... coz (sic) like you can get things wrong by thinking it goes a certain way, but actually no it doesn’t. So then with the computer you see exactly how the different things behave, when different factors come into play and stuff like that. Instead of me just imagining... coz (sic) I get that wrong sometimes.”*

The next branch in the network view deals with the impatient nature of Intuitive learners. The code is **"quick"** and the code description is "Fast reaction or action", (frequency is 16 and the density 3.) This highlights the importance of this feature of the ICS to the learners interviewed. Faiza (IVeGR) admits:

> *"But also you could change it, like it's faster. In a real life practical experiment you have to go get that and move on to get equipment and so on. But on the computer it's just quick coz (sic) you click a button and it's there immediately. And you don't waste time to understand..."*

The code quick is associated with the code **"own pace"** (frequency 30 density 5). This code means "Working at their own pace, not being rushed or pushed for time or able to work ahead". Faiza (IVeGR) said:

> *"Yes, I liked the fact that I could control the pace that I was working at... I could never do that in class."*

Jimmy (IviQA) confirmed this:

> *"It was also really good for me that I could control the pace that we were working at. I'd have complete control over the pace that we worked at with the simulation."*

The codes **"quick to set up"** (8-2) and **"quick results"** (8-3) are also part of the branch formed starting with the code "quick". **"Quick to set up"** means: "The simulation does not waste time in setting up the equipment as in a lab practical, all the apparatus is immediately available and set up correctly, all in working order" and **"quick results"** means: "The results of any changes done in the simulated practical are immediately visible." Desmond (SViQR) summed it up:

> *"...you are able to apply the different concepts and witness the results instantly."*

The codes **"quick results"** are part of the codes **"quick to set up"** and **"quick",** which is shown as a separate branch in the network view and the significance thereof was explained in Table 7. The code **"wrong results"** is associated with **"quick results"** and the code **"dislike practical"** which occurs in another branch of the network view as well. In this instance the code is used to demonstrate the ability of Intuitive learners (I) to be careless when they do practical work. The intuitive learners in the respondent group recognised the fact that the ICS would not allow them to make careless mistakes, as opposed to when doing a practical, where mistakes could result in incorrect answers. Bill (IViQR) said:

> *"...it never goes wrong so you understand better."*

The third branch of the network view seems quite complicated, but it simply demonstrates the creative and innovative nature of the intuitive learners. The code **"prefers CS"** (frequency 9, density 5) is *associated with the code family* and the meaning of this code as given in Table 7 means "Learners would have like to do the entire Science course using ICS's." Using this code enabled further refinement of the information given by learners making this statement. Branching off from this code are four separate branches, wherein the codes are either *part of* or *associated with* each other. Following the branches anticlockwise in Figure 24, the first branch encountered refers to the code **"dislike practicals"** (7-2). The intuitive learners in this study mentioned that they dislike doing practical for a number of reasons and would therefore prefer to do ICS only instead of practical experiments. Bill (IViQR) explained:

> *"I won't say that my best activity in Science is practical investigations. That's not one of the things I like. I must say I like it when there's a demonstration of some kind, showing us how to solve a problem like in physics. Even if it's chemistry, as long as it's interesting, but like I've said I can't see the things on a microscopic level. I don't like being involved in the experiment myself. I tend to mess it up. I just prefer the calculations... But I still don't like practicals, I don't like working with the equipment coz (sic) I'm clumsy... now that I've seen how easy the simulations are, I would just prefer to use simulations."*

Mojo (IViGA) agreed:

> *"I am not confident when we do the practicals because I am too scared that I will mess up something."*

Bill (IViQR) showed why this code is also part of the code **"wrong results"** in the previous branch mentioned:

> *"It's like in practicals, I can't understand what's going on in practicals because nothing ever gets the right result. I think what the textbook says the result must be and the result that I get is (sic) completely different."*

The next branch includes the codes **"expands effects"** (4-4), **"limits to expand effects"** (1-2) and **"computer game development"** (2-2). These codes are included in this network view to demonstrate that these intuitive learners prefer problems calling for innovation. These codes all have to do with their own ability to write computer programs and most of these learners do Information Technology (IT) as a chosen subject at school. According to Table 6 "expands effects means": "Add more to the effects simulated in the simulation, either by using better graphics or sound," "Limits to expand effects" means: "Creative learners understanding the limits in changing the visual effects of the ICS" and "computer game development" means: "The learner is involved in the development of computer games, he/she is interested in the programming side as such, applying Information Technology knowledge in the Scientific field." Bill (IViQR) said:

> *"I'm used to playing computer games with very good visual effects and because I do computer programming I know what the capabilities of the 3D engines are which supports these games and they can go into minute details. I know that the processing powers of computers are increasing and I'd like to see it used more and more. I know this is now Java design and web based stuff and it's limited, but if someone actually did this working from the Science syllabus, someone from a 3D visual company. They can design the simulation and then actually get the full blown 3D simulation with which you can interact, that will be very cool. I wish I had more time in this year so that I could try to do this. Maybe I could try to expand the effects it simulates. And add detail, for example when you move the cursor over an image, a pop up explanation would add to your understanding. If a person is doing it for the very first time and doesn't know anything about it and nobody actually explains to you what you are supposed to do, then I think having a description of what this is and why it might be happening, then that would make a big difference in helping people understand."*

The next branch in the network view shown refers to the codes dealing with the excitement of the intuitors that the ICS provided them with a different type of Science lesson. Because intuitors are innovative and insightful, the ICS provided them with a new way of learning Science. The code **"different Science lesson"** has a frequency of 40 and a density of 2. The meaning of this code identified inductively from the data is "Not the usual and ordinary lecturing format of a Science lesson." Faiza (IVeGR) said:

> *"The lesson was fun and an unusual way to learn about Science and the photoelectric effect...it is a good interesting way to engage with Science"*

Jimmy (IViQA) said:

> *"The science lesson was educational and fun and was nice for a change. The computer prac (sic), it was different because we have never done it before, it was something new that you could try come (sic) to grasp (sic). It was challenging and something different."*

The code **"learn differently"** (13-2) is part of the code "different Science lesson", but has a slightly different meaning: "To acquire knowledge in a different way to what the learner is used to, mostly referring to as not as in a formal lecture" Lelo (IViGR) said:

> *"It is also fun learning this way and I think it is really effective when I learn using the computer. Coz (sic) I can actually see it. I remember because I have learnt differently. Even*

> *when I read my book, I actually see the page. So with this, I could see the picture and I could remember it. I wanted to write the notes so badly in the exam coz (sic) I remembered it so clearly."*

"Different dimension" is a code which is *part of* the codes **"learn differently"** and **"different Science lesson"**. The frequency of "different dimension" is 23 and the density 2. The frequency is an indication of the importance of this slightly different angle of teaching/learning to the other two related codes in this branch. The meaning of this code is:" The learner enjoys the fact that the concept is looked at from a different angle, starting from a different viewpoint." Rina (IViGA) explained why the use of the ICS added another dimension for her to the lesson:

> *So I think, it's something different that's happening and that's how I get my information from it. I can see then what everything looks like and how it works and it makes pictures in my mind that I can remember. So this simulation thing is very good for people like me who struggle with Science because it's a different way of doing the Science. A way which is easy then to understand the new stuff (sic)..."*

This different dimension offered by the ICS added value to the intuitors in the respondent group. It appealed to their creative side and the need to look at things differently to keep them interested.

These quotes showed that the intuitive learners enjoyed the use of the ICS and the data indicate that these learners focused on the features of the ICS that deal with their creative abilities. They mostly mention features in the ICS which will appeal to the indirect gathering of data obtained from the ICS, showing that the learners felt that the ICS gave them insight and allowed them to think innovatively.

4.3.1.2.2 Sub-theme 4: Negative experiences of Intuitive learners when ICS was used.

This sub-theme deals with negative experiences that the intuitors had when using the ICS. The data is represented as part of the network view in Figure 25 and the code descriptors are represented in Table 8. The codes were collected inductively from the transcripts of the interviews.

Table 8: Descriptions of each code used in the Intuitive learner's code family- Negative

Code	Description
Dislike detail	The learner dislikes having to give attention to detail
Dislike graphs	The learner dislikes the theory and tabulating part of an investigation
Dislike repeats	The learner dislikes the repetitive nature of the ICS
No introduction	The learners were frustrated that they were not given an introduction to the ICS before the lesson

The *code family* created for the fourth subtheme: **Negative experiences of learners in the First Dimension of the FSLSM: Perception Dimension- Intuitive learners** appear in Figure 25 below. The red solid line arrows indicate the different codes (indicators) being *linked to* the code family. A full description of each code is provided in Table 8 above. In the network view there are several branches which can be identified. The first code of the branch is *linked to the code family*, but then other codes, which were also obtained inductively from the data are either *associated with each other*, or form *part of each other.*

In the conceptual framework as represented in Figure 12 (p. 47) it is stated that intuitors obtain their data indirectly, mostly by means of the unconscious, using speculation, their imagination and hunches. The respondent group was not specifically informed about the ICS before it was presented to them and this was a huge frustration amongst the intuitors. They had no idea where to start with the ICS and battled to link it with the concept of the photoelectric effect. The fact that these learners are normally impatient added to their frustration when they had to start with something completely unfamiliar to them. They could not make any link to previous theory discussed and felt that they did not have any reference point to start from.

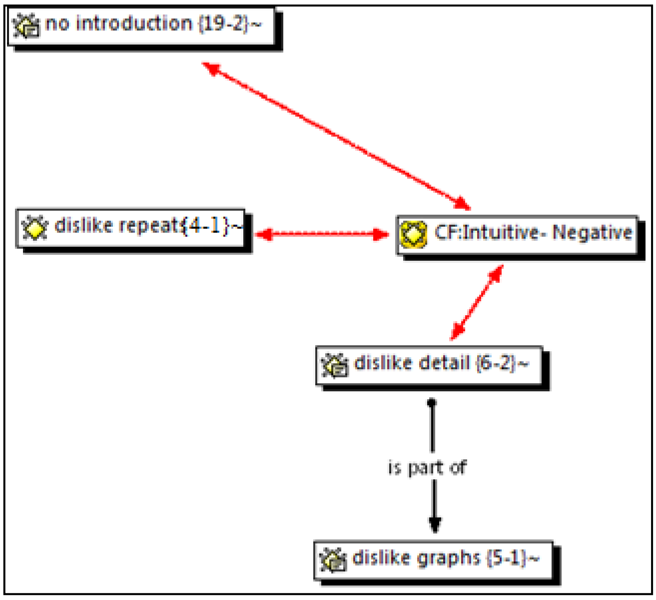

Figure 25: Network view of negative experiences of Intuitive learners with ICS

In Figure 25 a branch is visible which links the code **"no introduction"** (19-2) to the code family. The code descriptor was: "The learners were frustrated that they were not given an introduction about the ICS before the lesson." When Bill (IViQR) was asked what he would have changed in the lesson, he said:

" ... I would have liked that simulation is explained before it is used"

Faiza (IveGR) was asked what she disliked in the lesson:

"I would maybe say the fact that it lacked an explanation. I don't know, not that it wasn't explained properly but I was not sure why we were doing it."

And Jimmy (IViAQ) also explained what he disliked in the lesson:

"That we were not briefed before the lesson on what was going on. I did not like that at all...I think it would have been better if we had a briefing before the lesson...I always need to have an introduction before a lesson so that it would make sense to me coz (sic) then I know what I'm in for"

This data shows that intuitors need some abstract concepts to link their new information to when they perceive new information. The learners had no idea which principles, theories or concepts were used in this section of the work and they were frustrated because of that.

The next branch in this network view in Figure 25 deals with a code **"dislike repeats":** (frequency 4: density 1). The data shows that intuitive learners get bored quickly, especially if they understand the concept and would like to move on. Bill's (IViQR) criticism on the ICS was:

"It was a bit repetitive at times.'

Faiza (IVeRG) complained:

"I also did not like the fact that the exercise was a bit repetitive with the different metals. Like it was a bit repetitive and I really got annoyed with it."

And Jimmy (IViAQ) echoed their opinions:

"Sometimes it got boring coz (sic) it was repeating the effect with different metals."

The last branch visible in the network view in Figure 25 shows that intuitors are bored by detail. The codes which I have found inductively from the interview data were **"dislike detail"** (6-2) and **"dislike graphs"** (5-1). These codes are associated with each other and with the code family. "The learner dislikes having to give attention to detail" refers to the code "dislike detail". "The learner dislikes the theory and tabulating part of an investigation" refers to the code "dislike graphs". Mojo (IViGA) explained what he did not like about using the ICS:

"Counting the particles or estimating the numbers does not suit my style..."

Charmaine (SViAG) also explained:

"But I think the graphs were just not my style just because I did not understand them at all! I did not even look at them to try figuring them out. When I used them I was like (sic), I think I did everything wrong! Coz (sic)I did not understand. I did not know what I was looking at, like (sic) I really did not know what I was looking at. I would have liked to know what I was looking at, or some explanation telling me what I was looking at, or that this graph shows a relationships between this, that and that."

When Faiza (IVeGR) was asked what she disliked in the simulation, she did not hesitate to say:

"The graphs confused me slightly, I didn't like the graphs. I had to estimate the values, and I'm not particularly good with that kind of detail."

The data showed that negative or bad experiences of the intuitive learners are centred on the features of the ICS that would limit their collection of data internally. Most of the intuitive learners did not complain about the features of the ICS before they understood the concept of the photoelectric effect. They only complained after they had gathered the new information on the photoelectric effect, that the details in the ICS were boring and repetitive.

4.3.1.3 Theme 2: Input Dimension- Visual learners (Vi)

The second theme identified in this study deals with the Second Dimension identified in the FSLSM, namely the Input Dimension, and this dimension is subdivided into Visual (Vi) and Verbal (Ve) learners. The first subtheme to be discussed is then the positive experiences of visual learners using the ICS in Science.

4.3.1.3.1 Sub-theme 5: Positive experiences of Visual learners when ICS was used

Keeping the conceptual framework in mind I looked for codes inductively in the data corresponding to Figure 13 (p. 48), which is a summary of the properties associated with visual learners (Vi). Visual learners receive external information most effectively through their visual sense. If something is said to a visual learner, he/she will may forget or misunderstand it. The following codes, as summarised in Table 9, were identified inductively from the data, as applicable to the criteria of this dimension when the interviews were transcribed.

Table 9: Descriptions of each code used in the Visual learner's code: Positive

Code	**Description**
Different dimension	The learner enjoys the fact that the concept is looked at from a different angle, starting from a different viewpoint
Pictures/ diagrams	A visible image

Macroscopic	Large enough to be observed with the naked eye
Microscopic level	Not visible with the naked eye- referring to motion of or minute changes to atomic particles
Moving	Refers to active state of the image moving about while the simulation is played
Prefer video	The learner feels incompetent using the computer and would have preferred to just watch a video to show the microscopic changes taking place during the photoelectric effect
See effects	The effects of changing any variable during use of the ICS are visible to the learner
Visual	The learner refers to his/her own learning style as visual: the learner receives information by seeing the information e.g. a picture or diagram of the concept

The *code family* created for the first sub-theme **Positive Experiences of learners in the Second Dimension of the FSLSM: Input Dimension** appears in Figure 26 below. The code "different dimension" is linked with **Visual learners**, while codes such as "visual" and "pictures/diagrams" are associated with each other. According to the conceptual framework and specifically Figure 13 (p. 48), visual learners receive external information by what they see. Therefore any picture, diagrams, graph, film or demonstration would make perfect sense to them. The following discussion will use the branches in Figure 26 to explain why the visual learners felt that the ICS helped them obtain the new information effectively.

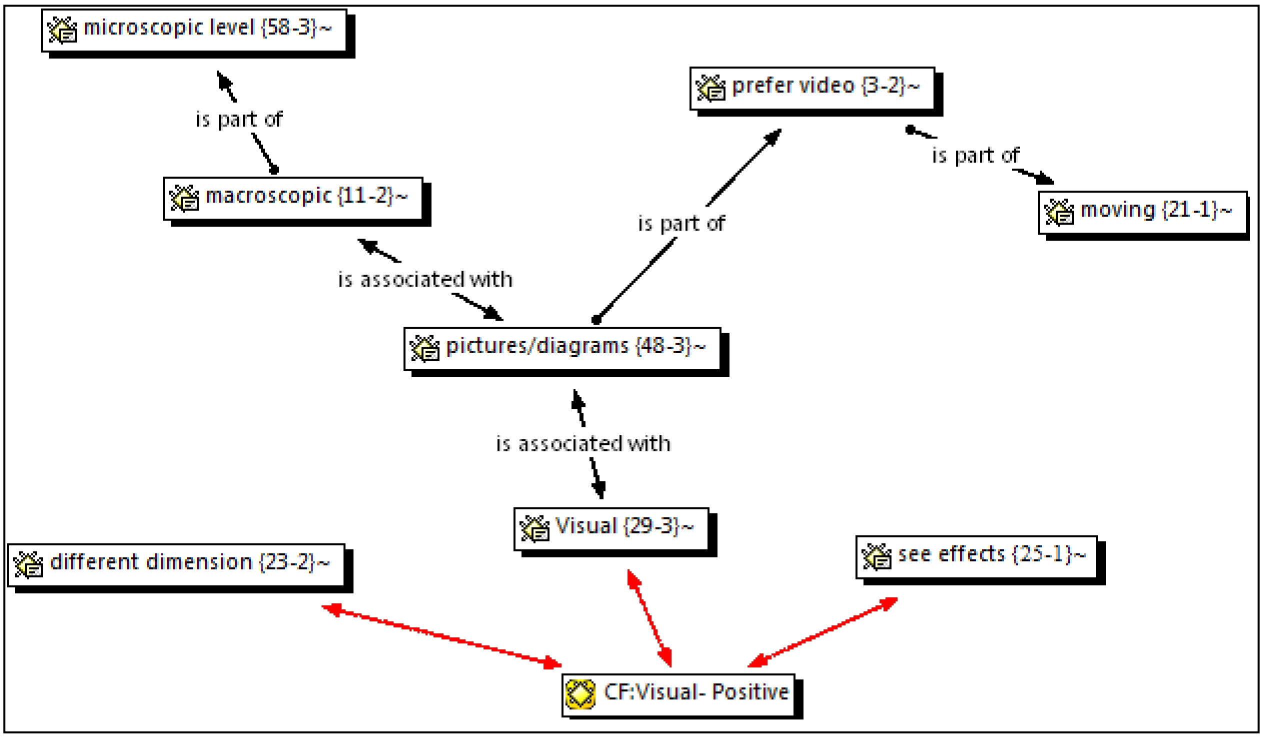

Figure 26: Network view of positive experiences of Visual learners with ICS

To explain this network view, the first branch encountered (clockwise) starts with the first code associated with the code family which is **"different dimension."** This code is mentioned twenty three times in the interviews (frequency of 23) and is linked to two different code families (density of 2). The code description as mentioned in Table 9 is "The learner enjoys the fact that the concept is looked at from a different angle, starting from a different viewpoint." The visual learners enjoyed the new and visual dimension brought in when using the ICS. Monty (SViGA) pointed out:

> *"We worked from a different dimension and we could see it happening."*

Fundile (SViQA) agreed:

> *"The simulation gives an alternative method and way of understanding the work we are busy with."*

Jimmy (IViAQ) said:

> *"The different way of looking at the experiment adds depth to your knowledge on the subject*."

Johan (SViAG) explained:

> *"The simulation adds a good technical aspect. Also helps me to understand a slightly abstract concept."*

And Kirsten (SViQA):

> *"The computer showed things in a different way that a practical couldn't. I wouldn't imagine seeing the electrons going through or the photons being released if I didn't see it on the simulation."*

The second branch in the network view starts with the code **"visual"** (29–3). This code was formed inductively from the data and referred to the learner being aware of the fact that they need visual images before they can remember or understand the fact, in other words, relating to their own learning style. Jacques (SViQA) said:

> *"Visual means that I need to see something and you can associate with it and remember it. It's not like...uhm... ok I saw it and know, but now you don't understand it. It's a good thing coz (sic) you see what's actually going on... ja...uhm (sic) and you understand it better. I've got a very good memory when things are visual. I can remember visual things very well."*

When Bill (IViQR) was asked which aspect of the ICS he found most useful his reply was:

> *"... I understand it much faster. It wasn't instantly but it was much quicker because I had a visual reference point."*

The next image in this branch shows the code **"pictures/ diagrams"** associated with the code family. This code means "A visible image" and has a frequency of 48 and a density of 3. The importance of this code is demonstrated. Fundile (SViQA) explains why he liked working with the ICS:

> *"I liked that there was a visual picture which helped explain the concept and I didn't have to imagine it. I was able to understand through what I physically saw. There is a clear visual of the concept you are learning. This helps with the understanding and remembering of it. I have a clear picture of what's being taught. I didn't have to use my imagination."*

Associated with the code "pictures/diagrams" are the two codes **"macroscopic"** and **"microscopic."** The meanings of these codes are: "Large enough to be observed with the naked eye" and "Not visible with the naked eye- referring to motion of or minute changes to atomic particles respectively." "Microscopic" had a frequency of 58 and a density of 3, whereas "Macroscopic" has a frequency of 11 and a density of 2. The codes are *associated with each* other because they both refer to the visual aspect of practical apparatus. The difference is simply that Macroscopic would refer to an ordinary practical that would be conducted normally in a Science class, whereas microscopic refers to an image which is not visible in a normal class practical. Charmaine (SViGA) gives her opinion about a macroscopic practical:

> *"I think in an ordinary practical, the only thing you can see if sort of the outside effect."*

And Fundile (SViQA) added to this:

> *"In a class practical I could see the effect but not the molecules."*

Jimmy (IViQA) said:

> *"In a class practical, like the one where we used the electroscope and the piece of zinc, you can't really discuss the details because you can't see the things that are happening inside."*

Therefore the microscopic feature of the ICS enabled the learners to understand the photoelectric effect. The following quotes show this in their own words, as Leroy said:

> *"In the simulation like I said, it's very clear what's going on. There's no experimental error there's no nothing (sic) going wrong, everything works exactly as it should work. So you have a perfect benchmark. You know exactly... ja (sic) it's like you know sort of the ideal result of whatever is happening. But with the practical sometimes it's a bit more like... ok I see it, I sort of see it, it's doing what it's generally supposed to do, but it's not as clear and then once I think you've seen it in the simulation you can be like (sic) "ok, well now this is supposed to happen"; "Ok I see this is happening, but now why is it not behaving exactly as it should?"*

and you sort of start to see where things are not as they should be... it's good to see the microscopic view and I think if you are aware of possible misconceptions then I think the simulation does that really well. If you do the physical experiment you see the effect but the concept is explained by the teacher or whoever is doing the demonstration. In the simulation you see the microscopic effect for yourself."

Bill ((IViQR) explained why he enjoyed seeing the microscopic view in the ICS:

"In the simulation I can see what's happening on a microscopic level that makes me know where the basic theory comes from and that makes everything concrete in my mind."

And Desmond (SViQR) added:

"You could see all the steps coz (sic) as the photon hits the metal ... uhm... you can see the electrons being emitted and you can see them going through so and then you could experiment. In the simulation you can actually see every little component and how everything works together."

Part of the code "pictures/diagrams" in the second branch of the network view is the code **"prefer video**." This code was included in the network view, just to prove that the visual learners realise that a moving visual to show how a process actually works, is better than just a static picture. The frequency of the code is 3, but it was included in two code families, which shows the importance of the code. The code is not related to the use of the ICS specifically. The learners were asked if they would prefer a video or a static diagram to explain a process. Victor (SViAQ) justifies his answer:

"A video would be better than just a picture, coz (sic) with a video you see how it works and maybe if you could add an audio that talks you through it, that would be really cool. A video would actually explain a lot of things."

Part of this code is a code called **"moving"** (21–1) which means; "Refers to active state of the image moving about while the simulation is played." The visual learners agreed that the moving picture was better than just a static picture shown. Leroy (SViRQ) explains why he thinks the moving picture was better:

"So when the electrons are actually moving it makes it more clearer (sic) in your mind and now forever in your mind you are thinking ok. You know now there's less confusion in your memory sort of."

When Mojo (IViGA) was asked which part of the simulation suited his learning style best, his answer was:

> *"The active, moving picture, where I can see the behaviour of the electrons as the intensity is altered."*

Rina (IViGA) explained what she liked best in the ICS:

> *"The simulation is a great aid because it's a visual in motion- it makes the idea more real and accessible."*

Jacques (SViQA) confirmed this:

> *"... the simulation is better, coz (sic) it's a visual, but at the same time it also shows you what's going on. The visual is not just a visual; it's a moving visual... now I understand it better if I watch what is actually going on."*

Leroy's (SViQR) explanation was:

> *"Nah, (sic) I think the simulation will be way better. Coz (sic) in the diagram things are just static, they are just there and you don't really get to actually...uhm it doesn't actually get into your mind that "ok, this is it." It's one thing to see it on the paper but then it's a completely different thing to see it actually moving like when they're animated. Oh, ok there are photons going and there is the current, more electrons coming out create a bigger current. So when the electrons are actually moving it makes it more clearer (sic) in your mind and now forever in your mind you are thinking ok. You know now there's less confusion in your memory sort of."*

The last branch on the network view of Figure 26 (p. 98) refers to the code **"see effects"** (25-1). The code descriptor is: "The effects of changing any variable during use of the ICS are visible to the learner" and the visual learners benefitted greatly from this feature of the ICS. Bill (IViQR) says why he enjoyed working with the ICS:

> *"I liked the fact that I could play around with the settings and instantly see the effects of any of those changes that I made."*

Charmaine (SViQR) confirmed this:

> *"I liked how I could see what was happening and the effects of each factor visibly happening right before my eyes (sic)..."*

Desmond (SViRQ):

> *"You could see all the steps coz (sic) as the photon hits the metal ... uhm... you can see the electrons being emitted and you can see them going through so and then you could experiment."*

And Monty (SViGA):

"With the simulation I could see the experiment and explain why the results change, coz (sic) I could see this. It's much easier and doesn't confuse me."

This data corroborates that a feature of ICS is its support of the visual learner's need of their sense of sight to obtain new information. They could perceive their external information effectively by seeing pictures of the photoelectric effect, but the picture was also animated movement. The microscopic ability of the ICS further enhanced the perception of the concept, because the learners could see the microscopic (and normally invisible) photons and electrons. The behaviour of the microscopic particles was also visible and the visual learners could see what the effects were when any changes were made to variables involved in the virtual experiment. There was no doubt that visual learners benefitted greatly from using the ICS by perceiving external information effectively.

