# THE ROLE OF EYE CONTACT IN PROMOTING EFFECTIVE LEARNING IN NATURAL SCIENCE IN THE SECONDARY SCHOOL

by

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## ABSTRACT

The study explores the role of eye contact in promoting effective learning in natural science in the secondary school using eye-tracking technology. A theoretical framework constituting the theories of Vygotsky, Piaget and Bandura inform the study. In the empirical inquiry in this study a purposefully selected group of eleven Grade 9-learners of mixed ability were eye-tracked by means of the Tobii 60 X-2 eye-tracker during individual viewings of a video-recording of a natural science lesson taught by the educator using a PowerPoint presentation. The Tobii 60 X-2 eyetracker establishes how a learner pays attention to information presented through educator narration, visuals and texts during teaching and learning. The findings indicate that, as the learners' areas of interest, their highest total fixation duration was firstly on the PowerPoint presentation, and secondly on the educator. Under-performing natural science learners showed shorter and less dense fixation in both areas of interest.

**KEY WORDS**

Eye contact
Eye-tracking
Learning
Natural Science
Education
Educator
Classroom
Secondary school
Grade 9-learners
Ability groups

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I declare that: THE ROLE OF EYE CONTACT IN PROMOTING EFFECTIVE LEARNING IN NATURAL SCIENCE IN THE SECONDARY SCHOOL is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

SIGNATURE: R. Volmink

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| **ADHD** | Attention Deficit Hyperactivity Disorder |
| **AFD** | Average Fixation Duration |
| **AOI** | Area of Interest |
| **IT** | Information technology |
| **MCQ** | Multiple choice questions |
| **ms** | milliseconds (one thousandth of a second) |
| **NS** | Natural Science |
| **OB** | Observation length |
| **PPT** | PowerPoint |
| **PVT** | Percentage of viewing time |
| **s** | seconds |
| **TBI** | Traumatic Brain Injury |
| **TFD** | Total fixation duration |
| **TVD** | Total visit duration |

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# CHAPTER ONE
# BACKGROUND, PROBLEM FORMULATION, AIMS AND METHOD

## 1.1 INTRODUCTION

Non-verbal communication as well as verbal communication functions powerfully in the realization of an effective teaching-learning environment in the classroom (Lemmer, Meier & Van Wyk, 2012). Miller (2005) maintains that as little as 7% of communication takes place through the spoken word; most communication takes place through non-verbal and by means of paralinguistic cues. Under the rubric of non-verbal communication, Miller (2005) includes facial expressions, proximity and closeness, hand gestures, body language and, of great importance to this study, eye contact or the lack of eye contact. Similarly, in their comprehensive taxonomy of non-verbal communicative behaviours, Zoric, Smid and Pandzi (2007) include oculesics, which is the act of intentionally or unintentionally making eye contact with an individual during communication. The importance of eye contact was highlighted in an early study by Janik, Wellens, Goldberg and Del'Fosso (1978) of the University of Miami, who found that 43% of a person's attention during communication is devoted to making eye contact with the other person, while only 12.6% of a person's attention is on the mouth of the other person. According to Carbone, O'Brien, Sweeney-Kerwin & Albert (2013), *eye contact* is referred to by means of various synonymous terms in the literature, such as gaze, eye gaze behavior, visual attention, and eye-to-face gaze.

In the classroom eye contact is a very important non-verbal teaching technique, which not only enhances the learners[1]' attention but also helps the educators[2] in the attainment of the desired learner results (Ayesha, Butt, Fanoos, Muhammad & Sharif, 2011: 41; Fredrickson, 1992:25; Zeki, 2009; Knapp, Hall and Horgan (2014) state that learners participate more frequently in class when they remain within eye contact range with the teachers. According to Ledbury, White and Darn (2004), a teacher's eye contact with the learners provides the crucial opportunity to collect information about the learner, as well as his or her engagement in the

[1] The terms 'pupil', 'learner' and 'student' are used interchangeably, according to the literature of origin, thus following the preferred terminology within the context of a specific national education system.

[2] The term 'educator' has been predominantly used throughout this text; the term 'teacher(s)' has been used in certain instances where it reflects the preferred terminology within the context of a specific national education system.

lesson; this can strengthen class participation in discussions, curb discipline problems, and motivate the learners. The abovementioned researchers (2004) pointed out that much teaching time is lost when the learners' gaze is fixed on the textbook, on slides, or the chalkboard, or is randomly wandering around the classroom. The importance of human eye contact can already be observed in very small babies who tend to focus more on the eyes of someone looking at them than on any other part of the face (Batki, Baron-Cohen, Wheelright, Connellan, & Ahluwalia, 2000:223). In a study which assessed the visual attention in toddlers, using eye-tracking technology, Carr, Jones and Klin (2008) reported that altered patterns of eye contact may be a biomarker for autism, and that by not making eye contact a child's social growth may be affected, namely by negatively influencing their ability to interpret and to react to emotional cues communicated by the eyes. According to the Montessori Teacher Training Blog (February 11, 2010), when the teachers make eye contact with their learners, they communicate the real intent of their verbal message. Thus, the importance of eye contact should not be underestimated during effective teaching and learning.

The introduction of many easily accessible modern technological tools, such as computers, Powerpoint, iPads and cell phones, has diminished the need for sustained eye contact between a child and the parent, and the learner and the educator in the classroom (Gregoire, 2015). Digital multitasking increasingly interrupts eye contact; yet eye contact remains fundamental to human learning. Educators should ensure sufficient opportunities for eye contact to occur in the classroom situation so that the benefits of modern technology can be effective and not destructive. Eye contact is essential for a child's socialization and for the development of social skills (Carbone et al., 2013). Engaging in effective, prolonged periods of eye contact in a classroom is a simple and cost-effective tool for learning, and can therefore enhance academic success, no matter whether schooling occurs in a poorly or a well-equipped school (Ledbury et al., 2004). Sustained and effective eye contact during teaching and learning is also a method which equals the 'playing field', since attention to eye contact can easily be employed by any teacher. The teacher and the learner are the key role-players at school, and where the classroom environment provides ample opportunity for eye contact, education is rendered more meaningful.

Against this background, this study explores the role of eye contact in promoting effective learning in natural science in the secondary school by making use of eye-tracking technology. Until recently, determining the extent and nature of eye contact as an indicator of student attention during class has been very difficult to monitor with any accuracy. However, new technology has provided a breakthrough in this endeavour (Smith, Mestre & Ross, 2010). Eye-tracking by means of eye-trackers is an innovative way which can produce reliable data whereby to better understand both the students' attention as expressed through eye contact, and the impact on the students' attention of how the teachers teach (Rosengrant, Hearrington, Alvarado & Keeble, 2011). The precision of eye-tracking methodology can aid in establishing the best way a learner assimilates information, and the impact that the educators, the visuals (including PowerPoint presentations) and the texts have on the learners' attention during lessons. Duchowski (2002: 455) explains that the eye-tracker in its diagnostic role is able to provide objective and quantitative evidence of a participant's visual and overt attentional processes. In particular, eye-tracking has also proved useful in determining student attention in the teaching of the natural sciences (Rosengrant, Thompson & Mzoughi, 2009; Ariasi & Mason, 2010). A large variety of eye-tracking devices and equipment are available (Duchowski, 2007). However, Tobii Technology, (2010) is the global market leader in eye-tracking and eye control. The company's products are widely used in the scientific community, in commercial market research, and as a means of communicating by people with disabilities.

Finally, internet-based literature search indicated that eye-tracking research in educational settings is in its infancy in South Africa. Only four studies were found in this regard. These are briefly summarised below.

In a collaborative study between the School of Education, the University of Durham, in Durham, in the United Kingdom, and the School of Education, the University of the Witwatersrand, in Johannesburg, South Africa, the use of new methods in eye-tracking technology was explored by investigating how young children view and interpret mathematical representations of multiplication (Bolden, Barmby, Raine & Gardner, 2015). The children participating in the study represented a range of attainment levels across the mathematical domain (three higher-, three middle- and three lower-attaining children) and were selected accordingly by their class teacher. The participants were required to view 13 static slides, one after the other, with each slide presenting a symbolic and a picture representation of multiplication problems. The data that were captured by the eye tracker and recorded were then analysed quantitatively (e.g., time on each slide, and time on each area of interest as specified in the software) and qualitatively (video recordings of each child's gaze trajectory during each representation were carried out, thereby allowing the categorisation of the different approaches adopted). The study showed that (a) the particular form of the number line representation used in this study was less successful than the other picture representations used (equal groups, array) in promoting multiplicative thinking in children, and (b) the success of the children to think multiplicatively with the 'groups' and the array representation was related to their general mathematics attainment levels. These findings have valuable information for teacher practice in that the teachers need to be clear about the possible drawbacks of particular representations. Even in using more successful representations, for lower-attaining children the progression in their understanding of the representation needs to be taken into account by the teacher. The study also highlighted that eye-tracking technology does have some limitations, but is useful in investigating young children's focus of attention whilst undertaking a mathematics assessment task (Bolden et al., 2015).

Another collaborative study between the School of Languages, the Vaal Triangle Campus, the North-West University, Vanderbijlpark and the Department of Linguistics, at the University of South Africa, was conducted. Van Rooy and Pretorius (2013) investigated the reading ability of Grade 4-learners in their home language, isiZulu, and in English (first additional language), using both eye-tracking activities and the traditional pen-and-paper reading comprehension assessment. The aim of the study was twofold: firstly, to compare bilingual reading performance in an agglutinating, (root words are united with little change of form or loss of meaning), in language (isiZulu) and an analytic, (frequent use of function words and changes in words to express relations), in language (English). The learners' eye-tracking profiles were obtained in both languages to see how they differed across the two languages. Their eye-tracking profiles were also analysed according to their comprehension performance in both languages. Secondly, the eye-tracking profiles in both languages were also analysed in terms of reading ability in order to determine how the eye-tracking profiles differed among strong, average and weak readers in the two languages. The pen-and-paper tests showed that the entire group read with relatively poor comprehension. The main findings from the eye-tracker indicated significant differences when the learners read in the two languages, on nearly all the selected eye-tracking variables. The eye movement profiles in isiZulu may be attributed to the longer word units in the conjunctive orthography (correct spelling) of isiZulu. However, although there were several significant differences in the eye movements between the reading ability groups in English, differences in eye movements due to differential reading skills did not emerge strongly in isiZulu (Van Rooy & Pretorius, 2013).

Kruger and Steyn (2013) used eye-tracking in an experimental study to determine whether reading subtitles enhances academic performance. The reading of the subtitles in a film was examined by means of a comprehension test. The study then looked at English subtitles in an English lecture. The results seemed to indicate that the number of words and the number of lines do not play a significant role in the processing of subtitles, but that the attention distribution across the different redundant sources of information results in the partial processing of subtitles (Kruger and Steyn, 2013).

Finally, Mabila, Gelderblom and Ssemugabi (2014) investigated the relationship between the digital proficiency and the user performance of students studying End User Computing when using the Learning Management Systems (LMS) at the University of South Africa (UNISA), an open distance learning institution. The students were categorised into four groups of a digital proficiency framework and eye-tracked while performing three assigned tasks. The findings show that the efficiency and effectiveness when using the LMS relate directly to the students' proficiency levels (Mabila et al., 2014).

Against this background this study entitled, 'The role of eye contact in promoting effective learning in natural science in the secondary school', is an attempt to add to this growing body of literature regarding eye-contact and eye-tracking within the field of education in South Africa.

### 1.1.1 The position of the researcher

I am a qualified natural science teacher and an experienced educator. I have taught natural science for 12 years at a school administered by the former Department of Education and Training in Cape Town (1987-1998), five years at an independent school in Cape Town (1999-2003), four years at a former model-C school (2004-2007) in KwaZulu Natal, and at a former model-C school (2008-2011) in Cape Town. This teaching experience gave me considerable exposure to different teaching conditions and to learners from diverse backgrounds. During this time I became convinced of the importance of eye contact during teaching and learning in order to achieve academic success. My experience showed me that, irrespective of social standing or gender, the key to effective learning hinges on making eye contact with the learner. I am currently involved with relief teaching at a suburban secondary school, as well as assisting with the Senior and Junior Science Fair.

## 1.2 PROBLEM FORMULATION

This study aims to address the main research question, namely what is the role of eye contact using eye-tracking technology in promoting effective learning in natural science in the secondary school? This research question is sub-divided into the following research questions:

i) What theoretical perspectives and relevant extant findings in the literature inform the use of eye contact, its relationship to attention, and its role in teaching and learning? (Chapter 2).

ii) What is the current state of the research concerning eye-tracking technology in the learning situation with particular reference to science learning as a means of determining visual attention, and to identify the gaps in the current research? (Chapter 3).

iii) How does a mixed-ability group of selected Grade 9-learners (natural science) distribute visual attention as measured by a Tobii X2-60 eye-tracker during the viewing of a video recording of a natural science lesson on the structure of the cell, with special reference to the educator and the PowerPoint as the two Areas of Interest (AOIs)? (Chapters 4 and 5).

iv) Based on the findings of the literature and the exploratory inquiry, what recommendations can be made for the improvement of classroom practice regarding the use of eye contact to effect optimal learning in the secondary school classroom, with particular reference to natural science? (Chapter 6).

## 1.3 THE AIMS OF THE STUDY

The main aim of the study is to explore the role of eye contact using eye-tracking technology in promoting effective learning in natural science in the secondary school. The objectives of the study are as follows:

i) to identify and explain the theoretical perspectives which inform the use of eye contact, its relationship to attention, and its role in learning;

ii) to describe the state of the existing research concerning eye-tracking technology in the learning situation as a means of determining visual attention, and to identify gaps in the current research;

v) to design and carry out an exploratory inquiry involving a mixed-ability group of selected Grade 9-learners and their distribution of visual attention as measured by a Tobii X2-60 eye-tracker during the viewing of a video recording of a natural science lesson on the structure of the cell, with special reference to the educator and the PowerPoint as the two (AOIs);

vi) based on the findings in the literature and the exploratory inquiry, to make recommendations for classroom practice regarding the use of eye contact to ensure optimal learning in the secondary school (Chapter 6)

## 1.4 THE RESEARCH DESIGN

The research question is addressed by a literature study and an exploratory inquiry.

### 1.4.1 The literature study

According to McMillan and Schumacher (2006:75), a literature review will add much to the understanding of the research problem and to help to place the results of the study in a historical perspective. Without conducting a review of the literature, it is difficult to build a body of existing scientific knowledge about educational phenomena. A review of the literature enables the researcher to do the following (McMillan & Schumacher, 2006:76):

1. To define and limit the problem. In this study I examined how eye contact is able to improve attention, and thus academic performance in the classroom.
2. To place the study in a historical perspective. In this study I investigated the importance of eye contact in effective learning through the literature review.
3. To avoid unintentional and unnecessary replication. The literature review indicated the state of previous research, and thus I endeavoured to avoid unnecessary repetition.
4. To select promising methods and measures. The literature review enabled me to choose an exploratory research design which made use of eye-tracking methodology as an appropriate method for this study.
5. To relate the findings to previous knowledge and to suggest further research. I contrasted the results of my study to the findings of previous research in order to

show how the study adds new knowledge, and how further directions for research could be conducted in a secondary school.

In this study the following literature sources were consulted, namely primary sources (journal articles); secondary sources (e.g., summaries of information gathered from primary sources); and tertiary sources (e.g., relevant textbooks) (Anderson & Poole, 2009:22).

### 1.4.2 The empirical inquiry

An exploratory inquiry, using eye-tracking methodology was used to obtain preliminary descriptive data regarding the learners' eye contact during the video presentation of a natural science lesson, with a view to determining what drew the greatest visual attention, the PowerPoint or the educator as AOIs.

A brief summary of the research design is given below. Full details are to be found in Chapter 4.

#### 1.4.2.1 The selection of the site and the sampling of the participants

The study was carried out at a public secondary school in Cape Town, administered by the Western Cape Education Department (WCED), selected by means of convenience sampling. Twelve (12) Grade 9 natural science learners were purposefully selected by maximum variation sampling (McMillan & Schumacher, 2010) to provide a group of mixed ability: four learners with an overall score of 80% or above in natural science; four learners with an overall score of 54% - 55%, and four learners with an overall score of 24% - 37% based on their results in the first semester, 2014. This information regarding the test scores was provided by the Head of the Department (natural science). During the data-gathering procedures, the eyes of one participant (participant 8) were not adequately calibrated, and her data were excluded from the study. Thus, the final sample comprised eleven (11) participants.

#### 1.4.2.2 Data-gathering

A 10 minute video recording on the topic, *The structure of the cell*, was prepared for the study. In the video recording, I (a qualified natural science teacher) presented the lesson using a

Microsoft PowerPoint (PPT) presentation comprising thirteen slides. As mentioned, the two designated AOIs were the PowerPoint and the educator. The participants viewed the recording, one at a time, in a designated venue at the school during school hours. The participants viewed the recording on a 17inch computer monitor in which a Tobii X2-60 eye-tracker, (supplied by the Department of Computer Science, University of South Africa), had been integrated to record eye-contact data. A qualified eye-tracker technician, Mr. A. Pottas of the Department of Computer Science, University of South Africa, operated the eye-tracking equipment. Mr. Pottas and I were present at all the viewings. After the video recording the participants completed an online Multiple Choice Question (MCQ) to assess their recall of the instructional content presented in the lesson, and they answered two think-aloud questions.

Before the recording I briefed the participants on the process, including the MCQ test. Any questions regarding the eye-tracker equipment were answered by me and/or the technician. After the process the participants were given the opportunity to ask any questions they may have. Each participant was involved for approximately 20 minutes. Before the viewing each participant's eye movements were noted by means of a calibration process for the eye-tracker to capture the correct positions of the participant's eye movements. This process was unobtrusive and lasted for about five minutes. The participants were asked to follow a flickering light moving across the blank computer screen. Calibration was measured automatically on the Tobii eye-tracker. As mentioned before, one participant's eyes were not adequately calibrated, and her data were excluded from the study.

After the viewing, each participant was asked to complete an online, multiple choice question paper (MCQ) consisting of 12 questions (10 closed questions and two open questions (cf. Appendix F). The purpose of the MCQ was to assess the recall of the instructional content. I also posed a think-aloud question to each participant at the end of the recording, and took down field-notes of their responses.

#### 1.4.2.3 The selection of the measurement instruments

As mentioned before, a large variety of eye-tracking devices and equipment is available. The Tobii Technology (2010) eye-tracker was chosen for the following reasons, namely it is a global market leader in eye-tracking and eye control; the company's products are widely used in the scientific community, in commercial market research and by people with disabilities as a means to communicate; Tobii technology (2010) is also used for research in the laboratories of the Department of Computer Science at the University of South Africa. For the purpose of this study, the Tobii X2-60 eye-tracker was selected from the range of Tobii products. The Tobii X2-60 eye-tracker is integrated in a 17-inch computer monitor, and the stimuli (i.e., what is viewed by the participant in the study), can be presented on the computer monitor. It delivers a high level of accuracy and precision which ensures that the research results are reliable. The Tobii X2-60 eye-tracker offers a higher tracking frequency for eye-tracking studies that require finer gaze-detail data (Tobii Technology, 2010).

#### 1.4.2.4 Data-analysis

The data gained by the eye-tracker was captured by the computer and analysed by the expert technician, using the analytic software, Tobii Studio (2015). It provided data on: i) the two AOI's on which the participant fixated), and ii) the fixation and visit duration on the two AOIs. Data were presented in the findings by means of gaze-plots, heat-maps and bar graphs, indicating the fixation and the visit duration.

#### 1.4.2.5 Validity and reliability

*Internal validity* is the degree to which the experimental treatment makes a difference in (causes change in) the specific experimental settings. *External validity* is the degree to which the treatment effect can be generalized across populations, settings, treatment variables, and measurement instruments. Factors that threaten internal validity are, for example history, maturation, pretest effects, instruments, the differential selection of the participants, mortality, and interactions of factors (e.g., selection and maturation). Threats to external validity include, namely the interaction effects of selection biases and treatment, the reactive effect of experimental procedures, and multiple-treatment interference (Dimitrov & Rumrill, 2003:159). Yin (2009:41) states that in order to construct validity the researcher must use multiple sources of evidence.

To obtain reliable and valid data in a non-experimental cross-sectional setting I used well-known eye-tracking technology which was operated by an expert technician. The calibration of the participants was carried out, and unusable data identified and omitted. The data-analysis was undertaken by the expert technician, using the appropriate Tobii software. Eye-tracking data were complemented by the findings of a MCQ test, the responses to the think-aloud questions and observations of the participants during data-gathering. Furthermore, the literature on eye-tracking studies was consulted to elucidate the findings. As the study was exploratory and descriptive, no attempt was made to generalize the findings.

#### 1.4.2.6 Ethical issues

The Code of Ethics for research involving human beings lay down guidelines and procedures for researchers to follow when they conduct research. These guidelines and procedures commonly relate to the methods of selecting the participants; obtaining consent from participants; allowing them to withdraw without coercion from the study if they should wish to do so; the instruments used for data-collection; the disclosure of the purpose of the research study; treating the participants professionally; protecting the participants' privacy, and ensuring their anonymity (Anderson & Poole, 2009:30).

In this study issues pertaining to ethics were dealt with as follows: Firstly, the written permission was obtained from the Ethics Committee of the College of Education, University of South Africa (cf. Appendix A); the Western Cape Department of Education (cf. Appendix B); the principal of the selected school (cf. Appendix C); the parents of the participants (cf. Appendix D); and the assent of the learner participants (cf. Appendix E).

The research did not infringe on the learners' right to privacy, or did not demand any extraordinary behaviour. Participation was voluntary and anonymous, and the right to withdraw or refuse certain questions was upheld. The participants and the schools with which they were associated were coded rather than being referred to by their names (McMillan & Schumacher, 2006). An electronic summary of the findings will be made available to the Western Cape Department of Education, and to the principal of the school on request, after the successful completion of the dissertation. A discussion will be held with the learner participants about the findings of the research after the successful completion of the dissertation.

## 1.5 DEFINITION OF THE KEY TERMS

### 1.5.1 Eye contact

In general, *eye contact* is a meeting of the eyes between two individuals. In human beings, eye contact is a form of non-verbal communication, and is thought to have a big influence on social behaviour (Johnson & Senju, 2008:127). In terms of eye-tracing research, *eye contact* refers to the point of gaze or the fixation point in the visual field (Tobii Technology, 2010:4).

### 1.5.2 Eye-tracking

*Eye-tracking* is the process of measuring either the point of gaze (where one is looking) or the motion of the eye relative to the head. An eye-tracker is a device for measuring eye positions and eye movement (Duchowski, 2002:454).

### 1.5.3 Fixation

Fixation is the pause of the eye movement on a specific area at which the person is looking during eye-tracking procedures (Tobii Technology, 2010:4).

### 1.5.4 Calibration

*Calibration* during eye-tracking is the procedure whereby the eye-tracker measures the features of the user's eyes, and utilizes them together with an internal, physiological 3- D eye model to calculate the gaze data (Tobii Technology, 2010:7).

### 1.5.5 Heat-map

A *heat-map* is a representation of the gaze behavior of an entire group of eye-tracking recordings. It indicates the various areas of the screen where the user has spent the most time looking during eye-tracking (Tobii Technology, 2008:10).

### 1.5.6 Gaze-plot

A *gaze-plot* is a representation of the user's eye movements on the screen, fixation by fixation during eye-tracking. Each fixation is represented by a dot. The larger the dot the longer the fixation on a particular part of the screen. (Tobii Technology, 2008:10).

### 1.5.7 Areas of Interest

*Areas of interest* refer to points on the screen where many fixations appear clustered close together; this suggests the presence of stimuli in the proximity of these fixations that attracts attention. These clusters are called *Areas of Interest* (Hedberg, 2000).

## 1.6 CHAPTER DIVISION

The study is organised according to the following chapters:

Chapter 1 presents the background to the study, the problem statement, the aims of the research and the research design.

Chapter 2 provides an overview of perspectives which inform the use of eye contact, its relationship to attention and its role in learning.

Chapter 3 describes the current state of research concerning eye-tracking technology and its use in determining visual attention in learning situations.

Chapter 4 explains the research design, including eye-tracking methodology and data-gathering and analysis procedures.

Chapter 5 integrates and presents the findings of the investigation.

Finally, an overview of the pertinent points of the study is given in Chapter 6. Guidelines are suggested for the improvement of eye contact in secondary school classrooms based on the literature and the empirical study. Final conclusions are drawn and recommendations are made for the improvement of practice and for further study.

## 1.7 CONCLUSION

The role and importance of eye contact to secure attention necessary for effective learning to take place in the classroom have been outlined. In the light of this, the problem formulation, the aims, the research design and the organisation of the exploratory study were briefly discussed.

# CHAPTER 2

# EYE CONTACT AND COMMUNICATION DURING TEACHING AND LEARNING

## 2.1 INTRODUCTION

This chapter comprises a literature review which explores the relevance of theories and extant themes which deal with eye contact and effective learning. This forms the conceptual framework of the empirical study.

## 2.2 THEORETICAL FRAMEWORK

As theoretical framework, the role of eye contact as indicator of attention in the teaching and learning situation draws on the work of Vygotsky, who investigated the role of social interaction in the learning situation, as well as the Piaget's work on cognitive development, and Bandura's social learning theory.

### 2.2.1 Vygotsky's sociocultural view of development

Vygotsky (1896-1934), the Russian psychologist, posited that the development of all higher cognitive processes has its origin in social interaction. During the later period of the development of his theory Vygotsky posited that a holistic view of learning during which the social, personal, intellectual, emotional and physical characteristics of a learner within his or her psychological environment should be taken into consideration (Yanitsky, 2014). In particular, Vygotsky (1978:26) emphasised the role of language in learning, and acknowledged the role played by sight and manipulation as follows, "Children solve practical tasks with the help of their speech, as well as their eyes and hands". Yanitsky (2014) concurs with Vygotsky regarding the fact that children develop as a result of the interaction with more mature members of society. Carbone et al. (2013) stress the role of eye contact in early language learning. The inability to make eye contact in social learning is the earliest and most obvious indicator of developmental delays. Vygotsky's (1978:68) most celebrated notion is the concept of the zone of proximal development, which he defined as "the distance between the actual developmental level as determined through independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers". Vygotsky's explanation of the Zone of Proximal Development expresses the difference between what a learner can do without assistance and what he or she can do with assistance as provided by the learning situation. This highlights the central role of adults and competent peers in the children's attainment of a certain level of cognitive development. Slavin (2009:43) explains the Zone of Proximal Development as what a child is capable of mastering with the assistance of a competent peer or adult and that the child is unable to do alone. "What is the zone of proximal development today will be the actual development level of tomorrow" (Vygotsky, 1978:87). The effective teacher is one who is aware and sensitive to the child's zone of proximal development and offers opportunities for relevant independent learning as well as collaborative activities to promote learning. *Scaffolding* is another important aspect of learning within the zone of proximal development. Hereby the teacher provides guidance through a wide range of learning aids, including media and illustrations, to assist the child to reach its full potential (Berns, 2013). Furthermore, by stressing the role of culture in cognitive development, Vygotsky indicates the importance of examining the sociocultural settings in which children grow up if we want to understand their cognition. Vygotsky (1978) looked at the unity and interdependence of learning and development, starting from a child's birth. Vygotsky's (1978) theory of social constructivism looks critically at the idea that learning either originates from environmental stimuli or on grounds of biological maturation. The Vygotskyan theory upholds the idea that learning takes place when an individual internalises social practices. Internalisation takes place through social interactions.

#### 2.2.1.1 Implications of Vygotsky's theory for eye contact during learning

Vygotsky's reference to learning through social interaction presupposes eye contact between a competent adult or a more competent peer and the learner. For Vygotsky (1978:26) these social interactions involve both verbal and non-verbal interactions. In my study (cf. Chapter 4), the learners interact in a virtual manner, non-verbally, with the learning content (the educator teaching a lesson and the learners' viewing on the computer monitor). The eye-tracker picks up the learners' non-verbal or eye movements to determine what holds their attention is during the virtual lesson. Verbal interaction occurs after the viewing when the educator asks the learner two think-aloud questions. The PowerPoint slides (cf. Chapter 4), including the text and the illustrations, provide the scaffolding for learning which assists the learner to acquire abstract concepts. Thus, my study recognizes the role of virtual social interaction during learning (through eye-contact), since the learner views the educator's narration while teaching a lesson, and it also incorporates scaffolding in the form of illustrations, diagrams and pertinent text in the learning of new content.

### 2.2.2 Piaget's theory of cognitive development

Jean Piaget (1896-1980), a leading developmental psychologist during the twentieth century, achieved much prominence through his work on cognitive development. Piaget (1972) emphasises the difference between development and learning as follows, namely *development* is a natural, spontaneous action linked to embryogenesis; *learning* is initiated by external situations. Piaget regarded cognitive development as taking place in stages. Each stage presents a new and distinguishable form of knowing; these stages are integrative in the sense that each stage incorporates the previous stage; the lower stages precede the higher stages and they are organised and structured. Each stage includes a period of preparation, when a person moves from one stage to the next, and a period of consolidation, when the learning is established in the learner's mind (Lourenco, 2014).

Piaget labels the four stages of cognitive development as follows, namely sensory-motor, pre-operational, concrete operational and formal operational. Piaget (1972) describes the first stage, the sensory-motor, pre-verbal stage, lasting approximately the first 18 months of life, as the stage where the practical knowledge that is established forms the basis of later representational knowledge. For example, an object that initially disappears from a baby's perceptual field is perceived by the infant as no longer existing. Later on, the infant will be able to spatially locate an object. This entails a progressive and unavoidable acquisition of a series of sensory-motor information that serves as the basis of later representational thought. Thus, Piaget stated that during the first 18 months, babies know their world in terms of their sensory perceptions, including vision (Piaget, 1936/1977). The role of vision and eye contact in infants is discussed in further detail (cf. par. 2.3.1). Piaget (1972) describes the second stage, the pre-operational stage, as being at the beginning of language and of the symbolic function, and therefore of representational thought. At this stage of representational thought, there is a reconstruction of all that was developed in the sensory-motor stage. For example, if the same liquid is poured into different shaped glasses, the pre-operational child will think that one glass may hold more liquid than another. Piaget (1972) indicates that during the third stage, the first concrete operations of classification, ordering, the construction of the idea of number, and spatial and temporal operations, are all expressed using objects. Finally, in the fourth stage, the child is able to reason on hypotheses and not only on objects. Piaget (1972) called this stage the stage of *formal* or of *hypothetic-deductive* operations. The child is now capable of constructing new operations and not simply the operations of classes, relations and numbers, as associated with the third stage (Slavin, 2009:38-39).

Furthermore, Piaget (1964) stresses that learning takes place through social interaction, including language, and human relationships. He posits that children learn as they interact with their physical environment and their social milieu. During learning the child continually adapts to the environment. Learning is not entirely child-centered or teacher-centered; the teacher should, however, organise classroom situations whereby the child can interact through experimentation and practical application. In this Piaget stresses the role of interaction with others during learning. He posits that the child can only innovate and develop cognitive constructions to the extent that he or she is involved in collaboration. Thus, the school should provide both independent and group learning opportunities. Children cannot organise their thoughts into a coherent whole unless they participate in thought exchanges, and work with others. In this sense, Piaget stresses that collective living is essential to the development of the personality (Lourenco, 2014).

#### 2.2.2.1 Implications of Piaget's theory for eye contact during learning

According to Piaget's (1972) first stage, babies experience the world in terms of sensory-motor information. This implies that eye-contact between the mother or the caregiver and the child takes place and constitutes one of the first external learning situations for the child. Piaget (1970) clearly expounded that learner-environment interaction involves both bodily sensorimotor activity and mental operations. The sensorimotor activity highlights the skills involving the process of receiving sensory messages and producing a response, which involves the eyes engaging with the educator. In Piaget's (1972) second stage, (cf. par. 2.2.1.1), he explains that in order for future learning to take place, the sensory-motor stage has to be well-established. In Piaget's (1972), third stage, (cf. par. 2.2.1.1) he indicates that the child is capable of concrete operations, based on objects. During my study a PowerPoint presentation is used as a teaching aid to engage the learner cognitively to be able to answer the multiple choice questions based on the lesson. Also, educators who have been informed theoretically would make use of technology to assist them in allowing the learners to acquire the ability to retain transmitted information (Piaget, 1970).

### 2.2.3 Bandura's social learning theory

Albert Bandura (1977) developed the social learning theory, which states that both cognitive and behavioural learning take place through observation, modelling and imitating others. Bandura (1977) stressed that children see how a model behaves and copies this behaviour. This is known as *modelling* or *observational learning*. Models may be the child's parents, brothers or sisters, other members of the family, teachers, coaches, friends, or even characters depicted by the media. When a child observes behaviour, he or she deduces information from what is observed; this knowledge is store in memory; generalisations and rules are devised about behaviour; the information may be retried and acted out at another time when the behaviour seems appropriate (Baker-Eveleth & Stone, 2008). Observational learning and modelling is very important during a child's socialisation in the family, the school and the community (Berns, 2013). As children grow older, identification plays a more important role in socialisation. *Identification* is the process by which the child takes on the characteristics, values and beliefs of the parent of the same gender or the nurturing parent or caregiver (Louw, Van Ede & Louw, 2004:308-309). This process of learning through observation, modelling and imitation not only allows meaningful learning to take place but also provides the child with knowledge regarding culturally and gender-appropriate body language, including appropriate eye contact skills during socialisation.

According to Bandura's (1977) theory, a range of factors influence the extent to which a child will imitate modelled behaviour. A sound relationship between the child and the caregiver will promote observational learning. People who act as models who are seen as physically powerful, competent or attractive are more likely to be imitated. Furthermore, punishment or reward will reinforce observational learning. If a child observes a model that is punished for certain behaviour, he or she will be less likely to imitate the behaviour (Berns, 2013).

#### 2.2.3.1 Implications of Bandura's theory for eye contact during learning

Albert Bandura's (1997) social cognitive theory highlights the impact of the social environment on learning. The behaviour of an individual is directly dependent on the situation and other actors who are in the situation. This theory asserts that the learners acquire information through observing others, and are able to decide what information they would like to retain and practice. This observation of another's behaviour would include the aspect of sight, and thus eye contact, pertinent to my study. Vital to learning, acquiring and performing a particular behaviour, is the learner's ability to assess whether to accept or discard the behaviour. This assessment by the learner of the behaviour would definitely include careful visual information as he or she observes the individual displaying the behaviour. To create a learning environment with social interactions (including meaningful eye contact) and exchanges between the educators and the learners present great challenges to the learning situation. With reference to Bandura (2007:1; 2002:121), technology plays a role in the "globalization of human interconnectedness", thus influencing how people use and apply technology within their societal and cultural environments. Bandura (1997) advocates that committed self-efficacy and exceptional motivation are necessary for individuals to be successful and productive in the information technological age. In order to ensure that the 21st century learner is adaptable, proficient and self-directed, Bandura (2003:482-484), recommends that our educational environments focus on the retention of skills, and not merely fixate on the acquisition of subject matter.

## 2.3 EYE CONTACT IN SOCIAL INTERACTION

It is generally understood that we are unable to access other human beings' internal thoughts and feelings. However, what we see and hear, allows us to infer what a human being seeks to communicate (McDaniel, Porter & Samovar, 2010:17). Dhu (2011:2) states that good eye contact plays a pivotal role in social interaction. Feng (2009) says that 55% of communication can be proportioned to body language. McDaniel et al. (2010: 262) maintain that one is able to send a limitless number of messages via the eyes. The ultimate interpretation of human communication is derived from non-verbal cues which may also deliver the emotional state of the person sending or receiving information (Gray & Moffet, 2010:7). Non-verbal communication, in particular eye contact, is essential in establishing a connection with the person you are communicating with (Gray & Moffet, 2010:8). Eye contact is a skill known as an *attending skill*, enabling the person communicating to convey interest, empathy and warmth. Also, eye contact should never make the listener feel uncomfortable. One needs to be sensitive to the appropriate eye gaze found in certain cultures (Gray & Moffet, 2010:10). Parise, Handl, Palumbo and Friederici (2011:842) used event-related brain potentials (ERP's) studies which looked at the components of language development by audiovisual perceptual integration. They state that eye gaze is an important communicative signal for mutual eye contact. Parise et al., (2011:852) conclude that new insights on the early stages of communicative development in humans is due to the interaction of eye gaze and speech.

Bayless, Glover, Taylor and Itier (2011:503) state that the ability to determine people's feelings hinges on social cues, especially eye gaze, which together with facial expression, can display various emotions, such as happiness, fear, surprise or anger. Bayless et al. (2011:483-484) did three investigations to indicate whether emotion has an influence on individuals causing them to look in a particular direction, by taking into consideration the magnitude of gaze orienting effects (GOE), and predicted that fearful and surprised, which represents widely opened eyes, would favour greater GOE, as opposed to angry and happy expressions, for which the eyes are narrowed. Brunet, Mondloch and Schmidt (2010:1-2) conducted studies where forty ten-year old children, whose parents had completed a childhood temperament inventor, were required to identify the shape and spacing of pairs of faces from a number of photographs. Their findings indicate that, when a child's temperament is one of shyness, he/she avoids looking at faces and making eye contact, and they were prone to making more identification errors of facial expressions (Brunet et al., 2010:12).

Effective eye contact allows one to share oneself in an open and honest manner with one's audience, as well as in engaging the flagging attention of the audience. Beebe (1974:22) found that an increased amount of eye contact during a presentation greatly enhances the credibility of the speaker. These findings also apply to the presentation of a lesson in front of a class of learners. Ledbury et al. (2004) continue to confirm that eye contact definitely adds to the perceived credibility conveyed by a speaker, and encourages educators to bring to the attention of the learners the importance of maintaining good eye contact when they are delivering a speech, since it results in greater credibility. Vrij, Mann, Leal, and Fisher (2009:328-329) conducted a number of experiments to determine what happens when you instruct a liar to tell a story and maintain eye contact, and when you allow a truthful person with cognitive overload to tell a story. A subject with cognitive overload is one where you engage the brain in a number of functions (Vrij et al., 2009:330). The liar then finds it difficult to maintain eye contact while relaying a story, since he or she has to engage an already overloaded brain with the fabrication of a lie. The truthful person finds it easier to maintain eye contact, only looking away to engage the overloaded brain, but not having to cope with weaving a lie, and therefore relates the story much easier. Eye contact plays a major role in identifying a liar. McDaniel et al. (2010:261) allude to just how powerful eye contact is by citing the following example, namely a professional poker player conceals his eyes behind dark glasses during an important tournament, since his eyes may reveal the strength or weakness of his hand.

Dean (2012:6-7) stresses the importance of eye contact during the transmission of important information in the health profession. Dean (2012) cites the following anecdote: When emergency workers who have rescued a patient, arrive at the hospital and need to hand the patient over to the clinician, valuable information is gained about the patient's condition by the clinician if eye contact is maintained by the emergency worker and the clinician. It is reported that fewer questions were asked when eye contact was maintained, thus wasting less valuable time. The idea of eye contact between the emergency worker and the clinician was regarded so strongly that a video recording was made of the interaction between the emergency worker and the clinician and it was discovered that the handover time between the emergency worker and the clinician was halved when eye contact was maintained. This freed the emergency worker to enable him to attend to other emergency situations. McGrath, Arar and Pugh (2007:105) stress the value of non-verbal communication, such as eye contact, when health professionals engage in diagnostic medical interviews with patients. Useful information can be produced when isolating non-verbal communication during the medical interview. Arar and Pubh (2007) draw attention to the fact that broken eye contact between the physician and the patient have been associated with less patient disclosure, while conversely, non-verbal skills, for example, eye contact, have been associated with patient satisfaction and compliance with medical regimens (McGrath et al., 2007:106-107). McGrath et al. (2007:115) allude to the fact that since there has been an emphasis on non-verbal communication, such as eye contact it has led to effective communication between doctor-patient, and also improved healthcare. Based on the importance of the latter, medical schools in many parts of the world are required to offer communication courses in order to receive accreditation. McGrath et al. (2007) also go on to say that using the eyes as a tool of communication in relationships between patient and health care professional is vitally important, since the major complaint arising between the health care professional and patients in the United States is the lack of eye contact (McDaniel et al., 2010:262). In this regard, Egan (2013:7-8) introduced the following acronym, SOLER, during the training of health professionals. SOLER indicates the following guidelines for health and social care workers when dealing with clients: **S - S**quarely face the client; **O -** maintain an **O**pen posture; **L** - **L**ean towards the client; **E** - maintain appropriate **Eye Contact** with the client; **R**-Be **R**elaxed.

Chen, Minson, Schön and Heinrichs (2013:1) investigated the effects of eye contact in situations involving persuasion. While eye contact may be associated with connection and trust in friendly situations, it is more likely to be associated with intimidation and dominance in hostile situations. According to Chen et al. (2013:4-7), eye contact may actually make the listener more hardened against persuasion when he or she already disagrees with the speaker. Direct eye contact makes the doubtful listener less likely to be convinced to change his or her mind. Chen et al. (2013) found that the more time the sceptical participants spent looking at the eyes of speaker on a video, the less they were persuaded by the speaker’s argument. Greater eye contact by the participants and greater receptiveness to the speaker’s opinion was found to be among participants who agreed with the speaker.

Wang, Newport and Hamilton (2010:2) discovered a direct link between eye contact and mimicry, and suggested that these findings have implications for understanding the role of eye contact as a controlling signal in human non-verbal social behaviour. In their study Wang et al. (2010:1) aimed to link eye contact and mimicry - the unconscious imitation of the behaviour of people. In the first experiment the participants viewed a movie of a head movement, followed by a hand movement with the hand open or closed. Before each hand action the individual in the movie made either direct eye contact with or averted their gaze from the participants. The participants were instructed to respond quickly to the hand movements of the person in the movie and their reaction time was recorded by means of a Polhemus motion tracker attached to their hands. The participants responded faster and also mimicked the individual in the movie to a far greater degree than when the individual averted his or her gaze.

Senju and Johnson (2008) studied the cognitive, neural and developmental basis of human communication and social interaction. They (2008:127) coined the term the *eye contact effect*, that is, when eye contact modulates certain aspects followed by cognitive processing. In order to examine their eye contact effect the participants performed a behavioural task while their brain activity was recorded. The behavioural tasks included looking at pictures of a face, making eye contact, and other distractor faces (inverted faces and a faces with averted eye gaze) while their  brain activity was being recorded. The eye contact stimuli produced an increase in brain activity in the participants, while the inverted faces resulted in a lack of the eye contact effect (Senju & Johnson, 2008:132). The behavioural task where a participant made eye contact resulting in brain activity synonymous with the anticipation of social interaction is known as the “eye contact effect” (Senju & Johnson, 2008:128).

More recently Myllyneva and Hietanen (2015:1) investigated whether the eye contact effect is triggered by the mere idea of a perceiver being seen by another individual, without the perceiver actually seeing the other individual. This was done while the participants were facing another person (a model) sitting behind a window. The visibility of the model, as well as the participants' perception of them being observed by the model or not, was manipulated. When the participants did not see the model but believed they were being seen by the model, there were less physiological responses in comparison to when both individuals saw each other. These physiological responses were measured by skin conductance, autonomic response and brain activity. Myllyneva and Hietanen (2015) concluded that in order for physiological reactions to take place in response to eye contact, the following two requirements need to be fulfilled, namely being seen by another individual and seeing that person. Mylleneva and Hietanen's work (2015:100) built on studies that demonstrated enhanced brain responses to the stimulus of eye contact by providing evidence that the participants' mental attributions play a major role in brain responses. When the participants viewed "live faces", they indicated greater brain responses than when compared to faces on a computer (Mylleneva & Hietanen, 2015:107-108). In another study Myllyneva, Ranta and Hietanen (2015:151) studied seventeen adolescent participants with Social Anxiety Disorder (SAD), and seventeen participants without SAD. The participants viewed stimuli which consisted of an actual person with either direct eye contact, averted gaze or closed eyes. The researchers measured the participants' autonomic arousal, (rate of heart beat), skin conductance responses, (level of sweating, since emotional arousal induce sweating), and electroencephalographic indices of the approach-avoidance-motivation area of the brain in order to indicate brain activity. The results provided strong evidence that, in the case of adolescents with SAD, eye contact with another individual is aversive and highly arousing by causing an increased heart rate, sweating and brain activity in the area of approach-avoidance, whereas the participants without SAD showed a greater propensity to reacting normally to direct eye contact (Myllyneva et al., 2015:156-157).

Akatemia (2015) conducted a study to test whether individuals' personalities control how they react to eye contact, and to ascertain if brain activity could be used to measure this reaction. The participants' electrical brain activities were recorded while they were looking at another individual who was either making eye contact or indicated a sideways averted gaze. In addition, the participants' personalities were assessedin advance via personality testing. The findings indicated that individuals engaging in eye contact displayed different brain reactions to individuals who did not make eye contact, leading to the conclusion that eye contact may increase the likelihood of initiating interaction with others. For some, eye contact may decrease this likelihood, based on differences in their personalities.

### 2.3.1 Eye contact and culture

The cultural dimensions in different societies add to the complexity of communication. This also relates to the meaning given by different cultures to non-verbal communication (McDaniel et al., 2010: 1). Singh and Rampersad (2010:1) depict culture as the essence of a group sharing common experiences, so that these experiences shape the way the group perceives the world around them. In a multicultural country like South Africa it is important that all the stakeholders involved in education, such as administrators, educators and learners, become culturally competent (Singh & Rampersad, 2010:3). Lustig and Koester (2006:343) concur that these stakeholders should become aware of their own cultural backgrounds and how they impact their values and beliefs, which ultimately influence the way they perceive other persons of different cultures. Lemmer et al. (2012: 50) point out that the misinterpretation of eye contact is an aspect that has frequently caused problems in cross-cultural communication.

In many parts of Africa avoiding eye contact by lowering the eyes as a sign of respect occurs during communication with an older person, or a person of higher status, and a younger person or a female. The younger person and the female have to lower their eyes as an indication of respect (Gestrin & Richmond, as cited in McDaniel et al., 2010:263). In support of the latter, McDaniel et al. (2010:263) quote the following Zulu saying, “The eye is an organ of aggression”. Lueckenotte and Meiner (2006:108) mention that older Native Indian Americans may not have eye contact with figures of authority. Similarly, direct eye contact in most East Asian cultures is deemed disrespectful. Moran, Harris and Moran (2007:64) point to the fact that Japanese children are taught at school to direct their gaze in the region of their teacher’s Adam’s apple. They therefore lower their eyes when speaking to a superior as a gesture of respect.

Hansen (2010: 38) encourages educators to acquire information regarding non-verbal communication, such as eye contact, according to the cultural context of their learners. Hansen (2010:37) indicates that some females may hold eye contact for an extended period, for example Hispanic women, whereas other females of most cultures may feel uncomfortable making extended eye contact, for example, Japanese, Koreans, and African-Americans, since they feel it is rude. Hansen (2010:38) encourages educators to establish a rapport with learners in a multicultural class by ensuring frequent eye contact with all the learners and by maintaining eye contact when the learners communicate with them. At the same time, she (Hansen, 2010) cautions that teachers should remain mindful of the fact that some learners' cultural heritage may forbid them from making eye contact with an authoritative figure, especially when they are being disciplined.

According to Western cultural expectations, in the classroom situation the teachers typically expect from the students to use direct gaze to show that they are attending to the lesson and understanding it. Deferred eye contact is taken to mean disinterest, a lack of engagement, or even as a sign of duplicity (Lemmer et al., 2012:50). Lueckenotte and Meiner (2006:108) concur that direct eye contact in the European-American culture is indicative of positive behaviour such as honesty and trustworthiness. Kathane (2004:273) confirms that in the Western culture a person could be judged negatively if he or she does not make eye contact, since this can be interpreted as being dishonest. Similarly, in the presence of a teacher, an Indian student is expected to maintain eye contact to show confidence and honesty (Singh & Rampersad, 2010:7). In particular, Americans are admonished to maintain eye contact with an audience (Gao, 2006: 61). Furthermore, Arabs prefer facing whoever they are engaging with in conversation. They find walking and talking impolite since they cannot make eye contact with their companion. They may then run ahead and endeavour to make eye contact with whoever they may be communicating with (Gao, 2006: 62).

Finally, Gao (2006:58) says that in order to analyse and comprehend the culture of a particular social group, the meanings of the language of that particular social group need to be considered. He continues to emphasise the avoidance of the misunderstanding of non-verbal ways of communicating. Different cultures use their eyes in various ways when communicating (Gao, 2006:62).

### 2.3.2 Eye contact and gender

Mulvaney (1994:2) says that communicative practices not only highlight differences between genders, but it also creates cultural concepts of gender. In Middle Eastern cultures direct eye contact between the sexes is forbidden except when married, since it is interpreted as a sexual invitation (Lueckenotte & Meiner, 2006:108). Eye contact is also determined by the complex interplay of culture, gender and religious conviction. According to Islamtoday.net, (2012), Muslim women often lower their gaze and try not to focus on the features of the opposite sex.

Muslim women do not make eye contact with men who are not their family members (Louw et al., 2004:89).

Sax (2005:4), a researcher and family physician, discovered that the parents of boys often visited his practice asking him to assess their child for Attention Deficit Disorder (ADD) on request from the school. Sax (2005) found that these boys did not need medication for ADD, but rather a teacher who understood the gender differences in hearing. Sax (2005) found that in most cases the teachers were correct in pinpointing the boy as having a deficit of attention, but that it was not due to an attention deficit disorder, but due to the child's inability to hear a soft-speaking teacher. The teacher talks in a voice which is comfortable for her and the girls in her class, but puts the boys to sleep, making it hard for the boys to listen and attend, let alone making eye contact. Sax (2005:11-38) also found that boys draw in verbs, (actions like fighting) and girls draw in nouns (flowers, trees) because of their differences in brain structure and vision. He shares the idea that as babies girls tend to focus on faces more when shown a moving mobile as well as their mothers' faces, whereas the boys focus more on the moving mobile than on the mother's face.

## 2.4 THE ROLE OF EYE CONTACT IN LEARNING AND TEACHING

Vision is becoming increasingly important as a source of information (Louw et al., 2004: 414) in all learning, and also in school education.

### 2.4.1 Eye contact and cognition in infants

Robert Fantz (1963:296-297) found that neonates between ten hours and five days old looked at a drawing of a face for longer than at, for instance, simple circles or even the various parts and features of a face drawn haphazardly. Carpenter (1974:742-744) indicates as that a neonate can recognise its mother as early as two weeks after birth. Louw et al. (2004:159) found two week-old babies looked at their mothers' faces for longer than at the faces of strangers, and they often looked away rather than look at a stranger's face. Additionally, Walton and Bower (1992) established that newborns (between 12 and 36 hours old) produced significantly more sucking responses in order to see an image of their mother's face, as opposed to the face of a stranger (Louw et al., 2004: 177).

Hoehl, Handl, Palumbo, Parise, Reid and Striano (2009:968) concur that eye gaze play an important role in the early development of an infant. They (2009:969) explain that neuroscience allows for the investigation of cognitive processes during the periods when infants engage in eye gaze with adults. Hoehl and Striano (2009:1) elucidate that emotional expression and the processing of eye gaze is fundamental to social learning. The researchers discovered that greater neural processing takes place in infants when they are confronted with a happy face than when they are presented with a neutral face or even a face with an averted gaze. The infants also engaged in direct eye gaze when they were shown a happy face as opposed to a neutral face or a face with an averted gaze. (Hoehl & Striano, 2009:9). Parise, Reid, Stets and Striano (2008:2) indicate that at four months of age infants are "strongly sensitive to specialized features of an adult needed for social communication".

Johnson, Amso and Slemmer (2003:1073) conducted a study to determine whether infants of four to six months, without prior knowledge of a particular moving object, were able to predict its pathway of movement after being exposed to the object's movement for two minutes, by using an eye-tracking paradigm which recorded their eye movements with a corneal reflection tracker. Johnson et al. (2003:1073) discovered that irrespective of the amount of exposure to viewing a moving object, the four month-old infants did not show an increased knowledge of anticipating the appearance of the moving object. On the other hand, the six month-old infants were able to track the moving object, as indicated by a pattern of eye movements. However, they discovered that the four month-old infants' ability to track the moving object improved if they were exposed to a randomly moving object for two minutes. They not only produced faster anticipations of the moving object, but also more anticipations, in contrast to the older infants who indicated no benefit from such training (Johnson et al., 2003:1073-1074). One of the conclusions of Johnson et al. (2003:1074) were that the proportion of the four to six month-old infants' ability to track a small moving object with saccadic (very rapid) and smooth eye movements depends on the speed of the object and the attentiveness of the infant. They indicated that the ability to continually view a moving object which was not previously seen by the infant is acquired by the age of six months. This includes the formation of object concepts. This observation is reinforced by Gredebӑck, Johnson and Von Hofsten, (2010:1) who stated that infants are attracted by moving objects and people, especially their faces, by using corneal reflection (CR) eye-tracking techniques. They reinforced the idea that eye-gaze is considered a major gateway to the infant's mind (Gredebӑck et al., 2010:1). These researchers (Gredebӑck et al., 2010: 8) indicated that an infant is able to track a moving object being concealed, which is known as *perceptual completion*, while considering that infants are only able to focus on visible objects at two to four months. Their study included the fact that infants look at actions which are purposeful; this confirms their ability to understand social interactions known as *social cognition* (Gredebӓck et al., 2010:9).

Eye contact or eye gaze influences the neural processing of emotional expressions in infants. Striano, Kopp, Grossman and Reid (2006:94) highlight inter-connectedness between eye gaze and emotional expressions. They state that in the infant brain, eye gaze and emotional expressions are not processed in isolation from each other. In their study Striano et al., (2006:87-90) indicated that four month-old infants respond with different mental states to various emotional expressions (neutral, happy or angry facial expressions). An electroencephalogram (EEG) was used to measure brain electrical activity in order to assess the neural processing of the faces displaying neutral, happy or angry emotional expressions, with direct and averted gaze. They ascertained that the infants indicated greater neural processing of angry facial expressions with direct gaze and less neural processing with averted gaze.

### 2.4.2 Eye contact in school settings

Brigham, Zaimi, Matkins, Shields, McDunnough and Jakubecy (2001:39-40) emphasise the eyes in relation to human cognition by focussing on the use of eye movement to comprehend text and pictures in education, and the role of eye movement in reading. Vision is extremely important in preschool where children develop the ability to distinguish detail in their environment. The perception of figure-ground improves rapidly between the ages of four to six years (Louw et al., 2004:236; Gallahue & Ozmun, 1995). Figure-ground perception is the ability to distinguish clearly between the object on which the attention is focused and the rest of the perceptual field (Louw et al., 2004:236).

According to Ayesha et al. (2011), teachers are of the opinion that eye contact is a very important non-verbal teaching technique which enhances the learners' attention and also helps in their producing favourable academic results. Ledbury et al. (2004:1) agree that the eyes are a powerful tool in respect of both the educator and the learner alike. They point out that teachers in all disciplines teaching in high schools are encouraged to develop a 'look' that conveys different instructions, and that has a disciplinary function. Ledbury et al. (2004:1-2) highlight the following positive roles in respect of teacher eye contact, namely eye contact can be used to welcome the learners into the classroom; to manage the class; to set the tone of a lesson; and to correct the learners. The teachers should encourage eye contact among the learners working in pairs or groups, whilst remembering to be sensitive to the view of various cultures regarding eye contact. Furthermore, the teachers should not 'stare' or gaze at the learners; this will make them feel uncomfortable. However, the teachers can save valuable teaching time by using eye contact to reward and correct. At all times, however, eye contact should be used according to individual needs and in a holistic way (Ledbury et al., 2004). Zhang (2006) indicated that the teachers can decide on whether to continue with an explanation, to stop for additional elaboration and clarification, or to speed up by observing the students' eye contact. Zhang (2006) also found that eye contact can be used to elicit responses from shy or hesitant students. Hollabaugh (2011:121-122) reported on the characteristics of the most exceptional teachers identified by Lemov in his book, "Teach like a Champion", where he shares techniques for effective teachers. Those were the teachers whose students, of low socioeconomic status, excelled in standardised tests in the United States. These educators indoctrinated their learners with the word "slant", to indicate that the learners' were slouching at their desks, that their attention was waning, and that poor behaviour has to be corrected. So, Hollabaugh (2011) draws the attention to the video footage of exceptional educators where they use the key word, 'slant' to elicit an immediate response of improved posture, attention, responsiveness and eye contact by the learners in the classroom. Hollabaugh (2011) also cites the word "track" being used by educators in various teaching scenarios to remind the learners to make eye contact with whoever was speaking in the classroom (Hollabaugh, 2011:124). Gravette and Geyser (2004:39) suggest that in order for optimal learning to occur a state of "relaxed alertness" is required, and this embraces a "healthy balance between support, interest, enjoyment and challenge". Alertness involves eye contact between the learner and the teacher, and the learner and the objects of learning. Similarly, Ellen (2000:26) encourages the educators to not only create an environment of acceptance and a safe place, including physical and emotional safety for learners by means of appropriate eye contact with the learners. Benzer (2012:470) reports on a survey taken by 100 teachers on a definition of body language. The teachers all identified the eyes as the most important features of the body. Benzer (2012:471) continues to say that while body language is perceived as important in the teaching process, the teachers did not receive any training in understanding body language. The teachers with knowledge about a learner, such as the avoidance of eye contact, may be able to indicate that a learner is upset or disinterested in the subject matter being taught. Benzer (2012:472) asserts that the "ideal teacher should have eyes that can communicate effectively" and that the "eyes can be used to sustain teaching, revealing attitude and messages" to the learners.