4.3.1.3.2 Sub-theme 6: Negative experiences of Visual learners when ICS was used

Sub-theme 6 deals with negative experiences of visual learners when they used the ICS. Keeping the conceptual framework in mind I looked for codes inductively in the data corresponding to Figure 13 (p. 48), which as mentioned before, is a summary of the properties associated with visual learners**.** As stated before, visual learners receive external information most effectively through their visual sense. The only code associated with negative experiences of visual learners that I could find in the transcription of the interviews, relates to verbal information. The teacher had given the learners only verbal instructions and a worksheet (Appendix E) on how to use the ICS. Most of the visual learners were confused by the time they had settled down in front of their computers in the computer centre, as they could not remember what they were supposed to do. The code applicable to this code family was **"demonstration"**. This code means: "the teacher shows learners an experiment"- the learners are not involved, they are only observing the process or physical practical as the teacher demonstrates the use of the physical apparatus. Learners enjoy the demonstration, and they don't feel unsure during this exercise. The network view (as shown in figure 27) created for this subtheme shows only one code involved in negative experiences of visual learners when using the ICS.

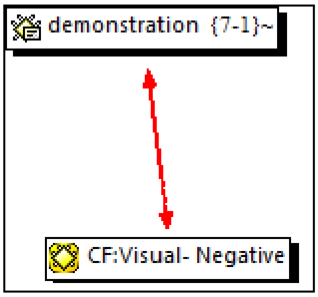

Figure 27: Network view of negative experiences of Visual learners with ICS

Fundile (SViQA) explained why he needed a visual demonstration before doing the ICS:

> *"It's like anything, if you see someone doing something, you remember."*

When Johan (SViGA) was asked what he would have changed in the lesson, his reply was:

> *"Not much, but maybe the teacher could explain more in depth about what we're going to do, or better still just give a quick demonstration of the simulation. Having a briefing or demonstration always helps to know exactly what we need to do with the simulation, what we need to achieve."*

These quotes support the statement that visual learners will forget what to do when they are just given verbal instructions, as they do not receive new information externally by means of their auditory sense.

4.3.1.4 Theme 2: Input Dimension- Verbal learners (Ve)

The second theme identified in this study deals with the second dimension identified in the FSLSM, namely the Input Dimension, which is subdivided into Visual and Verbal learners. Subtheme 7 then discusses the positive (good) experiences of **Verbal learners (Ve)** using the ICS in Science. The data for the *code families* was collected from the interviews.

4.3.1.4.1 Sub-theme 7: Positive experiences of Verbal learners when ICS was used

Once again I have used Figure 13 (p. 48) in my conceptual framework to look for codes inductively in the data. Figure 13 (p. 48) is a summary of the properties associated with verbal learners**.** Verbal learners receive external information most effectively through their auditory sense. Verbal learners also benefit by hearing something and then by repeating that information by saying it out loud. The following codes, as summarised in Table 10, were identified inductively from the data, as applicable to the criteria of this dimension when the interviews were transcribed.

Table 10: Descriptions of each code used in the Verbal learner's code family - Positive

Code	**Description**
Discuss	The learners enjoy talking about the theory/calculations/laws- engage in a discussion either with fellow learners or with the teacher
Explain	The teacher explains either the process or the law or even the use of the formula in a calculation or the learners explain the concept to each other during group work
Verbal	The learner knows that they receive new information in a verbal format, what they hear and then what they say

The *code family* created for the second subtheme **Positive Experiences of learners in the Second Dimension of the FSLSM: Input Dimension- Verbal learners** appear in Figure 28. The code verbal is linked with **Verbal learners** (which is the code family), while codes such as verbal and discuss are *associated with each other*. According to the conceptual framework and specifically Figure 13 (p. 48), verbal learners receive external information by what they hear. Therefore words, sounds lectures and any readings would be useful for them to receive new information. The following diagram (Figure 28) shows a network of codes obtained inductively from the data to discuss the positive experiences of the verbal learners when they used the ICS to obtain new information regarding the photoelectric effect.

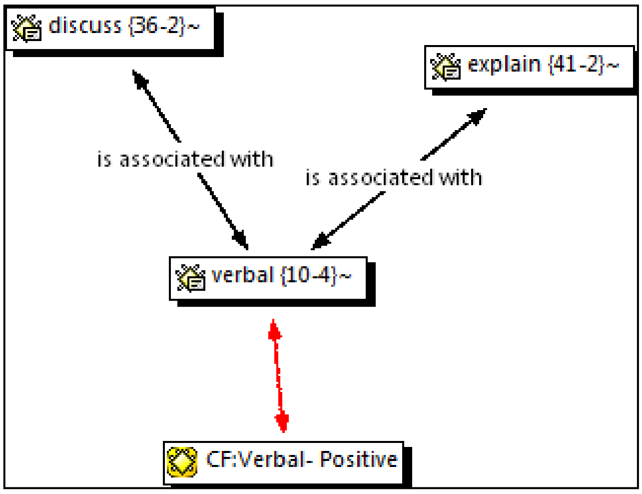

Figure 28: Network view of positive experiences of Verbal learners with ICS

To explain this network view, the first branch off the CF from the bottom starts with the first code associated with the code family which is **"verbal"** (10-4) and the code descriptor is "The learner knows that they receive new information in a verbal format, what they hear and then what they say." This refers to the learner being aware of his/her verbal learning style. Stuart (SVeQR) says:

"I like hearing everything... uhm... yeah I quite like (sic), if the teacher talks to me and I read it, I will have it solid in my head... I don't know it's just sort of naturally how I am. I'd much rather just hear you say, this is what we're going to learn and you should expect this and that and this is part of that."

Faiza confirmed this (IVeGR):

"I know that I understand concepts better when explaining it; or when they are explained to me. I know that I am a verbal learner."

The next code associated with the code family is **"discuss"** (36-2). This refers to:"The learners enjoy talking about the theory/calculations/laws- engage in a discussion either with fellow learners or with the teacher". When Faiza (IVeGR) was asked what she liked about the lesson she said:

"I liked the fact that I could speak to other people."

Stuart (SVeQR) was of the opinion:

"We discussed a lot of stuff (sic) while doing the simulation, often it was a lot of tangent stuff (sic) which were always interesting coz (sic) it relates... to ... stuff ....(sic) So that's the part I liked the most... That we could discuss what we were doing, while we were doing it."

The code **"explain"** (41-2) is also associated with the code **"verbal"** in the code family. Explain means "The teacher explains either the process or the law or even the use of the formula in a calculation or the learners explain the concept to each other during group work" thus referring to a discussion whilst doing the ICS. This was a positive experience for the verbal learners.

Referring to the code **"explain",** Faiza (IVeGR) said:

"People would ask questions while we were doing the simulation, sometimes I found that the questions were a bit off putting coz (sic) they were on totally different topics, but sometimes they actually did help and I was glad that someone asked the teacher that question, coz (sic) then it helped me as well."

Lee (SVeQA) told the researcher:

"But I have to do the steps myself and explain it to myself in order to understand it properly. It's all about me doing the thing, while I'm also talking about it. I learn a lot when I write and talk and explain the work to myself."

Stuart (SVeQR) felt that the ICS could actually help teachers to explain to other learners:

"The simulation is also very good coz (sic) it helps teachers as well. I feel ... coz (sic) it means they don't have to explain so much and so often ... if people don't understand when

you've explain it, you can show it to them and they should understand it better ... and I think it's quite a useful tool. I would also use the simulation if I want to explain the photoelectric effect to someone. When I explain it to someone else it also helps me to understand better."

The data shows that the ICS afforded the verbal learners the chance to discuss the photoelectric effect and also explain it to others. One learner mentions that the ICS would also be a useful tool for a teacher, because the teacher then does not need to explain the same concept over and over again, as the ICS would help the teacher. The importance of how effectively they learn when they explain to each other is also mentioned, as this deals with the needed feature of verbal learners to hear and then say something, in the Input Dimension of the FSLSM.

4.3.1.4.2 Sub-theme 8: Negative experiences of Verbal learners when ICS was used.

According to Figure 13 (p. 48) verbal learners receive external information most effectively through their auditory sense. This means that the environment where the learning takes place must be conducive to learning for verbal learners. The negative experiences for the verbal learners mostly had to do with the noise level of the group-work in the computer centre when the ICS was used. The following codes, as summarised in Table 11, were identified inductively from the data, as applicable to the criteria of verbal learners when the interviews were transcribed.

Table 11: Descriptions of each code used in the Verbal learner's code family - Negative

Code	Description
Dislike computer	Not comfortable using the computer at all; would prefer writing brief notes by hand or rather listen or do a physical activity
Group work	Working together with their peers, discussing, arguing and working together to complete a task
Listen	Verbally taking in information making use of hearing sense- auditory information
No introduction	The learners were frustrated that they were not given an introduction about the photoelectric effect before the lesson- they did not understand what they were seeing and did not like having to discover the effect by themselves
Quiet	The learner is distracted by any auditory stimulus and therefore needs the environment to be quiet
Add explanation	The learner would prefer to hear a verbal explanation of aspects in the simulation- either a teacher explaining or a voice over added in the simulation

The *code family* created for the second sub-theme **Negative Experiences of learners in the Second Dimension of the FSLSM: Input Dimension- Verbal learners** appear in Figure 29. The codes are *associated with* the different negative experiences of the verbal learners. For example the code "dislike computer" is *linked with the code family*, while codes such as "listen" and "quiet" are *parts* *of each other*. The codes “quiet” and “group-work” *contradict each other*. According to the conceptual framework and specifically Figure 13 (p. 48), verbal learners receive external information by what they hear. Therefore any auditory stimulus would either enhance or interrupt their learning process. Figure 29 shows a network of codes obtained inductively from the data to discuss the negative experiences of the verbal learners when they used the ICS to obtain new information regarding the photoelectric effect.

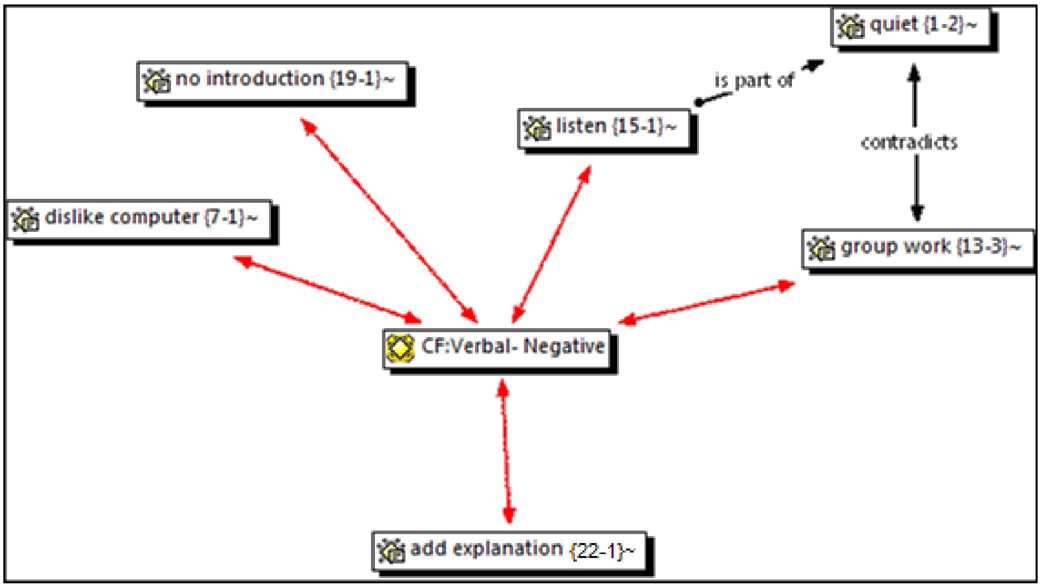

Figure 29: Network view of negative experiences of Verbal learners with ICS

The first code linked to the code family is **“dislike computer”** (7-1) and means “Not comfortable using the computer at all; would prefer writing brief notes by hand or rather listen or do a physical activity.” Two of the three of the verbal learners indicated that they were not comfortable using the computer at all, as it involved “too much reading”. Without realising that they were verbal learners, these learners knew that they did not like using the computer. They did not necessarily know why and even felt that it was “weird” not to like a computer, because this was not the norm amongst their peers. When Lee (SVeAQ) was asked what he did not like in the lesson his reply was:

> *“Honestly, working with the computer, because I’m just not a computer person so it was difficult for me to find the bearings of the whole thing. I would much rather listen to omeone explaining to me... Working with the computer is hard for me. I know it’s weird...”*

When Lee (SVeAQ) was asked what he would have changed in the lesson, he said:

> *“I think it would have been better for me if someone explained to me. I know that I would not have been doing the stuff myself, but it would have been the same outcome...I could have*

heard it and not get frustrated coz (sic) I'm struggling with the computer and I would still understand what's going on, coz (sic) I get to see it on the level that I like."

This information from the verbal learners showed that not all learners would benefit from using the ICS in the current format.

The next code linked to the code family is **"no introduction"** (19–1) and this code means: "The learners were frustrated that they were not given an introduction about the photoelectric effect before the lesson- they did not understand what they were seeing and did not like having to discover the effect by themselves." The verbal learners were frustrated because they felt that they were confused about what they had to do. Stuart (SVeRQ) summarises it as:

"I did not like it that we were kind of thrown into the water and told to swim. And sometimes it can get a bit frustrating even if you know what you have to do; you're not 100% sure if this is what you're getting. Maybe just add the sort of explaining about what we were supposed to be doing in a bit more detail, you know just a sort of explanation, like a walkover (sic) just so that people know exactly what to expect and then they don't feel clueless when it's not working too well. And it also gives people a method so that they can fill in the values and then take it from there."

The next branch on this network view associates the code **"listen"** to the code family**.** This code description is "Verbally taking in information making use of hearing sense- auditory stimulus" (15-1). Lee (SVeQA) knows that he finds it hard to concentrate when there are other noises around him:

"I didn't like having to listen in the noisy class because I just don't get to hear anything since I am easily distracted and so I zone out quickly. So in the end I know that I have to work somewhere quiet."

Faiza (IVeGR) was frustrated having to do the ICS in the noisy computer centre:

"I tried to read the work aloud and repeat it to myself, like I always do, but it was not possible in the computer centre. If I could have been somewhere where I could just listen to myself it would really have made a big difference."

Associated with the code "listen" is the code **"quiet",** (1-2), which means: "The learner is distracted by any auditory stimulus and therefore needs the environment to be quiet." Faiza (IVeGR) is aware of this:

"I know that I also should not have any noise around me coz (sic) then I would only listen to those and not what I should learn. I realise that I can focus clearer if there is just no music or

other people while I am learning, ideally it should just be me talking. So the computer centre was not the ideal place for me to do the simulation, although I did enjoy most of it and did learn from it."

With the entire class in the computer centre, the environment was too noisy for the verbal learners and therefore this was seen as a negative experience for them. The code **"group work"** (13-3) contradicts the code quiet, as it is impossible for a group of learners to work quietly when they are busy with an interactive activity. The verbal learners liked the fact that they could discuss the simulation with other learners (this was discussed under positive experiences of verbal learners), but the group-work was also a negative experience for them, because it was too noisy and distracted them at times. There were only three verbal learners amongst the seventeen respondents, which meant that they were outnumbered. Lee felt that he was in a difficult position and he said:

"It was quite noisy for me, and I was distracted a lot, but I appreciate working with my friends as well. I could discuss with them and then remember what was said."

It was a difficult situation for them, for although verbal learners need to have no auditory interruptions, it is important for them to talk to someone about the new information.

Associated with the code family was the code **"add explanation".** "Add explanation" means: "The learner would prefer to hear a verbal explanation of aspects in the simulation- either a teacher explaining or a voice over added in the simulation" with a frequency of 22 and a density of 1. This high frequency means that learners felt quite strongly about adding some verbal explanation to the ICS, as an improvement to the current ICS. The fact that there was no verbal explanation was seen as a negative experience for verbal learners and especially the weaker verbal learners who all wanted to have a verbal explanation of the ICS while working with it. Lee (SVeQA) suggested:

"I would have liked to have a thing added where if there's an action happening and there's a sound that's also talking about it while it is happening, then it easier for me to understand while you are listening at the same time."

When Faiza (IVeGR) was asked if she would have liked to have a verbal explanation added she admitted:

"I think initially it would have been fine, but I would have gotten annoyed with it. Like if it was repetitive then I would have really gotten annoyed with it. But actually I think it would have been nice to have that initially, but for a very short while."

Faiza (IVeGR) was academically stronger than Lee and explained why she did not actually need the ICS:

"I've noticed with subjects like Maths and Science and Life Science, I can just sit with my notes and if I read through them then I would understand. I wouldn't necessarily have to see a practical or a diagram of the processes and an application of it to understand it any better. Verbal means if someone tells me something then I will be able to understand it. So if I sit with my notes and I learn it, I understand it. So, yes it is a good interesting way to engage with Science, but I think I would have understood the concept just as well if a teacher had just explained it to me."

This sub-theme was interesting to analyse as the verbal learners made it clear that they would actually have understood the concept if it was just explained to them, without the use of the ICS. This is in line with the features of verbal learners, namely that they need their auditory sense to obtain new information externally. So, whether the distraction of many voices in the computer centre had been absent or even if a verbal explanation could be added to the ICS, it might not have made any difference to their use of the ICS to understand the photoelectric effect.

4.3.1.5 Theme 3: Understanding Dimension- Global learners (G) and Sequential learners (Q)

The third theme identified in this study deals with the Third Dimension identified in the FSLSM, namely the Understanding Dimension, which is subdivided into Global and Sequential learners, as shown by Figure 14 (p. 49) in the conceptual framework. Global learners understand new information by learning in fits and starts, whereas sequential learners follow a logically ordered progression, with the pace of learning dictated by the clock and the calendar. The data for Theme Three is not subdivided into positive and negative experiences of the learners, as the two learning styles are opposites of each other. The ICS benefitted both types of learners and from the interview data I concluded that they all had positive experiences with the ICS. The only issue was to subdivide the available data into experiences of either global or sequential learners. The network view of the Understanding Dimension as shown in Figure 30 shows a network of codes obtained inductively from the data to discuss the experiences of the global and sequential learners.

4.3.1.5.1 Sub-theme 9: Experiences of Global learners when ICS was used

Figure 14 (p. 49) shows that global learners learn and understand best in large jumps holistically; they need to see the bigger picture from the start. This means that they need to jump directly to more complex and difficult material, but this also means that they can feel out of step with their peers and feel incapable of meeting the expectations of their teachers. The following codes, as summarised in Table 12, were identified inductively from the data, as applicable to the criteria of this third dimension when the interviews were transcribed.

Table 12: Descriptions of each code used in the Global learner's code family

Code	Description
Global	In the understanding dimension (how a learner "grasps" a concept - this learner will start with the global picture and then go into detail
Own Pace	Working at their own pace; not being rushed or pushed for time

Sub-theme 9 deals with the experiences of global learners (G) using the ICS to understand the photoelectric effect in a Science lesson. A code family was created for each of the sub-themes and the data for the *code families* was collected from the interviews. The red line arrows indicate the different codes being *linked to the code family*. ATLAS.ti 6 uses solid black lines with double arrows to indicate the codes *associated with* the different positive (good) experiences of the learners (Archer, 2009). For example the code "own pace" is *linked with each code family*, while codes such as "sequence" and "sequential" are *associated with each other*. The code families "global" and "sequential" *contradict each other*, but the codes "sequence- prac then simulation" and "sequence simulation then prac" are *parts of each other*. The codes "quiet" and "group work" also *contradict each other*. According to the conceptual framework and specifically Figure 14, in the Understanding Dimension of the FSLSM, the order in which learners receive new information, will help them to understand new work.

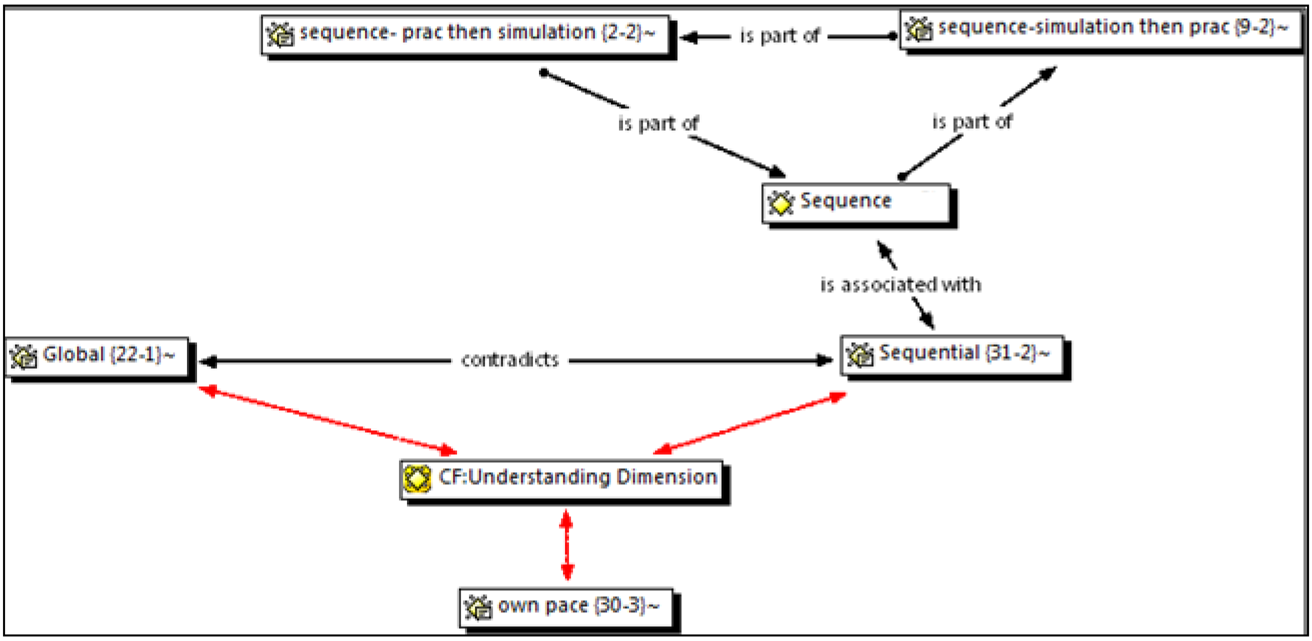

Figure 30: Network view of experiences of Global and Sequential learners with ICS

According to Table 12 the code **"global"** means: "In the understanding dimension (how a learner "grasps" a concept)- this learner will start with the global picture and then go into detail" (22-1). Charmaine (SVIGA) was excited to discover that she was a global learner:

> *"Global makes so much sense to me, I always wanna (sic) see the end result... even with reading... I'd rather know what happens in the end, and if it's boring then I won't read it. But that's what I wanna (sic) do. I want to know what happens in the end and then just go back and break it down like, you know? I can't build a building without seeing what it's gonna (sic) look like first."*

This "discovery of her learning style really meant a lot to Charmaine (SViGA):

> *"I always thought that I was just being impatient, wanting to go to or know the end but now I understand that it's simply my learning style and I don't have to feel bad* about it all the *time."*

When Charmaine (SViGA) was asked what she enjoyed most about using the ICS, she said:

> *"I think the best part for me was the global part. I got to see everything that happens and I got to see in between and when we saw the practical in class I could remember from the simulation what happened in the end."*

Rina (IViGA) confirmed why she liked using the ICS:

> *"I also liked the global part, I could first see the whole simulation and how it ends and then I could start again slowly and make sure I understand where it comes from."*

The next code linked to the network view is **"own pace"** and this code means that the learners were: "Working at their own pace, not being rushed or pushed for time" with a frequency of 30 and a density of 3. The importance of this feature of the ICS is clear from the frequency and the density of this code. Faiza (IVeGR) said what she liked best about the ICS was:

> *"And I could control the pace that I was working at. I could never do that in class."*

When Faiza (IVeGR) was asked which part of the ICS suited her learning style best, she confirms:

> *"I think especially the pace of the simulation"*

Lelo (IViGR) had the highest score on the ILS for Global (11). The first thing she mentioned when she was asked to tell the researcher about the lesson was:

> *"I could do what I wanted to do, I could just pace myself do to what I felt like doing."*

Rina (IViGA) added:

> *"In the simulation, I could determine the pace, so I could go back and do it again until I get (sic) it. Or I could go forward and then back..."*

Although the ICS on the photoelectric effect follows a logical sequence, the global learners liked using the ICS because they could browse through the ICS, go forwards and backwards; start again or go towards the end of the ICS and therefore they were not restricted in following any logical sequence. It is clear from these quotes how the global learners enjoyed using the ICS and how obviously they felt that it was a positive (good) experience for them to use the ICS. They agreed that the ICS suited their learning style.

4.3.1.5.2 Sub-theme 10: Experiences of Sequential learners when ICS was used

The next sub-theme is the experiences of sequential learners using the ICS to understand the photoelectric effect in a Science lesson. Sequential learners learn best when material is presented in a steady progression of complexity and difficulty. Keeping the conceptual framework in mind I looked for codes inductively in the data corresponding to Figure 14 (p. 49), which has a summary of the properties associated with sequential learners. As mentioned before, the network view of the Understanding Dimension as shown in Figure 30 shows a network of codes obtained inductively from the data to discuss the experiences of the global and sequential learners. According to the conceptual framework and, specifically, Figure 14 (p. 49), the order in which learners receive new information, will help them to understand new work. A code family was created for the sequential sub-theme and the data for the *code families* was collected inductively from the interviews. The following discussion gives data explaining the experiences of the sequential learners when they used the ICS. The following codes, as summarised in Table 13, were identified inductively from the data, as applicable to the criteria of this dimension when the interviews were transcribed.