Hains-Wesson (2011:4) conducted research on incorporating eye contact as a performance technique as a part of the learning experience. He investigated whether the students in his study thought that eye contact, together with awareness, voice and the display of passion were useful to the learning experience. He also investigated the factors which affect the lecturer's decision to incorporate eye contact in a lesson, and the attitudes the students have towards the impact of eye contact on the learning experience. Hains-Wesson (2011:8) found that 91% of the students agreed that eye contact helped them to pay attention, and 74% of the students said that it assisted them to be more enthusiastic about the topic, and it encouraged them to want to acquire more knowledge regarding the topic. A number of the students also associated the lecturer's use of eye contact with a display of passion for the subject; they equated lots of eye contact with the lecturer's obvious passion for the topic which in turn, encouraged them to listen to what the lecturer was saying. The majority of the lecturers commented that in order to create an attention-grabbing learning environment, they had to use the teaching space effectively, modulate their voices, and use eye contact to engage with the students (Hains-Wesson, 2011:9).

Haskins (2000:5) suggested that enhancing the classroom dynamism through pedagogical communication includes the teacher varying his or her physical movements, for example, eye contact. He describes an educator's immediacy of behaviour as one involving the reduction of physical and psychological distance between the educator and the learner. Haskins (2000:6) instructs the educators to maintain eye contact with their learners to improve their use of immediacy of behaviour. Slykhuis, Wiebe and Annetta (2005:509) conducted a study to determine how students attend to photographs related to science with audio narration, while being integrated with complimentary photographs. This study confirmed the fact that when the pre-service science teachers were shown a PowerPoint TM Presentation with embedded photographs, the students responded to this study by devoting more attention to the highly relevant photographs and not to the complimentary photographs, even though the students were distracted by the audio narration.

Notwithstanding the importance of eye contact between the teacher and the learner, it is also important not to make the learner feel uncomfortable with constant or excessive eye contact. Doherty-Sneddon (2006:49) writes that while we get useful information from the face when listening to someone, when a learner is asked a question, gaze aversion gives the learner a chance to think. Doherty-Sneddon (2006:49) alludes to a study done by psychologists at the Stirling University where more success was achieved by the learners when answering questions engaging in gaze aversion, so that eye contact should not be uncomfortable under certain circumstances.

Finally, eye contact made by learners in the act of communication in the classroom is a valuable aid in discerning learner behavior, attitudes and interests. Engaging in and maintaining eye contact is a sign of learner interest and motivation in respect of a topic (Neill & Caswell, 1993). Conversely, learners who dislike a subject or are disinterested in a topic are likely to avoid eye contact with the teacher (Miller, 2005). Those learners who are lacking in self-esteem and self-confidence are also most likely to try and avoid eye contact with the teacher (Pease & Pease, 2006). Similarly, learners who do not know the answer to a problem or wish to evade a question will endeavor to avoid eye contact with the teacher (Knapp & Hall, 1992). Furthermore, eye contact made by the learner can give the teacher an indication of the learner's comprehension of the new subject matter. In an investigation with college students Breed and Colaitua (2006) found a positive correlation between the amount of student eye contact with the lecturer and the student understanding the topic. Moreover, high grades were linked to increased time in making eye-contact with the lecturer. Furthermore, students who need help from a teacher will also often use eye contact as a signal for assistance (Zhang, 2006).

### 2.4.3 Cooperative learning

Donald, Lazarus and Peliwe (2008:84) point out that the theory of constructivism indicates that the acquisition of knowledge is actively constructed and not passively received. Piaget (1953) mentioned that knowledge is not imbibed but it is actively and continuously constructed and re-constructed as the individual develops greater cognitive abilities. As mentioned, Vygotsky (1978:56-57) describes knowledge as a social construction that is developed and learned through social interaction. This reinforces the idea of group-work where eye contact allows the exchange of information between peers. Gravett and Geyser (2004:36) share the idea that group-work should follow any teaching so that the learners can "act on" the learning content and stabilise neural patterns for successful learning.

During cooperative learning eye contact plays a vital role. Positive relationships across racial and ethnic lines occur as the learners interact with each other and learn in groups (Slavin, 2009:107). Ledbury et al. (2004) advocate cooperative learning activities in the classroom where the learners are encouraged to make eye contact with each other. Donald et al. (2008:109) state that during cooperative learning there is an increased degree of peer acceptance in respect of learners with disabilities or learning difficulties, and also between learners from different races and social classes, thus promoting social interaction and motivation. Lessow-Hurley (2009:98) states that the learners' desks should be set up in a manner which encourages conversation and allows eye contact during interaction between the learners, since language is learned through communication. The teacher should allow groups of four to cross-talk. Adolescents place a high value on peer group-work as a source of ideas and values; eye contact is promoted in such groups (Slavin, 2009:83).

### 2.4.4 Eye contact and classroom discipline

Cooper and Simonds (2011:172-173) share the effectiveness of regular eye contact as a deterrent to potential poor behaviour in the classroom since the offending learners are inclined to look at the teacher to see whether they are being observed when misbehaving. This makes it possible for the teacher to quell the situation quickly and restore a class environment conducive to learning. This use of corrective eye contact is corroborated by Ledbury et al. (2004). Sundblad (2006:1) describes how the impact of secondary school educators on the actions of troublesome learners was investigated and how the educators used verbal and non-verbal strategies to suppress disruptive behavior. Eye contact, among other strategies, was used as an important non-verbal strategy. Sunblad (2006:13) mentioned further observations where the educator used eye contact on a learner engaging in insolent behavior, and how this put an end to the objectionable behaviour. Benzer (2012) found that 82% of the teacher participants in his study on the role of body language in classroom management stated that they used eye contact to warn unruly learners.

Benzer (2012:471) argues that the teacher's use of eye contact to alert a learner without the other learners noticing is very useful in the classroom situation as it allows for a smooth implementation of discipline directed at the individual and not the whole class.

The judicious use of eye contact in the classroom by the teacher promotes positive discipline practices. For example, Zhu and Ji (2006: 80) maintain that with supportive eye contact a teacher can encourage a learner to volunteer an answer, even though he or she may lack confidence in the answer. Hsu (2006:4) maintains that teachers are able to communicate the fact that they like an individual learner with whom they are communicating by “immediacy behaviours”, that is, behaviour such as smiling, gestures, relaxed body language and eye contact, and therefore create positive classroom interaction. Hsu (2006:8) goes on to say that educators are able to convey immediacy behaviours very effectively with the appropriate eye contact; eye contact is thus a highly effective teaching mechanism. To support this, she conducted a survey amongst 303 students who were learning a second language, English, to show a positive correlation between non-verbal immediacy behaviour by the educator and the learners’ motivation to learn English as a second language. To corroborate this, Anguiano (2001:52-55) reported on how a first-year educator increased teaching time by using eye contact as an intervention technique to reduce the misbehaviour of learners in the classroom. Slavin (2009:347) says that learners seldom misbehave during interesting, varied and engaging lessons where the learner is actively involved and eye contact is maintained; misbehaviour arises from boredom, frustration or fatigue. Cooper and Simonds (2011:77) maintain that when one engages in eye contact, there is a willingness to communicate. They mention where a learner avoids eye contact when he or she does not know the answer to a question, thus hoping not be called on to answer. Cooper and Simonds (2011) indicate the usefulness of moderate eye contact to monitor and regulate the classroom, and highlight the effectiveness of a teacher giving a disruptive learner the ‘evil eye’.

### 2.4.5 Eye contact and technologically-based learning

Ozdener and Satar (2008:5) explain that technology (such as the video conferencing, web conferencing or internet-assisted telephonic interviews) presents innovative initiatives with the potential to create a virtual classroom with simulated face-to-eye learning taking place between the teacher/lecturer and the students and among groups of students during distance learning. Yuzer (2007:1) maintains that virtual eye contact between the student and the lecturer and among students in the virtual learning and teaching situation increases student attention, improves retention rates, promotes community-building among students and stimulates non-verbal communication and social relationships among all the participants in a distance learning-teaching situation. An example of such a platform is the Blackboard Collaborate (2015) programme which allows the distance learning educator to make online video presentations and the learner to respond immediately via online video responses; in all these cases virtual eye contact is realised. Lahiri and Moseley (2015:14) also promote social media as an emerging educational and a performance-improvement tool. They state that approximately 73% of adult online users use some kind of social media. In order to harness the potential of this burgeoning technology, social media is currently being reviewed appreciatively in educational settings. However, they also state that certain types of social media limit the possibility of face-to-face communication (eye contact) during human interaction (Lahiri & Moseley, 2015:20). For this reason, when implementing social media in the teaching process the following key questions should be posed, namely does social media enhance communication (verbal or non-verbal), or does it provide opportunities for social interactions (eye contact)? They conclude that online educators need to promote quality social interactions, which would include virtual eye contact. Used wisely, social media can promote meaningful online interaction with virtual eye contact between a community of learners and the educator (Lahiri & Moseley, 2015:23).

Dailey-Hebert and Dennis (2011) declare that secondary school students face an "unscripted future" characterised by novel technological developments. Online learning initially emerged to support and to enhance learning. The abovementioned researchers conclude (2011) that online learning has matured into a valuable medium in the process of the construction of knowledge by the learner and may be used in a variety of educational environments, including classroom-based learning (face-to-face by the educator and the learner), blended learning (educator-instruction as well as online instruction) and fully online courses. In these new learning environments learners can (at the touch of a keyboard) connect virtually with other learners and instructors, host video conferences in any part of the world, and collaborate in innovative ways to co-construct and co-create new information. Young learners today are enthusiastic and active participants in the acquisition of knowledge and should be introduced to technological skills that allow online learning that incorporates virtual eye contact. Dailey-Hebert and Dennis (2011:11-12) state that educators who incorporate new technologies into learning must seek ways in which online learning could connect the learners and provide experiences for their benefit, and also seek ways that online learning can still allow for virtual eye contact in the learning situation. Social presence in regard to the quality of online learning contributes to the intimacy of communication (Cobb, 2009:241). The latter is directly influenced by eye contact, smiling and personal topics of conversation (Cobb, 2009:242). Cobb (2009:247) conducted a survey of a group of students who enrolled for an online course in nursing in order to determine a correlation between social presence and overall satisfaction of the online course. He (2009:251) found that social presence (of which virtual eye contact formed an important part) was a major influential component in the quality of online learning. In contrast, Barak and Lapidot-Lefler (2011:436) emphasize that being online on the computer without a facility for eye contact with another fails to supply the valuable information which can only be provided by direct eye contact. The information supplied by direct eye contact includes admonition, confidence, confusion, embarrassment, honesty, pleading, security and trust (Barak & Lapidot-Lefler, 2011:436). They furthermore declare (2011:438) that the neglect of or the absence of eye contact in most online educational programmes results in poor emotional and behavioural effects, such as aggression. To address these kinds of negative effects of the online and social media revolution sweeping the world, Ellsberg (2010) started "Eye Gazing Parties". He felt that the depth of human intimacy in communication is being lost to social networking, and endeavoured to "lead an eye contact revolution". He (2010) organised gatherings where individuals were encouraged to sit opposite each other while getting to know each other, without any technological distractions like cellphones. In this regard, Miyauchi, Sakurai, Nakamura and Kuno (2004:392) developed a robot, known as ROBITA, which is capable of making eye contact by turning its 'eyes' (cameras) to a speaking person, and is also capable of accepting a simple hand gesture made by the person (a movement indicating 'come').When the robot makes eye contact with the person, its facial expression changes. Miyauchi et al., (2004:395) call this change of expression *active eye contact.* Once the facial expression of the robot changes, the individual is then able to make the simple hand movement, and the robot will proceed towards the individual.

#### 2.4.6 Eye contact and special-needs education

Miller (2011) encourages the inclusion of special-needs learners in regular classrooms, as they are able to see and model the behaviour of not only the educator, but of their peers as well. As mentioned earlier the inability to make eye contact in a social setting indicates serious developmental challenges in the child (Carbone et al., 2013).

##### 2.4.6.1 Autism

Guiliani and Pierangelo (2007: 9, 13) define *autism* as a spectrum disorder indicated by a certain set of behaviors, such as an impairment in communication, and the fact that the autistic child "may avoid eye contact" entirely or give momentary glances. Baron-Cohen, Bolton, Chandler, Charman, Elsabaggh, Hudry, Johnson and Mercure (2012:338) examined the link if neural sensitivity to eye gaze in infancy is associated to autism. Their findings support the notion that atypical sensitivity to eye gaze is characteristic of individuals with autism, and that atypical neural functioning precedes behavioural signs and symptoms of autism, which includes an aversion to eye contact (Baron-Cohen et al., 2012:341).

When teaching children with autism, Hourigan and Hourigan (2009:43) encourage educators to elicit appropriate social behaviour from the child. For example, when greeting a child and no response is reciprocated from the child, the educator should wait until the child responds by either making eye contact or giving a verbal response. Hourigan and Hourigan (2009:40) note a 10% to 17% increase in children diagnosed with autism in the United States per year. Therefore more educators should be adequately equipped to cope with a child with autism. They offer valuable advice in this regard. They (2009:40) concur that one of the symptoms of autism is the lack of direct eye contact. The challenge therefore exists for special needs educators to establish a communication strategy with the autistic child by taking advantage of non-verbal gestures such as gazes and hand signals which in turn, will encourage the child with autism to make eye contact in order to receive instruction (Hourigan & Hourigan, 2009:41-42). They furthermore (2009:41) draw attention to the fact that the failure to establish an adequate communication strategy with the child with autism could result in the child reverting to the zone of proximal development, proposed by Vygotsky, where he declares that a child will retreat to his or her "comfort zone" when feeling uncomfortable; this will influence their skills needed for learning.

Carbone et al., (2013:139) concur that many children with autism fail to develop the ability to make eye contact. They did research on methods to teach eye contact to children with autism. They explained that eye contact is needed in various social situations. The failure to engage in eye contact may result in significant implications for children with autism. Added to this, poor eye contact could seriously affect their education possibilities. Carbone et al. (2013:145) did a case study with children who have autism with the aim of extending the literature on eye contact responses and to teach the procedure derived from an analysis of motivational and discriminative variables responsible for the acquisition of eye contact found in typical children. The study involved a three year-old individual with autism, sitting across a table from the instructor. A vocal 'mand' (a type of instruction) was given, and when it was preceded by or met with eye contact, it was considered a positive response; no eye contact was a negative response. The term, ‘mand’ is derived from the verb *command*, which is part of Applied Behaviour Therapy which uses behavioural theory to teach people with autism how to respond appropriately, to make requests, and to behave as typically as possible. When the three year-old vocalised a ‘mand’ with eye contact preceding or accompanying the mand, then reinforcement by way of smiling and nodding by the therapist was used. No eye contact with the vocal ‘mand’ resulted in reinforcement being withheld. The result was a notable increase in eye contact by the three year-old child (Carbone et al., 2013:148).

#### 2.4.6.2 Attention Deficit Hyperactivity Disorder (ADHD)

Geng (2011:17), Loe and Feldman (2007), and Barkley (2006) state that individuals suffering from Attention Deficit Hyperactivity Disorder (ADHD) may come from all walks of life, irrespective of their intellectual abilities, culture, race or socioeconomic status. According to Geng (2011:18), ADHD students’ behaviours include distraction, hyperactivity and impulsivity. Galey (2007: 48) encourages educators to stand close to the ADHD individual and maintain eye contact when giving instructions. Geng (2011:17) supports the latter by stating that the educators’ non-verbal communication is essential in managing students’ ADHD.

#### 2.4.6.3 Fragile X Syndrome

Hall, Maynes and Reiss (2009:271) report that children with one of the most common forms of inherited developmental disabilities, known as Fragile X Syndrome (FXS), show aberrant forms of social behaviour, including aversion to eye contact. They (2009:272) conducted a study to examine to what extent behavioural treatment such as an increase in eye contact increases amenable behaviour.

#### 2.4.6.4 Traumatic brain injury

Turkstra (2005:1429) collected data on eye contact with adolescents and young adults with and without traumatic brain injury (TBI). She found that eye contact plays a role in social skills intervention in this age group. She concluded that adolescents without TBI focus on the face of their communication partners when listening to them, but when they speak, they spend less than half the time making eye contact. Adolescents with TBI displayed the same trend. Turkstra

(2005:1439) stresses that gaze plays an important part in turn-taking. Atypical gaze patterns may affect social interactions.

## 2.5 CONCLUSION

This chapter reviewed the theoretical perspectives that inform the use of eye contact by drawing on the works of Vygotsky's social interaction in the learning situation, Piaget's work on cognitive development, and Bandura's social learning theory. All three theories stress the role of social interaction in learning and observation of the other and the learning environment. Thus, individuals learn through the retention of information, internalisation, verbal and non-verbal interactions (such as eye contact) as well as mental operations and enactive experiences. Attention was given to the relationship of eye contact to attention, and the importance of its role in teaching and learning.

Chapter 3 examines the current state of the research concerning eye-tracking methodology in the teaching and learning situation.

# CHAPTER 3
# AN OVERVIEW OF EYE-TRACKING AND ITS USES IN EDUCATIONAL SETTINGS

## 3.1 INTRODUCTION

Chapter three focuses on the current state of the research concerning eye-tracking as a tool to monitor and measure eye contact in general and in educational settings in particular. Firstly, eye-tracking is defined and explained and the usefulness of eye-tracking in various general and educational settings is discussed. Thereafter, various types of eye-tracking devices are described, as well as their respective advantages. Finally, the implications of eye-tracking as a method to explore eye contact in educational settings are presented.

## 3.2 EYE-TRACKING

Eye-tracking has long been known and used as a method to study the visual attention of individuals. In the 1800s studies of eye movement were made using direct observations. In the 1900s Edmund Huey (1968:364-365) built an eye-tracker, using a sort of contact lens with a hole for the pupil of the eye to look through. The lens was connected to an aluminium pointer that moved in response to eye movement.

Jacob and Karn (2003:574) report that eye movement research flourished in the 1970s when much of the work focused on research in psychology and physiology, and explored how the human eye operates and what it reveals about the perceptual and cognitive processes. Recently eye-tracking in human-computer interaction has shown growth, both as a means of studying the usability of computer interfaces and as a means of interacting with the computer (Jacob & Karn, 2003:576). Anson and Schwegler (2012:151) also point to the increasing use of eye-tracking in the context of online learning and digital interaction. Nowadays eye-tracking equipment has become more easily available. It is no longer confined to a laboratory but can be used in other natural environments, for example, eye-tracking glasses can be worn by consumers in supermarkets during market research study or by learners in a classroom.

In essence, eye-tracking gathers data about gaze direction or eye movements. Poole and Ball (2005:1) define *eye-tracking* as the measuring of an individual's eye movements so that the researcher may know where a person is looking at any given time, as well as the sequence in which the individual's eyes shift from one location to another. According to the Tobii Technology (2010) White Paper, eye movements have three main functions which are considered important when visual information is processed.

They are discussed below.

### 3.2.1 Eye movements

a) Place the visual information on the *fovea* (area of clearest vision on the retina of the eye). To do this, fixations and saccades are used. A *fixation* is the pause of the eye movement on a specific area of the visual field when the eyes come to rest and are focused on a specific place (Anson & Schwegler, 2012:156; par. 1.5.3). Fixations usually last about 200-250 milliseconds (ms) (Anson & Schwegler, 2012:157). A millisecond is a thousandth of a second (Tobii Technology, 2010). *Saccades* are the rapid eye movements that occur between fixations, that is, the sporadic flick of the eyes between two points (Anson & Schwegler, 2012:156).

b) Keep the image stationary on the retina in spite of any head movements. This movement is commonly called a 'smooth pursuit' (Tobii Technology, 2010).

c) Prevent stationary objects from fading perceptually. This refers to the fact that eye movements keep the object in focus, otherwise the ability to see the object involved would slowly disappear out of sight. Movements used for this are called *microsaccades, tremors* and *drifts. Microsaccades* can be defined as small, jerk-like involuntary eye movements which occur during prolonged visual fixation. *Tremors* are defined as constant, rapid, back-and-forth movements of the eye. Visual processes deteriorate rapidly in the absence of retinal (part of the eye where the fovea or area of clearest vision occurs) image motion. A *drift* is defined as the gradual decrease in accuracy of the eye-tracking data compared to the true eye position (Tobii Technology, 2010).

Thus, eye-tracking is the process of measuring either the point of gaze (where one is looking) or the motion of an eye relative to the head.

An eye-tracker is a device for measuring eye positions and eye movement. The brain virtually integrates the visual images that are acquired through successive fixations onto a visual scene or object. Rather than perceiving an object or scene as a whole, people fixate on relevant features that attract their visual attention and construct the scene in the visual cortex of the brain, using the information acquired during those fixations. Furthermore, people only combine features into an accurate perception when they fixate and focus their attention on them. The more complicated, confusing or interesting those features are, the longer time people need to process them and, consequently, more time is spent fixating on them. In most cases people only perceive and interpret something clearly when they fixate on it or are very close to it. This eye-mind relationship is what makes it possible to use eye movement measurements to tell something about human behaviour (Tobii Technology, 2010).

## 3.3 EYE-TRACKING DEVICES AND RELATED SOFTWARE

An overwhelming variety of eye-tracking devices are available to the researcher. Brigham et al. (2001:42) categorise the following eye-tracking methods as ways or types of systems for collecting information about eye movements, namely measuring the reflection of light by the eye; electro-oculography (measuring the electric potential of the skin around the eyes); and applying a special contact lens that facilitates tracking of its position.

Gelderblom (2013) believes that combining eye-tracking with existing research methods offers insight previously unavailable to researchers and practitioners and allows for the development of new approaches and methodologies in order to gain greater insight into human behaviour. She describes the usability laboratory (where participants are studied for the sake of evaluating the system’s usability, such as designing more user-friendly websites based on where the participant fixates), as one which provides Human Computer Interaction (HCI) researchers with state-of-the-art evaluations.

In the ensuing section follows a description of a selection of eye-tracking equipment and what they are capable of doing. Eye-tracking equipment can be organised into two categories: equipment which is stationary and must be accessed in a laboratory, and equipment which is head-mounted and allows for freedom of movement (Anson & Schwegler, 2012).

### 3.3.1 Tobii

Tobii Technology is a world leader in eye-tracking technology and research (Tobii Technology, 2010). Tobii has a wide range of models of eye-tracking equipment, which include: Tobii X2-60 Eye-tracker Compact Edition, Tobii T120 Desktop Eye-tracker and the Tobii 1750 Eye-tracker (Tobii Technology, 2010).

As the global market leader in eye-tracking and eye control, Tobii Technology's (2010) products are widely used within the scientific community and in commercial market research and usability studies, as well as by people with disabilities as a means to communicate. Tobii also drives the innovation of eye-tracking technology in many other areas, offering the original equipment manufacturer (OEM) that makes devices from component parts bought from other organizations so that these components can be integrated into various industry applications, such as for use in hospitals, engineering, sports and entertainment. Founded in 2001, the company has received numerous awards for its innovations in respect of technology and its rapid financial growth. Tobii is based in Stockholm, Sweden, and has offices in the United States, Germany, Norway, Japan and China (Tobii Technology, 2010). Tobii technology is used also for research at the University of South Africa (Pottas, 2014).

#### 3.3.1.1 The Tobii X2-60 Eye-tracker

One of the current eye-tracking devices for indoor use is the Tobii X2-60 Eye-tracker (Figure 3.1), which has been used in the current study.

The features and the functionality of the Tobii X2-60 eye-tracker include the fact that it is a stand-alone eye-tracker that can be used by attaching it to monitors and laptops.

It is an unobtrusive eye-tracker that can be used in detailed research of natural behaviour. This eye-tracker allows the participant considerable freedom of head movement without affecting accuracy and precision. In addition, it is compatible with numerous software and stimuli, (what the participant looks at) and setup options (User's Manual. Tobii X2-60, 2014).

Since the Tobii X2-60 eye-tracker is a small potable eye-tracking lab (184 mm in length and weighing 200g), it could track large objects at close distances (up to 36 degree gaze angle).

During tracking, Tobii Eye-trackers use infrared illuminators to generate reflection patterns on the participants' corneas in their eyes. These reflection patterns are collected by image sensors. Eventually the gaze point (where the participant is looking) is established and tracked (User's Manual. Tobii X2-60, 2014). The specifications of the Tobii X2-60 include a sampling rate of 60 hertz, (Number of eye-tracking samples per second), and a standard deviation of approximately 0.1 hertz.

#### 3.3.1.2 The Tobii T120 Desktop Eye-tracker

**Tobii T120 Desktop Eye Tracker**

**Model:** T120 Desktop Eye Tracker
**Make:** Tobii
**Supplier:** Tobii Technology

**Description:** The Tobii T120 Desktop Eye Tracker is integrated in 17" TFT screen with built-in user camera and speakers. It is ideal for testing stimuli that can be presented on a monitor such as images, web images, web pages, software applications and video. Allows high tracking frequency for fine-grained data. The equipment resembles a computer screen with the eye tracking technology built in.

**Condition:** New
**Life Expectancy:** 5years

**Figure 3.1: The Tobii T120 Desktop Eye-tracker**

The Tobii T120 eye-tracker is an infrared video-based tracking system combined with hypercuity image processing. The Tobii T120 is integrated into a 43.2cm Thin Film Transistor (thin high quality flat panel monitor computer screen), with a maximum resolution of 1280 x 1024 pixels. There are five near-infrared light emitting diodes (NIR-LEDs) and a high resolution camera with a charge couple device (CCD) sensor. The camera samples pupil location and pupil size at the rate of 120Hz. Registration can be both monocular and binocular. The accuracy of eye position tracking is 0.5 degrees and the spatial resolution is 0.2 degrees (Ariasi & Mason, 2010:589-590).

During a recording the Tobii 120Hz Desktop Eye-tracker, (Eye-tracker: Products and systems -Tobii, 2010) collects raw eye movement data points every 8.3ms. Each data point is identified by a timestamp and “x & y” coordinates, which are then sent to the analysis application (e.g., Tobii Studio) database running on the computer connected to the eye-tracker. In order to visualise the data these coordinates will then be processed further into fixations and overlaid on a video recording of the stimuli used in the test.

By aggregating data points into fixations the amount of eye-tracking data to process is reduced significantly. Tobii Studio, (the analysis application), uses two types of fixation filters to group the raw data into fixations. These filters are composed of algorithms, (a step-by-step solution to a problem), that calculate whether raw data points belong to the same fixation or not. The basic idea behind these algorithms is that if two gaze points are within a pre-defined minimum distance from each other then they should be allocated to the same fixation, in other words the user has not moved the eyes between the two sampling points. In the clear view fixation filter it is also possible to set a time limit to the minimum length of a fixation. Another function of the filters is to check if the sample points are valid, e.g., discarding the points with no eye position data or where the system has only recorded one eye and failed to identify whether it is the left or the right eye, and is unable to estimate the final gaze point (Eye-tracker: Products and systems - Tobii, 2010).

Graphically fixations are typically represented by dots (larger dots indicate a longer fixation time, whereas saccades are indicated by lines between fixations). A screen shot showing all the fixations a person made on a specific image or webpage is typically called a ‘gaze plot’ (cf. 4.3.4.1). Another popular way to visualise eye-tracking data is through a heat map (cf. 4.3.4.1).