Table 13: Descriptions of each code used in the Sequential learner's code family

Code	**Description**
Own pace	Working at their own pace; not being rushed or pushed for time
Sequence	Order or progression of events
Sequential	In the understanding dimension of learning the learner "grasps" the concept by working step by step in an orderly fashion to get to the end
Sequence: Practical then simulation	If the learner had a choice they would choose the sequence of first doing the physical practical in class (Figure 16) so as to first see the macroscopic change and then do the computer simulation to see the microscopic changes taking place when electrons are released (Figures 17 and 18)
Sequence: Simulation then practical	If the learner had a choice they would choose the sequence of first doing the computer simulation to see the microscopic changes taking place when electrons are released and then the physical practical in class (Figure 16) to see the macroscopic change taking place when electrons are released

Figure 30 shows the network view for both global (G) and sequential learners (Q), but this discussion deals with the branch linking codes to the sequential code family. The first code linked to the sequential code family is **"own pace"** and was also discussed under sub-theme 9. This code was also relevant to the sequential learners, because the logical progression of the ICS added to their understanding of the photoelectric effect. Desmond (SViQR) made it clear why he liked using the ICS:

> *"I like the pace on the computer, it's good that you can do it at your own speed and then discover everything at your own time, no one is rushing you, whereas in class you have a limited amount of time or it's for marks or something so you don't want to mess around with all the stuff to discover something so you just work along according to the rubric."*

He reiterated this later on in the interview when he was asked what he liked best in the lesson:

> *"But the main thing for me was that I could work at my own pace and do what I wanted to do, ja (sic), to discover properly."*

Jacques (SViQA) said:

> *"I could stop or go back and so on, and I really liked that I was in control of the pace that I was working at. I can do the things at my own pace and if I don't understand I can go back and do it again and go slowly and step by step."*

Leroy (SviQR):

> *"you could go at your own pace."*

Lee (SveQA) explained why he enjoyed working with the ICS:

> *"For then it's easier if I work step by step and I see how it goes and when I do this, this is what's gonna (sic) happen. I also liked the fact that I could work at my own pace, I take my time, I can explain it to myself."*

Lee's comment takes us to the next code in the network view in figure 30, namely **"sequential."** The meaning of this code as mentioned in Table 13 is "In the understanding dimension of learning the learner "grasps" the concept by working step by step in an orderly fashion to get to the end." The frequency of this code is 31 and it is mentioned in 2 different code families. The sequential learners particularly enjoyed the logical order working with the ICS. Desmond (SViQR) points out:

> *"Well, the nice thing about the simulation is that you get to see every single step."*

He added:

> *"I know that I like to learn in steps. Using the computer allowed me to witness the photoelectric effect and it helped me identify the laws and concepts of the photoelectric effect instantly. I could work step by step and then I could actually explore the little details and then connect everything together, so with the threshold frequency you can actually bring it closer and closer to the uv ray and then from there you could see ok, this electromagnetic wave, its frequency is this much and the it has x amount of energy and then it would affect the metal."*

Leroy (SViQR) explained how important the first step or introduction of new work is to him:

> *"Well I understand that I need to have steps but I think I've always known that. If I don't have steps I will be working (sic) around in the dark and I don't (sic) know what's going on. I'd rather miss a section of work in the middle of a section, than to miss the introduction of any section. In the middle you can sort of find yourself whereas if you miss the beginning you don't know where you're going. And that was really cool with the simulation. I knew where to start and I could work step by step through the whole process."*

This was reiterated by Bill (IviQR):

> *"I know that if I don't know where I come from, I won't know where I'm going. If I don't know where it starts, I don't know where it ends. I've learnt that especially in AP Maths. I've seen it there most prominently. If I was not there at the start, you can tell me all the wonderful things that I can do with this equation, but it does not or help me, coz (sic) I don't know why I'm using it. That's why I liked working with this simulation. I could follow all the way, from the first photon of light to the last electron emitted, what the photoelectric effect was about."*

The code **"sequence"** refers to the order or progression of events and was included so that the next two codes could make sense. The learners were asked what they thought the order of doing practical exercises should be in order for them to understand the photoelectric effect. They were given two choices, the next two codes indicated on the network view. These were **"sequence- practical then simulation"** (2-2) which means "If the learner had a choice they would choose the sequence of first doing the physical practical in class (Figure 16) so as to first see the macroscopic change and then do the computer simulation to see the microscopic changes taking place when electrons are released (Figure 17, p. 57 and 18, p. 58)." The next code was **"sequence- simulation then practical"** (9-2) and this refers to "If the learner had a choice they would choose the sequence of first doing the computer simulation to see the microscopic changes taking place when electrons are released and then the physical practical in class (Figure 16, p. 57) to see the macroscopic change taking place when electrons are released (Figure 17, p.57 and 18, p.58)." The results were interesting, as the data proved. The global learners in the respondent group did not really have an opinion on any specific sequence to follow, whereas the sequential learners did. It seems as if the sequential learners with high scores on the ILS, such as Desmond (9), Jacques (7) and Kirsten (5) preferred to first do the simulation and then a macroscopic practical.

Desmond (SViQR) said:

> *"Then once you've done the simulation, then you can do the physical practical."*

Jacques (SViQA):

"But I would have liked to do the simulation first and then the practical. Coz (sic) then I didn't really understand the practical first in that way."

Kirsten (SViQA):

"It was better for me to first use (sic) the simulation. It's such a different way of teaching. It's not ... it's no longer just a teacher sitting there, talking to you. It's like everything involved all of it together. You can see it practically happening on a screen and then even if you do a prac (sic) on top of that, ja... (sic) I think it really helps a lot."

Leroy (SViQR) had a suggestion as to sequence of the entire process:

"Ok well first it would be the introduction, just an introduction to the photoelectric effect, an introduction to the equations as well, which we will use later on, uhm... a brief explanation of what the photoelectric effect was or is, a bit of an introduction to important terms like intensity, frequency and that sort of thing. Coz (sic) when I got there the paper was talking about it but I had no idea what that means. So that and then after the simulation then maybe the physical practical. Then after the prac (sic) then maybe some examples to do so that you can see in practise what's happening."

Stuart(SVeQR) was the only sequential learner who would have preferred to do the practical in class first and then the simulation:

"I would prefer to do the physical practical first and then the simulation as an option if you don't understand."

The ICS certainly appealed to both global and sequential learners, and the reason for this is mainly because the learners themselves are in control of which sequence they prefer to follow in order to understand the new information regarding the photoelectric effect.

4.3.1.6 Theme 4: Processing Dimension- Active learners (A) and Reflective learners(R)

The complex mental processes by which perceived information is converted into knowledge is the last theme identified in this study. This is the **Fourth Dimension identified in the FSLSM, namely the Processing Dimension, which is subdivided into Active and Reflective learners.** Active learners are doing something in the external world with the information gained. They are either discussing it or testing it or explaining it in some way. The first subtheme is then the positive experiences of active learners using the ICS to understand the photoelectric effect in a Physical Science lesson. A code family was created for each of the subthemes. The data for the *code families* was collected from the interviews.

4.3.1.6.1 Sub-theme 11: Positive experiences of Active learners when ICS was used

Keeping the conceptual framework in mind I looked for codes inductively in the data corresponding to Figure 15 (p. 50), which has a summary of the properties associated with **Active learners**. Active learners do not learn much in situations that require them to be passive; they work well in groups and tend to be experimentalists.

The meanings of the codes used in to create a network view for this dimension are now explained in Table 14.

Table 14: Descriptions of each code used in the Active learner's code family

Code	Description
Active during CS	The learners enjoy the fact that they are actively busy during the simulation, using their hands and senses. It is a positive experience for the learner and they feel that this adds to their learning experience
Change variable	The learners enjoyed the fact that they could change the settings of or the variables given in the simulation, there is a large range of variables to change, the learner is not restricted to a certain range available in a real class, with active experimentation
Discover through CS	The learners enjoyed discovering the concept of the photoelectric effect by using the simulation
Discuss	The learners enjoy talking about the theory/calculations/laws- engage in a discussion either with fellow learners or with the teacher
Doing things practically	These learners prefer to do hands-on experiments
Enjoy discovering	The learners enjoy discovering themes done in class or during science lessons on TV programmes or in books
Group work	Working together with their peers, discussing, arguing and working together to complete a task
Interactive	The learner is mutually active with the medium, can change variables on the simulation and see the effects of this change, without being scared that something could go wrong- learners feel that information is processed into knowledge when they are actively involved
Quick	Fast reaction
Quick results	The results of any changes done in the simulated practical are immediately visible
Quick to set up	The simulation does not waste time in setting up the equipment as in a lab practical, all the apparatus is immediately available and set up correctly, all in working order

Figure 31 shows a network of codes obtained inductively from the data to discuss the positive experiences of the Active learners (A) in the Processing Dimension. The red line arrows again indicate the different codes being linked to the code family. ATLAS.ti 6 uses solid black line double arrows to indicate the codes *associated with* the positive experiences of the active learners (Archer, 2009). For example the code "enjoy discovering" is *linked to each code family*, while codes such as "change variable/settings" and "interactive" are *associated with each other*. The codes "group work" and "discuss" are *parts of each other*. According to the conceptual framework and specifically Figure 15 (p. 50), active learners enjoy group work; they need to discuss work, argue and bounce ideas off each other. Active learners need to experience things to understand them; they are quick thinkers; they take action quickly; they are verbally fluent; they are willing to take risks and usually have good interpersonal and communication skills. Figure 31 shows the network view of the positive experiences of the Active learners in the Processing Dimension as identified in the FSLSM.

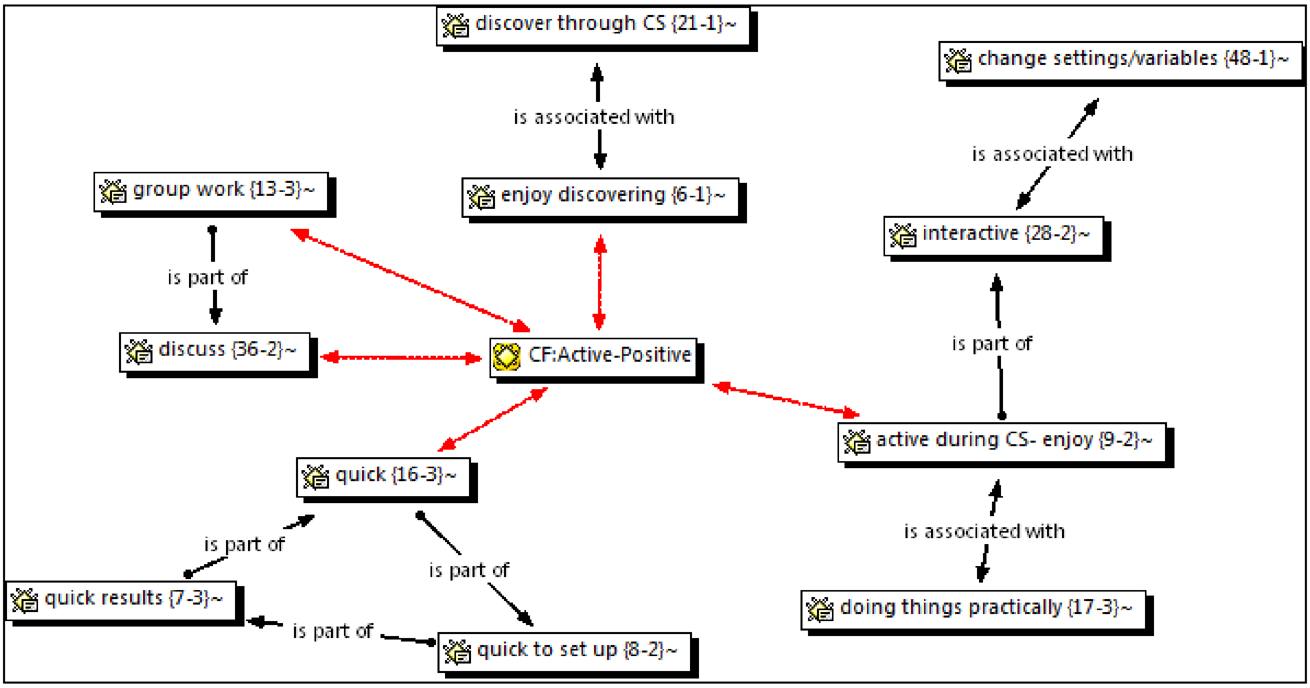

Figure 31: Network view of the positive experiences of the Active learners in the Processing Dimension as identified in the FSLSM

The first code in the network view in Figure 31 and linked to the code family is the code **"discuss".** This code refers to the 'The learners enjoy talking about the theory/calculations/laws- engage in a discussion either with fellow learners or with the teacher" and has a frequency of 36 and a density of 2. The importance of discussing things for an active learner is based on the feature mentioned that active learners enjoy discussing new information; they need to argue and bounce things off each other. This ICS was done in groups in the computer centre of the school, which meant that the learners had ample opportunity to discuss the ICS with each other. Charmaine (SViGA) said:

> *"When we did the simulation, we could have discussions and those types of things you know getting different opinions from everybody else, which was really nice."*

Fundile (SViQA) was of the opinion:

> *"I liked the discussions we had in the computer centre where the whole class was involved."*

Johan (SViGA) said:

> *"When we did the simulation I got to talk and explain and stuff like that (sic), which I think is a strength of mine, so you know I really did enjoy that. When you explain to someone you need to be able to formulate stuff (sic) and give it to them in a way that they actually understand it as well and when we discussed the simulation, it really helped me a lot."*

The **"group work"** code (13-3) is part of the code **"discuss".** According to Table 14 this means "Working together with their peers, discussing, arguing and working together to complete a task." As mentioned before, the ICS was done in groups in the computer centre. When Johan (SViGA) was asked what he enjoyed in the lesson his reply was:

> *"I enjoyed working in the group and I enjoy doing that kind of activity. You know a guy asks a question, you discuss it and then you give an answer. I wish we could do more of that."*

Kirsten (SViQA) said:

> *"I like discussing the stuff with friends as in a group practical, before or after class, does not really matter, even during class. I liked discussing the simulation with my friends and working with my friends and we all went... aw it so cool..."*

Charmaine (SViGA) explained why she liked doing the ICS in a group:

> *"In an ordinary prac (sic) or in this simulation it was nice to work in a group, simply because I don't have the confidence in terms of what I'm doing and because I can't see the end result in a practical. I always have that fear that it might just be the wrong result at the end and I don't know what's right. But at least when we're in a group someone can say "Actually, no, I know that that's the right result" or "You know we all have different inputs and ideas and things."*

And Victor (SViQA) agreed with them:

> *"Being in a group of people... uhm that helps me. I know without even having done that learning styles test that I like working in a group. I can work in a group and learn from it and come out of it having learnt a lot. So when we worked in a group with this simulation, I knew that it was right for me and I will understand it, coz (sic) we were working together."*

The next code associated with the code family is **"enjoy discovering"** (6-1). This code appeals to the active learner's side of being comfortable with trial and error. The meaning of the code is "The learners enjoy discovering themes done in class or during Science lessons on TV programmes or in books" and some of the learners discovered the same feeling when they did the ICS.

Johan (SViGA) said:

"I like to have "Aha" moments when I watch those programmes and I recognise topics that we've covered in class. So when I did the simulation, I also discovered things about the photoelectric effect which I did not know."

Associated with this code is the code **"discover through CS"** (21–1) which means "The learners enjoyed discovering the concept of the photoelectric effect by using the simulation." Charmaine (SViGA) explains why she thought the ICS helped her to discover the photoelectric effect:

"It allowed me to experiment with a concept and formulate my own answers instead of just memorising what the teacher says. It also allowed me to answer my own questions like, if I wanted to know what happens in a certain situation I could figure it out myself and not have to, you know, wait for the answer to be said. It was awesome! I really think it was very cool, coz (sic) everything was based on me and my abilities and it wasn't like somebody giving me a list of what to do and I just do it. I don't think I learn well that way. It was cool, coz (sic) I felt confident in the end."

Monty (SViGA) said:

"I learnt differently in the way that I had to figure out the concepts for myself while I was busy with the simulation and not just remember theoretical concepts given to me by my teacher. Doing the simulation was not really a challenge: it was more like a game for me, like (sic) I could change stuff and then saw (sic) what happened. I was playing around with stuff that wasn't really a challenge for me to figure out what's going on and stuff (sic)."

The next branch on the network view, following a clockwise direction, is the code **"active during CS-enjoy"** (9–2) which means "The learners enjoy the fact that they are actively busy during the simulation, using their hands and senses. It is a positive experience for the learner and they feel that this adds to their learning experience." The code associated with this is **"doing things practically"** (17-3) and this code means "These learners prefer to do hands-on experiments". These two codes are associated with each other, as they both refer to the learner being actively involved during a Science lesson as experimentalists, as opposed to being theoreticians only, characteristic of the opposite learning style in the processing dimension, namely reflective learners. Fundile (SViQA) explained why he enjoyed being actively involved:

"It's like anything, if you see someone doing something, you remember, but if you actually do it yourself it best to understand then."

Kirsten ((SViQA) said:

> *"I liked the fact that I was busy all the time. It was very nice that I was actively involved, when I changed something, I could see what happened."*

Lee (SveQA):

> *"That was really good coz (sic) I can at least see, this is what I have to do and when I do this, this is the result that I get. Being practical and active... Actually doing the work myself- because I understand it better when I do that.*"

Charmaine (SViGA) summarised what she understood as being active:

> *"Under active I understand that I like to be involved in what I'm doing and be busy all the time, not just sit in one place and just read. I wanna (sic) talk, I wanna (sic) listen, I wanna (sic) hear, I wanna (sic) see, I wanna (sic) feel and smell and do all sorts of funny things coz (sic) I need to absorb as much information as I can while I am busy. Now all of this I could do while I was busy with the simulation."*

"Interactive" refers to "The learner is mutually active with the medium, can change variables on the simulation and see the effects of this change, without being scared that something could go wrong- learners feel that information is processed into knowledge when they are actively involved," (28–2). The code **"change settings or variables"** (48-1) is associated with the code interactive. Johan (SViGA) mentioned what he enjoyed most while doing the ICS was:

> *"Well I think the part that I could change the things, the interactive part, I could change the variables and I could see the effects of what I did."*

Lee (SVeQA) stated what he enjoyed most when he was busy with the ICS as:

> *"I know that I have to use intensity in order to make it go faster or slower and I know that this is the colour I'm changing. I'm actually doing it myself, coz (sic) I mean I can also try to explain it to myself. If I know what I'm doing then I can also see it (sic). And then the questions asked about it, it will be easier to actually answer the questions, coz (sic) I know what I was doing..."*

And when he (Lee SVeQA) was asked what he would have changed in the lesson, he said:

> *"Not really anything. I think instead of a lesson about the photoelectric effect being by just talking and expecting us to listen, do not work. So, they shouldn't always talk, but rather give us work like this to do, so that we can have a better understanding by actually doing the work myself (sic)."*

The last branch in this network view includes codes that deal with the feature of an active learner to take action quickly. The codes are **"quick"**; **"quick to set up"** and **"quick results"**. These codes were discussed in detail in sub-theme 3 (Intuitive learners). Data from the active learners relating to these codes were:

Kirsten (SViQA):

> *"A simulation was quick, it was just there instantaneously and I liked that."*

She added:

> *"I enjoyed the quick and easy, the instantaneous change that you could see, not requiring much set up, that was very nice. I really liked the fact that you could spend the whole lesson doing the prac (sic) and not waste time in actually setting up the prac (sic) or cleaning up afterwards. In the same sense I really liked that you could see instantly what was happening on a graph. You didn't have to draw the graph or work it out or any of that."*

This data shows that the use of the ICS was a positive (good) experience for the Active learners. The ICS allowed them to process the new information about the photoelectric effect effectively as it allowed them to do group-work. Working in these groups meant that they could discuss the work, argue about the new concept and bounce ideas off each other. The ICS allowed the learners to experience the photoelectric effect to understand it. Because active learners are quick thinkers who take quick action, the quick availability of information in the ICS appealed to them. They could take risks and not be worried about the consequences, as the ICS allows them to conduct the photoelectric experiment in a completely safe environment.

4.3.1.6.2 Sub-theme 12: Positive experiences of Reflective learners when ICS was used

Reflective learners need to understand a concept before they experience it. This means that they are thoughtful and need time to interpret information. They have the capacity for sustained concentration and a desire to understand the work. Reflective learners prefer to work alone. Keeping the conceptual framework in mind, I looked for codes inductively in the data corresponding to Figure 15 (p. 50), which is a summary of the properties associated with Reflective learners. Table 15 gives descriptions of codes identified in the code family: "Positive experiences of the reflective learners using the ICS", when the interview data was processed.

Table 15: Descriptions of each code used in the Reflective learner's code family

Code	Description
Discover alone	A process of discovering things by themselves
Interpret	The learner is able to understand the meaning of the concept or to convey the meaning thereof to him/herself
Not break	Refers to the possibility of spilling chemicals or breaking glassware during a macroscopic practical as carried out in the lab itself

Not dangerous	Safe, not hazardous or threatening to health of the participant- mostly referring to the execution of some Scientific experiment
Own pace	Working at their own pace; not being rushed or pushed for time
Process	Figure out, think about, changing the information so that it makes conceptual sense to the learner
Repeat	The learner will be able to say or try the action again, so that they can understand better
Teach after reflection	Able to help someone else after the learner has had the chance to think about the matter at hand
Teach yourself	Through a process of trial and error, discovering how to do something by themselves
Think	A reflective cognitive action of processing thoughts
Unlimited repeats	It is possible to repeat the experiment an unlimited amount of times, not restricted by time or apparatus or quantities involved
Work alone	The learner was working by him/herself

The *code family* created for the twelfth subtheme namely the **Positive Experiences of learners in the Fourth Dimension of the FSLSM: Processing Dimension** appears in Figure 32 below. The codes such as: "own pace" and "not break" are linked with the code family **Reflective learners (R)-Positive**, while codes in the branches of the network, such as "think" and "interpret" are associated with each other. The code "discover alone" is a cause of the code "work alone", as this refers to the reflective learners discovering information by themselves when working alone. The code "unlimited repeats" is part of the code "own pace" and this refers to the possibility of repeating the simulation a unlimited number of times, when the learner works according to his/her own pace.

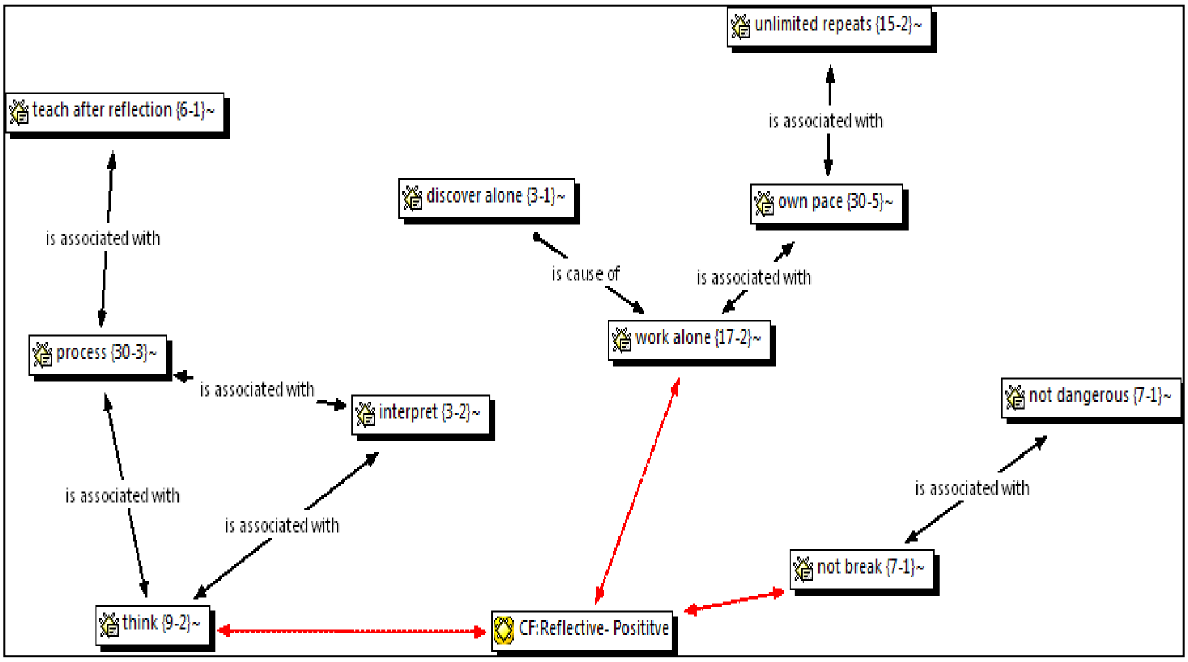

Figure 32: Network view of positive experiences of Reflective learners with ICS

The first code discussed in this network view in Figure 32 is **"think"**. It has a frequency of 9 and a density of 2. The code itself means "A reflective cognitive action of processing thoughts." This code is typical of any reflective learner as it is known that these learners are thoughtful. Leroy (SViQR) explained his version of how much he actually thought about Science:

> *"Like we're doing light now and I'm like (sic) "Oh I never knew that's what's actually going on." It's more of a way for you to see that's how things work sort of thing, I think Science helps me to become more aware of my environment. I mean on the day of the Matric dance my date comes to me and says she's going to wear pink and I'm like (sic) "Oh ok you're wearing pink" and I go home and I'm like (sic) but there are actually a billion shades of pink! "You see what I mean?" You actually realise what stuff is about. It makes me think more about the world around me."*

Bill (IViQR) mentioned what he knew about himself:

> *"When I have time to think about it, or rather sleep on it, it will make sense to me and I can learn it. That usually tends to work quite well."*

Desmond (SViQR) also explained what he knew about himself:

> *"Uhm... when I battle with homework or an exam question, I need some time to think about it. I can't just skip it and come back to it later. Let's say I'm doing another question or another section while I'm studying, it's on my mind coz (sic) I can't figure it out so it bothers me all the time. That is why I take so long to finish my exams. But I also need to learn and adapt for different situations..."*

Stuart (SVeQR) admitted:

> *"Personally I always knew that I can read and think about it and I should be fine generally. That's the reflective side, I like to think a lot and I do like to discuss what I've learnt or what I know, with people that (sic) are on the same wavelength as what I am."*

The code **"thinks"** is associated with two other codes in the network view, namely **"process"** (30-3) and **"interpret" (**3-2). These codes mean: "Figure out, think about, changing the information so that it makes conceptual sense to the learner" and "The learner is able to understand the meaning of the concept or to convey the meaning thereof to him/herself."

Respectively Leroy (SViQR) felt that the ICS really helped him to process and interpret the photoelectric effect. Firstly he explained how any ICS would help someone "process" and "interpret" any new or difficult concept:

"I mean you can just see it visually in 3D and stuff (sic) like that works. I mean, for example, electron orbital you can see "Oh there's the p orbital, there's the s orbital." It's not just like on the paper, its 3D. It's not just 1p 2p what's that? uhm... another thing is that it's interactive, that helps as well because it's like well you can see it and then you go: "Well let me see if I change this or let me add more energy. Let me see what happens now. And then maybe it's quicker and you're like (sic) "Ok, I added energy and now its quicker" and now you're like (sic) "Oh, ok so now the temperature rises and the reaction is quicker" and then you can discover stuff (sic) like that which I think sort of talks to you. So I think for a simulation to be user friendly it has to be productive and it needs to teach the content in a nice user friendly way but then it has to sort of explain that this is not the true size of a molecule in space and so on. So that everyone understands that even if you look at that molecule you must know that there are actually a billion of those out there in space, but for the sake of illustrating the simulation you can only look at one. Then the person will go (sic) "Ok "and conceptualise it."

And then he explained how the ICS helped him to process the photoelectric effect:

"Because, like I said, it's the whole thing... You get a microscopic explanation of what's going on and what would actually be happening if you could see electrons and you could see photons and you could see different frequencies and intensities so you can then think about it.... I think with the simulation it helps because now your mind is put at rest. Your mind's like (sic) "Oh so that's what it is." And your mind just accepts this information and takes it from there."