A heat map uses different colours to show the amount of fixations participants made in certain areas of the image or for how long they fixated within that area. Red usually indicates the highest number of fixations or the longest time, and green the least, with varying levels in between. An area with no colour on a heat map signifies that the participants did not fixate in the area. This does not necessarily mean they did not 'see' anything there, but if it was detected it may have been in their peripheral vision, which means that it was more blurred.

### 3.3.2 The Eye-gaze Response Interface Computer Aid (ERICA)

Brigham et al. (2001:42-43) indicate that the Eye-gaze Response Interface Computer Aid (ERICA) consists of an infrared light-emitting diode (LED) centred in the lens of a camera placed below a computer monitor where photographic information about the user's eye is collected at a rate of 60 times per second. The following information can be acquired, namely the total amount of time an individual spends viewing information; the time taken to respond with the mouse or key presses; the area the eyes rest to collect information, and the size of the pupil at each fixation.

### 3.3.3 Noldus Technology

Noldus provides the following two types of computer software: FaceReader and Observer XT. The FaceReader is computer software that recognises facial expressions indicating how people respond to stimuli and can provide valuable information to support the development of effective educational tools. The Observer XT is the software for the collection, analysis and presentation of observational data (Noldus Information Technology. Human Factors Research, 2013). Noldus technology is used at universities, research institutes and companies in many markets, such as consumer behaviour research, educational research, and market research, for example, How do people respond to a commercial's new design? (Noldus Facial expression recognition software, 2013).

Noldus Tools and Solutions focus on human-factors research. This is an area of psychology which centres on topics like workplace safety and human-computer interaction. It also includes research on infant behaviour, using the Observer XT to code infant behaviour with novel and familiar stimuli to track visual fixations to each stimulus (Vogel, Monesson & Scott, 2012: 372) and clinical communication research using the Observer XT to analyse doctor-patient interaction (Clayman & Gill, 2012). It also supports complex experiments and allows the researcher to combine behavioural data with physiological signals, eye-tracking and sensor readings.

The application areas for human behaviour studies, which include classroom observation carried out using The FaceReader and The Observer XT, are part of The Portable Observation Lab, all part of Noldus Technology. The stationary observation laboratories consist of fully integrated equipment, synchronous recordings and superior behaviour recording and analysis. The portable laboratory is built to fit into a convenient ‘Carry on Case’, and comes complete with The Observer XT and Media Recorder software to integrate and synchronise all video and data recordings. This is ideal for observing people in classrooms (Noldus Information Technology. The Observer XT Research, 2013).

### 3.3.4 Traktext

Traktext tracked the eye movements during the writing of ‘The Handbook of Metacognition in Education’ (Hacker, Keener & Kircher, 2009). Hacker et al. (2009:154-166) are educational psychology researchers who used eye-tracking to create an awareness of one’s learning or thinking processes, known as ‘metacognition’. In particular they focused on learning about the processes of reading and writing from a cognitive perspective by developing a system called *Traktext* which provides a record of everything the a person produces, deletes, or edits, in addition to the amount of time spent reading, writing or pausing on any one of the many computer screens while the person is being eye-tracked. These researchers were able to provide insight into the occasions when the reader or writer was working harder to create or interpret text, since greater cognitive demands lead to greater pupil dilation, which is collected by means of the eye-tracking software.

### 3.3.5 SensoMotoric Instruments

SensoMotoric Instruments (SMI) has been used for approximately 20 years in computer vision in high-performance eye movement. The SMI Gaze-based Interaction is usually head-mounted and often incorporated into glasses or headsets. The areas of gaze-based interaction research include the following, namely education, using voice inputs; research, using microscopes with eye control; and assistive (gaze interaction for the physically challenged) (Gaze-based

Interaction, 2008). SMI Eye-tracking Glasses (cf. Figure 3.2) were used by a leading German baby food brand to establish the best shopper experience with various shelf arrangements. The eye-tracking data suggested that changes in package design would assist shoppers to readily identify the product after seeing (fixating on) it.

Anson and Schwegler (2012:154) point out that until recently the eye-tracking equipment were stationary and connected to computer screens in a lab. Due to the advances in eye-tracking technology, portable units can be worn by individuals on their head allowing eye, head and hand movements, such as SMI Eye-tracking Glasses. They are worn normally like a pair of glasses. The setup and 1-point calibration can be performed within seconds. Binocular tracking delivers very accurate and reliable data of consumers' visual search patterns, at varying distances of all the packaging of products on display in a store. The high density (HD) scene camera displays a high level of detail, for example, when testing packaging designs by consumers who have agreed to wear the eye-tracking glasses it results in precise, accurate and dependable visual data being gained.

**Figure 3.2: Shopper with eye-tracking glasses looking at baby food**

The shopper is wearing eye-tracking glasses to establish what she is looking at. This information is valuable to market researchers because they are able to see what products are given preference.

### 3.3.6 The Remote Eye-tracking Device 250

The Remote Eye-tracking Device (RED 250) is SMI's unobtrusive high-speed (250Hz) and low latency (8ms) remote eye-tracking device which has been integrated into display technology, and is able to detect where a person's gaze is directed at (RED250, 2011).
The RED250 eye-tracking system was used in a study on driving safely, known as the 'GazeCom project', and the participants were in an experimental driving simulator. The participants reported that the gaze guidance was not consciously noticed and that the tracking technology worked subliminally. So the participants were not obstructed in any way by the wearing of the eye-tracking glasses, and therefore were tracked without them being consciously or constantly reminded of it. The eye-tracking therefore occurred naturally with great ease and no discomfort to the participant. Thus, the gaze contingent display technology reduced the number of car accidents (Subliminal Gaze Guidance, 2010). The 'GazeCom' project has shown that real-time gaze guidance realised with SMI eye-tracking technology helps users to deploy their limited attention resources more effectively, since this project has the potential to increase visual performance. Gaze guidance can be used to transfer expert knowledge to novices and to improve performance in tasks where safety is critical, (Subliminal Gaze Guidance, 2010). Chess players are also able benefit from eye-tracking (see Figure 3.3).

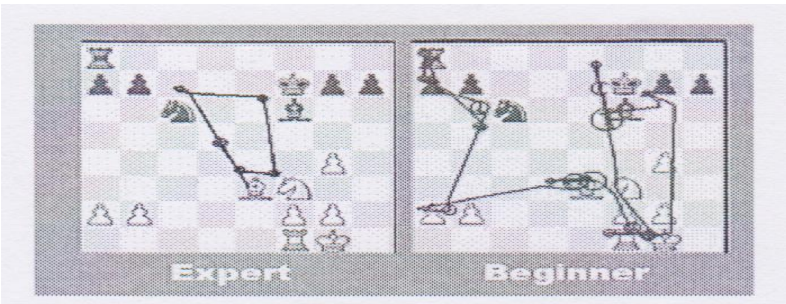



**Figure 3.3: The expert and beginner chess player**

The expert chess player displays methodical movements of chess pieces whereas the beginner (novice) displays erratic movements of the chess pieces.

### 3.3.7 Head-mounted Eye-tracking Device

The Sports, Professional Training and Education Research (SPARC) group at Roehampton University, London, makes use of the Head-mounted Eye-tracking Device (HED) to monitor the eye movements of athletes (see Figure 3.4). The HED records the athletes' surroundings from their point of view and overlays a cursor to indicate the gaze-position. The resulting overlay video is synchronised with video and audio output from other recording devices, so that the gaze position and other behaviour can be analysed and also stored for software analysis later (Sports, Professional, Training & Education – SensoMotoric Instruments, 2011).

**Figure 3.4: Head-mounted eye-tracking devices**

### 3.3.8 faceLAB

The faceLAB 5 is a portable eye-tracking device which can be used for research in a number of different environments (simulated or real), like aerospace environments. This would provide information in real time (as it is happening) to researchers.

The faceLAB 5, if used in a motor vehicle, could provide the researcher with the ability to customise deeper levels of research, since it is data generated in real world and real time (faceLAB5). For example, the researcher could see the motor vehicle driver reach over to tune his car radio, via the faceLab eye-tracking technology. Since this could prove to be a dangerous activity, where the driver bends down and is distracted, the researcher may think of placing the radio buttons on the steering wheel so that the driver could tune his radio without taking his eyes off the road (faceLAB 5, 2011). The faceLAB 5 has the ability to provide data on eye movement, head position and rotation, eyelid aperture and the pupil size of a participant. EyeWorks software can be integrated with faceLAB 5 to allow heat-maps, eye-gaze-analysis via video, still images, and web pages (faceLAB 5, 2011).

## 3.4 USES OF EYE-TRACKING

Feng (2011:1) advocates eye-tracking as a powerful tool that developmental scientists are able to use in order to study the development of the mind. Brigham et al. (2001:44-46) summarise the research findings around eye movement, through eye-tracking, which have been obtained through the use of eye-tracking devices as follows: eye movement develops from infancy to adulthood; for optimal vision to occur, objects must be brought to the area of clearest vision, the fovea, with a drift of less than five degrees per second; the visual world can only be seen clearly in small pieces; more visual attention is given to different aspects of a flashing object; and visual attention can be used to generate data about cognitive processes.

The uses of eye-tracking visual processes encompass many disciplines. Duchowski (2007:51-69) provides an overview of the uses of eye-tracking in the study of neuroscience, psychology, advertising and marketing (including product packaging), computer science, research on human factors, and industrial engineering. Anson and Schwegler (2012:151) described the nature of eye-tracking technology and its use in the study of discourse processes, like reading.

### 3.4.1 Eye-tracking studies of infants

Eye-tracking has cast new light on how we think about the cognitive development of children (Feng, 2011:1-7). Eye-tracking studies done with infants have presented valuable information regarding the infants' cognitive abilities. Johnson et al. (2003:1073) conducted a study to determine whether four to six month-old infants, (who had no prior knowledge of a particular moving object), were able to predict its pathway of movement after being exposed to the object's movement for two minutes, by using the methodology of eye-tracking to record their eye movements with a corneal reflection tracker. Johnson et al. (2003:1073) found that irrespective of the amount of exposure to viewing a moving object, the four month-old infants did not show an increased knowledge of anticipating the appearance of the moving object. On the other hand, six month-old infants were able to track the moving object as indicated by a pattern of eye movements. However, they discovered that the four month-old infants' ability to track the moving object improved if they were exposed to a randomly moving object for two minutes, and that they not only produced faster anticipations, but also more anticipations of the moving object in contrast to the older infants who indicated no benefit from such training. Johnson et al. (2003:1074) concluded that the proportion of the four month-old to six month-old infants' ability to track a small moving object with saccadic (very rapid eye movements) and smooth eye movements depends on the speed of the object and the attentiveness of the infant. They indicated that the ability to continually view a moving object which was not previously seen is acquired by the age of six months, which also included the formation of object concepts. This finding was reinforced by Gredebӓck et al. (2010: 1) (cf. 2.4.1) who used eye-tracking to determine the infants' attraction to moving objects and people. However, Gredebӑck et al. (2010) also found that the eye-tracking of infants is limited by the fact that the infants have selective attention spans, and it would therefore be difficult to allocate looking-time data to various processes such as the point of gaze.

### 3.4.2 Eye-tracking and the understanding of mathematics

Schneider, Heine, Thaler, Torbeyns, De Smedt, Verschaffel, Jacobs and Stern (2008:409) used the methodology of eye-tracking to investigate how learners develop number sense and estimation competence. They found that eye-tracking data produced valid, comprehensive and precise information about the children's developing number sense. In their study they investigated to what extent eye movements recorded during task solution reflected the child's use of the number line. By means of a cross-sectional design with 66 learners from Grades 1, 2, and 3 Schneider et al. (2008:409) indicated by means of eye-tracking data the children's fixations accurately mirror grade-related increases in number estimation competence; in Grades 2 and 3 they are narrowly linked to manual solutions to estimation tasks; in Grade 2 they are related to the children's competence to add numbers; are very methodically distributed over the number line; and corroborate previous findings concerning the learners' use of counting-up and orientation-point strategies. Finally, it was concluded by Schneider et al. (2008) that eye-tracking is a useful method in research on mathematical understanding and the identification of mathematical learning disabilities.

Philipp, Sowder, Valeski and Livyant (2006:1) used eye-tracking technology and individual interviews to investigate differences between the ways the following three groups perceive a mathematics lesson being taught by a researcher: prospective elementary school educators; practising educators; and mathematics educators. The three groups observed and analysed a videotape of a researcher engaged in teaching a learner in Grade 5-mathematics. This study by Philipp et al. (2006:3) indicated how one's background and training influence the interpretation of the video. They gauged the analysis of the three groups of participants by means of an analysis of fixation and the level of cognitive activity, which were measured and recorded with eye-tracking technology. Additional information was collected via interviews with the three groups. Philipp et al. (2006:31-33) discovered that of these three groups, the mathematics educators attended most closely to the learner; the practising educators paid more attention to the interviewer; the prospective educators paid more attention to the mathematical content.

### 3.4.3 Eye-tracking in the use of online media in learning

Anson and Schwegler (2012:163) pointed out that the increasing use of technology at every level of the education system starting at the preschool, has generated research on what the learners do when they look at and interact with computer screens.

#### 3.4.3.1 Schoolrooms

Schoolrooms is an online portal which allows access to resources selected by the educator and the librarian teams (Byerly, Holmes, Robins, Zang & Salab, (2006:1). It features library catalogues, electronic databases, and web sites selected by these educator and librarian teams. Byerly et al. (2006:1) conducted 135 observations of the way learners used Schoolrooms, using among others, eye-tracking. Ninety-seven learners were video-recorded using Morae usability software, while 38l learners were eye-tracked using the Tobii 1750 eye-tracking monitor. These observations were used to identify whether the learners were concentrating, confused, were reading, were quickly browsing, or were engaged in or ignoring parts of the webpages. 'Hot-spot' images were generated, (i.e., the data on which the learner fixated was captured by forming a heat-map so that different colours indicate the level of visual activity) (cf. 4.3.4.1 and see Figure 5.8). The red colours showed what most users were fixating on, while the greens indicated less viewing by the user. The screen-capture video was used to display the eye movements of the learner over the web pages, and indicated where the learner was looking while performing a given task. All this data revealed a usability and effectiveness report of the Schoolrooms online portal. The information gained from eye-tracking participants in Schoolrooms allowed the modification and enhancement of Schoolrooms to make it even more useful. Their results indicated that 88% of the Schoolrooms users said they would use it again.

#### 3.4.3.2 MetaTutor

MetaTutor is an experimental set-up eye-tracking, video and audio recording to measure the spectrum of the learners' cognitive, affective, meta-cognitive, and motivational processes (Azevedo, Johnson, Burkett, Chauncey, Fike, Lintean, Cai & Rus, 2011:11). MetaTutor is an interdisciplinary project that involves the design, development and evaluation of a web-based intelligent adaptive hypermedia system funded by the National Science Foundation (NSF) in the United States. MetaTutor is a multi-agent intelligent tutoring system (ITS) and hypermedia-learning environment, or SRL, which consists of 41 pages of text and diagrams. MetaTutor is designed to teach high school learners' about the human circulatory system, as well as to scaffold them in the use of self-regulating strategies. The four pedagogical agents (PAs) act as tutorial specialists in scaffolding the learners' in self-regulated learning (SRL). For example, Pam the Planner assists learners in setting up sub-goals for their learning session; Mary the Monitor helps the students to monitor their learning, including assessing the relevance of information to the sub-goal; and Sam the Strategiser prompts the students to deploy different SRL strategies, such as re-reading and summarising content. A fourth Pedagogical Guide, Gavin the Guide, introduces the learners' to the system and its many embedded features and assessments (e.g., self-report measures, pre- and post-tests). The experimental set-up of MetaTutor also includes eye-tracking, video and audio recording, among others, to measure the spectrum of the learners' cognitive, affective, meta-cognitive, and motivational (CAMM) processes as they interact with this complex and adaptive multi-agent Intelligent Tutoring System (ITS) (Projects & Research/ SMARTlab, 2011).

The efficacy of the MetaTutor, described in the above paragraph, was investigated by Azevedo, Johnson, Chauncey and Burkett (2010:225). Sixty-eight undergraduate students (average age 23) learned about the human circulatory system under one of three conditions: prompt and feedback (PF), prompt-only (PO), and control (C) condition. The PF condition received timely prompts from animated pedagogical agents to engage in planning processes, monitoring processes, and learning strategies, and also received immediate directive feedback from the agents concerning the deployment of the processes. The PO condition received the same timely prompts, but did not receive any feedback following the deployment of the processes. Finally, the control condition learned without any assistance from the agents during the learning session. Azevedo et al. (2010:246) discovered that by using the Tobii X2-60 eye-tracker, college students' learning about a challenging science topic with hypermedia can be facilitated if they are provided with adaptive prompting and feedback scaffolding designed to regulate their learning (Tobii X2-60, 2009). The students in the PF condition read less science materials and navigated through fewer hypermedia pages during the learning task.

### 3.4.4 Eye-tracking in science education

Rosengrant et al. (2009:249-250) were concerned about the great gap in knowledge between the abilities and skill levels of experts and novices, especially in physics. They conducted a study involving 11 students who studied electrostatics at Kennesaw State University in the US. The participants wore a head-mounted eye-tracker (i.e., Applied Science Laboratories Model 6000 Mobile Control Unit that included an Applied Science Laboratories head-mounted optics unit with scene camera). The eye-tracker provided a video showing exactly what the students focused on when answering questions posed by the researcher with regard to solving electrical circuit problems. The investigation was also audio- and videotaped. Rosengrant et al. (2009: 252) were able to establish differences between the novices and the experts regarding electrical circuits. The novices' eye-gaze patterns flitted back and forth across the electrical circuit information while the experts' eye-gaze patterns were methodical, followed a specific path and were not haphazard. Little (2012:1) adds insight to the abovementioned study by Rosengrant et al. He observed eight college students wearing eye-tracking Tobii Glasses from Tobii Technology to track their eye-gaze patterns during 70-minute pre-elementary lectures at Kennesaw State University. The study provided information pertaining to effective teaching techniques that aim to keep the students engaged and motivated to learn. For example, greater attention is solicited via the use of humour by the instructor and by the proximity of the instructor to the student, whilst the greatest inhibitors were 'digital distractions' such as mobile phones and Facebook.

Chen (2012) described a preliminary eye-tracking study in a science education class of eight university students wearing Tobii eye-tracking glasses (see Figure 3.4). The instructor of the class found that the attention of the students waxed and waned throughout the lecture and that the common assumption that the students' attention dwindles after 15 minutes of the start of the lecture, is therefore wrong. He concluded that the location where the students were seated influenced their level of attentiveness: students seated in the front and the middle of the class, were more attentive than those students sitting at the back of the classroom.

Tai, Loehr and Brigham (2006:185) investigated the capacity of eye-gaze tracking to identify the differences in the problem-solving behaviour of a group of individuals who possessed varying degrees of knowledge and expertise in three disciplines of science (biology, chemistry and physics). The participants were all pre-service science educators who were required to complete a multiple-choice science assessment while having their eye-gaze tracked and recorded. Tai et al. (2006) reported on their eye-gaze tracking, which included the path of eye movements (saccades) using an Eye Gaze Response Interface Computer Aid (ERICA), which in turn was monitored by GazeTracker software which stored and managed the eye movements

(Tai et al., 2006:194). Tai et al. (2006: 199-200) concluded that fewer eye movements occurred in the areas of their majors, meaning that the biology majors focused less on biology questions (which was familiar content) and spent more time on the physics and chemistry questions (which was unfamiliar content and thus required more attention). The analysis of the data revealed differences in the eye-gaze behaviour across different disciplines, and similarities among the participants with similar science backgrounds. These findings suggest that eye-gaze tracking may potentially be a useful approach to furthering a pre-service educator's understanding of a learner's problem-solving behaviour.

Slykhuis et al. (2005:509) conducted a study to determine how pre-service science teachers attend to photographs related to science with audio narration, while being integrated with complementary photographs. This study confirmed the fact that when the pre-service science teachers were shown a Powerpoint™ Presentation with embedded photographs, the students responded to the study by paying more attention to the highly relevant photographs and not to the complementary photographs, even though the students were distracted by the audio narration.

### 3.4.5 Eye-tracking and textual research

Anson and Schwegler (2012) highlighted the use of eye-tracking with a view to understanding reading and writing processes. When a person is reading sophisticated eye-tracking equipment mediated by computer technology can record the exact eye movements using a video-based system that collects data by measuring movement in the cornea and pupil of the eye. Eye-tracking data can thus provide a map of what a person is looking at while working with the text.

To understand the performance of young college students and older adults' reading skills in the presence of distracting information in texts Kemper, McDowd, Metcalf and Liu (2008:494) recorded their eye movements by using a head-mounted magnetic eye-tracker (the Applied Sciences Laboratories Model 504) worn by the research participants. A microcomputer controlled the eye-tracker. It was interfaced with a second microcomputer with the GazeTracker (cf. 3.4.4) software. In some sentences single-word distracters were presented either in italics or in red font. Distracters could be related or unrelated to the target text. Kemper et al. (2008:501) discovered that the older adults treated the sentences with distracters in a list-like fashion. Young adults, on the other hand, have a greater capacity to process these sentences, as well as the distracters.

Ariasi and Mason (2010:581) uncovered the effect of learning from a science text by undergraduate students of psychology by using the Tobii T120 eye-tracker. The researchers analysed the ocular behaviour of the participants as revealed by their eye movements while reading a science text. Ariasi et al. (2010: 595-598) prepared two texts about the phenomenon of tides, one with a refutational structure and the other with a standard expository structure. A 'refutational' text acknowledges a reader's alternative conceptions about the topic. The reader is able to refute aspects of the topic and then introduce scientific conceptions as viable alternatives. Forty university students were randomly assigned to the two reading groups: one group read the refutational text and one group read the non-refutational text. Each type of text elicited a different kind of cognitive processing as revealed by the eye-movement analyses. The findings via a posttest revealed that refutational text readers learned more than non-refutational text readers. Furthermore, all indices of the data collected by the eye-tracker regarding visual attention were as predicted by the researcher, namely learning took place only by the refutational text readers. The findings provided a comprehensive picture of the complex phenomenon of learning from informational text, which is one of the common tasks in school and academic contexts.

Ozcelik, Karakus, Kursun and Cagiltay (2009:445-448) focused on 52 undergraduate students where none of the participants indicated colour blindness, since the research hinged on identifying the colour coding effect by utilizing eye movement data. The purpose was to investigate the effect of colour coding on learning outcomes and to establish why learners performed better when colour-coded learning material was used as opposed to monochrome material. The participants' eye-tracking data were collected by means of the Tobii 1750 EyeTracker and the duration and number of the eye fixations were obtained with the aid of Tobii's Clearview software.

Popelka, Brychtova, Brus and Vozenilek (2012:99) investigated the problems encountered by everyday map users who do not easily understand the information found on a map. By means of a large group of map users (who are not mapmakers and cartographers) and by using eye-tracking information, the researchers were able to establish a user-friendly map design, map layout and map symbology which can easily be understood by any map user. The large group of map users perceived maps differently to the mapmakers and cartographers, and therefore their difficulty in being able to obtain information from the map, the strategy of map-reading, how easily map symbols can be interpreted, etc. were identified by using eye-tracking to see where the map-users fixated, and they supplied a greater explanation of the maps in those areas. Based on the results of eye movement analyses, these difficulties were overcome so that the large group of map users, who were without any expertise regarding the reading of maps, could now easily interpret a map.

Gagl, Hawelka and Hutzler (2011:1171) drew attention to the fact that the dilation of the pupil (not only because of variations of light) reflects cognitive demands, as well as emotional responses. Gagl et al. (2011:1172-1174) used 49 native German-speaking students with normal vision in a sentence-reading task and discovered that their pupils were larger when reading sentences with higher cognitive demands. This proved to be an exciting revelation since it offers a hope with regard to eye-tracking being able to present itself with cognitive information. Anson and Schwegler (2012: 160) highlighted the fact that pupil dilation is related to cognitive demands, which is unique to eye-tracking. They established that the greater the cognitive demands when reading, the greater the pupil dilation.

### 3.4.6 Eye-tracking and special needs

Johnson, Ok and Luo (2007:530) reported that children with autism are unable to readily process information via their eyes. Boraston and Blakemore (2007:894) used eye-tracking on children with autism. The study allowed normal adults and those with autism to look at photographs of faces. Boraston and Blakemore (2007:895) discovered that the ‘normal’ adults fixated on the core features (e.g., eyes, nose and mouth) when viewing faces, whilst the individuals with autism spent a smaller percentage of time fixating on the core features. They were able to clarify that when the individual with autism fixated on the mouth, it served as a great predictor of the individual’s social ability. In this way the researchers are hoping to close the divide between the performance on cognitive tests and the social abilities of individuals with autism via the use of eye-tracking.

Jones, Carr and Klin (2008:2) assessed the eye-tracking patterns in 2 year-old children as they watched video clips showing actresses peering directly into the camera to engage the children in interactions with rhymes such as ‘pat-a-cake’. Among the 66 participants, 15 had autism, 36 were typically developing toddlers, and 15 had developmental delays, but not autism. The results of this study revealed that the toddlers with autism preferred looking at the mouth during these video clips, while the developmentally delayed and healthy toddlers more often looked at the eyes. Furthermore, for the toddlers with autism, lower levels of fixation on the eyes of the actresses in the videos were associated with greater social impairment in everyday life.

Lin, Huan, Chan, Yeh and Chiu (2004:91) describe how they developed an eye-tracking system that responds to eye motion to assist with disability rehabilitation, as well as a joystick to play a computer game. The user has to look at the computer, a charge-coupled device will track images of the user's eyes, and a program will locate the centre point of the pupil in the images. The coordinates of the images are calibrated and transferred to the display and then to the game. Lin et al. (2004:91-92) also mention the diagonal-box checker search which allows the handicapped an opportunity to perform simple tasks without assistance from anyone since it not only gains computer information from tracking the face, but also from many search checkers.

### 3.4.7 Eye-tracking and computer interfaces

An interface is a set of instructions capable of instructing the computer to execute commands or instructions by the user interacting with it, via eye gaze or by using a mouse to click on the desired activity. Jacob and Karn (2003:576) report that in more recent times eye-tracking in human-computer interaction has shown some growth both as a means of studying the use of computer interfaces, (WIMP-i.e. windows, icons, menus and pointers), and as a means of interacting with the computer.

Crowe and Narayanan (2000:35) propose that aggregating, analysing and visualizing eye-tracking data in conjunction with other interaction data prove to be successful as tools for designers and experimenters in evaluating interfaces. Other interaction data are the software used for statistical analysis, and video and audio equipment. These interfaces equip the researcher with all the information needed to compile an accurate study of eye contact. Eye-tracking focuses exclusively on what the eyes are doing, and only a video recording will establish the other forms of attention, like body language, facial expressions and eye contact between individuals, etc.

Merwin (2002:39) emphasises the use of eye-tracking techniques to support interface and product design since the continual improvement of eye-tracking systems have increased the usefulness of this technique for studying a variety of interface issues. Other interface support to eye-tracking could be video equipment. The product design is based on the information reviewed by the researcher. For example, market researchers would be able to establish what packaging enables greater sales for a particular product, or how the product needs to be packed in order to gain greater attention from the consumer. All this information can be established through eye-tracking glasses worn by the consumer and using other interfaces like video capturing.

Oyekoya and Stentiford (2006:57) propose that eye-tracking offers a valuable short-cut in computer communications for visual tasks to yield extremely rapid search performances as opposed to text-based mechanisms to retrieve information using search engines such as Google and Yahoo. The abovementioned researchers conducted the following two experiments to establish their proposal. Firstly, they (2006:60-64) used a mix of graduates and administrative staff who had normal or corrected-to-normal vision, to gather data related to the participants' interests. The participants were asked to locate a target image on a computer screen. This information could therefore be available for image retrieval by inventing a suitable interface which, in this instance, would provide a system of varying interactions between image-processing and eye-gazing, in order to retrieve the desired information. The results of this study indicated that the participants fixate on foreground material in images, and that this behaviour may be employed to drive a prototype search interface which would respond rapidly to eye-gaze and supply the user with information at a faster pace than via the use of a mouse. Secondly, Oyekoya and Stentiford (2006:61-62; 64-65) found in another task-orientated experiment in which the participants were required to display no evidence of colour blindness, that the eye-tracking equipment revealed a faster response time when eye control was used to target an image than when the mouse was used to click on the image. The findings suggest that an eye-controlled interface should be used to retrieve information since it requires a minimal effort and cognitive load. The experiment explored the speed of visual processing involved in an image-target identification task when compared with a conventional input device such as a mouse. The 25 stimuli presented with a succession of thumbnail images where the target image was highlighted with a dark red border. Each participant was subjected to easy-to-find and hard-to-find images. The participants had to search for the target and then make a selection. Their results indicated a slower mouse response than when eye control was used via the eye interface. When using the mouse, the participants had to spend time locating both the cursor and the item to be selected, and then use the mouse to move the cursor to the item. Alternatively, the eye-tracker interface was quicker because only the selected item needed to be located and the participants had to fixate on the target for longer than 40 minutes per second before a screen change took place on the computer.

Granka, Joachims and Gay (2004: 478) used a commercial eye-tracker which utilizes a charge couple device (CCD) camera that reconstructs the participant's eye position through the Pupil-Center and Corneal-Reflection method. They investigated how computer users interact with the results page of a World Wide Web search engine using eye-tracking. The goal was to gain insight into how users browse the presented abstracts and how they select links for further exploration. Such understanding is valuable for an improved interface design, as well as for more accurate interpretations of implicit feedback when, for example, the user clicks on a mouse (i.e., click through) for machine learning. The research presented here obtained a more comprehensive understanding of *what* the user is doing and reading before actually selecting an online document. Ocular indices were able to determine the abstracts the user was viewing and reading, for how long, and in what order. The ocular indices included *eye fixations* which are defined as a spatially stable gaze lasting for approximately 200-300 milliseconds, during which the visual attention is directed to a specific area of the visual display. Fixations represent the instances when the acquisition of information and processing occur. Other indices, for example pupil dilation, are typically used as a measure to gauge the individuals' interest in the content they are viewing.

Granka et al. (2004:479) also employed eye-tracking in a study where 36 undergraduate students were given ten questions on various topics and varying in difficulty. The calibration of the eye-tracker ensured that the eye-tracking algorithms were tuned to each of the participants' eyes. The eye-tracking equipment was accurately aligned to only 26 of the 36 participants, and therefore the data of 10 participants were not viable. The participants were instructed to use the search engine, Google, to answer the questions. The researchers were able to establish how the participants interact with Google and how they select links for further exploration. Gaining this information proved invaluable for improved interface design, as well as for implicit feedback (e.g., click-through) for learning the computer. The click-through occurs when the mouse is used to click through various links to get to different sites.

### 3.4.8 Eye-tracking and marketing

Maughan, Gutnikov and Stevens (2007:336-339) randomly picked 198 participants from the British population who were under the impression that they were participating in a survey to improve their streets. However, the survey was for market research. This application of eye-tracking used for market research, is known as *visual marketing.* The eye-tracking results were stored in the software package, ClearView. The Tobii 1750 eye-tracker, (cf. par. 3.3.1.3), was used. The participants were asked to watch a slide show of street scenes, and their fixations on posters were tracked. The results of this experimental design were that the street posters received much more attention. The findings allowed the pre-production team in marketing to accurately predict the responses of the subjects to marketing material. However, the researchers also posed the following question: "Do we look more because we like something, or do we like something because we have looked at it more, and are thus more familiar with it, or both?"

### 3.4.9 Eye-tracking and gender research

Eye-tracking has also been used in the field of gender and status. De Wall, Nathan and Maner (2008:328) tested the hypothesis that people prefer to focus on men with status but not on women with status. The study by De Wall et al. (2008:335-336) included how well the human eye processes visual information. The researcher fitted the participants with an eye-tracker capable of measuring how the retina processed colour stimuli. Target photos with the following information was shown, namely an attractive male and female enjoying a high social status; an attractive male and female of low social status; an average-looking male and female with a high social status; an average looking male and female with a low social status. To measure the eye movements the researchers used an Applied Science Laboratory Series 5000 eye-tracker. This model eye-tracker samples the eye saccades at 60 samples per second, and is accurate to within 1-2 degrees visual angle. The eye-tracker was mounted on top of a small lightweight headband placed on the participants' heads and was equipped with a magnetic head tracker, which allowed for natural head movement throughout the stimulus presentation of the target photographs. The amount of time spent fixating on each face was recorded. De Wall et al. (2008: 337-338) discovered that the participants selectively attended to the high status men while no preferential attention was given to the high status women. This was in keeping with what they hypothesised. Although they did find that high status women capture the interest, they also discovered that physically attractive women captured interest. Male attractiveness appears to be more flexible since their status seems to be the overriding reason for capturing interest.

### 3.4.10 Eye-tracking and faked responses

Van Hooft and Born (2011:302-305) conducted a study aimed at investigating whether eye-tracking technology can improve our understanding of a faked response by surveying 129 university students who were instructed under two conditions: responding honestly and faking good instruction. In an experiment design, a Big Five personality test and an integrity measure were administered. Item responses, response latencies and eye movements were measured. Van Hooft and Born (2011) discovered by using the eye-tracking equipment that the participants showed less eye fixations when faking, also that the response times to the questions asked were 0,25 seconds (s) slower, and that faking is a more cognitively demanding process than responding honestly. Therefore, eye-tracking demonstrated its usefulness in detecting faking behaviour during instruction.

## 3.5 THE LIMITATIONS OF EYE-TRACKING

The following disadvantages were identified by researchers during various studies using eye-tracking methodology, as well as by Tobii, the eye-tracking manufacturer.

Ariasi and Mason (2010:582) used eye-tracking methodology to trace the global text processing of undergraduate students reading science texts, but found that this methodology, which "provides a rich collection of material, has the limitation of being obtrusive". Another limitation indicated by Ariasi and Mason (2010:589) was that the students who participated in the study had to have "normal or corrected-to-normal vision". If this was not the case then their data would be considered null and void. Ariasi and Mason (2010: 590) indicated that a larger 'track box' offered greater comfort because it allowed the user more freedom of head movement. An 'eye-tracking box' is the area in front of an eye-tracker within which the user can move around without the eye-tracker losing the ability to track the eyes.

Maltese, Balliet and Riggs (2013:81) tracked the gaze of students (at Indiana University) at a Geological Field course, using eye-tracking glasses. They found that eye-tracking research in field conditions was "technically demanding and operationally difficult". Maltese et al.

(2013:84) found that the eye-tracking equipment was not accurate in determining the exact point of gaze of the students and this was critical to the study. The following issues were cited as those that made eye-tracking difficult, namely since the students conducted studies by observing an object closely to taking in the overall features of a landscape, it required that the eye-tracking equipment needed to be properly calibrated for each of these situations to ensure valid results; the brightness of the sun caused the students to readjust their eye-tracking goggles, thus also interfering with its accuracy. According to Maltese et al. (2013:81, 84-85), most of their data-collection and analysis were based on “reviewing the scene video and did not require the eye-tracking information”. They also continued by saying that the limitations with the eye-tracking devices would cause them to use video equipment in future research “until access to better tracking instruments is readily available”. However, Jacob and Karn (2003:578) ten years earlier, stated the contrary to Maltese et al.’s point, by emphasising the fact that developers of eye-tracking systems have made great strides in reducing the barriers between the participant and the physical relationship with the eye-tracking equipment. They continued to say that recent advances in the equipment allow the eyetracked participant almost complete freedom of eye, head and full body movement while interacting with a product. Jacob and Karn (2003:578-580) conceded to the fact that the eye-tracking systems are far from optimized for usability research since the data extraction was labour intensive and that many problems existed in interpreting the data. Jacob and Karn (2003:586) cautioned researchers that they may have to use various eye-tracking systems on a trial-and-error basis before finding the suitable one to record the data for their particular study. Weigle and Banks (2008:1) set about establishing the accuracy of a gaze-tracking device by using a Tobii Technology T60 device, and discovered problems with the calibration of the eye-tracking device. In addition, they bemoaned the fact that it was difficult for the researcher to compare the data from different devices since commercial eye-tracking systems (including software and support) can cost $40,000 or more. Weigle and Banks (2008: 3-4) continued to indicate that eye-tracking involves the capturing of multiple reflections of light, (called Purkinje images) in the eye, which is used to compute gaze direction, but that the head motion transverse to the screen results in significant errors in the reported gaze position. Furthermore, when Weigle and Banks (2008:8) considered the accuracy of tracking, they found that the eye-tracker follows the motion of the eyes accurately, but does not precisely report the location of the eye-gaze position. They intimated that it may be due to an error on the part of the user, (e.g., abnormal visual motor response to the target), or problems with the calibration of the eyeglasses worn during tracking. However, Weigle and Banks (2008:11) argued that the eye-tracking device remains an excellent tool for determining relative positions and trajectories of eye gaze patterns.

Maughan et al. (2007: 336) highlighted the fact that although the ability to track eye movements have been in existence for over a century, eye-tracking investigations have been exclusively restricted to university laboratories since the eye-tracking equipment was unwieldy and inflexible. They go on to say that recently the eye-tracking equipment has become more commercially available, and able to be used in natural environments other than a laboratory.

Rosengrant et al. (2009:252) stated that if the eye-tracker is not calibrated correctly then the data provided were questionable. According to Tobii Technology (2010), several factors can affect the accuracy of the eye-tracking results, for example, eye movements, the calibration procedure, and drift and ambient light. Images or scenes are seen by eye movements and fixating on AOIs in the visual field. During steady fixations the human eye is in constant motion and small involuntary movements are triggered to avoid perceptual fading since an overstimulation of the light receptors causes the neurons to cease to respond to the stimulus. Thus, even if a person perceives that he or she is looking at a specific spot, his or her eyes are actually moving between different locations around the spot, and the accuracy of the results are influenced by human vision accuracy limitations. For this reason the participants' eye movements must first be calibrated before commencing an eye-tracking research project (cf. 1.5.4). During calibration the eye-tracker measures the characteristics of the participant's eyes and uses them together with an internal, physiological 3D eye model to calculate the gaze data. During calibration the participant is asked to look at specific points on the screen, also known as *calibration dots*. The participant does not have to keep his/her head completely still, as long as his or her eyes are kept on the moving dots. Inaccuracies could be caused by various factors such as the user not actually focusing on the point, or being distracted during calibration, or the eye-tracker not being set up correctly. It is during this time that current light conditions and the characteristics of the participants' eyes are identified.

Lastly, researchers must reckon with 'drift' - the gradual decrease in accuracy of the eye-tracking data compared to the true eye position. Drift can be caused by different factors, such as variations in the physiology of the eye (e.g., degree of wetness) and variations in the environment (e.g., sunlight variations). However, drift problems only emerge if the test conditions change radically or if the eye-tracking session is long. In these cases recalibration would have to occur (Tobii Technology, 2010:6-9).

Gredeäck et al. (2010:15-16) indicated the two properties to help reduce the gap between observable behaviour and underlying processes (i.e., whatever is being investigated) are that the eye-tracking data have to be assessed over time, and that the ability to anticipate visual behaviours are invaluable when discussing the networks responsible for a particular pattern of eye movements. In terms of research with infants, Gredebäck et al. (2010:15) caution that infants have selective attention spans, and it could therefore be difficult to allocate looking-time data to various processes. Moreover, the value of establishing a relationship between the infants' gaze and underlying processes remains.

## 3.6 CONCLUSION

This chapter examined the current state of the research concerning eye-tracking technology by giving an explanation of various eye-tracking devices and related software. The use of eye-tracking methodology was described in various learning situations as a means of determining visual attention leading to establishing a basis for valuable information being acquired. Finally, the limitations of eye-tracking in current research were described.

The next chapter, Chapter 4, will describe the research design of the empirical inquiry.

# CHAPTER FOUR
# THE RESEARCH DESIGN

## 4.1 INTRODUCTION

This chapter presents the research design of the study. This study aims to address the main research question, namely what is the role of eye contact using eye-tracking technology in promoting effective learning in natural science in the secondary school? This research question is sub-divided into the following research questions:

i) What theoretical perspectives and relevant extant findings in the literature inform the use of eye contact, its relationship to attention, and its role in teaching and learning?

ii) What is the current state of the research concerning eye-tracking technology in the learning situation with particular reference to science learning as a means of determining visual attention, and to identify the gaps in the current research?

iii) How does a mixed-ability group of selected Grade 9-learners (natural science) distribute visual attention as measured by a Tobii X2-60 eye-tracker during the viewing of a video recording of a natural science lesson on the structure of the cell, with special reference to the educator and the PowerPoint as the two AOIs?

iv) Based on the findings of the literature and the exploratory inquiry, what recommendations can be made for the improvement of classroom practice regarding the use of eye contact to effect optimal learning in the secondary school classroom, with particular reference to natural science?

To address the third sub-question, the distribution of the eye contact of a mixed ability sample of Grade 9-learners in natural science as measured by the Tobii X2-60 Eye-tracker was explored by means of an exploratory and descriptive study. This was done during the viewing of a video recording of a lesson on the structure of the cell. Special reference was made to the educator and the PowerPoint as the designated AOIs.

This chapter provides a detailed overview of the sampling strategy, data-collection and data-analysis, measures to ensure reliability and validity, and ethical considerations.

## 4.2 THE RESEARCH APPROACH

Since my research question focused on eye contact, my supervisor encouraged me to pursue the feasibility of eye-tracking methodology and advised me to attend the Eye-tracking South Africa (ETSA) Conference held between the 29th and the 31st of August 2013 in Cape Town (ETSA, 2013). This proved to be beneficial and confirmed the decision to use eye-tracking to obtain valid data regarding the benefits of eye contact in the classroom. Eye-tracking methodology was covered in detail in chapter 3 with special attention to Tobii eye-tracking technology (cf. par. 3.3.1; par. 3.3.1.1; and par. 4.3.3.1 – to follow).

The aim of the empirical study was to explore and describe the distribution of the eye contact of a mixed ability sample of selected Grade 9-learners as measured by a Tobii X2-60 eye-tracker during the viewing of a video recording of a natural science lesson on the structure of the cell with special reference to educator and the PowerPoint as the designated AOIs. I decided on an exploratory research design using the Tobii X2-60 Eye-tracker, (cf. par. 3.3.1; Figure 4.1). In particular, eye-tracking methodology (cf. par. 3.2; 3.3; 3.3.1.1) enables the researcher to produce evidence-based research which aims to bring scientific authority to whether eye contact is necessary, for example, between the educator and the learner in a secondary school natural science classroom.

## 4.3 THE RESEARCH DESIGN

A non-experimental exploratory research design was decided upon. According to McMillan and Schumacher (2010:53), exploratory research is commonly carried out in new areas of inquiry. Such studies may be qualitative or quantitative. Exploratory studies frequently study phenomena that have not been researched before. The appropriate methodology required the use of highly sophisticated technology: the Tobii X-60 eyetracker used to obtain precise measurements of eye movements. The aim was not to understand the participants’ experiences from their point of view (McMillan & Schumacher 2010). Thus qualitative methodology was not deemed inappropriate in this study.

### 4.3.1 The research site

A co-educational multicultural English medium secondary public school situated in a suburb of Cape Town was selected by means of a combination of purposeful and convenience sampling. Firstly, the school offers natural science as part of the secondary school curriculum. Secondly, I have a strong professional relationship with the school, since I not only taught there for approximately five years, but am often called upon to do relief-teaching at this school. This facilitated access to the school as research site.

### 4.3.2 Sampling

Maximum variation sampling was employed to select twelve Grade 9-learners (N=12) from the population of 190 Grade 9-learners enrolled for natural science at the school. According to McMillan and Schumacher (2010:327), maximum variation sampling is used to obtain maximum differences of perceptions of a topic among information-rich participants. In this study I selected learners with different academic achievements in natural science. The sample was comprised as follows: four top-performing learners who had achieved 80%+ in natural science in the first semester of 2014; four average-performing learners who had achieved an average of 55% in natural science in the first semester of 2014; and four under-performing learners who had achieved below 40% in natural science in the first semester of 2014. To obtain the sample, I requested the Head of the Department of natural science to select the learners according to these criteria. He gave me the twelve names based on the learners' grades in term one and two in 2014 (the first semester). The study thus constituted a case study, that is a particular instance of a phenomenon (McMillan & Schumacher 2010); in this instance the measurement of eye movements of a particular sample of learners during the viewing of a natural science lesson.

Furthermore, the sample and the group size were determined on grounds of practical considerations. All the participants were tested individually due to the nature of the eye-tracking equipment. The sample size was determined according to the time required for each participant - approximately 20 minutes for each learner/participant: (12 learners x 20 minutes each = 4 hours). This equated to approximately two school days (25-26 August, 2014) needed for eye-tracking. This had implications for both the expert technician who operated the eye-tracking equipment and the learners. The technician took leave from his employer for the purpose and had to travel from Pretoria to Cape Town. Moreover, each participant had to miss a lesson at school. With the permission of the parents and the teaching staff, each participant was allowed to choose a lesson they could miss and where they could easily catch up the work (generally the participants chose practical lessons, such as Art). As mentioned in par. 1.4.2.1, calibration was unsuccessful in the case of participant 8, and her data were excluded from the study. Therefore, the final sample comprised eleven (11) participants. The small sample size meant that no statistical significance could be attributed to possible differences in the three groups' eye-tracking data. However, as this study was exploratory, and this was not considered a drawback.

Thereafter, I allocated a number to each participant (e.g., participant 1, participant 2, etc.) so that the identity of each participant was kept confidential. Participants 1 to 4 were the top-performing learners, participants 5 to 8 were the average-performing learners, and participants 9 to 12 were the under-performing learners (see Table 4.1).

#### 4.3.2.1 The assignment of the participants

As mentioned above, the Grade 9 natural science Head of the Department assigned the twelve learners to me after consultation regarding the criteria as outlined above. Table 4.1 presents the profile of the participants (except the data for participant 8, due to calibration problems).

**Table 4.1: Profile of the participants**

| Participants | Gender | Age in years | Grade for natural science (semester one, 2014) | Home language |
|---|---|---|---|---|
| **1.** | F | 14 | 91 % | English |
| **2.** | M | 15 | 89 % | German |
| **3.** | F | 15 | 85 % | English |
| **4.** | F | 14 | 55 % | English |
| **5.** | M | 14 | 55 % | English |
| **6.** | F | 14 | 55 % | English |
| **7.** | Missing | Missing | Missing | Missing |
| **8.** | M | 14 | 37% | Zulu |
| **9.** | F | 14 | 27% | Xhosa |
| **10.** | M | 14 | 26% | Xhosa |
| **11.** | F | 14 | 24% | Xhosa |

### 4.3.3 Data-gathering

The Tobii X2-60 (cf. par. 3.3.1.1; Figure 4.1) Eye-tracker was used as data-gathering tool.

#### 4.3.3.1 Apparatus: The Tobii X2-60 Eye-tracker

The data-collection instrument was the Tobii X2-60 Eye-tracker (cf. par 3.3.1.1; Figure 4.1) which is designed to accurately collect data regarding eye contact within a minimally invasive experimental setting. The Tobii eye-tracking system monitors participants' eye movements while watching the stimulus. The eye-tracker records the eye movements sample by sample. The software (Tobii Studio, 2015) running on the computer was responsible for interpreting the fixations within the data.

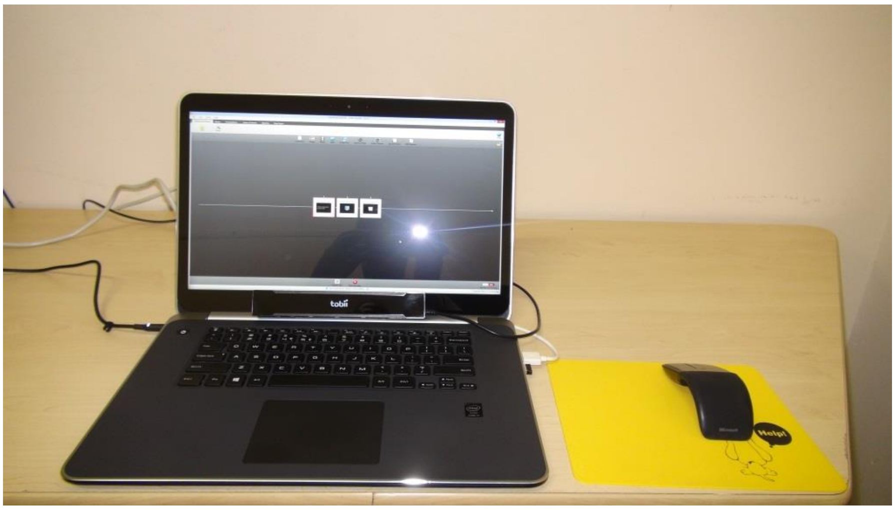



**Figure 4.1: The laptop with the unobtrusive Tobii X2-60 Eye-tracker**

A single computer set-up was used where the technician and the participant shared the same computer. The Tobii X2-60 eye-tracker was attached to a Thin Film Transistor (TFT) panel in the 17-inch computer monitor, so no moving part was visible. It delivers a high level of accuracy and precision which ensures that the research results are reliable. This technology makes it possible for the computer to record exactly where the participant is looking (Tobii in brief, 2013). Near infrared illumination is used to create the reflection patterns on the cornea and the pupil of the eye of the user, and two image sensors are used to capture the images of the eyes and the reflection patterns. Advanced image processing algorithms and a physiological 3D model of the eye are then used to estimate the position of the eye in space and the point of gaze with high accuracy (Tobii Technology, 2010).

The Tobii X2-60 Eye-tracker was used to collect the following data regarding AOIs Interest as depicted by gaze-plots, heat-maps and bar graphs.

A video recording was concurrently made of each participant by the Tobii X2-60 Eye-tracker during eye-tracking. I later viewed the video recordings and made notes with reference to the recording. However, no visual data from the recording was presented in order to protect the participants' identities (cf. 1.4.2.6; 4.5).

#### 4.3.3.2 The research setting

I created an environment free from disturbances in a sufficiently illuminated room assigned by the principal for the purposes of the research. A booth (see Figure 4.2) created by means of a screen, prevented unnecessary distractions while the participant watched the stimulus. Thus, disturbances such as glare, reflections and any distractions were excluded. All the participants were tested individually. Each participant was seated comfortably on a chair at a distance of 700mm. from the computer screen on which the stimulus was portrayed.

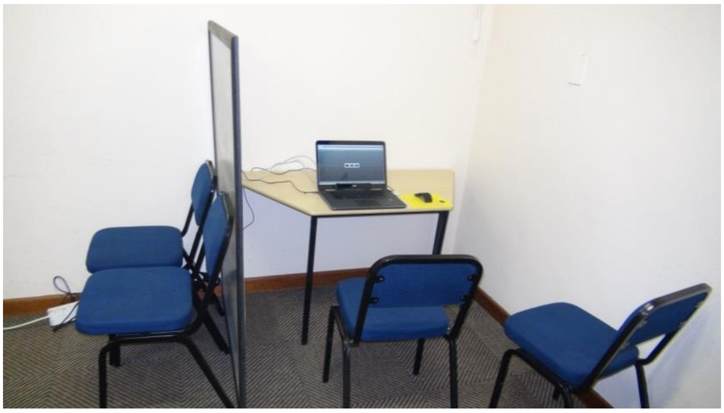


**Figure 4.2: The booth**

#### 4.3.3.3 Procedures

Mr A. Pottas (B.Sc. Hons. Computer Science), an eye-tracking technician employed at the School of Computing, University of South Africa, administered the equipment. He brought the Tobii X2-60 Eye-tracker from Pretoria to Cape Town, set up the eye-tracker, calibrated each participant and collected the data. Prior to the research all the procedures to meet ethical requirements were made. A detailed description of the latter is given in paragraph 1.4.2.6 and section 4.5). Prior to the data-collection, I informed the participants about the aims of the study. I showed the participants the Tobii X2-60 Eye-tracker and explained that it would pick up information regarding their eye-movements.

The calibration procedures are discussed below:

In order for the eye movements to be accurately recorded by the eye-tracker, the participant has to be calibrated (cf. 1.5.4). Therefore, before the eye-tracking recording commenced, the technician took each participant through a calibration procedure. During this procedure, the eye-tracker measures the characteristics of the participant's eyes and uses them together with an internal, physiological 3D eye model to calculate the gaze data. In the case of the Tobii X2-60 Eye-tracker, calibration is performed by asking the participant to follow the path of a dot as it moves across the screen. The eye-tracker then gives a visual report of the quality of the eye-tracking. A poor calibration would show a lot of lines, known as 'noise', outside the dot. Alterations to the participant's position or the monitor can be made and recalibration can be performed until the researcher is satisfied (Tobii Technology, 2010). As mentioned before, inadequate calibration due to poor body posture led to the exclusion of participant 8 from the data-analysis and findings. The reason for calibration is that each individual has different eye characteristics, and the eye-tracking software needs to model these in order to be able to estimate the gaze accurately (Basics Eye tribe Document, 2014).

Figure 4.3 shows the recommended calibration pattern used to calibrate, using the Eye Tribe Tracker. A minimum of 9 calibration locations covering most of the screen is recommended. Using more locations (e.g. 12 or 16) will improve the accuracy of the gaze coordinates computed by the system.


**Figure 4.3: Temporary image showing the 9 calibration points**

In contrast to the Eye Tribe tracker, the Tobii X2-60 Eye-tracker uses 9 points and a green dot to be followed by the participant.The percentage of calibration refers to how quickly or easily the eyes of the participant were calibrated and is not related to the success of the calibration, since each individual has different eye characteristics.

Walter (2007) says that in order to know where the participant's eyes are fixating on the computer screen, you must first 'teach' the computer what the eye looks like when the participant is fixated on known locations on the screen. This is what happens during the calibration and validation procedure. During a calibration session, the participant fixates on 9-13 points on the screen while the eye-tracker monitors the eye. After the calibration is performed, the computer then 'validates' the information by re-presenting the targets and determining whether its estimation of eye position is indeed close to the known position of the targets. If errors are found to be minimal, the calibration is indicated as being successful (green bars appear on the Eye-Tracker Monitor), and the trials may start. The latter is what Mr Pottas would have seen before allowing the participant to proceed with the viewing of the stimulus.

Harezlak, Kasprowski and Stasch (2014) explored the possibilities of how to simplify and shorten the process of calibration without losing the accuracy of the eye mapping function, including the place where the participant looks at on the screen. Harezlak et al. (2014) investigated participants being calibrated using differing amounts of points, up to 29 points, to create the possibility of ensuring the shortest possible calibration time with great accuracy and precision of  the formulation of a calibration model.

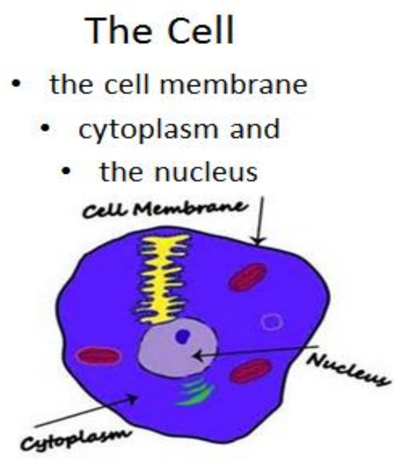
#### 4.3.3.4 PowerPoint presentation: A lesson on the cell

The topic of the lesson was 'The cell'. The participants only had prior knowledge on the basic structure of the cell – the cell membrane, cytoplasm and nucleus. This prior knowledge was established with the assistance of the natural science Grade Head. The content of the lesson presented during eye-tracking comprised more detailed subject matter regarding the structure of the cell. The lesson forms part of the current natural science syllabus: Cells as the basic units of life, Senior Phase (Grades 7-9) (National Department of Basic Education, 2012) but had not yet been covered at the time of data-gathering, according to the Grade Head. Thus it comprised an introduction to new subject matter. (The source for the information used to compile the PPT was: De Fontaine, J., Gordon, D., McKay, I. & Webb. J. 2007. *Science Alive Grade 9: Teacher's Book.* Cape Town: Nolwazi Educational Publishers.)

The viewing time of the lesson was 594s (9m 54s) and was based on the PowerPoint presentation: slides 1 to 13. A verbatim transcript of the lesson follows below. A pointer was used to point to specific items on the slides. These moments are recorded in the transcript below.

**SLIDE 1**

This is a lesson about the cell. You have been taught that the basic structure of the cell consists of the cell membrane, cytoplasm and the nucleus.




Today we will consider these three structures in greater detail. (*I point to the cell membrane, the cytoplasm and the nucleus*).

**SLIDE 2**

Let's start with the cell membrane (*the heading appears on slide 2*). The cell membrane may also be called the plasma membrane or plasmalemma (*appears on slide 2*). The cell membrane surrounds the cell and consists of the following: (*I point to the terms: phospholipids, proteins and carbohydrates)*. I explain the following information about phospholipids, proteins and carbohydrates:

Phospholipids are a class of lipids (fats) and they repair and maintain cells so as to keep them fluid and whole. We find a rich source of phospholipid in egg yolk (see slide 3).