The code associated with process is **"teach after reflection"** (6-1) which means "Able to help someone else after the learner had the chance to think about the matter at hand." Stuart (SVeQR) explained why this was possible:

"I like to think a lot and I do like to discuss what I've learnt or what I know, with people that (sic) are on the same wavelength as what I am. I also find that I like teaching people. That's always a good thing to make sure you know what you think you know. If you think that you understand, that will show whether you understand definitely. But I prefer teaching someone on a one-on-one and this was possible for me when we did the simulation in class. I was working with my one friend (sic) who did not understand, but I could help him, coz (sic) I had time to think about the whole thing."

If we follow a clockwise direction on Figure 32 the next code in the network view is **"work alone"** (17-2) and the code **"discover alone"** (3-1) is a cause of "work alone". According to Table 15 the meaning of these codes are: "The learner was working by him/herself," and "A process of discovering things by themselves", important aspects for any reflective learner. Lelo (IViGR) admitted:

> *"I also don't like to work in groups; I prefer to work alone... I want to be on my own when I learn. When I worked with the simulation it was nice for me coz (sic) I could work alone and then think about things."*

Stuart (SVeQR) also mentioned this:

> *"I'm more of an individual worker myself, I like doing experiments myself and then if I fail, I fail."*

The code associated with work alone is **"own pace"** (30-5) and it is clear how important this feature of the ICS was to the respondent group, because of the high frequency (30) and density (5). The code means "Working at their own pace; not being rushed or pushed for time." Leroy (SViQR) explained why he specifically liked working with the ICS:

> *"It was nice to work on your own because like I said, you go at your own pace, but in the same breath sometimes it was sort of if you didn't understand something, it was kind of (sic), "Ok so now you know that it does this, but why does it do that?" So you sit for a bit and then, you're like (sic) "Ok this is why."*

Desmond (SViQR) added:

> *"Using the computer allowed me to witness the photoelectric effect and it helped me identify the laws and concepts of the photoelectric effect instantly. I could work at my own pace and then I could actually explore the little details and then connect everything together, so with the threshold frequency you can actually bring it closer and closer to the uv ray and then from there you could see "Ok this electromagnetic wave, its frequency is this much and the it has x amount of energy and then it would affect the metal..." But the main thing for me was that I could work at my own pace and do what I wanted to do, ja (sic) to discover properly."*

And Stuart (SVeQR) said:

> *"Another thing that I liked a lot was the fact that I could work at my own pace. I've always found that I work quite fast and then sometimes when things go slowly I get bored and that's just my personal thing. I like going over topics and then I know that I don't really like sitting on them (sic) even though it would probably be good for reinforcement, I prefer to do that in my own time, at home. This was a good thing working with the simulation."*

The code **"unlimited repeats"** (15-2) is associated with the code **"own pace."** These codes are associated with each other because they all refer to the feature of an ICS where it is possible to repeat any steps of the ICS at their own pace and the relevance (and importance) thereof for learners. The following quotes all refer to the positive experiences of reflective learners with the repeatable feature of the ICS. Bill (IViQR) said:

> *"You aren't practically doing it but you are given the ability to run the experiment an unlimited amount of times in a theoretical environment, so you can actually see what is happening regardless if in real life it is happening at a micro level. So you could repeat any steps that you didn't get, until you get it."*

When he was asked which part of the lesson he enjoyed most, his reply was:

> *"I liked the fact that we were able to do the simulation over and over and play around with the settings and instantly see the effects."*

The last branch in the network view deals with the cautious nature of reflective learners. The codes found inductively from the data were: **"not break"** (7-1) and **"not dangerous"** (7-1). Descriptions for these codes can be found in Table 15. Bill (IViQR) stated:

> *"Without worrying about breaking equipment thus I feel more relaxed which helps me focus on the experiment results... It was less stressful because it couldn't break. But I still don't like practicals, I don't like working with the equipment coz (sic) I'm clumsy. So the simulation is perfect for me. I could relax and not worry about breaking anything or messing up anything. I know what I'm doing with a simulation."*

Leroy (SViQR) said:

> *"I liked the computer simulation because it is a cheaper method of reproducing conditions or influencing conditions which are maybe too expensive or too dangerous to do in a lab or ja... In this simulation, we could even use dangerous levels of radiation without the fear of going extra lengths or whatever else."*

And Stuart (SveQR) added:

> *"...and that's the whole point of a simulation. You want to do something which is dangerous in a safe way. But as real as possible."*

The data support the features of reflective learners indicated on Figure 15 (p. 50) in the conceptual framework. The reflective learners felt that the ICS allowed them the time to understand the concept of the photoelectric effect before they could experience it. The ICS gave the reflective learners time to be thoughtful and time to interpret the new information. Because reflective learners have the capacity for sustained concentration they enjoyed using the ICS because their thought processes were not interrupted. This gave them a desire to understand the work. The learners were given a choice whether they could work alone or in a group: Reflective learners prefer to work alone and they enjoyed the freedom of the choice. The ICS allowed them to process the information about the photoelectric effect in their own time, on their own.

4.3.2 Results from interviews before and after use of ICS

4.3.2.1 Theme 5: Learning styles

An unexpected theme which evolved from the data, dealt with the code **"learning styles"**. Most of the learners had no idea what a learning style was before this study and it was interesting to note the positive feedback from the learners regarding their learning styles. Some of the learners conducted their own research to find out more about it, others just asked the researcher to explain what it all meant. The end result was that that they were excited to know that they were unique in their approach to how they learn and the discovery that there was an existing model explaining their own behaviour to them, made sense to them and they found it motivating. The description for this code was: "Learning style refers to the way individuals prefer to process new information and strategies they adopt for effective learning". The frequency of this code was 30, which is high and of particular significance in this study. The following quotes show how that data supports the view that knowing about their learning style motivated the learners. Bill (IViQR) explains:

> *"But before I did the test, I could never pinpoint it, but I did have an idea of what works for me and what doesn't work for me. It was basically trial and error and I decided on certain things and certain methods to study, but this now pin points it for me so now I know, if there are any more things which can slightly maybe deviate from it I would know how to improvise for it. Now it makes it much more easier (sic) for me to focus on what I'm doing."*

The following quotes are some of the learner responses to the following question: **"Does knowing what sort of learning style you are best at, help you in any way?"**

Charmaine (SViGA) responded by saying:

> *"Yes especially the global and the active part. I always thought that I was just being impatient, wanting to go to or know the end but now I understand that it's simply my learning style and I don't have to feel bad about it all the time. There's actually a reason why I am the way I am. I can use that now in terms of now (sic) I can build proper mind maps that, you know start at the end and then I can break it down in terms of the work. I think it will help me*

in terms of my studies and doing it efficiently and not just try doing the prescribed way of sitting down and studying and read a book and summarise it."

Desmond's (SViQR) answer to the same question was:

"I was surprised about my learning style because my studying methods were very different to my learning style but I think I can get used to this learning style. I will have to adjust my studying methods so that I can benefit from knowing about my learning style and ultimately my learning entirely. It has shown me where my key strengths are. It makes so much sense to me coz (sic) I know that I like to learn in steps. We have been told that we must start with an exam question that you are most comfortable with, but I know that I have to start with the first question. At least do the first question before I do any of the others... and now I know that's because I'm sequential. Uhm... when I battle with homework or an exam question I need some time to think about it. I can't just skip it and come back to it later. Let's say I'm doing another question or another section while I'm studying, it's on my mind coz I can't figure it out so it bothers me all the time. That is why I take so long to finish my exams. But I also need to learn and adapt for different situations, but it nice to know that I am reflective learner."

Fundile (SViQA):

"Yes it does coz (sic) now I can see that I can focus more on studying in that style to improve my marks and make sure that I am able to acquire the knowledge required in the most effective way possible for me and not waste time."

Jimmy (IViQA):

"Yes as you know how to optimise your learning. With the exams around the corner, I am going to take that on board."

Johan (SViGA):

"Well, I do think it helps in a certain sense, ... I did have a rough idea of what I am, ... looking at this, this just puts names to what I knew I was you know. I mean (sic) I knew that I was active coz (sic) I have to move around while I'm learning stuff. So, I mean (sic) it will help. The sensory stuff, I didn't know that I was sensory but now I do know, so in terms of studying and so on, I will definitely take these things into account."

Kirsten (SViQA):

"A lot of it I knew about myself but I didn't know that there was a word for it. Now I know and it makes perfect sense to me. Yes, it indicates the way in which I must learn to increase understanding to reach my full potential. I've always known that I'm visual, but to know this kind of stuff does help. I know that I'm a sensory person coz (sic) I know that I use my senses,

I feel a lot when people talk and I relate to them and stuff. And I think that's also part of the active thing, because I'm a people's person."

Lee (SVeQA):

"I guess I've always had a kind of brief idea (sic) of what I am and because of my filing systems and everything, with my organisation of my work, uhm... coz (sic) I will always know what to put where, coz (sic) it always has to be in order. If I leave it here, I need to find it here again. So I understand that I'm sequential, coz (sic) I always work step by step. If I have to do a calculation, I have to use each and every step and then I understand it. But I have to do the steps myself and explain it to myself in order to understand it properly. It's all about me doing the thing, while I'm also talking about it. I learn a lot when I write and talk and explain the work to myself. I understand how my brain works when it comes to learning and it is actually true in this regard because the results of my learning style are a true indication of how I see things and understand them."

And Rina (IViGA) even felt that she could now convince her mother why she had started a study group:

"Under active it means that I have to participate in the learning process; I need to get it myself. Okay not get it myself but I need to be working when I learn and it will be good when I work in a group to explain to someone. And you know ma'am, I started a study group, recently and my mom doesn't understand why I need to. She thinks because I'm teaching the other people, I'm helping them more than I'm helping myself and it's not true! I need an introduction before I can do something...My mom is a step by step person and then when I do step by step, I stop. I lose interest. I think that's my problem why I'm not interested; I need to see the end."

These quotes have shown that the learners benefitted by knowing what their learning styles were. They were inspired and motivated at a time in their Grade 12 year, when they really needed it. They felt that they understood themselves and others better, and were even more tolerant with each other.

4.4 Discussion of the results

This study found that the ICS added value to the learning experience of all the different types of learners identified according to the FSLSM. The four dimensions mentioned in this learning model addresses the reception of new information, the sensory channel used for receiving this new information, how the learner progresses towards understanding this information and how the information is comprehended and converted into knowledge. In this study, the photoelectric effect was a new concept in Science (thus new information) given to the Science learners. This new information was to be explored by the learners. This study investigated what the experiences of these learners were, when they used the ICS to help them process the new information and convert this knowledge into understanding the photoelectric effect. The purpose of the study was to find out if learners with different learning styles would have similar or different experiences when they used the same ICS to master a new concept.

Keywords in the research question are underlined as: *What are the experiences of learners with different learning styles when an Interactive Computer Simulation (ICS) is used to aid teaching the photoelectric effect in a Science classroom?* Guided by these keywords the findings which emerged from the data were mainly that the learners with different learning styles had different experiences when they used the ICS. Of particular interest was that these different experiences were in accordance with the capabilities of each learning style identified in the four dimensions indicated in the FSLSM by Felder & Silverman (1988).

4.4.1 Positive experiences of learners using the ICS with reference to their learning style

The *positive experiences* of the learners are summarised in the network view visible in Figure 33. For the sake of clarity, the network was designed according to the different dimensions in the FSLSM. Codes associated *with more than one code family is indicated in grey*, for example the code different dimension" is associated with the both the code families "Intuitive" and "Visual," but the rest of the codes are colour coded. The key indicates which colour refers to which learning style. The learning styles are discussed in the same format as Figure 11 (p. 40) and are subdivided into the four dimensions as identified in the FSLSM (Felder & Silverman, 1988).

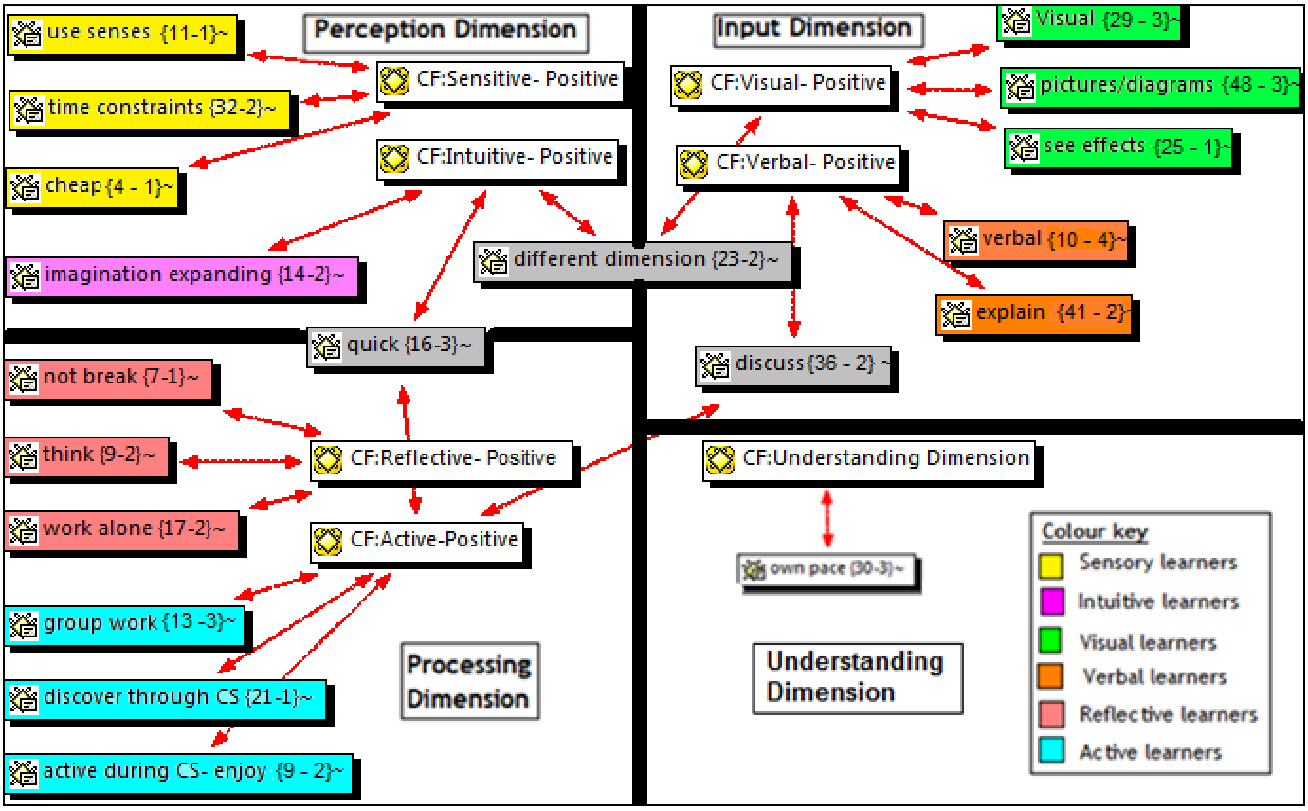

Figure 33: Positive experiences of learners using the ICS with reference to their learning style

The following discussion of the network view in Figure 33 starts with the code families "**Sensory/ Sensitive**-positive" and "**Intuitive**-positive" as indicated. These code families form part of the *First Dimension* of the FSLSM namely the Perception Dimension. These codes show the difference between the information perceived by learners belonging to the two learning styles that form part of this dimension.

According to Figure 33 **"Sensory"** learners mentioned in their interviews that **"using their senses", without "time constraints" in a "cheap"** manner of conducting an experiment, was valuable to them to perceive information, when they used the ICS. This is in line with the information shown in Figure 12, mentioned in the conceptual framework, which states that sensitive learners perceive new information externally; they need to work without being pushed for time, as they are methodical, meticulous and slow and that they are cautious by nature. "For those who study perceptual learning, the consequence of learning is that one gets closer to the world, not further" (Lindgren & Swartz, 2009). By using the ICS, the sensory learners felt that they could understand the photoelectric effect, because it enhanced the type of information they could absorb in order to perceive the new information. Perception helps guide action, and action helps shape the predictions of perception (Lindgren & Schwartz, 2009).

The opposite learning style of this First Dimension refers to the code family **"Intuitive."** The data collected showed that when intuitive learners used the ICS they perceived the information in a **"different dimension," "quickly"** and felt they could use their **"imagination"** whilst busy with the ICS. Once again the data substantiated Figure 12 (p. 47), as it suggested that the intuitive learners perceive new information internally, quickly and in a complicated way. This is in line with Lindgren and Schwartz's (2009) statement: "the benefits of perceptual learning do not stop with perception. The ability to see important distinctions prepares learners to understand conceptual treatments that depend on and explain these differences. To promote perceptual learning, people need exposure to appropriate variability." The intuitive learners appreciated the different dimension which the ICS brought to their Science lesson.

The *Second Dimension* mentioned in the FSLSM refers to the Input Dimension, which refers to the sense organ used by learners to receive information. As mentioned before, Paivio's (1971) dual coding hypothesis is that people encode both a picture and its verbal interpretation. By creating two retrieval paths, the chances of remembering new information is enhanced (Lindgren & Schwartz, 2009). The permeability and mutual reinforcement of visual and verbal processes is important for Science education. According to Figure 33 (p. 133) the data obtained from the interviews showed that the code family **"Visual learners"** enjoyed the ICS because they could receive new information from the ICS, about the photoelectric effect **"visually"** by **"pictures/diagrams"** and they could actually **"see the effects"** of any changes made during the course of the experiment. This was mentioned in Figure 13 as important feature for visual learners as they depend on their sight to obtain new information.

The opposing learning style in this dimension refers to **"Verbal"** learners. Figure 33 (p.133) indicates that the verbal learners felt that the ICS enabled them to obtain information verbally, that they enjoyed **"discussing"** and **"explaining"** the ICS amongst themselves. The verbal learners felt that they could learn effectively by using the ICS, as they could use their auditory sense to obtain new information about the photoelectric effect.

This shows that not only did both visual and verbal learners have a positive experience by using the ICS to obtain new information by using a preferred sensory organ, but it also confirms the picture superiority effect of the ICS by combining the visual and the verbal effect for all the learners in the Input Dimension. Scientific visualisation tools help scientists see patterns that might have been overlooked in a stream of numbers. More generally, converting concepts to space has been an important scientific tool for the discovery of structure (Lindgren & Schwartz, 2009).

The *Third Dimension* indicated in the FSLSM refers to the **sequence** of the events leading up to **“Understanding”** new information. The learners all indicated that the ICS allowed them the freedom to choose which sequence they wanted to use when working with the ICS. Sequential learners worked in a step by step fashion when they used the ICS to understand the photoelectric effect, and global learners could use the ICS in fits and starts- in line with the sequences indicated in Figure 14 (p. 49) as relative to both types of learners in the Understanding Dimension. Lindgren & Schwartz (2009) indicated that “Science education simulations can illuminate the deep structure beneath surface changes. In some cases, simulations “purify” phenomena, so that it is easier to see the deep structure without the noise of incidental variation.” The learners indicated that the ICS enabled them to structure the new information about the photoelectric effect in such a way that it made sense to them and they could understand the concept by following the sequence which they preferred in this Understanding Dimension.

The *Fourth dimension* in the FSLSM refers to the Processing Dimension. In this dimension new information is comprehended and converted into knowledge and the dimension is subdivided into the code families **“Active”** and **“Reflective”** as indicated in Figure 33. The codes associated with the code family **“Active”** shows the relevance of the data obtained to Figure 15 (p. 50). The codes **“Active during CS-enjoy,” “discover through CS,” “group work,” “discus”** and **“quick”** all refer to the properties associated in the conceptual framework with active learners. The data shows that the learners felt that they could process the information properly while they were busy with the ICS. They felt that the ICS enabled them to be actively busy, they could work in groups, and they could retain the information and understand it by doing something active with it. The learners felt that the ICS allowed them to experience the photoelectric effect so that they could understand it. In addition, they could bounce ideas off each other while working in their groups. The power of human interception lies in its ability to entertain and facilitate possible actions (Lindgren & Schwartz, 2009), a statement illustrated in this finding.

The code family **“Reflective”** refers to the opposite learning style in the fourth dimension, namely the reflective learners. The codes associated with this code family were **“not break,” “think” and “work alone”.** The data substantiates the features of reflective learners as indicated in Figure 15 (p. 50) in that the learners felt that the ICS allowed them to process the new information in a thoughtful manner. The ICS appealed to their cautious manner and using the ICS allowed them to work on their own, so that they could use their capacity for sustained concentration properly. Reflective learners enjoyed processing the information about the photoelectric effect internally and following a structured method whilst working alone.

4.4.2 Negative experiences of learners using the ICS with reference to their learning style

The negative experiences of learners who used the ICS are subdivided into code families relating to the learning styles identified in the FSLSM (Figure 34). Negative experiences with the use of the ICS were only relative to two dimensions of the FSLSM, namely the *First (Perception) Dimension* and the *Second (Input) Dimension*. The codes associated with each code family is also colour coded to make it easy for the reader to understand which code families are associated with the specific code family, for example the codes “dislike repeats” and “dislike detail” are both associated with the code family “Intuitive-negative”. A grey code refers to a code associated with more than one code family; the only code in this network view associated with two code families is no introduction” – associated with both Intuitive and Verbal.

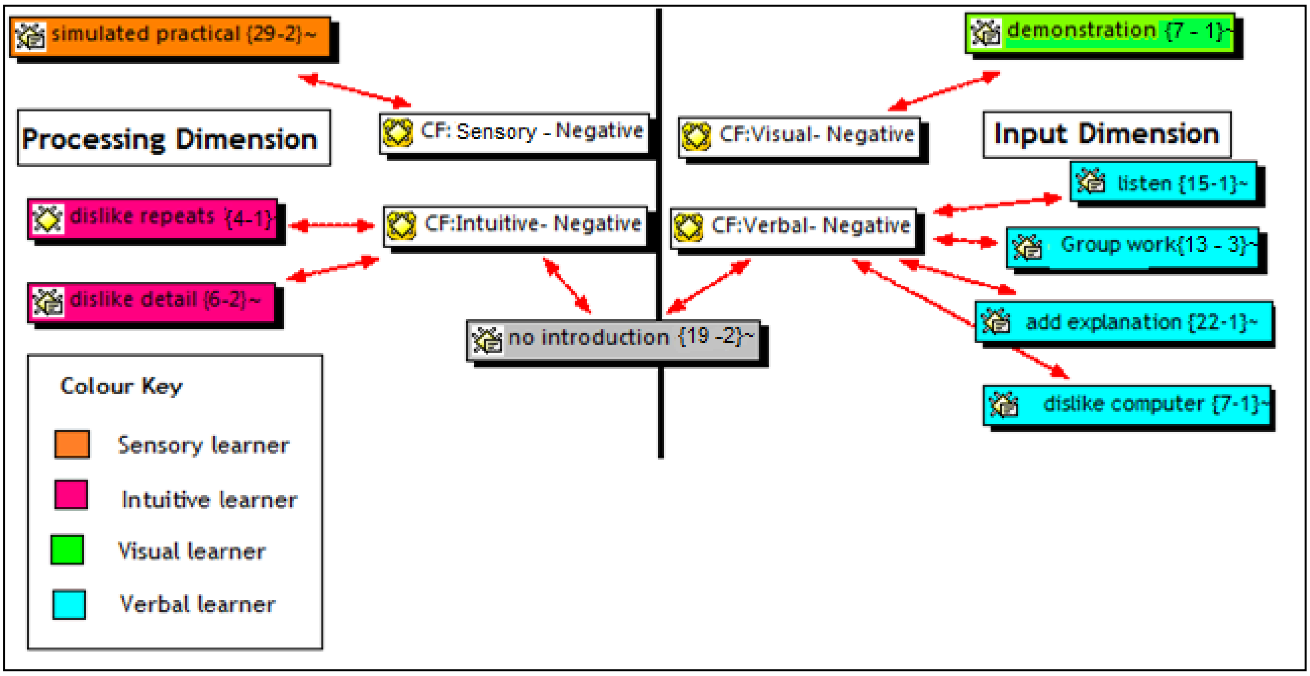

Figure 34: Negative experiences of learners using the ICS with reference to their learning style

The *First Dimension* mentioned in the network view in Figure 34 of the negative experiences of the learners when they were busy with the ICS is the Perception Dimension. In this dimension the learner takes certain types of new information in and the dimension is subdivided into Sensitive and

Intuitive learners. The code **"simulated practical"** is associated with the code family **"Sensitive-negative"** since sensitive learners enjoy "hands on" experiences. A few learners mentioned in their interviews that the ICS did not involve the "real practical deal". They could not set up actual apparatus and they felt that they could not use all their senses while busy with the ICS, as would be the case in a real school laboratory. However, these learners were aware of the limitations of this specific practical in a school laboratory. The intuitive learners were irritated by the repetitive and detailed nature of the ICS. They felt that they got bored with the detail and the repetitive nature of the ICS, once they actually got the information regarding the photoelectric effect. Intuitors need change and enjoy complications, which were not possible in this simulation. The codes **"dislike repeats"** and **"dislike details"** are associated with the **"negative experiences of the intuitive learners."** A code which is associated with another code family is the code **"no introduction."** Although intuitors enjoy complications, they were irritated because there was no proper introduction to the use of the ICS before the lesson. The intuitors felt that they would have preferred to have some theoretical background before the lesson, as it would have given them some abstract concepts as a starting point to the lesson. The nature of the intuitors added to these dislikes of the learners when they were using the ICS, as they prefer problems calling for innovation when they need to take new information in.

The *Second Dimension* in this network view in Figure 34 (p. 136) is the Input Dimension. This dimension refers to the sensory organ used by the learners to receive external information most effectively. The code **"demonstration"** is associated with the code family **"visual learners-negative"** and this refers to the negative experiences of the visual learner, before the ICS was used. These visual learners complained about the fact that they were not given a demonstration before they were allowed to use the ICS. They felt that they were confused at the start of the lesson, because they did not have a visual reference point to start from. The learners felt that a quick visual demonstration of the ICS and the associated features thereof would have added to the value of the lesson. The verbal learners complained the most about the ICS. As seen in Figure 34 (p. 136) the code family **"verbal-negative"** has four codes associated with it. These associated codes are **"listen", "group work", "add explanation", "dislike computer" and "no introduction",** since verbal learners use their auditory sense to perceive external information most effectively. This means that they need to hear the new information. This proved a frustration for the verbal learners, as the ICS was done by the full class in the computer centre of the school. This meant that the verbal learners had too many auditory stimuli at once. The rest of the class were talking to each other, discussing the ICS and explaining it to each other. Although verbal learners prefer talking about their new discovery, they want to do it on a one-on-one level. The rest of the class caused distracting noise for them and they had to **“listen”** to too many people talking around them. This then explains why the code **“group work”** is also associated with the negative experiences of the verbal learners, as they would have preferred not to have the ICS done by the entire “noisy” group at the same time. The codes **“add explanation”** and **“no introduction”** are actually related to each other. Most learners felt strongly that they did not like the way in which the teacher just left them to do and discover the ICS by themselves. The verbal learners felt that a short introduction, explaining verbally what the ICS was about and how it should be done, would have added to their learning experience. The code **“dislike computer”** was an unforeseen one, but an important one. This referred to the possibility that a verbal learner does not like using a computer as the learner knows that he/she receives external information by hearing. This means that in spite of all the positive experiences which the learner might have had with the ICS, the most ideal way for a verbal learner to obtain new information, would still be auditory.