Good sources of protein include eggs, nuts, seeds, vegetables and fish. One of the functions of protein is communication between the cells (see slide 4).

Good sources of carbohydrates include fruit, milk, potatoes, grain and yoghurt. One of the functions of carbohydrates is that it is used by the body for energy (see slide 5).

The Cell membrane

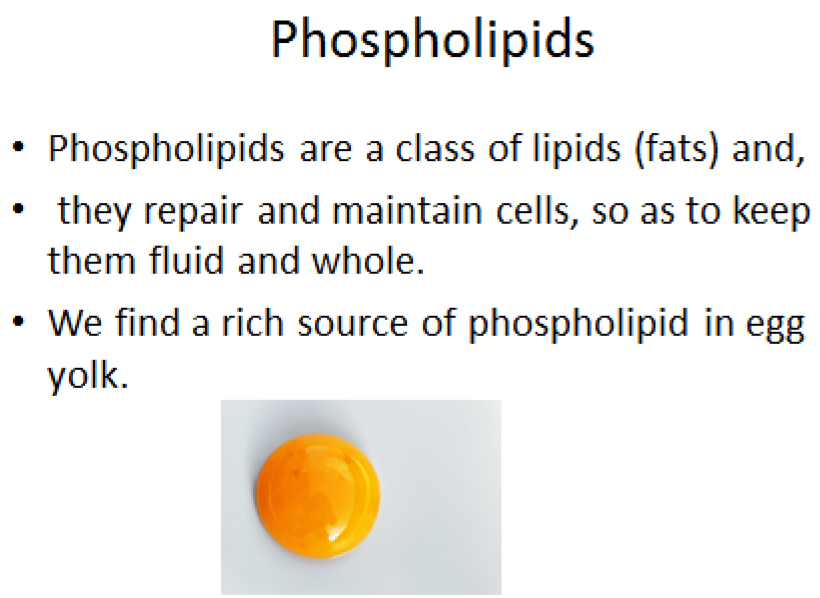
- The cell membrane may also be called a plasma membrane or plasmalemma.
- The cell membrane surrounds the cell and consists of **phospholipids, proteins and carbohydrates.**

**SLIDE 3**

(*The heading Phospholipids, as well as information on slide 3 appears simultaneously*.)

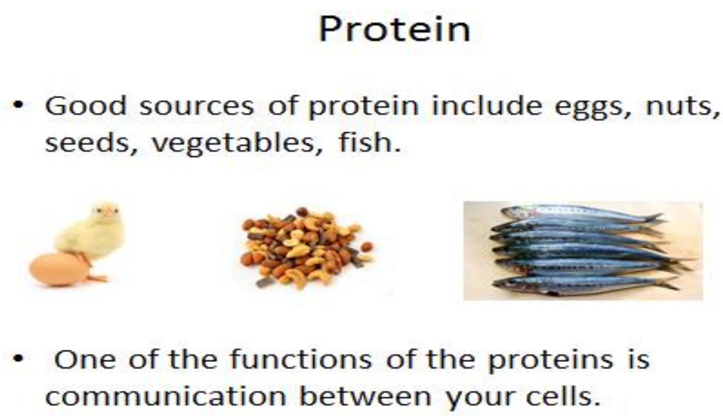
I explain that drying a cell will cause the death of that cell, since it will no longer be able to function.

We find a rich source of phospholipid in egg yolk (*slide 3 appears with the picture of the egg*). That's the yellow part of the egg. (*I point to the yolk).*



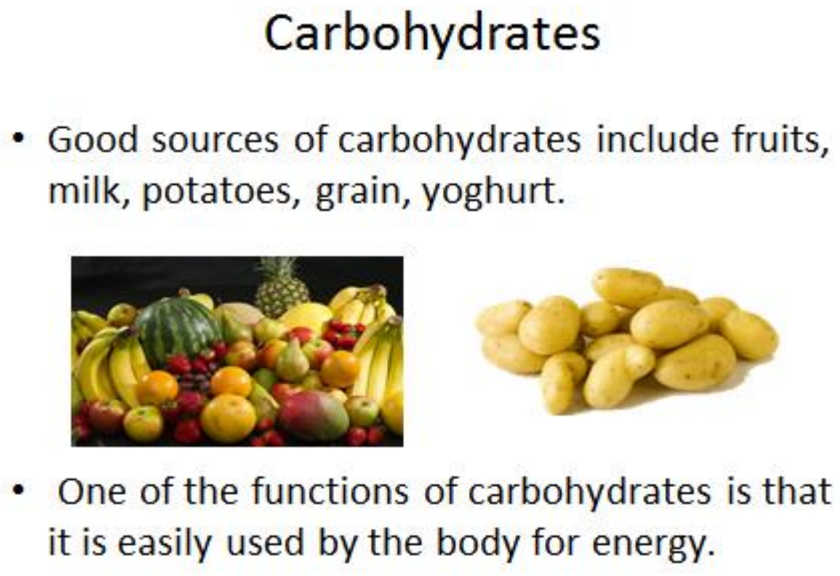

**SLIDE 4**

Slide 4 appears with the heading: Proteins. I state that good sources of protein include eggs, nuts, seeds, vegetables and fish (*illustrations appears simultaneously on the slide*). I state a function of proteins. (*I point to each illustration respectively*.)



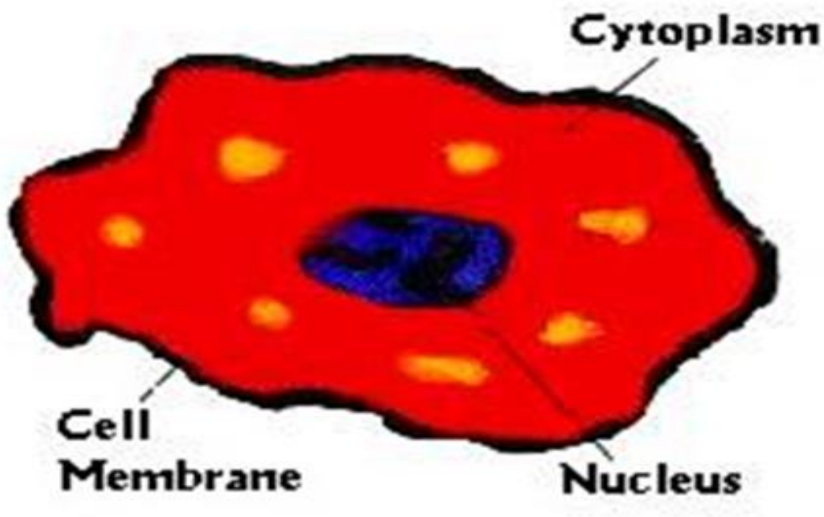

**SLIDE 5**

The heading: Carbohydrates, appears on slide 5. I state that good sources of carbohydrates include fruits, milk, potatoes, grain, yoghurt (*illustrations appear on slide 5 as well as the function of carbohydrates*). I explain that 'carbo-loading' occurs when athletes eat carbohydrates to ensure a supply of energy to complete a race.




**SLIDE 6**

I point to the surrounding cell membrane and explain that it is a delicate sheet that allows substances to enter or exit the cell, permitting some substances through while blocking others.



**SLIDE 7**

I state that the membranes can be classified into the following types: impermeable, permeable, semipermeable or selectively permeable (*labelled list appears*).

Membranes

- impermeable,
- permeable,
- semipermeable or
- selectively permeable.

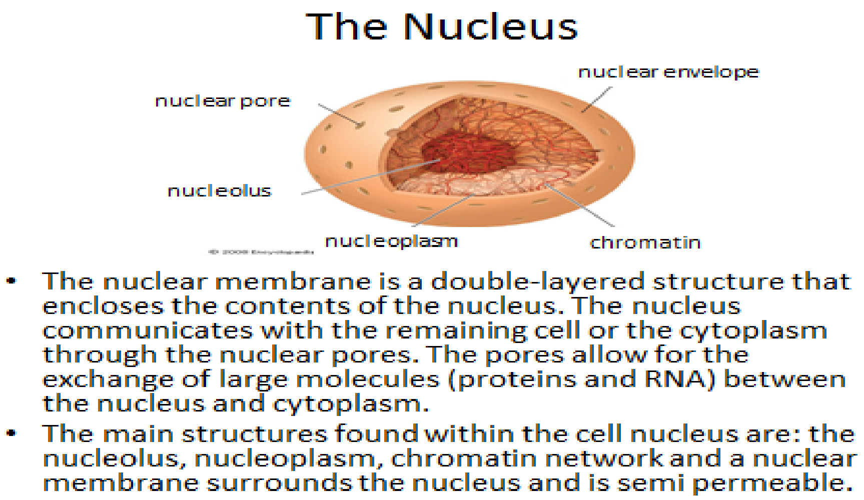
**SLIDE 8**

I explain the function of each type of membrane (*each function pops up one by one on the slide according to being mentioned in the narrative*).

- An impermeable membrane do not allow any substances to pass through.
- Permeable membranes are those that let solvents and solutes, like ions and molecules, to pass across it.
- Semi permeable membranes allow only solvents, like water, to pass through it.
- Selectively permeable membranes allow solvents and only some specific solutes, like ions and organic molecules to pass through, while blocking others.
- The cell membrane is selectively permeable.

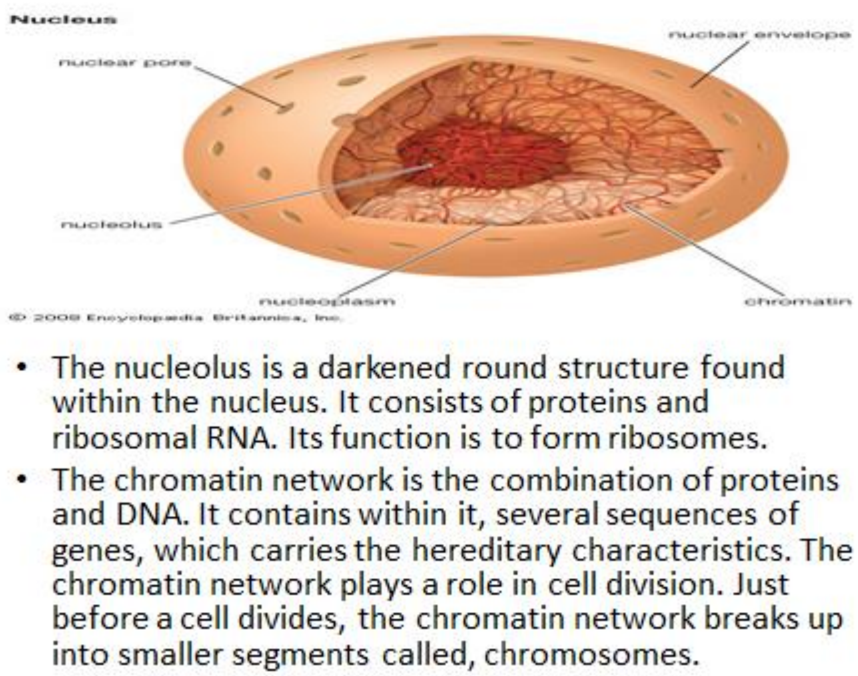
**SLIDE 9**

I explain that the illustration is a three-dimensional diagram of the nucleus. I point to parts of the nucleus and explain each part, repeating the information on the slide. I repeat the fact that the cell membrane is selectively permeable and the nucleus is semi-permeable. I refer back to the definitions given earlier on (see slide 8).



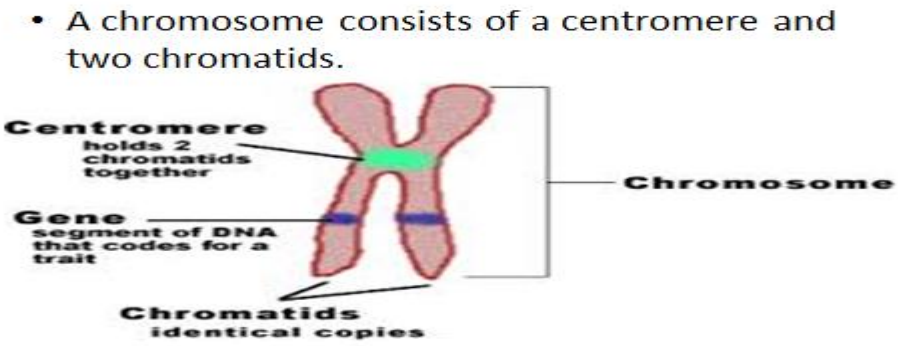

**SLIDE 10**

I explain the nucleolus and the chromatin network according to the information given on the slide.



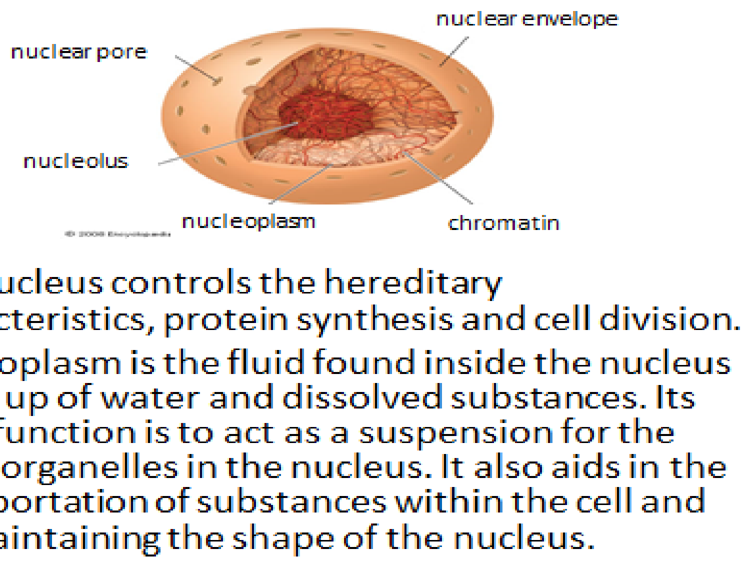
**SLIDE 11**

I point out the various parts of the chromosome.



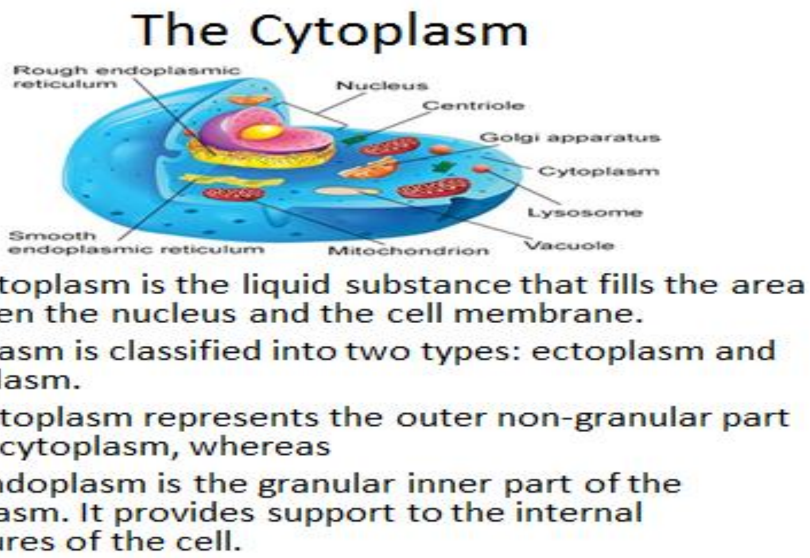

**SLIDE 12**

I explain the parts of the nucleus and its functions. The terms are explained: **hereditary characteristics** are those characteristics that we inherit from our parents, like height, skin colour; **protein synthesis** is the production of proteins; **cell division** occurs when one cell divides into two, and two cells into four.




**SLIDE 13**

I refer back to the three basic parts of the cell by pointing to the diagram and announcing: the cell membrane, nucleus and cytoplasm (*cf. Slide one and prior knowledge*). I then introduce the cytoplasm. I point to the area between the nucleus and the cell membrane and explain to the learner that the cytoplasm is the liquid substance that fills this area. I go on to explain that the cytoplasm is classified into two types: the ectoplasm (*I point to ectoplasm on the diagram on slide 13*) and the endoplasm *(I point to endoplasm on the diagram of slide 13*). I go on to explain that the ectoplasm represents the outer, non-granular part of the cytoplasm (*I point to ectoplasm on the diagram of slide 13*) and the endoplasm represents the granular inner part of the cytoplasm, and provides support to the internal structures of the cell (*I point to the endoplasm and the internal structures*: *the smooth endoplasmic reticulum, mitochondrion and golgi apparatus on slide 13).*




#### 4.3.3.5 The administration of the Multiple Choice Questionnaire (MCQ)

After each participant viewed the video-recorded lesson, a researcher-designed paper and pencil multiple choice question (MCQ) test (cf. Appendix F) was administered to assess the participants' recall of the instructional content of the video-recorded lesson. The MCQ test comprised ten questions. The questions consisted of the subject matter which I dealt with during the video-recorded lesson only, such as definitions and examples. The draft MCQ and memorandum was seen and approved by the Head of Department, natural science, to ensure that the prior knowledge of the Grade 9-learners would enable them to adequately understand and be able to answer the questions. I scored the completed tests after the inquiry was completed with a memorandum and the Head of Department moderated the scores.

The same test was administered online to each participant immediately after the participant had viewed the lesson. Two think-aloud questions followed the MCQ. The first ‘think-aloud’ question comprised the following, “Was the subject matter difficult or easy?” The participants indicated their answers to the ten MC questions and the first ‘think-aloud’ question on a sheet prepared for the purpose. I posed the second ‘think-aloud’ question verbally and made field-notes on each participant respectively. The question was, “Were you satisfied with the manner in which the educator conveyed the subject matter? State a reason for your answer.”

#### 4.3.3.6 Field notes

Descriptive field notes were made during the presentation and viewing of each slide (cf. 5.8). Field notes can be defined as notes made by the researcher during when observing an experiment or when out in the field (McMillan & Schumacher 2010). In the case of this study the notes were ancillary to the inquiry which rested on the measurements of eye-tracking by the Tobii X2-60 eyetracker.

### 4.3.4 Analysis of the data

The eye-tracking data were analysed by the technician using the analytical software, Tobii Studio. This software has its own analytic capabilities and allows large amounts of data to be analysed for easy interpretation (Tobii Studio, 2015). The data-analysis generated bar graphs, gaze-plots and heat-maps.

I analysed the test scores for the MCQ test manually, and the think-aloud question according to my field notes.

#### 4.3.4.1 Presentation of the data

During a recording the Tobii X2-60 collects eye movement data points every 16.6 ms. Each data point was identified by a time-stamp - the current time of an event that is recorded by the computer in ms. and, ‘x,y’ coordinates, and sent to the analysis application (e.g., the Tobii Studio database running on the computer connected to the eye-tracker). In order to visualise the data these coordinates are processed further into fixations and overlaid on a video-recording of the stimuli used in the test. By aggregating data points into fixations the amount of eye-tracking data to process is reduced significantly.

In this study the visual data regarding AOI's are presented by bar graphs, indicating fixation duration, gaze-plots and heat-maps.

a) The educator and the PowerPoint (cf.4.3.3.4) represented the two AOIs in this study (cf.1.5.7), and were the two zones used by the data-analysis software for analysis (Pottas, 2014).

b) A *gaze-plot* is a visual representation which demonstrates an individual participant's visit on the visual field (cf. 1.5.6). A fixation is represented by each dot. The larger the dot, the longer the duration of the fixation. The lines between the dots resemble saccades (Nielsen & Pernice, 2010:13). The different colours are an indication of the various sequences of the eleven participant eye movements across the monitor (What is a Gaze Plot and a Heat Map? 2015). Gaze-plots can be used to illustrate the gaze activity of a single participant (using one colour) over the whole eye-tracking session, or of several participants (using many different colours).

c) Heat-maps are the best-known visualization technique for eye-tracking studies (cf.1.5.5). "In a heat map a screen shot is colour coded according to the number of looks each part attracts: the red areas are where users looked the most; the yellow areas indicate fewer fixations, and the blue areas indicated the least looked areas. If an area is grey it did not attract any fixations", according to Nielsen and Pernice (2010:11).

## 4.4 RELIABILITY AND VALIDITY

### 4.4.1 Validity

According to Graziano and Raulin (2004:101), the *validity* of a measure is defined as how accurately it measures what it is intended to measure. The *internal* validity has to allow the researcher to draw accurate conclusions about cause-and-effect and other relationships within the data (Graziano & Raulin, 2004:101-102). In order to eliminate other possible explanations for my results observed so as to ensure internal validity, I carefully regulated the environmental conditions by exposing the participants to the exact same conditions: all the participants watched the same stimulus (the video-recorded lesson) in the same environment.

The *external* validity is the extent to which the conclusions drawn can contribute more to knowledge (Graziano & Raulin, 2004:103). Even though my research setting was an artificial setting, it is a direct simulation of a focused classroom setting capable of delivering data regarding direct eye contact between the educator and the learner, as well as no eye contact between the educator and the learner.

### 4.4.2 Reliability

*Reliability* is the consistency with which a measuring instrument yields a consistent result when the entity measured remains the same (Leedy & Ormrod, 2013:91). I used the Tobii 2X-60 eye-tracker with each of the 12 individual participants, who were seated the same distance from the monitor, viewing the monitor with the stimulus, and they completed the same MCQ test, including the two think-aloud questions. Data-analysis, using the PowerPoint and the educator as designated AOIs, was done by an expert technician using the Tobii Studio software analysis especially designed for use with the Tobii 2X-60 Eye-tracker (Tobii Studio, 2015).

### 4.4.3 Limitations of eye-tracking

While eye-tracking could offer valuable information regarding the connection between eye contact and learning, we have to take note of the fact that it necessitates the use of individual participants at work.

Firstly, data are lost when participants look away from the monitor while being tracked. Also, an excessive volume of data can be generated during eye-tracking studies (Tobii Technology, 2010). My study generated 40GB of data and it took a while to generate it into useable data. Participant 8 was not tracked since the participant slouched in the chair and the eye-tracker was unable to track the participant (this was clearly evident when I reviewed the video footage of Participant 8) (cf. par 5.2) and she was excluded from the study. So, we had three participants, (Participants 5, 6, 7), instead of four, (cf. par. 5.2), but it did not affect the observations of the data, since only the averages were considered.

Secondly, this study does not seek to give information regarding pupil dilation to substantiate cognitive information; however, this is beyond the scope of the study. The study seeks to gather data based on eye-contact or absence thereof, and how it impacts learning. Perfectly-controlled conditions are generally not possible in a secondary school classroom. Thus, there may be a trade-off between experimental rigor and practical authenticity as in this study, I created a highly controlled environment which may be far removed from a real classroom (see Figure 4.2).

Drift has also been identified as a limitation of eye-tracking. *Drift* is defined as the gradual decrease in accuracy of the eye-tracking data compared to the true eye position. Drift can be caused by different factors, such as variations in eye physiology (e.g., the wetness of the eyeball, tears), (cf. par. 3.2), and variations in the environment (e.g., sunlight variations). The environment of the study was not affected by variations. (cf. par. 4.3.3.2 & Figure 4.2). However, drift problems only have a significant effect if the test conditions change radically or if the eye-tracking session is long. The Tobii X2-60 is able to cope well with drift (Tobii Technology, 2010). The following technical information clearly indicates that drift will not adversely influence the eye-tracking data: Drift < 0.3degrees; Data rate 120 Hz; Freedom of head movement 30x22x30cm; Binocular tracking: yes; T/X firmware: embedded; Weight : ~3 kg (Technical Specifications/Tobii.com, 2013). Furthermore, the eye-tracking session was kept as short as possible and only lasted 20 minutes, which included the completion of the MCQ.

Finally, in this study I attempted to keep the environment stable, but I had no control over individual eye physiology. As mentioned before, all the participants had their eye movements calibrated before the commencement of the study by the expert technician (cf. par. 4.3.3.3), and one participant (no. 8) was excluded from the study due to inadequate calibration.

## 4.5 ETHICAL MEASURES

Whenever human beings who have the potential to think, feel and experience physical or psychological distress are the focus of investigation, researchers must look closely at the ethical implications of what they are proposing to do (Graziano & Raulin, 2004:104). The first principle of ethical conduct during research is to do no harm (Lichtman, 2010). There should be a reasonable expectation by those participating in a research study that they will not be involved in any situation in which they might be harmed.

In the case of this study the participants were not exposed to any harm or danger since the eye-tracker is unobtrusive technology and allows effective binocular eye-tracking of the participant's eye movements. It also creates a distraction–free test environment, ensuring the natural behaviour of the participants and valid research data (Eye-tracking Features, 2013).

Furthermore, any individual participating in a research study has a reasonable expectation that the research is voluntary, anonymous and confidential The participant is entitled to expect that such information will not be given to anyone else (Lichtman, 2010:54-55). These principles were adhered to in this study, according to the following steps:

Ethical clearance was obtained from:

a) the Ethics Committee of the College of Education, University of South Africa (Appendix A);
b) the Western Cape Department of Education (Appendix B);
c) the principal of the school (Appendix C);
d) written consent from the parents of the participants (Appendix D); and
**e)** written assent from participants (Appendix E).

Additionally, an undertaking was made to provide a written summary of the research to the Western Cape Department of Education, the principal and staff of the school and the participants and parents, on the successful completion of the study. Data will be stored in a password locked computer in a safe personal office at my home for a period of five years.

## 4.6 CONCLUSION

This chapter described the rationale for the choice of an exploratory research approach for this study. Full details regarding the selection of the site, sampling, data-gathering using the Tobii X2-60 Eye-tracker, data-analysis, the presentation of the data and measures taken to ensure reliability, validity and compliance with ethical demands were provided.

In the next chapter the findings are presented and discussed.

# CHAPTER 5
# PRESENTATION OF THE FINDINGS

## 5.1 INTRODUCTION

This chapter presents the findings of the exploratory, descriptive study of the role of eye contact using eye-tracking methodology during the viewing of a natural science lesson by Grade 9 natural science learners in a selected school. The study addressed the third research question, namely How do a mixed-ability group of selected Grade 9-learners (natural science) distribute eye contact as measured by a Tobii X2-60 eye-tracker during the viewing of a video-recording of a natural science lesson on the structure of the cell, with special reference to visual attention to the educator and the PowerPoint presentation as the designated AOIs? (Chapter 1).

The chapter is organised as follows: First of all an overview is given of the two-day process of data-gathering using the Tobii X2-60 eye-tracker as administered by an expert technician, and the difficulties encountered during calibration. Thereafter the findings generated by means of the Tobii Studio data-analysis software according to the two AOIS are presented in three sections, namely the findings according to the gaze-plots, the findings according to the heat-maps, and the findings according to the total fixation duration (TFD) presented in bar graphs; and the findings according to the total visit duration (TVD) presented in bar graphs. The results of the MCQ and the observation of the participants are also presented. Finally, the chapter is concluded with a discussion of the key findings.

## 5.2 OVERVIEW OF THE PROCEDURES OF DATA-GATHERING

On Monday, 25 August 2014 (the first day of data-gathering), the technician and I met with seven of the twelve participants for approximately twenty minutes each. The following procedures followed in the dedicated space allotted for the study:

1. Each participant took a seat in front of the monitor and was asked if he or she was seated comfortably. Before the data-gathering commenced, each participant was taken through a calibration (cf. 1.5.4) procedure. During calibration the eye-tracker measures the features of the participant's eyes and uses them together with an

internal, physiological 3D model to determine the gaze-data (Tobii Technology, 2010:7). The technician explained the calibration process, and questions were answered.

2. The technician duly calibrated each participant's eyes by requesting them to look at specific points on the screen, known as calibration dots, and to follow the dots moving across the screen (Tobii Technology, 2010:7).
3. The participant was left alone in the booth having been instructed to click the spacebar to activate the video-recording and to watch the lesson (cf. par. 4.3.3.4) while the eye-tracking equipment was engaged (cf. Figure 5.1).
4. Finally, the MCQ's test and the first 'think-aloud' question was completed, namely "Was the subject matter easy/difficult?" The students viewed the questions online and wrote down the answers on an answer sheet (cf. Figure 5.2).
5. I conducted a brief exit interview with each participant, using the second think-aloud question, namely "Were you happy with the way the educator presented the lesson? State a reason for your answer." I made notes of each response. Each participant was given a little snack to say "thank you". All the participants left in good spirits and appeared to have enjoyed the research.
6. During the eye-tracking, each participant was videoed from the back without disclosing their identities; this footage was not be used in the study but it supplied complementary information to the second 'think aloud' question (cf. Appendix B).