4.5 Conclusion

In this chapter, I presented interview data which was collected in Nelspruit during 2011. In the next chapter I will discuss my findings on the basis of a literature control. I will identify the trends and possible explanations for these trends. My research question is answered, and I will reflect on my research study and draw conclusions from the case study. I will also discuss the limitations and significance of the study and make recommendations for further research.

CHAPTER FIVE

Findings and conclusions

5.1 Introduction

In this chapter I will answer the research question that guided this study, followed by a discussion and reflection of the study, I will point out limitations of the study and make recommendations for future research. The research question which guided this study is: *What are the experiences of learners with different learning styles when an Interactive Computer Simulation (ICS) is used to aid teaching the photoelectric effect in a Science classroom?*

5.2 Summary

The research question asked what the experiences of the learners with different learning styles was, when an ICS was used to aid teaching the photoelectric effect in a Science classroom. The following discussion summarises both the positive and negative experiences of the learners identified during this study.

5.2.1 Positive experiences of learners using ICS

Table 16 is a summary of the positive features of the ICS identified by the learners themselves. The learners mentioned these as positive experiences which they've had in the lesson where they have used the ICS to help them understand the photoelectric effect and linked it to a specific feature of the ICS itself, or to the lesson while they were busy interacting with the ICS. While a certain feature was mentioned as a positive experience by learners of one learning style, the same feature was not necessarily important to a learner with a different learning style.

Table 16: Positive experiences of learners using ICS with specific reference to learning style

Perception Dimension		**Input Dimension**	
Sensing	**Intuitive**	**Visual**	**Verbal**
Can use senses	Can use imagination	See moving simple pictures of process taking place	Can explain process to myself or someone else
No time constraints	Quick setup and results	See effects of any changes	Can discuss
Cheap to use	Shows different dimension	See visual different dimension	
Understanding Dimension		**Processing Dimension**	
Global	**Sequential**	**Active**	**Reflective**
Don't have to follow any sequence	Can do it step by step	Active because its interactive	Enough time to think about all
		Discover how it works	Cannot break, so can focus on concept
		Work in group	Work alone

This table shows that the ICS had assisted the teacher in explaining the concept of the photoelectric effect to the learners. This data is in line with current literature on the properties of each learning style in the FSLSM (Felder & Silverman, 1988). Figures 12 (p. 47); 13 (p. 48); 14 (p. 49) and 15 (p. 50) were used to identify the properties associated with each learning style and Table 16 (above) confirms that learners with different learning styles will experience different components of the ICS in different ways.

5.2.2 Negative experiences of learners using ICS

The next theme which emerged from the data dealt with the negative experiences of learners with some features of the lesson where they used the ICS to help them understand the photoelectric effect. Only two of the dimensions which form part of the FSLSM could be identified where specific negative features were mentioned. The Perception Dimension (where certain types of new information is received by learners) and the Input Dimension (where sensory organs are used to receive new information) were affected. It is useful to note that it was not necessarily the ICS itself which provided the learners with these negative experiences, but rather the circumstances during the lesson while they were using the ICS. This theme was discussed in section 4.3.1 (p. 78). Table 17 shows a summary of these "negative" features of the lesson.

Table 17: Negative features of the lesson with use of ICS with specific reference to FSLSM

Perception Dimension		Input Dimension	
Sensory	**Intuitive**	**Visual**	**Verbal**
Not real equipment	Repetitive	Need demonstration	Group work makes too much noise
	Boring detail		Dislike computer
	Need introduction		Need explanation before

These negative experiences could be used as positive criticism on the lesson, if an ICS is used to assist a teacher. It has been found in other studies that there is no real difference in a learner's conceptual understanding, whether real or virtual equipment is used in Science (Baser & Durmus, 2010). This means that the issue that the sensory learners have with no real equipment being used, does not hold any credibility in them understanding the concept. The most important sub-theme presenting itself here is that the teacher must be involved in the lesson and that the teacher must introduce, demonstrate and explain the ICS before the start of the lesson. These negative experiences of the learners must be used as a guideline for teachers to plan their lesson properly, and include all the learning types.

In Table 1 (p. 15), several capabilities which could be provided by modelling software and their potential contribution to the Science learning environment was identified by Papadouris and Constantinou (2009). Table 1 (p. 15) was then used as a guideline and the following discussion confirms that this study also found that the ICS is a useful tool to aid understanding new concepts in Science. Learners identified the following unique capabilities of an ICS (as opposed to a textbook or physical practical) when the photoelectric ICS was used. Previous studies mention the advantages of using ICS in Science (Blake & Scanlon, 2007; Eskrootchi & Oskrochi, 2010; Papadouris & Constantinou, 2009; Lindgren & Schwartz, 2009), but the following findings point out the capabilities provided by this specific ICS on the photoelectric effect, which helped the learners to understand this new concept of the photoelectric effect. This would not have been possible without the use of the ICS.

5.3 Findings

5.3.1 Finding 1 (a): Virtually conduct an experiment that would normally require unsafe conditions

The Perception Dimension in the FSLSM deals with the type of new information perceived by learners and is subdivided into external (Sensory learners) and internal (Intuitive learners) information (Felder & Silverman, 1988). This first finding shows that the **sensory learners** appreciated that it was possible to conduct this experiment with light of different frequencies and intensities, a situation that would not normally be available in a school laboratory (Subtheme 1, section 4.3.1.1.1, p. 78). The equipment would have been expensive and the frequencies of the light used from the electromagnetic spectrum, would definitely have been unsafe to use. The sensory learners were aware of this "safe experiment" made possible by using the ICS. It was therefore possible for them to evaluate the validity of theoretical principles about the photoelectric effect in conditions that could not be established naturally. According to Figure 21 (p. 76) there were 11 sensory learners and 8 of these learners commented on this feature. Johan (sensory learner) mentions:

> *"You know especially if you don't have that much experience, not much can go wrong*.

This supports the findings of Papadouris and Constantinou (2009), who also mentioned the positive feature of conducting ICS experiments in safety.

5.3.2 Finding 1 (b): Setting up of experiment quickly and with ease

The other type of learner in the Perception Dimension is the **Intuitive learner**. They perceive new information internally and would therefore be very impatient with external "equipment" (Subtheme 3, section 4.3.1.2.1, p. 88). For these learners, it was a positive experience to not have to bother setting up physical equipment and they could skip steps in the method (Felder & Silverman, 1988). The ICS allowed them to focus on their internal information- linking the process on the screen to theories, memories or hunches. They did not have to clean up afterwards, which meant that they had more time to spend with the abstract concepts which they preferred. Of the 6 intuitive learners (Figure 21, p. 76), 4 mentioned how they appreciated this feature of the ICS, for example, Bill says:

> *"...also the fact that it did not require lots of set up and we actually had more time to work out what was going on rather that spending it on setting it up or something."*

Felder and Brent (2005) mention how impatient Intuitive learners are and how this could affect their perception of new information. The ICS thus addresses this issue, by enabling the Intuitive learner to "set up their experiment quickly."

5.3.3 Finding 2: Bringing about a different dimension

Intuitive learners need to be able to use their imagination (Figure 12, p. 47) and despite all the concrete information supplied by the ICS (which was appreciated by the sensory learners), it allowed the intuitive learners to use their imagination (Subtheme 3, section 4.3.1.2.1, p. 88). The ICS showed them the basic photoelectric concepts, but because they could see the basics, it inspired them to be creative and think innovatively, regarding the concepts around the photoelectric effect. Mojo (intuitive learner) said:

> *"Yes because you actually see how the things work (sic) and then I could think of other possibilities where this might be useful. It added depth to my understanding because it was easy and different at the same time."*

"It is always important to make sure that intuitive learners are given the opportunity to be innovative, as this inspires greatness amongst the learners" (Felder, 2012). The ICS enabled the intuitive learners to do just that. It was mentioned in Chapter 4 that several of the learners mentioned that this exposure to the ICS opens new possibilities for them in the post graduate field. They felt that it would be possible to combine careers in Information Technology and Science, which would mean that they would not have to make a choice between these two choice subjects (refer to page 90).

5.3.4 Finding 3: Visualisation of abstract physical systems

In the *Input Dimension*, two types of learners can be distinguished, namely visual and verbal learners. It was interesting to note which features of the ICS was important to visual learners and how this differed from the features mentioned by the verbal learners. Figure 21 (p. 76) shows that there were 14 visual and 3 verbal learners. All 14 **visual respondents** commented on how easy it was for them to understand the photoelectric effect, because the entire abstract process was visible, as it showed them a simple animated diagram (Subtheme 5, section 4.3.1.3.1, p. 97). The results of this study shows that they could see the actual photons of different coloured light falling on the metal plate and they could see the effect of how changing the intensity of the incident light changed the amount of photons released, as it was a picture showing more or fewer photons released. The learners could see for themselves that for any frequency change, the colour of the light released changed, as the picture showed it clearly. The results show that learners were able to see how the electrons were released from the metal only if the correct frequency of light fell on the specific metal plate. Any light of a lower frequency would not release electrons from the metal plate. This made the concept *threshold frequency* "visible." The microscopic view made possible in the ICS was mentioned and appreciated by most of the learners- they were aware that electrons and photons are actually not visible without expensive equipment such as electron microscopes, equipment not readily available, and certainly not in a school laboratory. This confirms the study of Felder and Silverman (1988) which points out how important it is for a visual learner to use his sense of sight to obtain new information. Johan (who is a strong visual learner) made the following statement:

> *"I think the simulation is good coz (sic) I prefer to see stuff and I could see everything in this simulation. I would remember something like this on a piece of paper more than people just telling me stuff (sic) that way. It was great to literally be able to see how everything just fitted in with each other."*

Statements like this one were in line with the studies of Papadouris and Constantinou (2009) and Lindgren and Schwartz (2009) where the authors made reference to the importance of the visual capabilites provided to learners by the ICS, which then enable the learners to develop their own mental model to represent the abstract and inferred concepts associated with (in this specific case) the photoelectric effect, such as *metals releasing electrons when a photon of light strikes it*.

It was interesting to note that all three the **verbal learners** made it clear that they enjoyed discussing the ICS with others, but that seeing the pictures in the ICS, did not make any difference to the input of the new (scientific) concept, namely the photoelectric effect (Subtheme 7, section 4.3.1.4.1, p. 104). The verbal learners knew that they would have understood the concept, if it was just properly explained to them, as was pointed out by Faiza in the following quote:

> *"I wouldn't necessarily have to see a practical or a diagram of the processes and an application of it to understand it any better, so the it was nice to use the simulation and I enjoyed discussing it with my friends, but I would have understood the photoelectric effect without having used the simulation."*

In a traditional teaching milieu, verbal learners are often seen as not being attentive enough during the explanation of a new concept because they might seem to not be giving the teacher undivided attention while the teacher is explaining new work. This is often just the opposite. A verbal learner is actually concentrating very hard when a teacher is explaining new work and by not looking at the teacher, they are focussing on using their auditory sense to its full capacity. The data in this report indicates that an ICS would therefore only be useful to a verbal learner, if they could explain the ICS and therefore a new concept to a fellow learner, or if they could discuss the ICS with each other.

Figure 13 (p. 48) highlights the important features of learners in the Input Dimension and this finding supports the studies on capabilities of visual and verbal learners, as mentioned by Felder and Silverman (1988); Felder (1993) and Felder et al. (2002).

5.3.5 Finding 4: Gained deeper understanding of the physical phenomenon

In the Understanding Dimension of the FSLSM (Figure 14, p. 49) it is mentioned that this dimension focuses on how the learner progresses towards understanding. The sequence (or lack thereof) determines how the learner progresses towards understanding. There were 10 **sequential learners** and 7 **global learners** in the respondent group (Figure 21, p. 76). Finding 4 shows that the ICS helped them to gain a deeper understanding of the photoelectric effect because they followed different sequences whilst working with the ICS (Subtheme 9, Section 4.3.1.5.1, p. 111; Subtheme 10, Section 4.3.1.5.2, p. 114). In the end they all agreed that the ICS enabled them to translate the ideas gained in the ICS to the photoelectric effect. The learners could predict the results of other experiments relating to the photoelectric effect and they could describe how these results lead to the photon model of light, which were the goals set out originally when the learners were introduced to the photoelectric effect. This meant that the learners had "*developed the skill to select and combine appropriate representation formats to communicate certain ideas*" (Papadouris & Constantinou 2009, p. 531). Desmond (a sequential learner) explained:

> *"Using the computer allowed me to witness the photoelectric effect and it helped me identify the laws and concepts of the photoelectric effect instantly. I could work at my own pace and then I could actually explore the little details and then connect everything together, so with the threshold frequency you can actually bring it closer and closer to the uv ray and then from there you could see ok this electromagnetic wave, its frequency is this much and the it has x amount of energy and then it would affect the metal. So the steps that I could follow made so much sense to me."*

Charmaine (a global learner) explains her positive experience with the ICS:

> *"The simulation made so much sense to me. I wanna (sic) see the end result... even with reading... I'd rather know what happens in the end, and if it's boring then I won't read it. But that's what I could do with the simulation. I wanted to know what happens in the end and then just go back and break it down like (sic) into these little pieces again, you know? I can't build a building without seeing what it's gonna (sic) look like first. I really enjoyed that part of the simulation"*

These two quotes almost contradict each other, but for both these learners it made perfect sense to follow their own specific sequence so that they could understand the photoelectric effect. Felder and Soloman (1997, p. 3) confirms this with the following statement:

> Sequential learners tend to gain understanding in linear steps with each step logically following the previous one. Global learners tend to learn in large jumps, absorbing material almost randomly without seeing connections and then suddenly "getting it."

It would not have been possible to cater for these two opposite sequences in a normal lesson, so the ICS enabled these learners to follow their own sequence.

Some of the learners were also aware of misconceptions that could be formed while working with the ICS, such as the sizes of the particles involved. Stuart (sequential learner) explained:

> *"For example with the photo electric effect you can see the electrons hit and you can see the electrons liberated even though you know they try to make it look as best as possible and it's a bit surreal coz they are really big practical's, but it's just to tell you right this* is it (sic) *and if you understand, it does not really matter to you."*

This showed that the ICS enabled these learners to translate their ideas from one representation to another and that they could even format alternative representations of the photoelectric effect.

5.3.6 Finding 5: Collection of pseudo-experimental data

The Processing Dimension of the FSLSM deals with how information is comprehended and converted into knowledge (Figure 15, p. 50). Active learners need to do something with the information, while reflective learners need to think about it. Finding 1(b) discusses how important it was to the sensory learners that the experiment could be set up quickly and with ease, whereas in this finding (finding 5), 5 of the 6 **reflective learners** mentioned that it was a positive experience to "discover" how easy it was for them to "collect the correct, required data." It was a relief to the reflective learners not to be worried about having to make sure that they were collecting the correct values for variables, before attempting to draw a graph, as the ICS "provided" them with the "correct" values (as generated by the software in the program). They could concentrate on reflecting on the concepts involved with the photoelectric effect and not waste time worrying about the accuracy of the data gathered (Subtheme 12, Section 4.3.1.6.2, p. 123). Bill (reflective learner) explains:

> *"Normally in a practical, it is just very irritating because I don't get the result, so I can't see how I can get marks for the work and then I look for a replacement. So now I know that I can do that same practical by doing a simulation and not worry about the results, because they will be correct."*

Three reflective learners appreciated that the graphs that needed to be drawn at the end of the experiment were instantly available and they did not have to waste time using graphing skills to draw the graph. The learners felt that the ability to evaluate their own mental model of the photoelectric effect model was of value to them and gradually improve their own understanding of the model. Any cognitive conflicts that were generated could be dealt with quickly, as was mentioned in the study of Papadouris and Constantinou (2009).

However, the **active learners** did not understand the graphs that were drawn as part of the ICS and they would have preferred if the graphs were not there at all (Subtheme 11, Section 4.3.1.6.1, p. 118). They felt that they did not understand the relationships between the variables and that the graphs just confused them. They would rather have drawn their own graphs, from the values obtained by the ICS. This is in line with Figure 15 (p. 50), as active learners need to do something with the information before they can process it. By being busy themselves with the drawing of the graph, they are processing the new information.

Charmaine (active learner) said:

> *"I think the graphs that were just there, were just not my style (sic), because I did not understand them at all! I did not even look at them to try figure (sic) them out. When I used them I was like (sic), I think I did everything wrong! Coz I did not understand. I did not know what I was looking at, like I really did not know what I was looking at. I would have liked to know what I was looking at, or some explanation telling me what I was looking at, or that this graph shows a relationships between this, that and that. I think if I could have drawn the graph myself from a table given to me by something in the simulation, I am sure I could have figured it out (sic)."*

Active learners have shorter attention spans and find it hard to maintain their focus for long periods of time (Felder, 1994) which means that not all the features in the ICS were seen as positive by all the learners. Eight of the 11 active learners (Figure 21, p. 76) complained about not understanding the graph supplied by the ICS.

5.3.7 Finding 6: Interactive control variables

As mentioned in Finding 5 and according to Figure 15 (p. 50) the Processing Dimension deals with the way in which new information is converted into knowledge. The ICS provided the **Active learners** with some active learning. They felt that the use of the ICS added to their skills with respect to conducting a valid experiment through the appropriate control of the variables. They felt that they had learnt much by being able to conduct the experiment themselves, because they were interactively involved in changing the variables in the experiment when using the ICS. Johan (active learner) said:

> *"I enjoyed the simulation coz (sic) I had an active role in doing it. Because, me myself, I am changing the things and I am doing it, I'm not just watching somebody else explain it. So I think it really helped me understand"*

This is supported by the studies of Felder (1994) and Eskrootchi & Oskrochi (2010).

The self-confidence of **Reflective learners** was enhanced, as they knew from the start of the experiment that it was a risk-free environment. The interactive ICS provided practise in trial-and-error analysis and this gave the reflective learners time to reflect on the photoelectric effect. Desmond (reflective learner) said:

> *"I also felt safe working with the computer coz (sic) there was not any equipment that I could break and I could not really do anything wrong."*

This also allowed both active and reflective learners the opportunity to identify causal relationships between the variables and irrelevant parameters. This supports Lindgren & Swartz's (2009) statement that "the controlled and replicable nature of simulations makes them ideal for delivering optimal variability for perceptual learning. A key feature of simulations is the repetitive process of configuring and testing."

5.3.8 Finding 7: Group work versus working alone

The last finding of this study highlights the feature of an ICS which allowed the learners to work either in groups or work alone. **Active learners** are energized by other people (Felder, 1994) and therefore the ICS provides them with the opportunity to work through the ICS in a group, discussing and solving the interactive simulation together. Rina (active learner) said:

> *"I really enjoyed working in a group when we did the simulation and teaching others and helping them and I think I also learn a lot when I help other kids... you know I like to work with lots of people and talk a lot and it is nice to talk about the subject that I like so much.*

At the same time, the ICS provided the opportunity for the **reflective learners** to work on their own and they could complete the task at home. In Figure 21 (p. 76) it is mentioned that there are 6 reflective learners and all of them mentioned how much they enjoyed being able to work alone. They felt confident knowing that they could work on their own. Desmond (reflective learner) explained why he liked working with the ICS:

> *"I liked working on my own; it was much nicer than working in a group."*

Both types of learners (Active and Reflective) gained by using the ICS to learn about the photoelectric effect. Active learners were able to discuss, argue and work out their ideas by bouncing them off others; thereby using their most effective learning tool. Reflective learners were allowed to take the information in, process it introspectively and then respond, which is their most effective learning tool (Felder, 1994).

5.4 Limitations of the study

Data were gathered from a small number of learners and generalisation of the results is impossible. However, generalisation was not an aim of the study. Another limitation is the fact that the interviews and observations were all done in Term 3 with a Matric group of Science learners. The class teacher was not part of the study and more data regarding the teacher's knowledge of the learners could have been gathered. As my presence in class already influenced the teaching process, I did not want to intrude furthermore on the learners' learning process. I am aware that different researchers could interpret my data differently. My own perspective is bound by space, time and personal experience. Even though my conclusions were carefully scrutinised and confirmed or not confirmed by my supervisors, as well as my participants, the possibility that subjectivity may have influenced my findings cannot be ruled out.

5.5 Recommendations for future research

An unexpected outcome of this study was that knowing about and understanding their learning style, motivated the learners. This however, was beyond the scope of this study. Although learning styles has been criticised by many academics, the learners in this study were empowered when they could attribute their differences to a learning style. I would recommend the following for future studies:

1. To use a larger number of learners from three different scholastic backgrounds- for example using learners from under resourced schools, partially resourced schools and well resourced schools.
2. To do a study where the learner is unaware of his or her learning style during the course of the observation.
3. Where both learner and teacher are unaware of the learning style during the course of the observation.
4. Divide the group into two groups: group A does the simulation, group B the actual experiment. Test their understanding or learning of the concept. Then swop the groups (A experiment; B simulation) and repeat the experiment. Their understanding of the concept will (obviously) be better so now you ask them to assess which (experiment or simulation) worked better for them as individuals and then compare their answers to their learning styles as well as the test conducted after

round 1. Here the researcher would need to know the learning styles to ensure representation of each style in each group but the learners do not need to know their own styles.

5.6 Conclusions

The ICS played an important role in helping the learners understand the photoelectric effect and the experiences which the learners had when they used the ICS, could be linked to all four the dimensions of the FSLSM. Learning styles should be taken into account when teaching with technology (Grasha & Yangarber-Hicks, 2000) and the results of this study showed why it would be beneficial for a Science teacher to do just that. No two learners approach learning in exactly the same way and I concur with Keefe's (1987) definition: A learning style is a *"characteristic cognitive, affective, and psychological behaviour that serve as relative stable indicators or how learners perceive, interact with, and repsond to the learning environment"* (Felder, 2010, p. 1).

A learning style model *"specifies a small number of dimensionis that collectively provide a good basis for designing effective instruction*" (Felder, 2010, p. 1). Like all models they are incomplete but potentially useful representations of reality, and should be judged by how well they characterise and interpret observations and inform professional practice. Many instructors have made effective use of learning styles in planning their teaching and many studies have been published attesting the usefulness of common models for both metacognitive and pedagogical purposes (Felder & Brent, 2005).

Several studies have indicated that computer simulations are as productive a learning tool as hands-on equipment, given the same curricula and educational setting (Triona & Klahr, 2003), so the benefits of using an ICS as a tool cannot be disputed. The challenge would be for the teacher to make sure that he/she chooses his/her ICS carefully. Both the choices of which ICS to use and when to use the ICS are vital. In an ideal world, the most effective way of teaching Science would be to do experiments with learners using the real practical equipment and supplement it with the use of an ICS. The sequence of using these tools would depend on the theme and concept at hand.

In this study, the benefits of using the ICS to assist in teaching the photoelectric effect to the Grade 12 Science learners was clear, as shown in the data in Chapter Four. The benefits of using the ICS, whilst keeping the learning styles of the learners in mind, were illustrated in the data as well. It was shown that the ICS provided both learning styles in the *Perception Dimension* with the type of information which they needed to take in; and it provided both visual and auditory sense organs with information in the *Input Dimension*. The learners had the freedom to follow any sequence to

Understand the new information and they could *Process* the new information actively or by reflection, when they used the ICS.

Kierkegaard (1946 cited in Felder & Brent, 2005, p. 69) said that "*true instruction begins when instructors understand their learners*". It is also important to be aware of the different attitudes that learners have towards learning; the different ways they approach it, and how instructors can influence both the attitudes and approaches of the learners. It is important for teachers to gain that awareness, because the more successful they are in doing so, the more effectively they can design instruction that benefits all of their learners. In turn, the better the learners understand the strenghts and weaknesses associated with their attitudes and preferences, the more likely they are to learn effectively while they are at school and throughout their careers (Felder & Brent, 2005).

This study used quantitative data collected from 46 Grade 12 Science learners in Mpumalanga through the ILS questionnaire which allowed me access to data collected through a high quality instrument. Qualitative data through interviews, observations, and field notes were collected from seventeen Grade 12 Science learners. Both sets of data were integrated in the analysis and interpretation. The findings given at this point are based on the integration and synthesis of both quantitative and qualitative data collected from seventeen Science learners in Mpumalanga. In each case, the evidence that supports the findings has been presented or referred to. Given the data collected in this study, it was possible to move beyond the specific evidence-based findings to culminate the findings from this research in my conclusion.

Each of the themes which emerged was inferred from the wealth of evidence gathered and interpreted in the research. The research question was: *"What are the experiences of learners with different learning styles when an Interactive Computer Simulation (ICS) is used to aid teaching the photoelectric effect in a Science classroom?"* The conclusion of this study is then: An ICS will assist a teacher in teaching a difficult concept in Science, as it accommodates all types of learning styles, with the provision that the teacher chooses the ICS well and plans the lesson properly. Given the enormous workload of Science teachers nowadays; an extremely loaded syllabus and the huge expectations from teaching authorities in our present day, teachers can do with all the added help available to prepare our youth for the future.

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LIST OF APPENDICES

Appendix A: ILS Questionnaire

NC STATE UNIVERSITY

Index of Learning Styles Questionnaire

Barbara A. Soloman
First-Year College
North Carolina State University
Raleigh, North Carolina 27695

Richard M. Felder
Department of Chemical Engineering
North Carolina State University
Raleigh, NC 27695-7905

Directions

Please provide us with your full name. Your name will be printed on the information that is returned to you.

Full Name

For each of the 44 questions below select either "a" or "b" to indicate your answer. Please choose only one answer for each question. If both "a" and "b" seem to apply to you, choose the one that applies more frequently. When you are finished selecting answers to each question please select the submit button at the end of the form.

1. I understand something better after I
   - **(a)** try it out.
   - **(b)** think it through.
2. I would rather be considered
   - **(a)** realistic.
   - **(b)** innovative.
3. When I think about what I did yesterday, I am most likely to get
   - **(a)** a picture.
   - **(b)** words.
4. I tend to

- **(a)** understand details of a subject but may be fuzzy about its overall structure.
- **(b)** understand the overall structure but may be fuzzy about details.