Figure 5.1 illustrates how a participant watches the ten-minute natural science lesson on the Cell on the computer in which the eye-tracker is embedded.

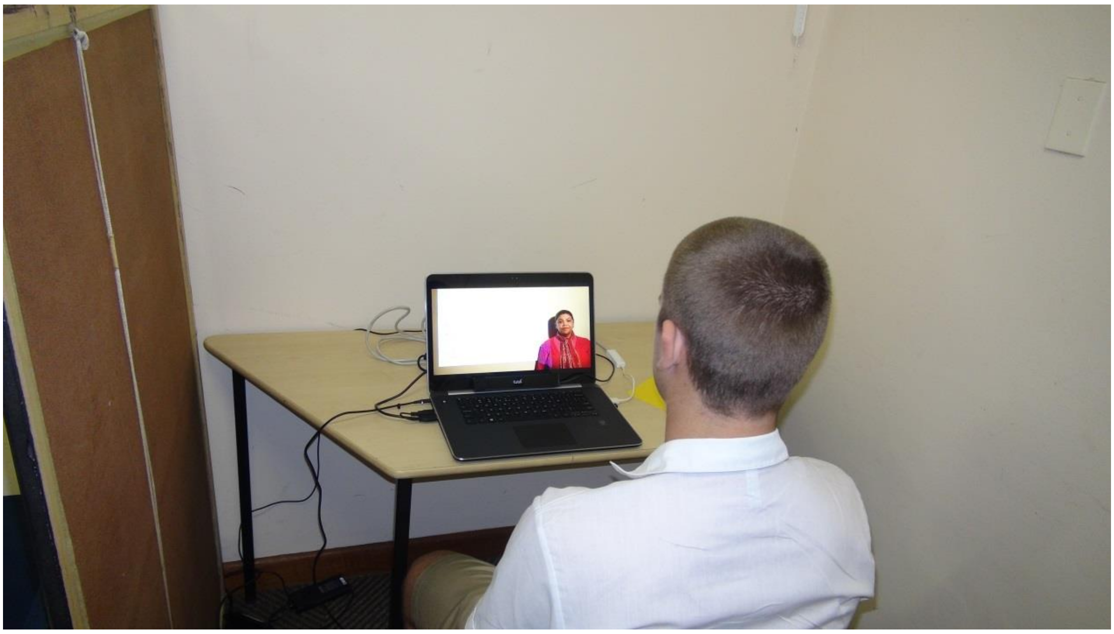


**Figure 5.1: A participant watching recorded lesson during eye-tracking**

Figure 5.2 illustrates a participant who is engaged in taking the MCQ test on the structure of the cell, and answering the first think-aloud question by recording her answers on an answer sheet.

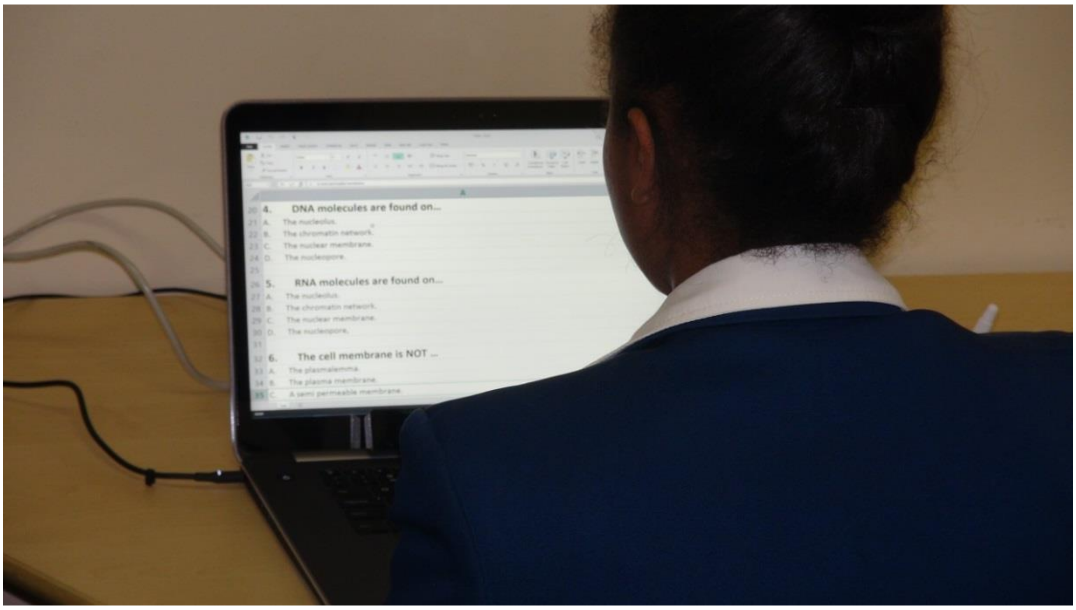



**Figure 5.2: A participant completing an online MCQ test**

On Tuesday, 26 August 2014 the same procedure as the previous day was followed with the other five participants. As was mentioned above (cf. also par 4.3.2), participant 8, an average-performing natural science learner, could not be eye-tracked on 26 August, 2014 since she sat in a slouching position during calibration. Therefore the eye-tracker was unable to pick up the movements of her eyes. As she was among the last of the twelve participants who took part on the final day of data-gathering, her participation could not be repeated. Thus, this participants' eye-tracking data could not be used in the generation of the gaze-plots, heat-maps and graphs. Her responses to the think-aloud questions and the MCQ were also excluded from the findings. The data were generated on the scores of eleven (11) participants: four participants in the top-performing natural science learner group, three participants in the average-performing natural science learner group and four participants in the under-performing natural science learner group.

All the participants were very cooperative and enthusiastic during the data-gathering. The technician was very professional in his explanation and operation of the equipment, and this helped to put the participants at ease. He was also able to explain any questions on eye calibration and the equipment. During data-gathering 40 GB of data were gathered by means of the eye-tracking programme embedded in the computer.

Table 5.1 provides participant data regarding the calibration. Eye colour does not affect the use of the eye tracker or the calibration process (Tobii Technology, 2010)

**Table 5.1:** Calibration data

| PARTICIPANTS | % of CALIBRATION |
|---|---|
| **Participant 1** | 43% |
| **Participant 2** | 39% |
| **Participant 3** | 41% |
| **Participant 4** | 42% |
| **Participant 5** | 40% |
| **Participant 6** | 36% |
| **Participant 7** | 31% |
| **Participant 8** | Missing |
| **Participant 9** | 37% |
| **Participant 10** | 43% |
| **Participant 11** | 37% |
| **Participant 12** | 29% |

Table 5.1 indicates that the participants (with the exception of participant 8) presented with useful data, and therefore they were deemed as being successfully calibrated. For a full discussion of calibration and the difficulties related to it, refer to chapter 4, par. 4.3.3.3.

Furthermore, the mean for the calibration per ability group was also calculated, as follows: the mean for the top-performing group was 41.3%, for the average-performing group it was 35,6%, and for the under-performing group it was 36.5% (cf. Table 5.1). The mean was calculated by adding the scores per ability group and dividing the sum by the number of participants in the group.

### 5.2.1 Slide 13

The heat-maps and gaze-plots are based on the eye-tracking of the participants' visual attention on Slide 13, as illustrated in Figure 5.3. Slide 13 was chosen since it was the last slide in the lesson, and it was reasoned that the participants would have had sufficient time to have relaxed during earlier slides. Slide 13 presented a balance of information between the diagram and the text. In addition, in consultation with the natural science teacher, it was confirmed that the information on Slide 13 formed part of the Grade 9 syllabus. However, the subject matter had not yet been covered at the time of data-gathering and was new to all the participants. The total viewing time was 104s (1m 44s).

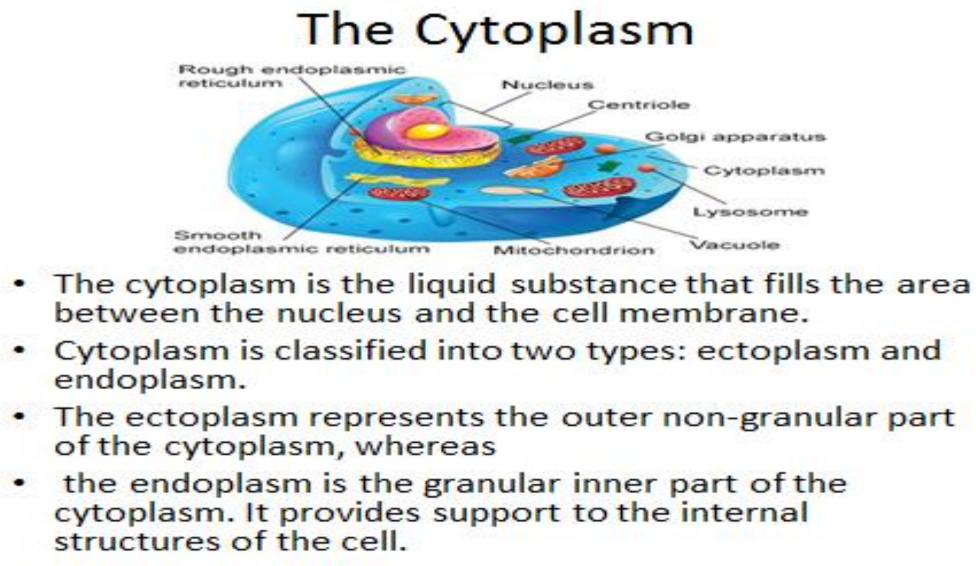



**Figure 5.3: Slide 13: The cytoplasm**

Figure 5.3 (Slide 13) presents the slide: The Cytoplasm. This includes a labelled colour cross-section illustration of the cell. The following nine parts of the cell are labelled: Nucleus; Centriole; Golgi apparatus; Cytoplasm; Lysosome; Vacuole; Mitochondrion; Smooth endoplasmic reticulum; Rough endoplasmic reticulum. Thereafter, four bulleted statements were made regarding the structure of the cytoplasm.

For a full description of the narrative presented on this slide, see chapter 4 par. 4.3.3.4. Slide 13 was repeated in this section to facilitate reading since the ensuing discussion on the heat-map and gaze-plot referred to it.

## 5.3 FINDINGS: GAZE-PLOTS

A *gaze-plot* is a visual representation which demonstrates an individual participant's visit to the stimulus, and provides a qualitative view of the data (Tobii Technology, 2010; cf. par.1.5.6). The gaze-plot shows each participant's eye movements, fixation by fixation. A fixation is represented by each dot. The circles or dots are the fixation points, where the participants' fovea (the area of clearest vision on the eye) stopped briefly to take in information. The larger the dot, the longer the duration of the fixation. The numbers indicate the order of the fixations, and the size of each circle indicates the length of a fixation, with larger circles signifying longer fixations. The numbers on the dots represent the pathway that the eyes moved (the starting point where the eyes first fixated is number 1, and so on). The different colours are an indication of the various sequences of the participants' eye movements across the computer monitor (each participant is represented by a colour). The lines connecting the circles are the saccades (rapid eye movements), the movements between fixations (Ross, 2009).

### 5.3.1 Combined gaze-plot

Figure 5.4 presents the combined participant data on a gaze-plot based on Slide 13.


**Figure 5.4: Combined gaze-plot**

A gaze-plot gives a general picture of how he learners distributed their visual attention to the PowerPoint and to the educator's face (Yang et al., 2013:218). Figure 5.4 indicates that the participants focused predominantly on the face of the educator and the diagram of the cell in Slide 13. Figure 5.4 also indicates that the learners looked specifically at to where the educator pointed with a pointer on Slide 13: the label, Ectoplasm. These areas are indicated by the labels attached to the figure.

### 5.3.2 Gaze-plots per ability group

A gaze-plot was also generated for each of the three ability groups respectively. The results are presented as follows:

(a) Gaze-plot for the top-performing natural science learners (Figure 5.5)

(b) Gaze-plot for average-performing natural science learners (Figure 5.6)

(c) Gaze-plot for under-performing natural science learners (Figure 5.7).

#### 5.3.2.1 The gaze-plot for the top-performing natural science learners

The blue square in Figure 5.5 represents the PowerPoint (Slide 13) and the green circle represents the face of the educator. The four colours (turquoise, blue, green and yellow) represent the fixations generated by each of the four top-performing natural science learners respectively (cf. par 4.3.2). Each learner was assigned a colour. Based on the density of the dots representative of fixations, Figure 5.5 indicates that the densest fixation of the top-performing natural science learners was on the PowerPoint and on the eye area of the educator.

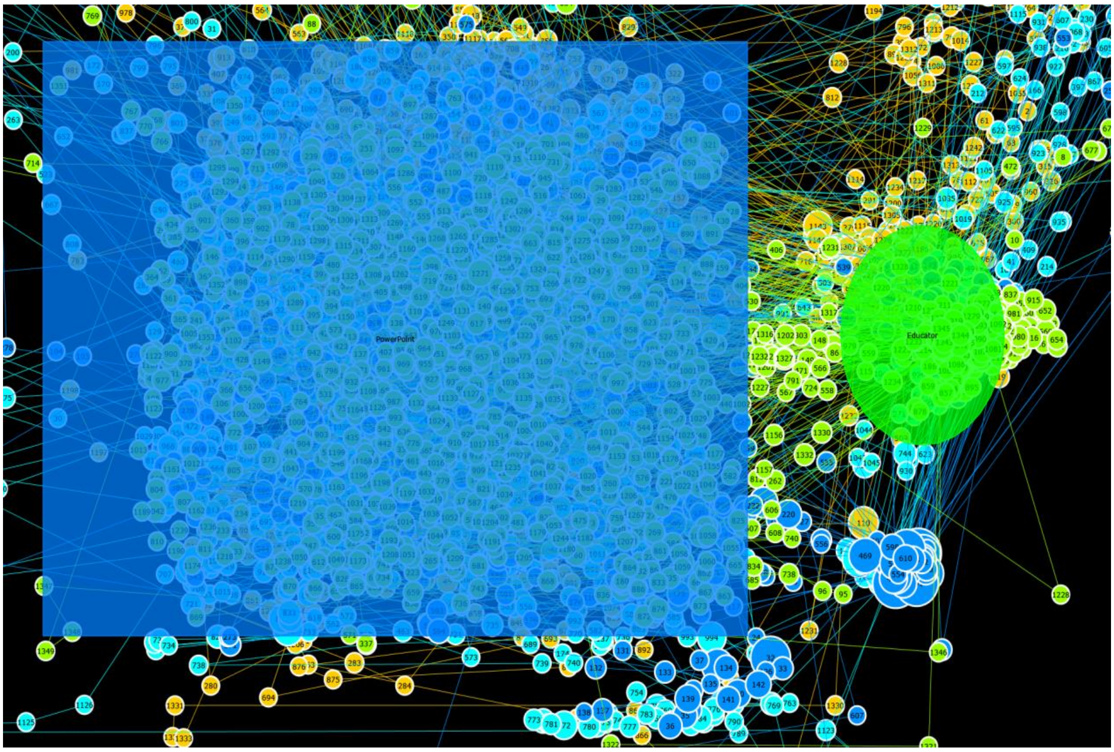



**Figure 5.5: Gaze-plot for the top-performing natural science learners**

#### 5.3.2.2 The gaze-plot for the average-performing natural science learners

The blue square in Figure 5.6 represents the PowerPoint (Slide 13) and the green circle represents the face of the educator. The three colours (turquoise, mauve and blue) represent the gaze-plots generated by each of the three average-performing natural science learners respectively (excluding participant 8). Each learner was assigned a colour.

Based on the density of the dots representative of fixations, Figure 5.6 indicates that the densest fixation was on the PowerPoint and the face of the educator, especially the mouth area.

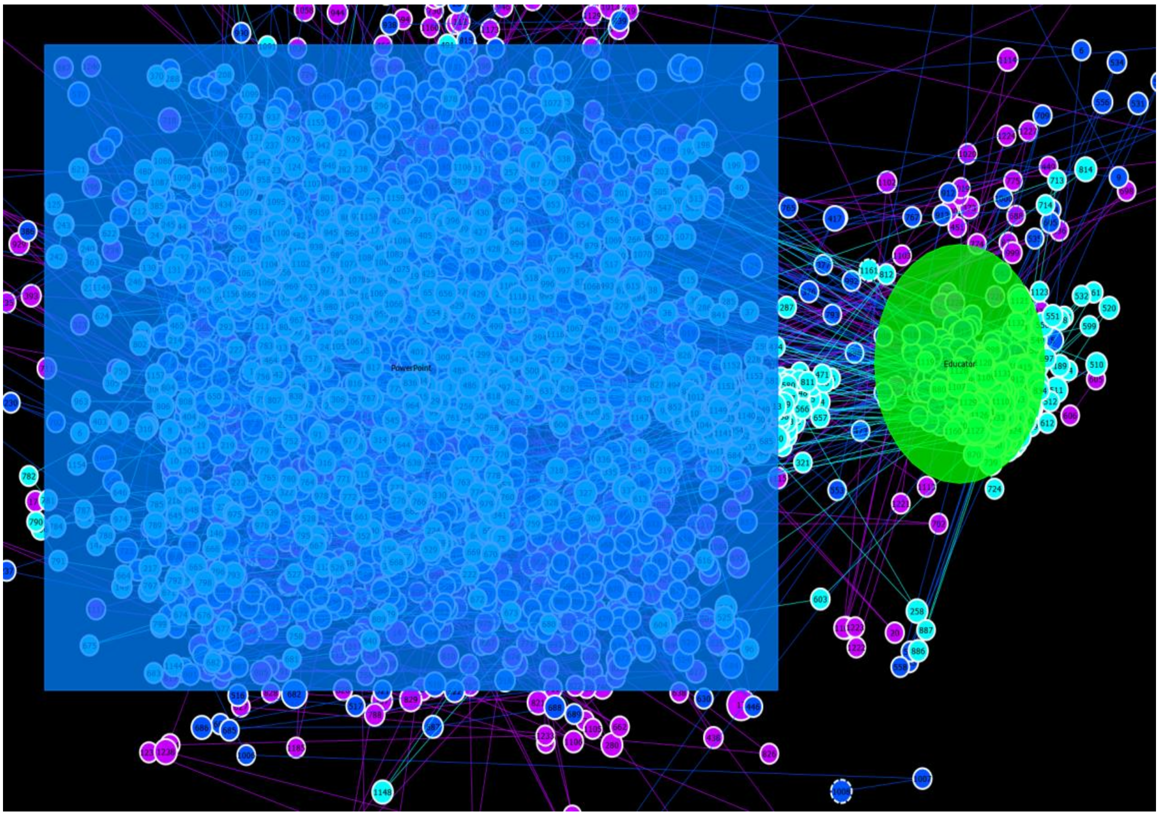



**Figure 5.6: Gaze-plot for the average-performing natural science learners**

#### 5.3.2.3 The gaze-plot for the under-performing natural science learners

The blue square in Figure 5.7 represents the PowerPoint (Slide 13) and the green circle represents the face of the educator. Four colours (green, mauve, light pink and orange) represent the gaze-plots generated by each of the four under-performing natural science learners respectively (cf. par. 4.3.2). Based on the density of the dots representative of the fixations, Figure 5.7 indicates that there was a moderate fixation on the PowerPoint and the educator, which was far less dense than the fixations of the top-performing natural science learners (cf. Figure 5.5) and the average-performing natural science learners (cf. Figure 5.6).

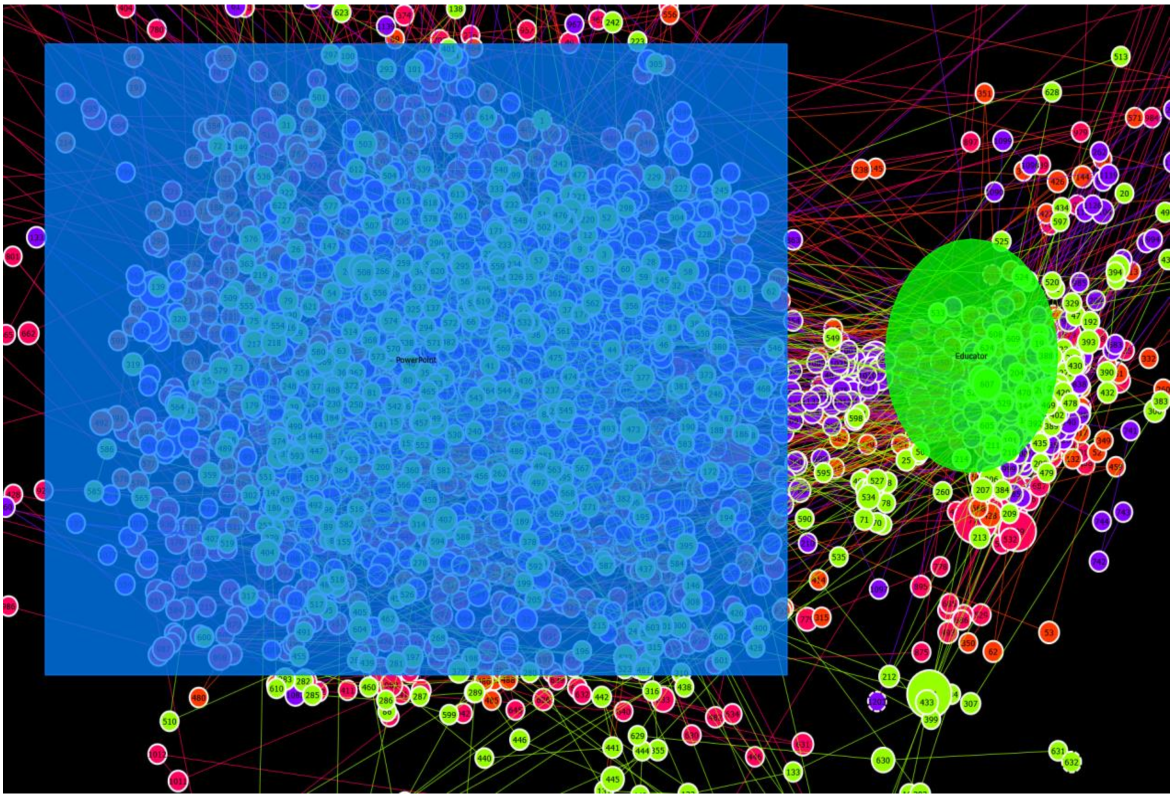


**Figure 5.7: Gaze-plot for the under-performing natural science learners**

### 5.3.3 Discussion on gaze-plots

The combined gaze-plot (Figure 5.4) indicates that the densest fixation, and thus the learners' greatest visual attention, was given to the PowerPoint slide. This implies that the learners paid considerably more attention to Slide 13 than to the educator. Only a small number of differences can be detected for the different zones on the slide. However, the density of the fixation appeared stronger on the term 'ectoplasm' to which the educator pointed during instruction. This suggests that the narration by the educator and her reference to a key term by pointing to it helped the learners to locate critical information on the slide.

Furthermore, the gaze-plots per ability group show a gradual decrease in the density of fixations on the PowerPoint and on the educator's face as one moves from the top-performing natural science learners (cf. Figure 5.5) to the average-performing natural science learners (cf. Figure 5 .6) and then to the under-performing natural science learners (cf. Figure 5.7). This suggests that the better-performing students (top and average-performing learners) indicate higher visual attention than the under-performing group. The decreased attention to both the PowerPoint and the educator's face on the part of the under-performing group could be an indication that the learners were struggling with the new material presented during the lesson, and this led to less focused fixations. In this regard, Rosengrant et al. (2009) observed a difference in the visual attention patterns of expert and novice students regarding electrical circuits. The novices who were struggling with new and challenging content tended to have more erratic patterns of fixations than the experts who were more able to access the content. This finding has implications for the development of strategies for the effective instruction of learners with a low interest in the subject matter or who are struggling to cope with new content.

## 5.4 FINDINGS: HEAT-MAPS

A heat map uses different colours to indicate the number of fixations the participants made in certain areas of the image or for how long they fixated within that area, thus providing a qualitative view of the data (Tobii Technology, 2010; cf. 1.5.5). Red usually indicates a high number of fixations or the longest time, and green the least, with varying levels inbetween. An area with no colour on a heat map signifies that the participants did not fixate in the area. This does not necessarily mean they did not 'see' anything there, but if it was detected it may have been in their peripheral vision, which means that it was more blurred.

### 5.4.1 Combined heat-map

Figure 5.8 presents the combined participant data on a heat map based on Slide 13.

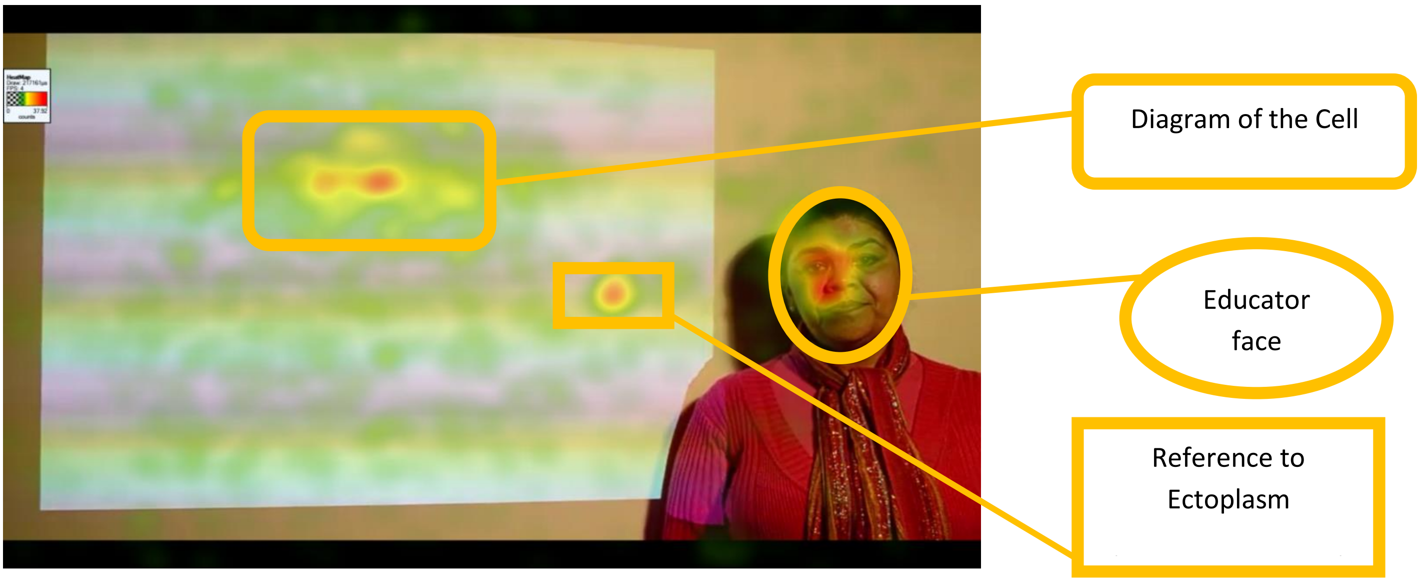



**Figure 5.8: Combined heat-map for all the participants**

The heat-map gives a general picture of how the learners distributed their visual attention to the PowerPoint (Slide 13) and to the educator's face (Yang et al., 2013:218). Figure 5.8 indicates that the educator's face, particularly her eyes, received a considerable amount of attention as indicated by the red area over her right eye. This suggests that although the participants were looking at a video-recording, which did not allow direct social interaction, they still fixated on the eyes of the educator, thus making 'virtual' eye contact (cf. par. 2.4.5).

Figure 5.8 indicates that two particular zones of the PowerPoint presentation received the most attention. This was, firstly, the diagram (the cell structure). The bigger red area represents the diagram of the cell with the cytoplasm, which received the most attention on the PowerPoint. The second area was the term 'ectoplasm', to which the educator specifically pointed while teaching. In the transcript of the recording (cf. par. 4.3.3.4) the educator stated that the cytoplasm consists of two parts, the ectoplasm and the endoplasm, and she pointed to these two terms. She first pointed to the term, 'ectoplasm'. This is where the learners fixated, and this accounts for the second smallest red area.