5. When I am learning something new, it helps me to
   - **(a)** talk about it.
   - **(b)** think about it.
6. If I were a teacher, I would rather teach a course
   - **(a)** that deals with facts and real life situations.
   - **(b)** that deals with ideas and theories.
7. I prefer to get new information in
   - **(a)** pictures, diagrams, graphs, or maps.
   - **(b)** written directions or verbal information.
8. Once I understand
   - **(a)** all the parts, I understand the whole thing.
   - **(b)** the whole thing, I see how the parts fit.
9. In a study group working on difficult material, I am more likely to
   - **(a)** jump in and contribute ideas.
   - **(b)** sit back and listen.
10. I find it easier
    - **(a)** to learn facts.
    - **(b)** to learn concepts.
11. In a book with lots of pictures and charts, I am likely to
    - **(a)** look over the pictures and charts carefully.
    - **(b)** focus on the written text.
12. When I solve math problems
    - **(a)** I usually work my way to the solutions one step at a time.
    - **(b)** I often just see the solutions but then have to struggle to figure out the steps to get to them.
13. In classes I have taken
    - **(a)** I have usually gotten to know many of the students.
    - **(b)** I have rarely gotten to know many of the students.
14. In reading nonfiction, I prefer
    - **(a)** something that teaches me new facts or tells me how to do something.
    - **(b)** something that gives me new ideas to think about.
15. I like teachers
    - **(a)** who put a lot of diagrams on the board.

(b) who spend a lot of time explaining.

16. When I'm analyzing a story or a novel
    - **(a)** I think of the incidents and try to put them together to figure out the themes.
    - **(b)** I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.
17. When I start a homework problem, I am more likely to
    - **(a)** start working on the solution immediately.
    - **(b)** try to fully understand the problem first.
18. I prefer the idea of
    - **(a)** certainty.
    - **(b)** theory.
19. I remember best
    - **(a)** what I see.
    - **(b)** what I hear.
20. It is more important to me that an instructor
    - **(a)** lay out the material in clear sequential steps.
    - **(b)** give me an overall picture and relate the material to other subjects.
21. I prefer to study
    - **(a)** in a study group.
    - **(b)** alone.
22. I am more likely to be considered
    - **(a)** careful about the details of my work.
    - **(b)** creative about how to do my work.
23. When I get directions to a new place, I prefer
    - **(a)** a map.
    - **(b)** written instructions.
24. I learn
    - **(a)** at a fairly regular pace. If I study hard, I'll "get it."
    - **(b)** in fits and starts. I'll be totally confused and then suddenly it all "clicks."
25. I would rather first
    - **(a)** try things out.
    - **(b)** think about how I'm going to do it.
26. When I am reading for enjoyment, I like writers to
    - **(a)** clearly say what they mean.

- **(b)** say things in creative, interesting ways.

27. When I see a diagram or sketch in class, I am most likely to remember
    - **(a)** the picture.
    - **(b)** what the instructor said about it.

28. When considering a body of information, I am more likely to
    - **(a)** focus on details and miss the big picture.
    - **(b)** try to understand the big picture before getting into the details.

29. I more easily remember
    - **(a)** something I have done.
    - **(b)** something I have thought a lot about.

30. When I have to perform a task, I prefer to
    - **(a)** master one way of doing it.
    - **(b)** come up with new ways of doing it.

31. When someone is showing me data, I prefer
    - **(a)** charts or graphs.
    - **(b)** text summarizing the results.

32. When writing a paper, I am more likely to
    - **(a)** work on (think about or write) the beginning of the paper and progress forward.
    - **(b)** work on (think about or write) different parts of the paper and then order them.

33. When I have to work on a group project, I first want to
    - **(a)** have "group brainstorming" where everyone contributes ideas.
    - **(b)** brainstorm individually and then come together as a group to compare ideas.

34. I consider it higher praise to call someone
    - **(a)** sensible.
    - **(b)** imaginative.

35. When I meet people at a party, I am more likely to remember
    - **(a)** what they looked like.
    - **(b)** what they said about themselves.

36. When I am learning a new subject, I prefer to
    - **(a)** stay focused on that subject, learning as much about it as I can.
    - **(b)** try to make connections between that subject and related subjects.

37. I am more likely to be considered
    - **(a)** outgoing.

- **(b)** reserved.

38. I prefer courses that emphasize
    - **(a)** concrete material (facts, data).
    - **(b)** abstract material (concepts, theories).

39. For entertainment, I would rather
    - **(a)** watch television.
    - **(b)** read a book.

40. Some teachers start their lectures with an outline of what they will cover. Such outlines are
    - **(a)** somewhat helpful to me.
    - **(b)** very helpful to me.

41. The idea of doing homework in groups, with one grade for the entire group,
    - **(a)** appeals to me.
    - **(b)** does not appeal to me.

42. When I am doing long calculations,
    - **(a)** I tend to repeat all my steps and check my work carefully.
    - **(b)** I find checking my work tiresome and have to force myself to do it.

43. I tend to picture places I have been
    - **(a)** easily and fairly accurately.
    - **(b)** with difficulty and without much detail.

44. When solving problems in a group, I would be more likely to
    - **(a)** think of the steps in the solution process.
    - **(b)** think of possible consequences or applications of the solution in a wide range of areas.

When you have completed filling out the above form please click on the Submit button below. Your results will be returned to you. If you are not satisified with your answers above please click on Reset to clear the form.

Submit Reset

Dr. Richard Felder, felder@ncsu.edu

Appendix B: Example of learner's ILS results

NC STATE UNIVERSITY

Learning Styles Results

Results for: [redacted]

```
ACT                                     X                 REF
     11   9   7   5   3   1   1   3   5   7   9   11
                         <--  -->

SEN                               X                       INT
     11   9   7   5   3   1   1   3   5   7   9   11
                         <--  -->

VIS  X                                                    VRB
     11   9   7   5   3   1   1   3   5   7   9   11
                         <--  -->

SEQ                                                  X    GLO
     11   9   7   5   3   1   1   3   5   7   9   11
                         <--  -->
```

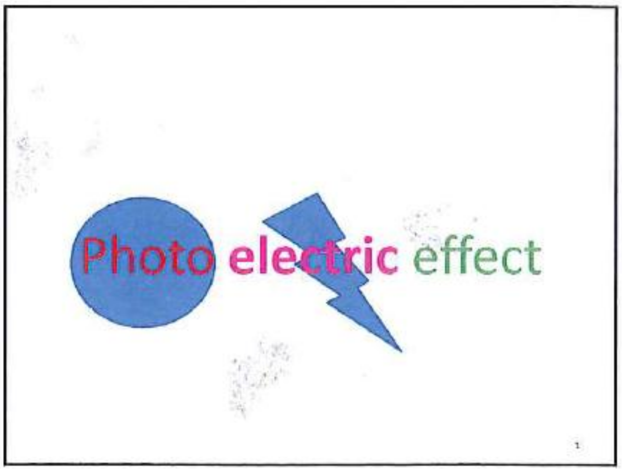
- If your score on a scale is 1-3, you are fairly well balanced on the two dimensions of that scale.
- If your score on a scale is 5-7, you have a moderate preference for one dimension of the scale and will learn more easily in a teaching environment which favors that dimension.
- If your score on a scale is 9-11, you have a very strong preference for one dimension of the scale. You may have real difficulty learning in an environment which does not support that preference.

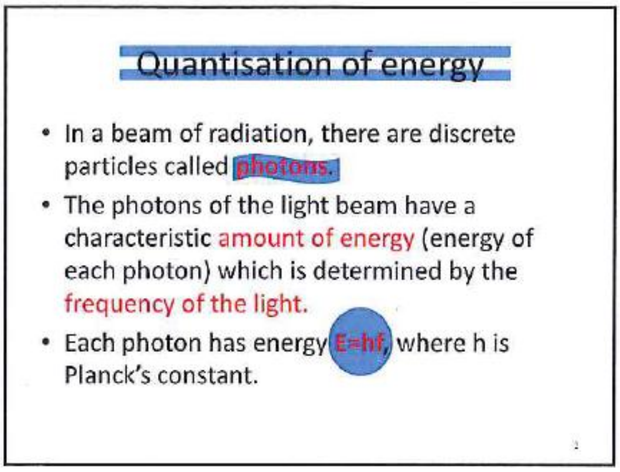
We suggest you print this page, so that when you look at the explanations of the different scales you will have a record of your individual preferences.

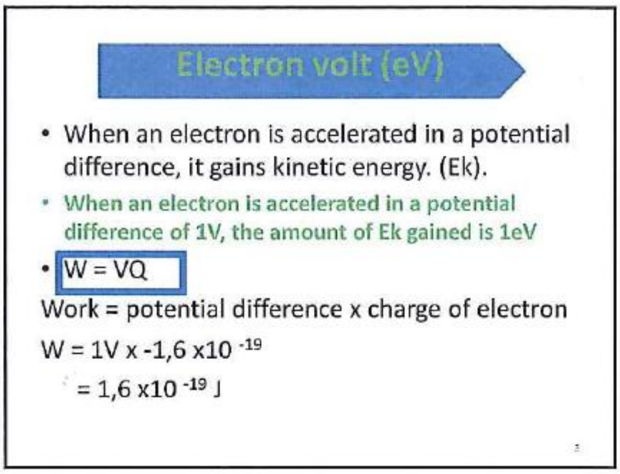
For explanations of the scales and the implications of your preferences, click on Learning Style Descriptions.

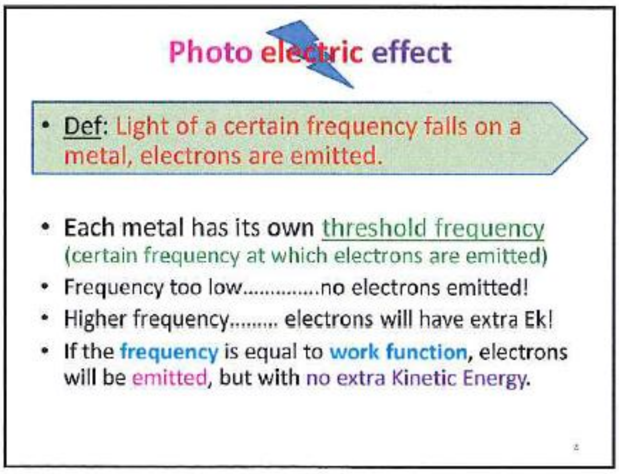
For more information about learning styles or to take the test again, click on Learning Style Page.

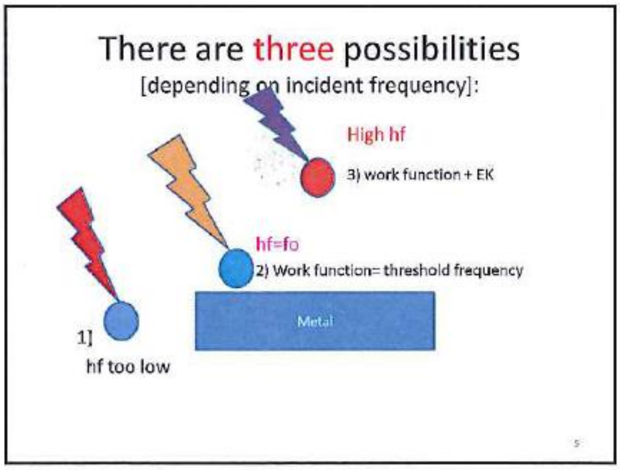
Appendix C: PowerPoint presentation

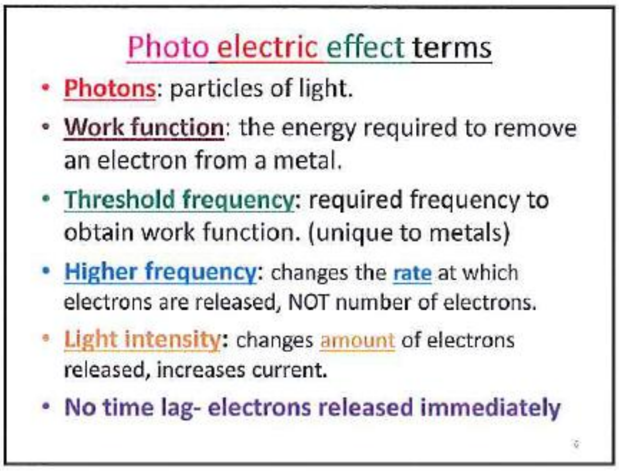












Appendix D: Worksheet on prior knowledge

Photoelectric Effect Investigation- Prior Knowledge

Name: ________________________________ Date: ____________________

1. What is the electromagnetic spectrum?

____

____

____

2. How do these waves originate?

____

____

____

3. What is the speed of all electromagnetic waves?

____

4. Write down the wave equation:

____

5. Explain, in terms of this wave equation, how it is possible to have an entire electromagnetic spectrum of waves.

____

____

____

6. What is a photon?

____

7. What determines the energy of a photon?

____

8. Which equation will be used to calculate the energy of a photon of light?

____

9. Explain:

9.1 Where an electron volt originates from.

____

9.2 Give a definition for ONE electron volt

____

9.3 Which equation will you use to determine the value of 1eV?

____

10. Complete this table of information about electromagnetic radiation.

$$1 \text{ eV} = 1{,}6 \times 10^{-19} \text{ J}$$

Frequency, (Hz)	**Wavelength (nm)**	**Energy (J)**	**Energy (eV)**
$5{,}33 \times 10^{14}$		$3{,}52 \times 10^{-19}$	
$5{,}58 \times 10^{14}$			2,3
$8{,}96 \times 10^{14}$			3,7
$1{,}04 \times 10^{15}$		$6{,}88 \times 10^{-19}$	
$1{,}07 \times 10^{15}$			4,4
$1{,}09 \times 10^{15}$		$7{,}20 \times 10^{-19}$	

11. Complete the following sentences:

11.1 The frequency of electromagnetic radiation __________ as its wavelength increases.

11.2 The wavelength decreases as the frequency ________________.

11.3 The energy of electromagnetic radiation increases as its ____________ increases.

Appendix E: Instructions and worksheet on interactive simulation on photoelectric effect

WORKSHEET on the Photoelectric effect

Name:___________________________________

Date:___________________________________

http://phet.colorado.edu/en/simulation/photoelectric

Use the simulation obtained from the website above to answer Questions 1-3 on investigating Photoelectric effect.

Question 1

1. Select Sodium for the target material
2. Set the intensity at 10%
3. Check the current vs intensity and the electron energy vs light frequency graphs
4. Move the wavelength to about 800 nm
5. Move the wavelength bar slowly towards lower wavelengths in steps of 50 nm and write down everything you observe

Answer these questions:

a) Look at the circuit and decide what charge the particles have.
   Charge = ___________________

b) Name this type of subatomic particle: __________________

c) What is the wavelength when you start to see particles leaving the target?_______

d) What is the corresponding frequency for this wavelength?________________

e) What happens to the speed and quantity of electrons as you decrease the wavelength (increase the frequency) of the incident radiation?

____

f) Do all the electrons travel at the same speed for a particular wavelength? _______

g) How do you know this? ____

h) Complete the table of results for sodium (on the next page).

Table of results for SODIUM as a target

Wavelength (nm)	Particles	Current (A)	Electron energy (eV)
700	none		
650			
600			
550			
500			
450			
400			
350			
300			
250			
200			

Question 2: Repeat steps 1 – 5 for all the other target materials and fill in the tables below.

ZINC

Wavelength	Particles	Current	Electron energy (eV)
700	none	0	0
650			
600			
550			
500			
450			
400			
350			
300			
250			
200			
150			

COPPER

Wavelength	Particles	Current	Electron energy (eV)
700	none	0	0
650			
600			
550			
500			
450			
400			
350			
300			
250			
200			
150			

PLATINUM

Wavelength	Particles	Current	Electron energy (eV)
700	none	0	0
650			
600			
550			
500			
450			
400			
350			
300			
250			
200			
150			

CALCIUM

Wavelength	Particles	Current	Electron energy (eV)
700	none	0	0
650			
600			
550			
500			
450			
400			
350			
300			
250			
200			
150			

QUESTION 3

1. Select sodium for the target material and set the intensity at 0%.
2. Check the current vs intensity and the electron energy vs light frequency graphs.
3. Increase the intensity gradually until you reach 100% and write down what you observe on the speed, the number of electrons leaving the target and current.
4. Complete the table below by making a cross in the correct column.

	Speed of the fastest electrons(v_{max})			Number of electrons being emitted			Current produced		
	No effect	Decrease	Increase	No effect	Decrease	Increase	No effect	Decrease	Increase
Increase frequency for a fixed intensity									
Increase intensity for a fixed frequency									

a) What happens to the speed of the electrons as the intensity of radiation increases?

____

____

____

What does this tell us about the relationship between speed and intensity of radiation?
-

____

____

____

b) What happens to the kinetic energy of the electrons as the intensity of radiation increases?

____

____

____

c) What is the effect of increasing the intensity on the number of electrons leaving the metal target?

____

____

____

What do think is happening here (to cause this effect)?

____

____

____

In your own words on a piece of A4 paper, write down what you so far know and understand about the photoelectric effect.

(What is happening? What causes it to happen? Does it happen in the same way for all metals? What causes an increase in the number of electrons emitted? How does colour (frequency) of light affect the photoelectric effect?)

Appendix F: Worksheet for learners on content matter after use of simulation

Worksheet to assess knowledge after simulation

NAME: ______________________________ DATE: __________

Question 1

(a) The minimum frequency at which electrons start leaving the metal is called the **threshold frequency** and the corresponding energy is called the **work function** of the material, Set the intensity at 50% and determine to the nearest 5 nm the wavelength of light that allows electron emission for each of the 5 target metals.

____

____

____

b) Calculate their threshold frequency and work function.

____

____

____

c) Complete the table below.

Metal	Wavelength (nm)	Threshold frequency (Hz)	Work function (eV)
Sodium			
Zinc			
Copper			
Platinum			
Calcium			

Question 2

Calcium has a work function of 2,7 eV.

Calculate :
(a) It's threshold frequency and its corresponding wavelength.

____

____

____

(b) The maximum velocity of the electrons produced when calcium is illuminated by light of wavelength $3{,}6 \times 10^{-7}$ m.

____

____

____

Question 3

a) (i) Describe the photoelectric effect.

____

____

____

____

____

____

(ii) Explain how the photoelectric effect provides evidence for a particle nature of electromagnetic radiation.

____

____

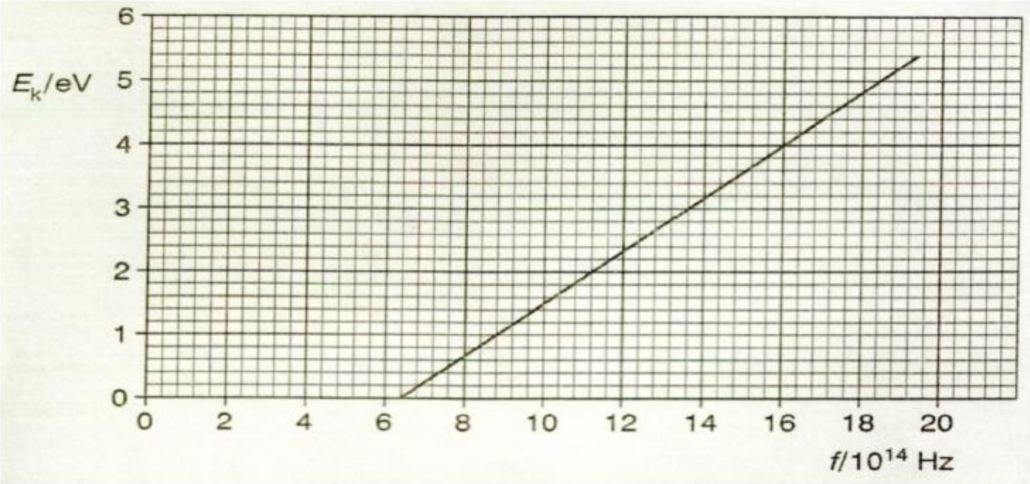
____

____

____

____

b) The graph below shows how the maximum kinetic energy (E_k) of a photoelectron from a particular material varies with the frequency (f) of the electromagnetic radiation that causes the emission of the photoelectrons.



Use the graph to determine:

(i) the threshold frequency for this material.

____

____

____

____

____

____

(ii) the maximum kinetic energy of photoelectrons from this material when it is illuminated with electromagnetic radiation of frequency 18,0 x 10^{14} Hz. Give your answer in joules.

____

____

____

____

____

____

iii) Use the photoelectric equation and your answer to (i) to determine the Planck constant.

c) Electromagnetic waves have a wave and a particle nature. This is known as the wave/particle duality.

i) Describe a situation in which the particles interact with materials.

ii) Describe a situation in which electromagnetic-radiation is considered as a wave. (Camb 2000)

Appendix G: Observation schedule

Observation sheet **Mpumalanga**

Date: ________________ **Class: __________________**

Context **Comments**

1) Learners initial reaction to lesson: Class as whole / individuals different? Difference between boys / girls?	
2) Learner participation: more /less, types of questions different than usual?	
3) My perception of learner attitude, why?	

4) Does the different teacher make a difference? In what way?	
5) How are learners reacting to me being in the back of class and not teaching? Does it make a difference in lesson?	
6) Any problems with applying technology?	
7) Aspects of the technology use that was valuable to the learning of the topic?	
8) Aspects of the technology use that was not valuable to the learning of the topic?	

9) What went unexpectedly wrong?	
10) What went better than or as well as hoped?	
11) What did the learners do wrong?	
12) Class control?	
13) Class behaviour	
14) How did the learners engage with the activity?	

15) What could have been done differently?	
16) How do active/reflective learners engage with simulation?	
17) How do sensory/intuitive learners engage with simulation?	
18) How do visual/verbal learners engage with simulation?	
19) How do sequential/global learners engage with simulation?	
20)What could have been done differently?	

Appendix H: Interview schedule for learners before use of simulation

Learner Interview schedule <u>before</u> simulation:

1. How do you feel about Science?

____

____

____

____

2. How do you feel about the marks that you get for Science?

____

____

____

3. What mark do you currently get for Science? ____________________

4. Do you feel as though you are achieving what you want to achieve or do you feel that you can do better?

____

____

____

5. If you can do better, what is holding you back from doing better?

____

____

____

____

5. Are you hoping to use Science in your future career, and why are you, or why are you not?

____

____

____

____

6. What made you choose Science as one of your subjects?

____

____

____

____

7. How much of your homework time do you commit to Science? Why?

____

____

____

8. Do you have any other Science interests outside of school? Do you participate in any other Science activities outside of school?

____

____

____

9. Which of the different Science topics you have done in class so far this year do you like best? Why?

____

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____

____

10. Which of the different Science topics you have done in class so far this year do you like least? Why?

____

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____

____

11. What sorts of activities do you like most in the Science classroom? Why?

____

____

____

____

12. What sorts of activities do you like the least in the Science classroom? Why?

____

____

____

____

13. What sort of experience do you have with computers? Tell me about the sorts of things that you like to use computers for when you are at home

____

____

____

____

14. Do you have internet at home? If yes, what do you use the internet for? If no, do you have access to the internet outside of school? (where, when, how often)

____

____

____

____

15. Do you know what a computer simulation is? Explain to me in your own words what you think it is...

____

____

____

____

16. Have you ever used a computer programme that shows simulations? If so, what was it for?

____

____

____

____

17. Do you think using a computer simulation could help your learning of a concept in a Science lesson?

____

____

____

____

18. In what way do you think?

____

____

____

____

19. Currently you are learning about the photo electric affect in class. Describe a typical lesson...

____

____

____

____

20. What do you do during a typical lesson?

____

____

____

____

Appendix I: Interview schedule for learners after use of simulation

Learner Interview Schedule after simulation:

1. Tell me about the lesson that you have just had in which you used the computer.

2. What did you like or not like in this lesson?

3. Do you think that you learn differently when you use the computer? If yes, what way? If no, why not?

4. Can you describe what aspects of the lesson would you have liked to have done differently?

5. What do you think that using the computer allowed you to do that you would have not been able to do in an "ordinary" lesson?

6. Which part of the lesson did you enjoy most?

7. Which part of the lesson did you enjoy the least?

8. You learnt more about your preferred learning style. How do you understand your preferred learning style?

9. Does knowing what sort of learning style you are best at, help you in any way? How does it help/not help?

10. Which part(s) of using the computer simulation has specific relevance to your learning style? (In other words- the parts that you like most about the simulation and you feel suits your learning style)

11. Which part(s) of using the computer simulation has no relevance to your learning style? (In other words the parts that you like least about the simulation and you feel do not suit your learning style).

10. Do you think interacting with a computer simulation adds value to Physical Science? Why or why not?

11. Is there anything else you would like to tell me about this experience?

Appendix J(a): Letters of informed consent: Participant (learners above 18)

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education
Department Science, Mathematics and Technology Education

21st June 2011

Letter of Informed Consent for participation in the study investigating: Experiences of learners when a simulation is used in Science

Dear Participant,

We are inviting you to participate in a research undertaking investigating the experience of learners when a computer simulation is used in a Physical Science classroom.

The researcher guarantees that in this study, non-disclosure, no betrayal, informed consent and confidentiality agreements will be prioritized. The respondents, schools and institutions will not be identified by names and where pseudonyms are used they shall not link or identify the real and actual.

Ethical procedures will be followed in that the interviews will be conducted privately, on a one-on-one basis at the ideal location which will be approved by the research participant.

All protocols will be observed. The interviews will be conducted in a manner that will ease or overcome apprehension and increase openness and at the commencement of the interview each respondent will be shown the interview schedule and more information will be obtained through probes.

The researcher will conduct the interviews and record them electronically which will later be transcribed and analysed. Participants will be asked if they consent to the audio-tape recording of the interview. The interviewees will be free and the research participants as adults will be allowed to exercise their rights and freedoms during the course of the interview.

Should you choose to participate in this research; the following research activities will be required of you:

1. Participation in a one-to-one conversational interview lasting approximately 30 minutes in which your ideas about your experiences as a learner in a physical science classroom are discussed.
2. There may be follow-up discussions to check accuracy of my analysis and to allow for your comments and changes to the analysis if need be.

The research results, in the form of a dissertation will be used to meet the requirements for a Masters in Education degree in Computer Integrated Education, Department of Science, Mathematics and Technology Education at the Faculty of Education, University of Pretoria.

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University of Pretoria
Groenkloof Campus
PRETORIA, 0002
Republic of South Africa

Tel: Number: (+27) (0)12 420 2077
Fax: Number: (+27) (0)12 420 5621

Email address: maryke.mihai@up.ac.za
www.up.ac.za/education

The dissertation will therefore become public domain for the scrutiny of examiners and the academic community. The findings may as such be used for publication in academic articles and for presentation at academic conferences.

I hereby request your participation in this study. I guarantee that I will abide by the University of Pretoria's research ethics regulations and will use the information for the purposes of this study only.

Your participation is voluntary and you may withdraw your participation at any stage during the research process, prior to the reporting of the findings for the project. You will also have the opportunity to review the findings prior to publication and will be able to provide advice on the accuracy of this information.

It is important to note that your name and identities of offices, institutions will be withheld in the reporting of the data. No information that you share will be disclosed to other individuals in a way that will allow them to identify contributions that you may make to the research.

As such, confidentiality and anonymity will be guaranteed. If you are willing to participate in this research, please sign below in the space provided by this letter as a declaration of your consent i.e. that you participate willingly and that you understand that you may withdraw from the study at any time prior to publication of findings.

Participants Signature: **Researcher's Signature:**

Date:

Further more, to collect research data it is sometimes necessary to use a voice recorder, or dicta phone so that no important information that you may share is lost before it can be captured and analysed.

If you consent to electronic recording of the interview please sign below:

Participants Signature: **Researchers Signature:**

Date:

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Email address: maryke.mihai@up.ac.za
www.up.ac.za/education

Should you have any queries about the research and / or the contents of this letter, please do not hesitate to contact my supervisor or myself for further information.

Yours faithfully

MEd Candidate and Researcher – Isabel de Beer - (cell: 083 415 4148)

Research Supervisor - Mrs. Maryke Mihai (Cell: +27 82 430 2928)

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Appendix J(b): Letters of informed consent: Parents of minors

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education
Department Science, Mathematics and Technology Education
21st June 2011

Dear parent/guardian,

I am a student studying through the University of Pretoria. I am currently enrolled for my MEd (Computer Integrated) Degree in the Faculty of Education. One of the requirements of my degree is that I conduct research and write a research report about my work. I would like to ask your permission for your child to take part in this research.

The project is titled: **The learning experiences of learners with different learning styles when using simulations in the Physical Science Class**

In studying Chemistry learners are expected to understand the nature of chemical reactions which involve atoms and molecules which are invisible to the naked eye. This makes it difficult for some learners to understand the mechanics of chemical reactions at the level of atoms and molecules. Computer simulations have the unique property of visibly showing the learners what actually happens on a molecular level. In addition the learner is able to manipulate variables involved in the change of these reactants involved in a reaction and in so doing, predict what such changes will have on the mechanics of the reaction. This explanation of the concept would be limited without the use of an interactive computer simulation.

The purpose of this study is therefore to investigate what the experiences of learners with different learning styles will be, when interactive simulations are used in Physical Science to scaffold these learners in understanding Science. In so doing, this study will allow a better understanding of how the use of computer simulations will change learners' understanding of Science.

If you give permission, your child will be asked to agree to take part in this research. No learner will be forced to take part if they do not want to and they will not be penalised if they choose not to do so. Your child can also withdraw at any time.

Learners will be asked to complete an electronic questionnaire to determine what type of learning style they prefer. Some respondents will then be selected to be interviewed face to face. The ILS Learning Style questionnaire is available on the Internet or on request from my supervisor or from myself at the contact numbers below. The interview questions are designed to determine how the learners feel about Science in general and the experience with the computer simulation in particular. These questions are also available from myself or my supervisor. It should not take more than half an hour to complete the questionnaire. The questionnaire will be given to your child at a time and venue that will be determined in consultation with the school. Learning time will not be sacrificed for this purpose.

Information obtained from the questionnaires will only be used for academic purposes. Information given by participants will be treated with confidentiality and will not be discussed with anyone. Ethical procedures will be followed in that the interviews will be conducted privately, on a one-on-one basis at the ideal location which will be approved by your child. Finally, I have to produce a research report and a scholarly article will be written about the findings, but no one will be able to trace any information back to your child or to the school.

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Email address: maryke.mihai@up.ac.za
www.up.ac.za/education

If you agree to allow your child to take part in this research, please fill in the consent form provided below. If you have any questions, do not hesitate to contact my supervisor or me at the numbers given below, or via e-mail.

Consent form

I, parent / guardian of ______________________________________ (name of child), give permission / do not give permission (delete what is not applicable) for my child to take part in the research project titled: **The learning experiences of learners with different learning styles when using simulations in the Physical Science Class.**

I understand that my child will be asked to agree before he / she will take part. My child will be asked to fill in a short questionnaire that will determine his / her learning style and answer interview questions about his / her feelings about Science and their experience after the use of a simulation in Science.

I understand that the researcher subscribe to the principles of

- *voluntary participation* in research, implying that the participants might withdraw from the research at any time.
- *informed consent*, meaning that research participants must at all times be fully informed about the research process and purposes, and must give consent to their participation in the research.
- *safety in participation*; put differently, that the human respondents should not be placed at risk or harm of any kind e.g., research with young children.
- *privacy*, meaning that the *confidentiality* and *anonymity* of human respondents should be protected at all times.
- *trust*, which implies that human respondents will not be respondent to any acts of deception or betrayal in the research process or its published outcomes.

Signature: ________________________ **Date:** ________________

Should you have any queries about the research and / or the contents of this letter, please do not hesitate to contact my supervisor or myself for further information.

Yours faithfully

MEd Candidate and Researcher – Isabel de Beer - (Cell: 083 415 4148)

Research Supervisor - Mrs. Maryke Mihai (Cell: 082 430 2928) (012) 420-2077

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Appendix J(c): Letters of informed consent: Minors

LETTER OF INFORMED CONSENT TO A MINOR CHILD
A research project of the University of Pretoria

Project title: The experiences of learners when a computer simulation is used to aid teaching the photoelectric effect

Was read to children under the age of 18 years

Why am I here?

Sometimes when we want to find out something, we ask people to join something called a project. In this project we will want to ask you about yourself and we will ask you to participate in activities focused on your own development and learning. Before we ask you to be part of this study we want to tell you about it first.

This study will give us a chance to see how we, together with your school and teachers, can help you address career and learning challenges that you may have here at school. We also want to help you gain some skills in your learning here at school so that you can be better equipped to support yourself during your education and after leaving school. We are asking you to be in this study because your parents/guardians have agreed that you can be part of our study.

What will happen to me?

If you want to be part of our study you will spend some time with us answering some questions and participating in some activities. This will be done at 2 different times when we come to your school this year - once sometime soon then again for a second visit later on in the term. The questions and activities will be about you and your career development and learning. There are no right or wrong answers, only what you feel is best. You will also be asked to join some other children in a group, just like at school, except this time it would be playing games and talking.

If you agree, we would like to take audiovisual footage of you during some of the project activities. People will be able to hear your voice if we decide to play the audio material during discussions, as well as reports we write about the project. However, we will not tell anyone your name.

Will the project hurt?

No, the project will not hurt. The questions and activities can take a long time but you can take a break if you are feeling tired or if you don't want to answer all the questions at one time. If you don't want to answer a question or participate in an activity, you don't need to. All of your answers will be kept private. No one, not even someone in your family or your teachers will be told your answers.

Will the study help me?

We hope this study will help you feel good about yourself and learn more about yourself and what you can do in school and one day when you want a job or career, but we don't know if this will happen.

What if I have any questions?

You can ask any questions you have about the study. If you have questions later that you don't think of now you can phone Mrs de Beer at 0834154148 or you can ask us next time we come to visit you here at your school.

Do my parents/guardians know about this project?

This study was explained to your parents/guardians and they said you could be part of the study if you want to. You can talk this over with them before you decide if you want to be in the study or not.

Do I have to be in the project?

You do not have to be in this project. No one will be upset if you don't want to do this. If you don't want to be in the project, you just have to tell us. You can say yes or no and if you change your mind later you don't have to be part of the project anymore. It's up to you.

(a) Writing your name on this page means that you **agree to be in the project** and that you **know what will happen to you** in this study. If you decide to quit the project all you have to do is tell the person in charge.

Signature of the learner　　　　　　　　　　**Date 21st June 2011**

Signature of the researcher　　　　　　　　　　**Date 21st June 2011**

(b) Writing your name here means that you agree that **we can take audiovisual footage** of you during the project and share these during discussions, as well as reports that we write about the project. We will not share your name with the people who see the images. If you decide that we should rather not take photographs of audiovisual footage of you in the project, all you have to do is tell the person in charge.

Signature of learner　　　　　　　　　　**Date 21st June 2011**

Signature of researcher　　　　　　　　　　**Date 21st June 2011**

If you have any further questions about this study you can phone the investigator, Mrs Isabel de Beer If you have a question about your rights as a participant, you can contact the University of Pretoria, Faculty of Education Ethics committee at 012 420 3751.

Appendix K(a): Permission letter: Chairman of the Governing Body

ONE AND ALL

Penryn College
P.O. Box 16424
Nelspruit 1200

30th June 2011

University of Pretoria
Faculty of Education
Department of Science, Mathematics and Technology Education

Dear Mrs de Beer

Re: Request to undertake research about simulations in a Science classroom.

This is to acknowledge your letter dated 21st June 2011 where you are requesting permission to conduct research on the grade 12 Physical Science learners on the campus of Penryn College.

This letter serves to confirm that permission is hereby granted to you to conduct such research.

We look forward to the outcome of your research and wish you all the best in your endeavour.

Yours faithfully

Tim de Wet
Chairman
Penryn College

Appendix K(b) Permission letter: Headmaster

Penryn College

30th June 2011

University of Pretoria
Faculty of Education
Department of Science, Mathematics and Technology Education

Dear Mrs de Beer

Re: Request to undertake research about simulations in a Science classroom

This is to acknowledge your letter dated 21st June 2011 wherein your requested permission to conduct research on the grade 12 Physical Science learners on the Penryn College campus.

This letter serves to confirm that permission is hereby granted for you to conduct such research.

We look forward to the outcome of your research and wish you all the best in your endeavour.

Yours sincerely

Greg Theron
Executive Head
Penryn College
(013) 7589000
head@penryn.co.za

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Appendix L: All Codes Used

All current codes

HU: Simulations and learning styles
File: [C:\Users\Isabel\Documents\Scientific Software\ATLASti\TextBank\Simulations and learning styles.hpr6]
Edited by: Super
Date/Time: 2012-08-03 18:03:23

Able to programme
Created: 2012-01-06 16:09:34 by Isabel de Beer
Modified: 2012-05-12 15:47:54
Families (1): Computer literate
Quotations: 9
Comment:
Learner takes Information Technology as subject and is able to write computer programmes

---

Active during simulation- enjoy
Created: 2012-03-26 14:48:21 by Isabel de Beer
Modified: 2012-06-06 11:57:02
Families (1): positive experiences with CS-ALL
Quotations: 9
Comment:
The learner enjoys the fact that they are actively busy during the simulation, using their hands and senses. It is a positive experience for the learner and they feel that this adds to their learning experience.

Add detail
Created: 2012-01-23 15:33:17 by Isabel de Beer
Modified: 2012-05-12 15:34:37
Families (2): Negative experiences with CS-ALL, change simulation
Quotations: 6
Comment:
The learner feels that there is a need to add more detail to make the task easier to understand, more explanation required, or learners had to guess what the values on the graphs would be, due to lack of detail on graphs which frustrated them- this was very prominent amongst sequential learners, they all would have liked to see more detail added.

Add explanation
Created: 2012-01-23 15:33:43 by Isabel de Beer
Modified: 2012-05-12 16:38:46
Families (2): Negative experiences with CS-ALL, change simulation
Quotations: 22
Comment:
The learners would like to add an explanation before the simulation is used, to make it clear what is expected of the learner when doing the simulation. They expect the teacher to explain what the different keys stand for and how they function on the simulation- in other words how to change the variables on the simulation a very important aspect for verbal and sequential learners.

Add sound
Created: 2012-01-24 21:13:55 by Isabel de Beer
Modified: 2012-05-12 15:45:17
Families (2): Negative experiences with CS-ALL, change simulation
Quotations: 6
Comment:
Sensitive learners would like to change the existing simulation by adding sound in the form of sound effects to the simulation.

Apply CT In Science
Created: 2012-01-22 18:19:22 by Isabel de Beer
Modified: 2012-05-03 14:20:15
Families (2): Computer literate, change simulation
Quotations: 3
Comment:
The learner feels the need to apply Computer Technology in Science, by writing a programme or developing a computer game, which can then be used to explain a Scientific principle in another way.

Boring
Created: 2012-01-14 11:45:04 by Isabel de Beer
Modified: 2012-04-21 14:46:23
Families (1): Bad- Science
Quotations: 9
Comment:
Learner finds the activity, (usually theory) tedious or tiresome, he/she are not interested in continuing with the activity and is therefore easily distracted.

Can't see
Created: 2012-01-06 15:14:24 by Isabel de Beer
Modified: 2012-06-06 15:09:04
Families (1): Bad- Science
Quotations: 14
Comment:
The learner feels that the content is too abstract, only theory, he/she is frustrated because there are no applications visible in everyday life around them, they feel that the Science is disconnected to his/her everyday existence.

Can see
Created: 2012-01-06 15:14:11 by Isabel de Beer
Modified: 2012-06-06 15:32:08
Families (1): Good- Science
Quotations: 44
Comment:
The learner enjoys the fact that he/she can see applications of the Scientific theory in their everyday life around him/herself.

Change settings/variables
Created: 2012-01-22 18:16:24 by Isabel de Beer
Modified: 2012-06-06 11:52:10
Families (1): positive experiences with CS-ALL
Quotations: 30
Comment:
The learners enjoyed the fact that they could change the settings of or the variables given in the simulation, there is a large range of variables to change, the learner is not restricted to a certain range available in a real class, active learners benefit from this specifically as they process information by active experimentation.

Change simulation- graphs
Created: 2012-03-28 09:48:24 by Isabel de Beer
Modified: 2012-05-12 15:11:24
Families (2): Negative experiences with CS-ALL, change simulation
Quotations: 4

Change simulation- picture
Created: 2012-03-28 09:44:11 by Isabel de Beer
Modified: 2012-05-12 15:47:54

Families (1): Negative experiences with CS-ALL
Quotations: 5

Cheap
Created: 2012-01-13 10:28:09 by Isabel de Beer
Modified: 2012-06-06 10:39:34

Families (1): positive experiences with CS-ALL
Quotations: 4
Comment:
The learner's opinion on what is not expensive, a low-priced, low cost, affordable way to do experiments.

Chemistry
Created: 2012-01-06 14:05:19 by Isabel de Beer
Modified: 2012-04-21 15:50:34
Quotations: 26
Comment:
Pure chemistry- includes branches of quantitative, qualitative, organic and inorganic chemistry.

Computer game development
Created: 2012-01-07 08:58:03 by Isabel de Beer
Modified: 2012-05-03 14:20:31
Families (2): Computer literate, change simulation
Quotations: 2
Comment:
The learner is involved in the development of computer games, he/she is interested in the programming side as such, applying Information Technology knowledge in the Scientific field.

Computer literate
Created: 2012-01-06 16:08:36 by Isabel de Beer
Modified: 2012-03-28 09:25:34
Families (1): Computer literate
Quotations: 18
Comment:
The learner is familiar with and can use computer software with confidence- eg Microsoft Office, Photoshop etc.

Confident
Created: 2012-01-06 13:59:53 by Isabel de Beer
Modified: 2012-06-06 10:43:32
Families (1): positive experiences with CS-ALL
Quotations: 5
Comment:
The learner is positive; sure; convinced that he/she is able to improve or engage with a the computer simulation, he/she knows that its correct.

Confused - no order
Created: 2012-03-26 21:50:00 by Isabel de Beer
Modified: 2012-08-03 17:46:37
Families (2): Bad- Science, change simulation
Quotations: 4
Comment:
The learner get very confused if a step by step sequential method is not followed. This means that the learner feels frustrated by the global approach of the teacher.

Control variables
Created: 2012-01-13 10:28:30 by Isabel de Beer
Modified: 2012-06-06 11:55:56
Families (1): positive experiences with CS-ALL
Quotations: 16
Comment:
The learner can manipulate the different variables themselves, with specific reference to this simulation- the colour (frequency) of light used, the intensity of the light used, the potential difference applied over the plates.

Dangerous
Created: 2012-01-13 10:27:53 by Isabel de Beer
Modified: 2012-06-06 10:15:08
Families (1): positive experiences with CS-ALL
Quotations: 6
Comment:
Not safe, hazardous, threatening to health of the participant- mostly referring to the execution of some Scientific experiments.

Definitions
Created: 2012-01-13 10:19:07 by Isabel de Beer
Modified: 2012-04-21 15:13:05
Families (1): Good- Science
Quotations: 3
Comment:
The use of certain terminology applicable to a specific concept- especially useful to intuitive learners- often linked to the formula used in an equation.

Demonstration
Created: 2012-01-06 15:56:55 by Isabel de Beer
Modified: 2012-05-03 13:26:33
Families (1): learning styles
Quotations: 7
Comment:
The teacher shows learners experiment- the learners are not involved, they are only observing the process or physical practical as the teacher demonstrates the use of the physical apparatus, learners enjoy the demonstration, they don't feel unsure during this exercise: Active, Sensory, Visual, Sequential and Global learners enjoy watching a demonstration .

Different dimension
Created: 2012-01-28 07:42:28 by Isabel de Beer
Modified: 2012-06-06 10:13:13
Families (1): positive experiences with CS-ALL
Quotations: 21
Comment:
The learner enjoys the fact that the concept is looked at from a different angle, taking a different viewpoint.

Different Science lesson
Created: 2012-01-22 18:14:54 by Isabel de Beer
Modified: 2012-06-06 11:38:29
Families (1): positive experiences with CS-ALL
Quotations: 40
Comment:
Not the usual and ordinary format of a Science lesson (which is mostly inactive lecturing of facts by teacher).

Discover through simulation
Created: 2012-03-28 13:14:57 by Isabel de Beer
Modified: 2012-06-06 11:39:47
Families (1): positive experiences with CS-ALL
Quotations: 20
Comment:
The learners enjoyed discovering the meaning of the photoelectric effect by using the simulation.

Discuss
Created: 2012-01-08 13:47:29 by Isabel de Beer
Modified: 2012-05-03 14:11:11
Families (1): positive experiences with CS-ALL
Quotations: 33
Comment:
The learners enjoy talking about the theory/calculations/laws- engage in a discussion either with fellow learners or with the teacher- active learners process information this way and verbal learners receive their information this way.

Dislike Chemistry
Created: 2012-03-10 11:24:15 by Isabel de Beer
Modified: 2012-04-21 14:55:22
Families (1): Bad- Science
Quotations: 4
Comment:
The learner does not have a interest in/ would prefer not to do or be involved in the Chemistry section of the syllabus.

Dislike computer
Created: 2012-01-28 09:12:13 by Isabel de Beer
Modified: 2012-08-03 17:55:48
Quotations: 7
Comment:
Not comfortable using the computer at all, would prefer writing brief notes by hand or rather doing a physical activity, a fact mentioned by active learners.

Dislike detail
Created: 2012-03-10 11:41:30 by Isabel de Beer
Modified: 2012-05-03 14:03:46
Families (1): Negative experiences with CS-ALL
Quotations: 6
Comment:
The learner dislikes having to give attention to detail.

Dislike graphs
Created: 2012-03-10 11:35:08 by Isabel de Beer
Modified: 2012-04-21 14:58:39
Families (1): Bad- Science
Quotations: 4
Comment:
The learner dislikes the theory and tabulating part of an investigation

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Dislike individual work
Created: 2012-03-10 11:29:25 by Isabel de Beer
Modified: 2012-05-03 14:00:08
Families (1): Negative experiences with CS-ALL
Quotations: 2
Comment:
The learner prefers to work in a group, does not like working on his/her own.

Dislike lack of detail
Created: 2012-03-10 11:33:54 by Isabel de Beer
Modified: 2012-05-12 15:30:29
Families (2): Negative experiences with CS-ALL, change simulation
Quotations: 3
Comment:
Details are important to this learner and the fact that there was a lack of detail was frustrating, especially for the sequential learners.

Dislike Physics
Created: 2012-03-11 12:12:53 by Isabel de Beer
Modified: 2012-04-21 14:59:48
Families (1): Bad- Science
Quotations: 13

Dislike practicals
Created: 2012-03-10 11:31:41 by Isabel de Beer
Modified: 2012-06-06 10:43:32
Families (1): Bad- Science
Quotations: 7
Comment:
The learner does not like doing the practicals- the responsibility of working with the physical equipment and possibly breaking or damaging it is simply too much for the learner.

Dislike taking down notes
Created: 2012-03-26 15:04:14 by Isabel de Beer
Modified: 2012-06-06 11:18:19
Families (1): Bad- Science
Quotations: 4
Comment:
The learner does not like to take down notes during a lesson, normally as he/she cannot keep up with the pace and then fall behind,

adding to their confusion.

Dislike theory
Created: 2012-03-10 11:25:13 by Isabel de Beer
Modified: 2012-04-21 14:59:57
Families (1): Bad- Science
Quotations: 7
Comment:
The learner finds the theoretical side extremely boring.

Distracted
Created: 2012-01-12 07:05:02 by Isabel de Beer
Modified: 2012-04-21 15:00:00
Families (1): Bad- Science
Quotations: 10
Comment:
The attention of the learner is diverted from the lesson or the activity that he/she is busy with.

Do homework
Created: 2012-01-08 14:33:42 by Isabel de Beer
Modified: 2012-04-21 15:01:12
Families (1): Good- Science
Quotations: 13
Comment:
The learner is diligently doing all the homework every day, or at least tries to do as much as possible (to familiarise him/herself with the types of questions to be asked, or to practise doing similar calculations)

Doing things practically
Created: 2012-03-26 20:38:38 by Isabel de Beer
Modified: 2012-06-06 14:55:21
Families (1): Good- Science
Quotations: 17
Comment:
Active learners like to keep themselves busy by using their hands practically, either by being busy with the practical equipment or just marking homework.

Enhance graphical user interface
Created: 2012-01-29 16:13:14 by Isabel de Beer
Modified: 2012-05-12 15:47:54
Families (3): change simulation, Computer literate, Negative experiences with CS-ALL
Quotations: 3
Comment:
The buttons and the captions that the learners are interacting with while doing the simulation.

Enjoy calculations
Created: 2012-03-11 08:17:45 by Isabel de Beer
Modified: 2012-04-21 15:04:54
Families (1): Good- Science
Quotations: 9
Comment:
These are learners who enjoy doing the mathematical calculations involved in Science- algebraic calculations are used in Science, mostly in the physics part of the syllabus, but also forms part of the chemistry syllabus, to a lesser extent. Individual learners have individual preferences.

Enjoy discovering
Created: 2012-03-28 13:10:56 by Isabel de Beer
Modified: 2012-04-21 15:04:58
Families (1): Good- Science
Quotations: 7
Comment:
The learners enjoy discovering themes done in class or during Science lessons on TV programmes or in books- a positive experience in Science as subject.

Enjoy Science
Created: 2012-03-11 08:39:45 by Isabel de Beer
Modified: 2012-04-21 15:05:00
Families (1): Good- Science
Quotations: 16
Comment:
The learner enjoys Science as a subject in school, regardless of the marks he/she gets.

Expanding effects
Created: 2012-01-23 15:32:31 by Isabel de Beer
Modified: 2012-05-12 15:34:37
Families (3): change simulation, Computer literate, Negative experiences with CS-ALL
Quotations: 4
Comment:
Add more to the effects simulated in the simulation, either by using better graphics or sound- mentioned by the Visual learners taking Information Technology as subject- they would be able to suggest specific possible changes in the simulation itself.

Explain
Created: 2012-01-08 13:38:38 by Isabel de Beer
Modified: 2012-06-06 15:43:27
Families (1): Good- Science
Quotations: 41
Comment:
The teacher explains either the process or the law or even the use of the formula in a calculation or the learners explain the concept to each other during group-work.

Faster
Created: 2012-01-22 18:11:08 by Isabel de Beer
Modified: 2012-06-06 15:39:35
Families (1): positive experiences with CS-ALL
Quotations: 4
Comment:
Usually refers to the quicker pace needed to keep up.

Frustrated
Created: 2012-01-11 21:11:31 by Isabel de Beer
Modified: 2012-06-06 09:32:19
Families (1): Bad- Science
Quotations: 11
Comment:
Disappointment or feeling of failure with the activity.

Global
Created: 2012-01-07 09:31:29 by Isabel de Beer
Modified: 2012-06-06 09:53:38
Families (1): learning styles
Quotations: 21
Comment:
In the understanding dimension (how a learner "grasps" a concept) - this learner will start with the global picture and then go into detail.

Good Science reputation
Created: 2012-01-06 14:56:01 by Isabel de Beer
Modified: 2012-04-21 15:15:34
Families (1): Good- Science
Quotations: 9
Comment:
Respectability of Science as subject- the subject is labelled as a "good to have" (despite the individual's interest or abilities) for any future career.

Group work
Created: 2012-01-07 11:22:02 by Isabel de Beer
Modified: 2012-05-03 14:11:17
Families (1): positive experiences with CS-ALL
Quotations: 13
Comment:

Working together with their peers, discussing, arguing and working together to complete a task, mostly a practical or a work session. This is a positive experience for active learners.

Help
Created: 2012-01-14 08:50:12 by Isabel de Beer
Modified: 2012-04-24 16:49:39
Families (1): positive experiences with CS-ALL
Quotations: 7
Comment:

To assist in some way - with the simulation or a calculation or a practical or just to understand the theory.

Imagination expanded
Created: 2012-01-12 08:27:55 by Isabel de Beer
Modified: 2012-05-12 16:16:06
Families (1): positive experiences with CS-ALL
Quotations: 5
Comment:

To picture or fabricate an idea about a concept in one's mind.

Improve marks
Created: 2012-01-07 09:35:21 by Isabel de Beer
Modified: 2012-04-21 15:24:09
Quotations: 28
Comment:

The learner is aware of the fact that their Gr 11 and current Gr 12 marks are not what they can achieve and that they need to improve their marks, they are confident that their marks will improve- by using a different exam technique, practise calculations more, more study time etc.

Inaccurate graphs
Created: 2012-01-24 21:28:10 by Isabel de Beer
Modified: 2012-05-12 15:16:08
Families (2): Negative experiences with CS-ALL, change simulation
Quotations: 6
Comment:

The graphs given in the simulation were very inaccurate, values had to be estimated and points on the graphs were difficult to identify. Values on both the x and y axis were very unclear- frustrating for sequential learners.

Interactive
Created: 2012-01-14 08:52:39 by Isabel de Beer
Modified: 2012-06-06 15:57:07
Families (1): positive experiences with CS-ALL
Quotations: 26
Comment:

Learner is mutually active with the medium, can change variables on the simulation and see the effects of this change, without being scared that something could go wrong- valuable experience with the CS for active learners, learners feel that information is processed into knowledge when they are actively involved.

Interesting
Created: 2012-01-06 13:35:54 by Isabel de Beer
Modified: 2012-04-21 15:22:22
Families (1): Good- Science
Quotations: 57
Comment:

The subject matter is fine, the concepts are fascinating and the learner is intruiged by it, they find it satisfying. It is a slightly more intellectual approach.

Internet
Created: 2012-01-08 12:32:00 by Isabel de Beer
Modified: 2012-03-28 09:25:45
Families (1): Computer literate
Quotations: 9
Comment:
Access to and using the world wide web, using the fact that the information available here is continuously updated.

Interpret
Created: 2012-01-13 10:03:41 by Isabel de Beer
Modified: 2012-06-06 15:56:31
Families (1): positive experiences with CS-ALL
Quotations: 8
Comment:
The learner is able to understand the meaning of the concept or to convey the meaning thereof to his/herself.

Intuitive
Created: 2012-01-06 13:34:57 by Isabel de Beer
Modified: 2012-06-06 14:27:47
Families (1): learning styles
Quotations: 3
Comment:
In the Perception dimension of learning, the learner perceives the world by intuition, laws, theories or memories.

Learn
Created: 2012-01-11 18:44:11 by Isabel de Beer
Modified: 2012-04-21 15:27:31
Families (1): learning styles
Quotations: 9
Comment:
To acquire mentally, to "master the concept."

Learn differently
Created: 2012-01-22 18:12:20 by Isabel de Beer
Modified: 2012-06-06 15:43:27
Families (1): positive experiences with CS-ALL
Quotations: 13
Comment:
To acquire knowledge in a different way to what the learner is used to, mostly referred to as not rote learning.

Learning style
Created: 2012-01-22 18:24:53 by Isabel de Beer
Modified: 2012-04-21 15:26:07
Families (1): learning styles
Quotations: 31
Comment:
Learning style refers to the way individuals prefer to process new information and strategies they adopt for effective learning.

Like simulation
Created: 2012-01-22 18:05:43 by Isabel de Beer
Modified: 2012-06-06 15:43:27
Families (1): positive experiences with CS-ALL
Quotations: 54
Comment:
The learners liked working with the ICS for different reasons, examples of what they liked in the ICS.

Limits to expand effects
Created: 2012-01-23 15:51:21 by Isabel de Beer
Modified: 2012-05-03 14:21:49
Families (2): Computer literate, change simulation
Quotations: 1

Listen
Created: 2012-01-10 07:43:40 by Isabel de Beer
Modified: 2012-04-21 15:29:57
Families (1): learning styles
Quotations: 15
Comment:
Verbally taking in information making use of hearing sense- the verbal learners receive their information this way.

Logical
Created: 2012-01-13 10:15:39 by Isabel de Beer
Modified: 2012-04-21 15:31:22
Families (1): Good- Science
Quotations: 8
Comment:
Deducted from a proven experiment- deductive and consistent.

Macroscopic
Created: 2012-01-23 16:26:58 by Isabel de Beer
Modified: 2012-04-21 15:31:38
Families (1): Good- Science
Quotations: 10
Comment:
Large enough to be observed with the naked eye.

Mark homework
Created: 2012-01-14 09:04:15 by Isabel de Beer
Modified: 2012-04-21 15:31:51
Families (1): Good- Science
Quotations: 2
Comment:
Mark the previous day's homework with the teacher's help and guidance.

Microscopic level
Created: 2012-01-06 15:17:46 by Isabel de Beer
Modified: 2012-06-06 15:32:08
Families (1): positive experiences with CS-ALL
Quotations: 56
Comment:
Not visible with the naked eye,- referring to motion of or minute changes to atomic particles.

Misconceptions
Created: 2012-01-08 13:34:23 by Isabel de Beer
Modified: 2012-05-12 16:16:06
Families (2): Negative experiences with CS-ALL, positive experiences with CS-ALL
Quotations: 7
Comment:
Wrong interpretation of a visual usually because of the scale used in an animation- this was mostly mentioned by the visual learners as something to be aware of. They felt that as long as they were aware of it, it would not become a problem and hinder the learning process.

Moving
Created: 2012-01-22 18:07:20 by Isabel de Beer
Modified: 2012-06-06 15:49:04
Families (1): positive experiences with CS-ALL
Quotations: 19
Comment:
Referring to an active state of moving about, while the simulation is played.

New study method
Created: 2012-01-12 06:51:01 by Isabel de Beer
Modified: 2012-04-21 15:33:11
Families (1): learning styles
Quotations: 5
Comment:
The learner acknowledges that learning does not only take place by rote learning certain theory- they see the value of changing their learning method to something that would suit their learning style.

No explanation
Created: 2012-01-28 06:56:51 by Isabel de Beer
Modified: 2012-05-03 14:22:11
Families (2): Negative experiences with CS-ALL, change simulation
Quotations: 5
Comment:
The sequential learners were frustrated with the fact that the simulation was not discussed beforehand.

No introduction
Created: 2012-01-28 06:58:01 by Isabel de Beer
Modified: 2012-05-12 10:22:01
Families (2): Negative experiences with CS-ALL, change simulation
Quotations: 19
Comment:
The sequential learners were frustrated that they were not given an introduction about the photoelectric effect before the lesson- they did not understand what they were seeing and did not like discovering the effect for his/herself.

No music
Created: 2012-01-28 06:53:35 by Isabel de Beer
Modified: 2012-04-21 15:36:39
Families (1): learning styles
Quotations: 2
Comment:
Verbal and reflective learners realising that they should not have any other verbal distractions while they are studying eg listening to music does not add to their learning experience.

Not active
Created: 2012-01-08 12:57:09 by Isabel de Beer
Modified: 2012-05-03 14:00:13
Families (1): Negative experiences with CS-ALL
Quotations: 2
Comment:
Refers to physically being active, involving their entire body, not only sitting in front of a computer and being active with only hands while sitting down.

Not actual apparatus
Created: 2012-01-08 13:31:26 by Isabel de Beer
Modified: 2012-06-06 13:37:39
Families (1): Negative experiences with CS-ALL
Quotations: 6
Comment:
It is a virtual picture only, it does not include the physical apparatus as would be during a macroscopic practical in class, they are not able to use their senses to perceive the simulation- a frustration mentioned by sensory learners.

Not break
Created: 2012-01-24 21:20:00 by Isabel de Beer
Modified: 2012-06-06 10:43:32
Families (1): positive experiences with CS-ALL
Quotations: 6
Comment:
Refers to the possibility of spilling chemicals or breaking glassware during a macroscopic practical as it is carried out in the laboratory itself.

Not enjoy calculations
Created: 2012-03-11 08:23:47 by Isabel de Beer
Modified: 2012-04-21 15:38:25
Families (1): Bad- Science
Quotations: 4
Comment:
Algebraic calculations used in Science, mostly in the physics part of the syllabus, but also forms part of the Chemistry syllabus, but to a lesser extent. These learners feel that they would have done better in Science if they did not have to do scientific calculations at all.

Not enjoy demonstration
Created: 2012-03-11 08:32:53 by Isabel de Beer
Modified: 2012-04-21 15:38:44
Families (1): Bad- Science
Quotations: 1
Comment:
The teacher shows learners experiment- the learners are not involved, they are only observing the process or physical practical as the teacher demonstrates the use of the physical apparatus, learners do not enjoy the demonstration, they don't feel part of the exercise, they want to be more involved.

Not Science career
Created: 2012-01-06 14:52:06 by Isabel de Beer
Modified: 2012-04-21 15:38:46
Families (1): Bad- Science
Quotations: 8
Comment:
Learner will not be pursuing a career in Science specifically.

Not suit learning style
Created: 2012-01-23 15:32:03 by Isabel de Beer
Modified: 2012-05-12 15:12:38
Families (1): learning styles
Quotations: 7
Comment:
Not aiding a specific learning style.

Not true reflection
Created: 2012-01-12 08:18:00 by Isabel de Beer
Modified: 2012-08-03 17:49:45
Quotations: 2
Comment:
The learner feels that the "bad" mark which they are currently getting for Science does not reflect their true understanding and interest in the subject.

Not understand
Created: 2012-01-06 15:02:22 by Isabel de Beer
Modified: 2012-04-21 15:40:17
Families (1): Bad- Science
Quotations: 26
Comment:
Frustrated with the topic matter mostly because they can't comprehend the concept.

Not used CS before
Created: 2012-04-21 09:50:00 by Isabel de Beer
Modified: 2012-08-03 17:55:24
Quotations: 3

Ordinary lesson
Created: 2012-01-08 13:46:19 by Isabel de Beer
Modified: 2012-03-26 22:57:28
Quotations: 25
Comment:
Coming into class, marking homework, discussing problems, listening to explanation on further section, doing examples of new homework, starting homework.

Own pace
Created: 2012-01-23 16:35:24 by Isabel de Beer
Modified: 2012-06-06 11:29:22
Families (1): positive experiences with CS-ALL
Quotations: 28
Comment:
Working at their own pace, not being rushed or pushed for time, able to redo as many times as needed or could forward to the end of the simulation and then coming back to the beginning again.

Physics
Created: 2012-01-06 15:08:13 by Isabel de Beer
Modified: 2012-04-21 15:47:01
Families (1): Good- Science
Quotations: 8
Comment:
Science of the material world- eg mechanics, waves and light, atomic structure and the electromagnetic spectrum

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Pictures/diagrams
Created: 2012-01-22 18:20:29 by Isabel de Beer
Modified: 2012-06-06 15:49:04
Families (1): positive experiences with CS-ALL
Quotations: 15
Comment:
A visible image.

Pop-up explanation
Created: 2012-01-28 11:06:28 by Isabel de Beer
Modified: 2012-05-03 14:18:17
Families (1): positive experiences with CS-ALL
Quotations: 4
Comment:
A text box opening up when the cursor moves over a certain area on the computer, with a written explanation of a certain aspect.

Practicals
Created: 2012-01-06 15:19:39 by Isabel de Beer
Modified: 2012-06-06 15:02:08
Families (1): Good- Science
Quotations: 31
Comment:
Practical experimentation in class conducted by learners themselves, learners are engaging with the physical equipment, using their senses- feeling, seeing, smelling, hearing.

Practise calculations
Created: 2012-01-10 08:42:11 by Isabel de Beer
Modified: 2012-04-21 15:48:41
Families (1): Good- Science
Quotations: 8
Comment:
By doing homework the learner recognises that they are doing repetitive calculations using the same formula, thereby teaching him/herself to recognise a certain type of question asked in the exam/test.

Precise results
Created: 2012-01-23 15:30:56 by Isabel de Beer
Modified: 2012-06-06 11:34:35
Families (1): positive experiences with CS-ALL
Quotations: 3
Comment:
The results of an experiment should be very accurate and precise, it is not always possible in a physical practical, but it could be expected in a simulated practical as the parameters are set.

Predictable
Created: 2012-01-15 16:16:59 by Isabel de Beer
Modified: 2012-05-03 14:13:09
Families (1): positive experiences with CS-ALL
Quotations: 2
Comment:
To make a statement on the basis of an observation.

Prefer briefing
Created: 2012-01-28 09:44:22 by Isabel de Beer
Modified: 2012-06-06 09:28:05
Families (1): Negative experiences with CS-ALL
Quotations: 18
Comment:
The learner would have changed the lesson and probably enjoyed the simulation more, if they had been briefed about the simulation and what to expect before the time, global learners would have preferred to just have a broad overview of what to expect.

Prefer Chemistry
Created: 2012-03-11 08:42:03 by Isabel de Beer
Modified: 2012-04-21 15:54:08
Families (1): Good- Science
Quotations: 12

Prefer demonstration
Created: 2012-03-27 09:01:57 by Isabel de Beer
Modified: 2012-05-03 14:15:03
Families (3): positive experiences with CS-ALL, Good- Science, learning styles
Quotations: 3

Prefer Physics
Created: 2012-03-11 08:54:49 by Isabel de Beer
Modified: 2012-04-21 15:54:11
Families (1): Good- Science
Quotations: 15
Comment:
If given a choice the learner would rather do the Physics section of the Science syllabus.

Prefer practical
Created: 2012-01-28 16:45:43 by Isabel de Beer
Modified: 2012-06-06 11:57:02
Families (1): Good- Science
Quotations: 22
Comment:
The learner still prefers the experience of doing the physical macroscopic practical, involving the actual apparatus and all their senses- this has specific value to sensitive and active learners.

Prefer simulation
Created: 2012-04-21 10:24:28 by Isabel de Beer
Modified: 2012-06-06 10:43:32
Families (1): positive experiences with CS-ALL
Quotations: 7

Prefer video
Created: 2012-01-28 09:20:48 by Isabel de Beer
Modified: 2012-05-12 16:34:03
Families (1): positive experiences with CS-ALL
Quotations: 2
Comment:
Learner is feeling incompetent using the computer and would have preferred to watch a video to show the microscopic changes taking place during the photoelectric effect.

Process
Created: 2012-01-11 20:39:21 by Isabel de Beer
Modified: 2012-06-06 15:07:12
Families (2): learning styles, positive experiences with CS-ALL
Quotations: 14
Comment:
Figure out, think about, changing the information so that it makes conceptual sense to the learner.

Quick
Created: 2012-01-13 10:25:41 by Isabel de Beer
Modified: 2012-06-06 14:58:22
Families (1): positive experiences with CS-ALL
Quotations: 14
Comment:
Fast reaction.

Quick results
Created: 2012-01-24 21:09:39 by Isabel de Beer
Modified: 2012-06-06 15:02:08
Families (1): positive experiences with CS-ALL
Quotations: 6
Comment:
The results of any changes done in the simulated practical are immediately visible.

Quick to set up
Created: 2012-01-11 20:36:35 by Isabel de Beer
Modified: 2012-06-06 15:02:08
Families (1): positive experiences with CS-ALL
Quotations: 7
Comment:
The simulation does not waste time in setting up the equipment as in a lab practical, all the apparatus is immediately available and set up correctly, and in working order.

Real life event
Created: 2012-01-10 08:46:47 by Isabel de Beer
Modified: 2012-04-21 12:03:09
Families (1): positive experiences with CS-ALL
Quotations: 14
Comment:
A virtual experience on the computer of a real life event - not necessarily scientific in nature.

Reflective
Created: 2012-01-06 13:34:40 by Isabel de Beer
Modified: 2012-06-06 15:07:12
Families (1): learning styles
Quotations: 17
Comment:
In the processing dimension of learning information is comprehended and turned into knowledge by this learner by making observations in a situation and then converting that into knowledge.

Remember
Created: 2012-01-23 16:25:57 by Isabel de Beer
Modified: 2012-04-22 13:02:06
Families (1): learning styles
Quotations: 2
Comment:
Learner can bring to mind again.

Repeat
Created: 2012-01-12 13:00:12 by Isabel de Beer
Modified: 2012-04-24 17:06:32
Families (1): positive experiences with CS-ALL
Quotations: 3
Comment:
The learner will be able to say or state this again, even practise calculations so that they can understand better.

Research projects
Created: 2012-01-07 09:02:55 by Isabel de Beer
Modified: 2012-04-22 13:02:51
Families (1): Good- Science
Quotations: 11
Comment:
Projects required by the syllabus- the learner receives a topic and must then hand in a small research project on the matter, following the correct scientific method.

Satisfied
Created: 2012-01-06 13:45:54 by Isabel de Beer
Modified: 2012-04-22 13:02:59
Families (1): Good- Science
Quotations: 4
Comment:
Content with their current achievement or marks in Science.

Scary
Created: 2012-01-11 21:21:26 by Isabel de Beer
Modified: 2012-04-22 13:03:37
Families (1): Bad- Science
Quotations: 2
Comment:
A very negative emotion experienced by the learner in the science class.

Science as subject
Created: 2012-01-10 09:37:17 by Isabel de Beer
Modified: 2012-04-22 13:03:47
Families (1): Good- Science
Quotations: 18
Comment:
A general feeling about the subject- are they coping, do they struggle (why) or do they enjoy it and find it interesting.

Science career
Created: 2012-01-10 07:26:39 by Isabel de Beer
Modified: 2012-04-22 13:03:51
Families (1): Good- Science
Quotations: 11
Comment:
Planning to pursue a scientific career.

Science difficult
Created: 2012-01-06 13:48:23 by Isabel de Beer
Modified: 2012-04-22 13:03:59
Families (1): Bad- Science
Quotations: 11
Comment:
The learner recognises that Science is a difficult subject and that they need to work very hard to achieve good marks for the subject.

Science Homework
Created: 2012-01-07 11:06:31 by Isabel de Beer
Modified: 2012-04-22 13:04:27
Families (1): Good- Science
Quotations: 20
Comment:
The amount of time they are forced to engage with Science as homework- not including any projects.

Science interests
Created: 2012-01-07 11:09:00 by Isabel de Beer
Modified: 2012-04-22 13:04:29
Families (1): Good- Science
Quotations: 10
Comment:
Referring to extra-curricular Scientific interests not required from learner in school syllabus such as MinTek competition, TV programmes like Mythbusters; National Geographic; Brainiac; Magazines such as Popular Mechanics; Books like Horrible Science.

Science marks
Created: 2012-01-10 08:32:52 by Isabel de Beer
Modified: 2012-04-22 13:04:31
Families (1): Good- Science
Quotations: 20
Comment:
Specific reference to their current Science mark- and what the learner' thoughts as to the reason for that mark.

Science required
Created: 2012-01-06 14:52:39 by Isabel de Beer
Modified: 2012-04-22 13:05:12
Families (1): Good- Science
Quotations: 2
Comment:
A good mark in school Science as subject is required by University before learner will be allowed into a specific course.

Science tutorials
Created: 2012-01-12 08:23:52 by Isabel de Beer
Modified: 2012-04-22 13:05:15
Families (1): Good- Science
Quotations: 2
Comment:
Helping groups of scholars struggling with Science as subject.

Scientific reasoning used
Created: 2012-01-07 09:45:39 by Isabel de Beer
Modified: 2012-04-22 13:05:17
Families (1): Good- Science
Quotations: 2
Comment:
Certain way of reasoning taught when specific scientific steps are followed.

See effects
Created: 2012-01-22 18:17:01 by Isabel de Beer
Modified: 2012-05-03 14:18:29
Families (1): positive experiences with CS-ALL
Quotations: 11
Comment:
The effects of changing anything during the simulation or practical is visible to the naked eye.

Sensitive
Created: 2012-01-07 09:30:20 by Isabel de Beer
Modified: 2012-06-06 13:37:39
Families (1): learning styles
Quotations: 16
Comment:
In the perception dimension of learning, the learner perceives the world through their senses and facts.

Sequence- prac then simulation
Created: 2012-01-28 16:32:15 by Isabel de Beer
Modified: 2012-05-03 14:11:40
Families (1): positive experiences with CS-ALL
Quotations: 2
Comment:
If the learner had a choice they would choose the sequence of first doing the physical practical in class (uv light, electroscope and piece of zinc- to demonstrate the release of electrons) so as to first see the macroscopic change and then do the computer simulation to see the microscopic changes taking place when electrons are released.

Sequence-simulation then prac
Created: 2012-01-23 16:59:33 by Isabel de Beer
Modified: 2012-05-03 14:11:36
Families (1): positive experiences with CS-ALL
Quotations: 9
Comment:
If the learner had a choice they would choose the sequence of first doing the computer simulation to see the microscopic changes taking place when electrons are released and then the physical practical in class (uv light, electroscope and piece of zinc- to demonstrate the release of electrons) to see the macroscopic change taking place when electrons are released.

Sequential
Created: 2012-01-06 13:35:28 by Isabel de Beer
Modified: 2012-06-06 11:50:04
Families (1): learning styles
Quotations: 32
Comment:
In the understanding dimension of learning the learner "gets" the concept by working step by step in an orderly fashion to get to the end.

Simulated practical
Created: 2012-01-10 07:40:14 by Isabel de Beer
Modified: 2012-06-06 14:26:11
Families (1): positive experiences with CS-ALL
Quotations: 29
Comment:
A virtual representation of a science experiment, available on the computer, usually interactive.

Static
Created: 2012-01-28 12:47:54 by Isabel de Beer
Modified: 2012-06-06 11:52:10
Quotations: 8
Comment:
Static pictures, not an animated or real moving picture, showing effects of changes - mentioned by visual learners as an important and valuable aspect of the simulation, over and above diagrams or pictures.

Suits learning style
Created: 2012-01-22 18:28:15 by Isabel de Beer
Modified: 2012-06-06 15:07:12
Families (1): learning styles
Quotations: 23
Comment:
The learner feels that this type of activity actually suits their learning style as they understand it.

Teach after reflection
Created: 2012-03-26 22:47:34 by Isabel de Beer
Modified: 2012-05-03 14:15:20
Families (1): positive experiences with CS-ALL
Quotations: 6

Teach yourself
Created: 2012-01-23 16:40:40 by Isabel de Beer
Modified: 2012-06-06 11:18:19
Families (1): positive experiences with CS-ALL
Quotations: 14
Comment:
Through a process of trial and error, discovering how to do something.

Tests or exams
Created: 2012-01-10 08:45:28 by Isabel de Beer
Modified: 2012-08-03 17:51:06
Families (1): Bad- Science
Quotations: 10
Comment:
Specifically referring to writing a test or exam- the stress accompanying the activity and the need to work fast in order to complete the task in the limited amount of time allowed.

Textbooks
Created: 2012-01-09 09:04:06 by Isabel de Beer
Modified: 2012-04-22 14:52:22
Families (1): Good- Science
Quotations: 7
Comment:
Books used as a guideline for the learner to supplement work discussed in class.

Theory
Created: 2012-01-07 11:16:00 by Isabel de Beer
Modified: 2012-06-06 11:50:04
Families (1): Good- Science
Quotations: 15
Comment:
Definitions; properties and laws, abstract concepts and facts.

Tidy
Created: 2012-01-08 12:57:28 by Isabel de Beer
Modified: 2012-06-06 14:52:55
Families (1): positive experiences with CS-ALL
Quotations: 2
Comment:
No mess during an experiment or no need to clean up afterwards - saving a huge amount of time.

Time constraints
Created: 2012-01-06 14:03:51 by Isabel de Beer
Modified: 2012-08-03 17:49:28
Quotations: 32
Comment:
Limited amount of time available, pushed for time when they work in class or write tests/exams (also amount of time needed to spend on Science homework).

Tiredness
Created: 2012-01-14 11:34:55 by Isabel de Beer
Modified: 2012-04-22 14:53:39
Families (1): Bad- Science
Quotations: 3
Comment:
The physical experience of being tired - due to physical factors.

Understand
Created: 2012-01-06 15:00:55 by Isabel de Beer
Modified: 2012-06-06 15:56:31
Families (2): learning styles, positive experiences with CS-ALL
Quotations: 123
Comment:
Comprehend; making sense of the topic matter they are engaging with, enjoy doing it.

Unhappy
Created: 2012-01-06 13:56:18 by Isabel de Beer
Modified: 2012-04-22 14:54:03
Families (1): Bad- Science
Quotations: 14
Comment:
Discontent; disappointed (with specific reference to their current Science mark).

Unlimited repeats
Created: 2012-01-22 18:13:02 by Isabel de Beer
Modified: 2012-04-24 17:06:04
Families (1): positive experiences with CS-ALL
Quotations: 15
Comment:
It is possible to repeat the experiment an unlimited amount of times, not restricted by time or apparatus or quantities involved.

Unmotivated
Created: 2012-01-11 18:06:27 by Isabel de Beer
Modified: 2012-04-22 14:55:17
Families (1): Bad- Science
Quotations: 11
Comment:
The learner recognises that their own slackness also plays a role in their struggle with science, they are slightly indifferent to the issue at hand.

Use of social media
Created: 2012-01-07 08:59:24 by Isabel de Beer
Modified: 2012-03-28 09:26:08
Families (1): Computer literate
Quotations: 16
Comment:
Engages regularly with the Internet such as YouTube; Facebook; Emails; Twitter; Computer games, downloads music or videos from the internet, watches movies on their computers.

Used simulation
Created: 2012-01-13 10:29:18 by Isabel de Beer
Modified: 2012-04-21 12:03:56
Families (1): positive experiences with CS-ALL
Quotations: 12
Comment:
Learner has used simulations before and found them quite useful.

Useful tool
Created: 2012-01-15 17:02:58 by Isabel de Beer
Modified: 2012-06-06 15:43:27
Families (1): positive experiences with CS-ALL
Quotations: 14
Comment:
The learner finds tha simulation a useful tool to supplement their learning experience in Science.

Verbal
Created: 2012-01-10 08:30:45 by Isabel de Beer
Modified: 2012-06-06 15:38:05
Families (1): learning styles
Quotations: 19
Comment:
In the input dimension of learning , the learner receives information in a verbal format, what they hear and then what they say.

Verbal explanation
Created: 2012-01-28 07:44:15 by Isabel de Beer
Modified: 2012-06-06 09:32:19
Families (1): Negative experiences with CS-ALL
Quotations: 7
Comment:
The learner would prefer to hear a verbal explanation of aspects in the simulation- either a teacher explaining or a voice over added in the simulation.

Verbal learner battling to listen
Created: 2012-03-26 14:53:37 by Isabel de Beer
Modified: 2012-04-22 20:42:23
Families (1): Bad- Science
Quotations: 2
Comment:
Verbal learner who find it difficult to listen and then apply what he heard.

Visual
Created: 2012-01-06 13:35:09 by Isabel de Beer
Modified: 2012-06-06 15:56:31
Families (2): learning styles, positive experiences with CS-ALL
Quotations: 126
Comment:
Under the input dimension the learner receives information by seeing the information eg a picture of the concept.

Waiting for download
Created: 2012-01-22 18:17:31 by Isabel de Beer
Modified: 2012-08-03 17:55:48
Quotations: 3
Comment:
Connecting to the www and waiting for the simulation to download, as opposed to loading the simulation of a network.

Weak in Science
Created: 2012-01-10 07:24:31 by Isabel de Beer
Modified: 2012-08-03 17:49:06
Quotations: 14
Comment:
Not achieving in science, getting very low marks for the subject, battling to understand and learn the work.

Work alone
Created: 2012-01-12 11:15:37 by Isabel de Beer
Modified: 2012-06-06 11:31:41
Families (1): positive experiences with CS-ALL
Quotations: 14
Comment:
Learners working by themselves.

Work not difficult
Created: 2012-01-13 10:07:41 by Isabel de Beer
Modified: 2012-04-22 20:45:25
Families (1): Good- Science
Quotations: 2
Comment:

A realisation that it is the idea of Science which is difficult, the way questions are asked, expecting the learner to apply their knowledge in some way or another.

Writing notes
Created: 2012-01-07 11:59:01 by Isabel de Beer
Modified: 2012-04-22 20:45:55
Families (2): Bad- Science, Good- Science
Quotations: 29
Comment:

Learner making their own notes while teacher explains concept (mostly helping themselves to stay focussed during the lessons)- it is a positive experience for Active learners.

Wrong results
Created: 2012-01-22 18:36:22 by Isabel de Beer
Modified: 2012-04-22 20:46:00

Families (1): Bad- Science
Quotations: 4
Comment:

The results of an experiment is not what its expected to be.