### 5.4.2 Heat-maps per ability group

A heat-map was also generated for each of the three ability groups respectively. The results are presented as follows:

(a) the heat-map for top-performing natural science learners (Figure 5.9);
(b) the heat-map for the average-performing natural science learners (Figure 5.10);
(c) the heat-map for the under-performing natural science learners (Figure 5.11).

#### 5.4.2.1 Heat-map for the top-performing natural science learners

The blue square in Figure 5.9 represents the PowerPoint slide and the green circle represents the face of the educator. The red colour indicates that the educator's face received considerable attention (see green circle). Attention to the PowerPoint was in the area of the diagram of the cell (Slide 13), where a faint yellow colour is detected, since the dots are closely aligned (white circle). The small green area to the right indicates the location of the term 'ectoplasm', which also received some visual attention from the top-performing group.

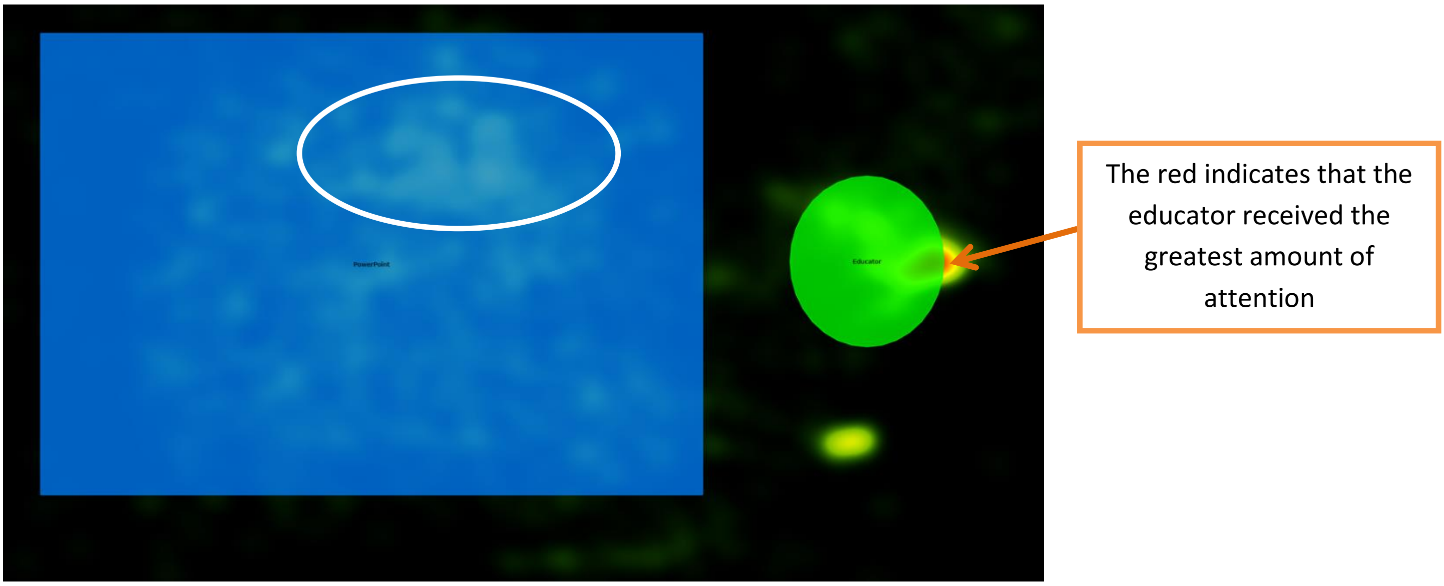



**Figure 5.9: Heat-map for the top-performing natural science learners**

### 5.4.2.2 Heat-map for the average-performing natural science learners

The blue square in Figure 5.10 represents the PowerPoint slide and the green circle represents the face of the educator. The fixations were mainly on the educator (the orange circle) and the diagram of the cell (Slide 13) on the PowerPoint. The term 'ectoplasm' to which the educator pointed also received attention (white circle).

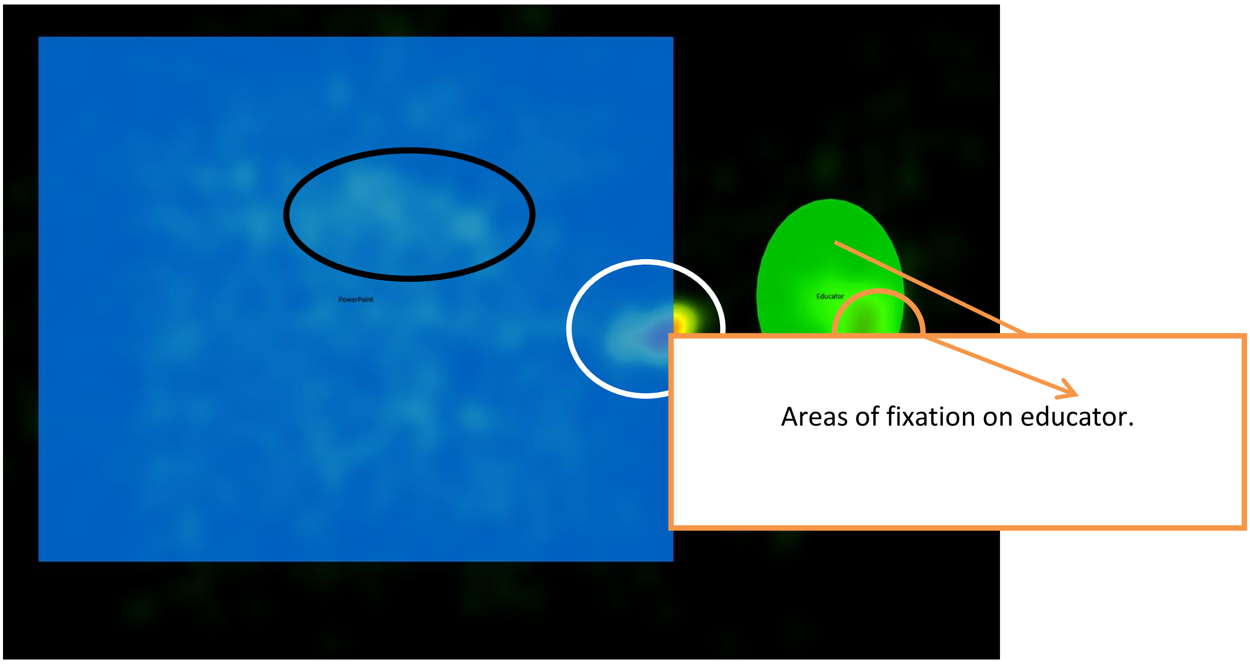



**Figure 5.10: Heat-map for the average-performing natural science learners**

#### 5.4.2.3 Heat-map for the under-performing natural science learners

The blue square in Figure 5.11 represents the PowerPoint slide and the green circle represents the face of the educator. The under-performing natural science learners fixated on the educator's face (mustard oval), followed by a slighter fixation on the diagram on Slide 13 (white circle).

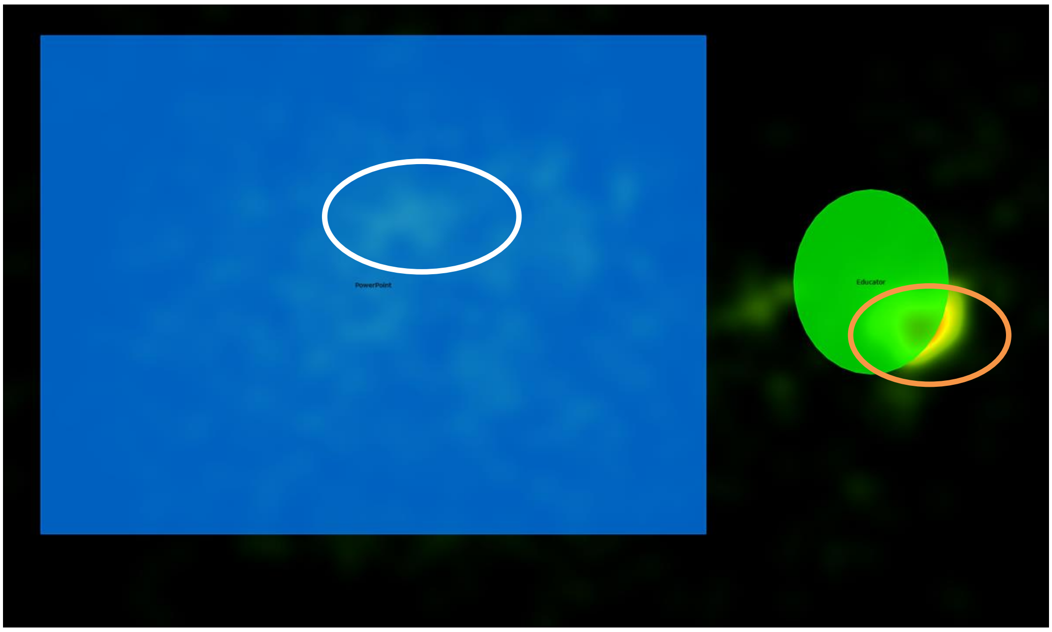


**Figure 5.11: Heat-map for the under-performing natural science learners**

### 5.4.3 Discussion on heat-maps

The combined heat-map (Figure 5.8) adds new information to the visual attention distribution as provided by the combined gaze-plot (Figure 5.5). In this case the learners' greatest visual attention was concentrated on both the educator's face and the PowerPoint (Slide 13) in the zone of the diagram. Some attention was also given to the zone where the term 'ectoplasm' occurred and to which the educator drew specific attention. As was the case with the gaze-plot (cf.5.2.2), this suggests that the narration of the educator and her reference to a key term by pointing to it helped the learners to locate critical information on the slide.

While all three ability groups showed considerable attention to the educator, the top-performing natural science learners focused strongly on the educator's eye area (Figure 5.9). The average-performing natural science learners and the under-performing natural science learners focused mainly on the mouth-area of the educator (Figures 5.10 and 5.11 respectively). Furthermore, the heat-maps also show a gradual decrease in fixations on educator's face and the PowerPoint (indicated by the colour red) as one moves from the top-performing natural science learners (cf. Figure 5.9) to the average-performing natural science learners (cf. Figure 5.10) and then to the under-performing natural science learners (cf. Figure 5.11). This suggests that the better-performing students (top and average) showed higher visual attention than the under-performing group. In this regard the heat-maps per ability group confirm the findings of the gaze-plots per ability group. The decreased attention to both the PowerPoint and the educator on the part of the under-performing group could be indicative of difficulty with the content (cf. Rosengrant et al., 2009) This has implications for developing strategies for the effective instruction of under-performing learners to keep them on task (cf. Bolden et al., 2015).

## 5.5 FINDINGS: TOTAL FIXATION DURATION (TFD)

The findings are discussed according to total fixation duration (TFD) and the average fixation duration (AFD) on the entire lesson (Slides 1-13). The total viewing time of the lesson was 594s (9m 54s) (cf. 4.3.3.4).

The *total fixation duration* is defined as the sum of the duration of the fixations in seconds on an AOI (Yang et al., 2013:212), or the fixation length (Tobii Technology, 2008:11). The *average fixation duration* is defined as the average duration in seconds on an AOI (Yang et al., 2013:212). There are two different ways of presenting the data for the different AOIs, either as the results of the different individual participants per AOI, or as the averages of all the participants per AO1 (Tobii Technology, 2008:11).

Figure 5.12 indicates a) the TFD for the different individual participants and b) the AFD of all the participants for the two different AOIs in this study, namely the PowerPoint and the educator.

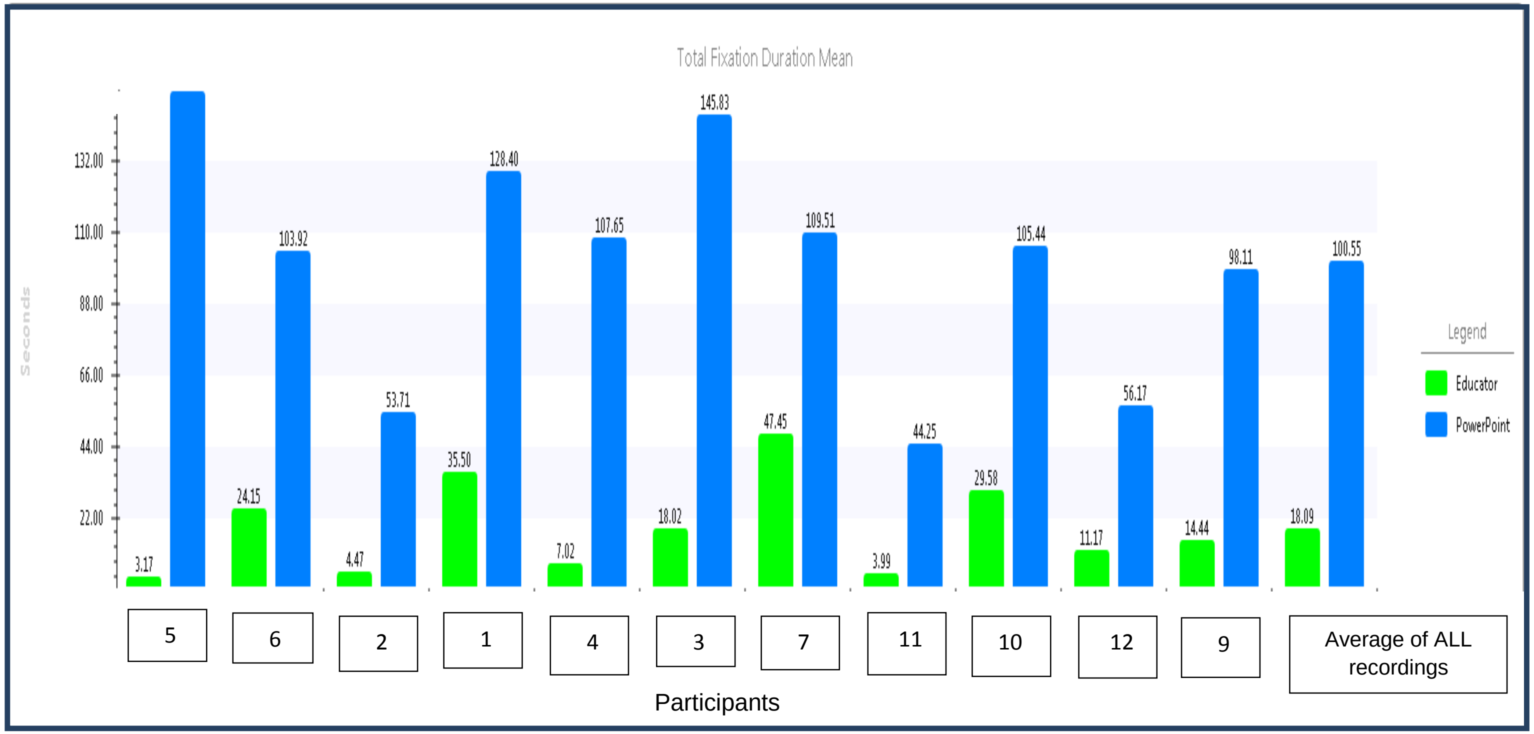



**Figure 5.12: TFD for the individual participants and AFD of the participants combined**

In Figure 5.12 the y-axis represents time in seconds from 0 to 154.00s. The x-axis indicates the TFD on the PowerPoint (the blue bar) and the TFD on the educator (the green bar) for each individual participant and the AFD for all the participants (last pair of bars). Note that the x-axis in Figure 5.12 depicts the numbered participants in the sequence in which they participated during the data-gathering.

### 5.5.1 AFD per ability group

Table 5.2 gives a comparison of the AFD and the percentage of the viewing time (PVT) per ability group on the PowerPoint and the educator respectively. The AFD per ability group was calculated by adding the TFD scores of each participant in the group and dividing the sum by the number of participants in the group. By way of explanation, and with reference to Figure 5.12 and Table 5.2 above, the AFD of the top-performing group on the PowerPoint was calculated as follows: 128.40s (Participant 1) + 53,71s (Participant 2) + 145,83s (Participant 3) + 107,65s (Participant 4) / 4 = 108,89s. The same calculation procedure was followed for the other two groups.

The percentage viewing time (PVT) was also calculated per ability group. Yang et al. (2013:212) defines the *percentage viewing time* as the TFD divided by the total viewing time. By way of explanation, the PVT for the top-performing group on the PowerPoint was calculated as follows: 108.89s/594s x 100 = 18,31%. The same calculation procedure was followed for the other two groups, the average and the under-performing natural science learners.

**Table 5.2:** Comparison of AFD and PVT per ability group

| Ability Group | PowerPoint: AFD | PowerPoint: PVT | Educator: AFD | Educator: PVT |
|---|---|---|---|---|
| Top performing natural science learners (N=4) | 108.89s | 18,31% | 16.25s | 2,73% |

| | | | | |
|---|---|---|---|---|
| Average performing natural science learners (N=3) | 101.8s | 20,63% | 24.92s | 4,17% |
| Under-performing natural science learners (N=4) | 75.99s | 12,78% | 14.79s | 2,48% |

AFD = Average fixation duration

PVT = Percentage viewing time

Table 5.2 indicates that the AFD on the PowerPoint by the top-performing natural science learners was 108,89s (PVT 18,31%), followed by the average-performing group, which was 101,8s (PVT 20,63%) and lastly, the under-performing group, which was 75,99s (PVT 12,78%). In this regard, Rosengrant et al. (2011) found that the fixation duration given to particular information on a particular location on the visual field is an indicator of efficient information processing. The authors (2011) liken this to a spotlight that focuses a strong light on a particular target. When the spotlight illuminates the target, it provides the viewer with clear information. The AFD of the top-performing group on the PowerPoint (108,89s) could thus suggest that this group processed PowerPoint information more efficiently than the under-performing group, whose AFD was far shorter (75,99s). The poorer performance of the under-performing group in the MCQ test per ability group presented later in paragraph 5.7 also supports this conclusion.

Table 5.2 indicates that the longest fixation on the educator was by the average-performing natural science learners (24,92s or 4,17%), followed by the top-performing group (16,25s or 2,73%) and lastly, the under-performing group (14,79s or 2,48%). Once again, the AFD of the under-performing group (14,79s) was the shortest, and the shorter duration of attention given to the educator's narration could mean that the information was not processed as efficiently as was done by the average- and top-performing groups. The poorer performance of the under-performing group in the MCQ test per ability group presented in paragraph 5.7 also supports this conclusion.

### 5.5.2 AFD for all the participants combined

The last pair of bars on the x-axis in Figure 5.12 indicates the AFD of the participants combined as follows: the AFD on the educator is 18.09s; the AFD on the PowerPoint is 100.55s. The AFD was calculated by adding all the individual participants' scores pertaining to the educator (green bar) and the PowerPoint (blue bar) respectively and dividing the sum by the total number of participants (11). The PVT on the educator was 3,04% and on the PowerPoint, 16,9%. These findings are tabulated in Table 5.3 below.

**Table 5.3:** AFD and PVT for all the participants

| **Participants** | **PowerPoint: AFD** | **PowerPoint: PVT** | **Educator: AFD** | **Educator: PVT** |
|---|---|---|---|---|
| 1-11 | 100.55s | 16,9% | 18,09s | 3,04% |

AFD = Average fixation duration
PVT = Percentage viewing time

The AFD presented above indicates that the participants attended primarily to the PowerPoint slide: the fixation duration on the PowerPoint was roughly five and half times longer than the total fixation duration on the educators' face. The total fixation duration serves as an indicator of a participant's visual attention, and is also an indicator of sustained focus on information while filtering or ignoring extraneous information (Rosengrant et al, 2011). This also corroborates the findings obtained from the gaze-plots and the heat-maps (cf. 5.3 and 5.4). This has implications for instructional practice in that the teachers need to be clear about the benefits and drawbacks of PowerPoint presentations; the teachers should be aware that visual presentations capture a major part of the learner's attention during instruction, and they should take this into consideration when planning instruction. This is confirmed by Bolden et al. (2015) who recommend that teachers should take heed of both the benefits and the drawbacks of slide presentations, and recognition should be given to the fact that lower-attaining children may focus their attention on information in slide presentations less successfully than higher-attaining children.

## 5.6 FINDINGS: TOTAL VISIT DURATION MEAN (TVD)

This section presents the findings according to the total visit duration (TVD), also referred to as Observation Length (OB), on the entire lesson (Slides 1-13). The total viewing time of the lesson was 594s (9m 54s) (cf. 4.3.3.4).

The *total visit duration* is defined as the total time in seconds for every time a participant has looked within an AOI, starting with a fixation inside the AOI and ending with a fixation outside the AOI (Tobii Technology, 2008:11). Therefore, the TVD shows in seconds how much time a participant on average spent looking within an AOI (Tobii Technology, 2008:15). There are two different ways of presenting TVD findings for different AOIs: either as results of the different individual participants per AOI, or as averages over all participants per AO1 (Tobii Technology, 2008:11).

The next sections first present the findings on the TVD per ability group.

### 5.6.1 Findings for the top-performing natural science learners

Figure 5.13 indicates the findings for the TVD for the top-performing natural science learners according to a) the TVD for the different individual participants and b) the average of all the participants. The y-axis represents the time in seconds, indicated in intervals of 57s. The x-axis represents the TVD on the PowerPoint (blue bar) and the TVD on the educator (green bar) for the individual participants, and lastly, the average for all the participants (last pair of bars).

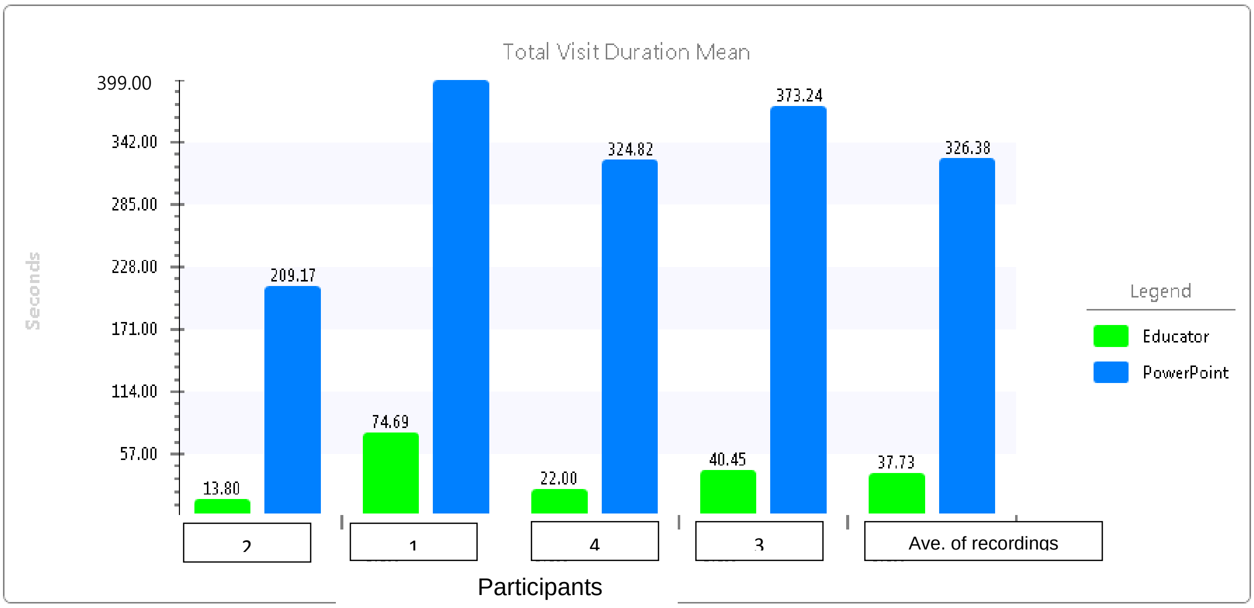



**Figure 5.13: TVD for the individual participants and the average of participants combined: the top-performing group**

Figure 5.13 indicates that Participant 1 had the longest TVD on the PowerPoint (399.00s) and the longest TVD on the educator (74.69s). Interestingly, participant 1 achieved 80% in the MCQ (cf. Table 5.4). This suggests that the observation length on both the PowerPoint and the educator in this case may relate positively to performance. In contrast, participant 2 had the shortest TVD on both the PowerPoint (209.17s) and the educator (13.80s). Although participant 2 achieved the second highest mark (89%) for natural science in the first semester, 2014 (cf. Table 4.1), his performance in the MCQ test was poor (40%) (cf. Table 5.5). This suggests that his poor performance in the MCQ could have been influenced by the shorter observation length.

Figure 5.13 indicates that the average TVD on the PowerPoint of all the participants in the top-performing group was 326.38s. The average TVD on the educator of all the participants was 37.73s. The average TVD was calculated by adding the score for each individual participant in the group on the PowerPoint and the educator respectively and dividing each total by the number of participants (4).

### 5.6.2 Findings for the average-performing natural science learners

Figure 5.14 indicates the findings for TVD for the average-performing natural science learners according to a) the TVD for the different individual participants and b) the average of all the participants. The y-axis represents the time in seconds indicated in intervals of 79s. The x-axis represents the TVD on the PowerPoint (blue bar) and the TVD on the educator (green bar) for the individual participants, and lastly, the average for all the participants (the last pair of bars).

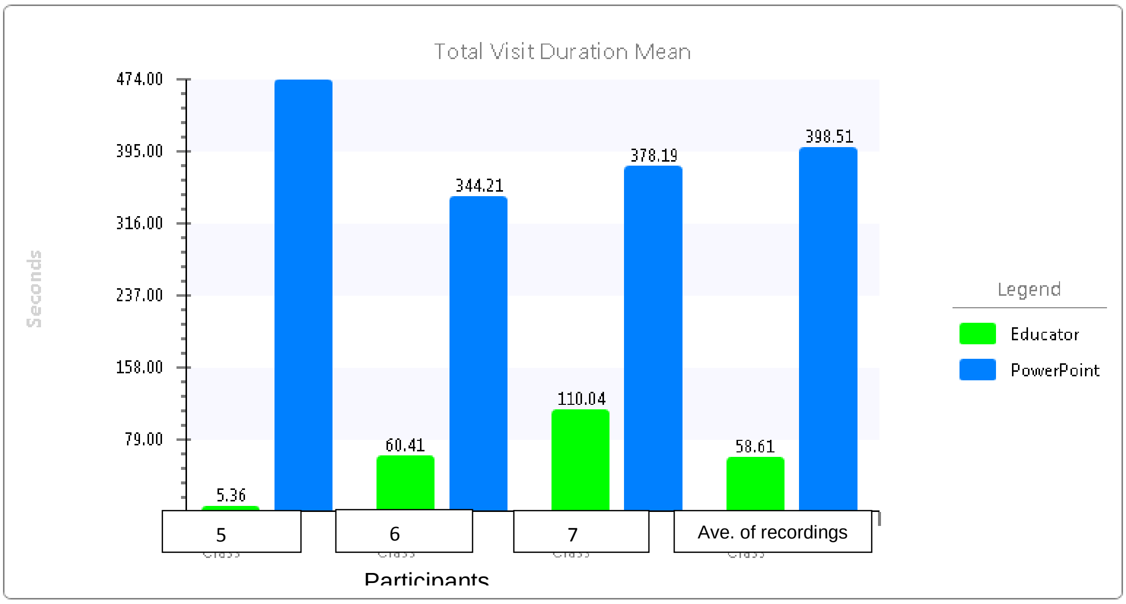



**Figure 5.14: TVD for the individual participants and the average of participants combined: average-performing group**

Participant 5 had the longest TVD on the PowerPoint (474.00s) but the shortest on the educator (5.36s). Participant 5 achieved 40% in the MCQ test, and indicated that the subject matter was difficult (cf. Table 5.5) This suggests she may have needed the longer observation length on the PowerPoint to grasp the new information. Participant 6 had the shortest TVD on the PowerPoint (344.21s). Participant 7 had the longest TVD on the educator (110.04 seconds).

Figure 5.14 indicates that the average TVD on the PowerPoint of all the participants in the average-performing group was 398.51s. The average TVD on the educator of all the participants was 58.61s. The average TVD was calculated by adding the score for each individual participant in the group on the PowerPoint and the educator respectively and dividing it by the number of participants (3).

### 5.6.3 Findings for the under-performing natural science learners

Figure 5.15 indicates the findings for the under-performing natural science learners according to a) the TVD for the different individual participants, and b) the average of all the participants. The y-axis represents the time in seconds indicated in intervals of 89.50s. The x-axis represents the TVD on the PowerPoint (blue bar) and the TVD on the educator (green bar) for the individual participants, and lastly, the average for all the participants (the last pair of bars).

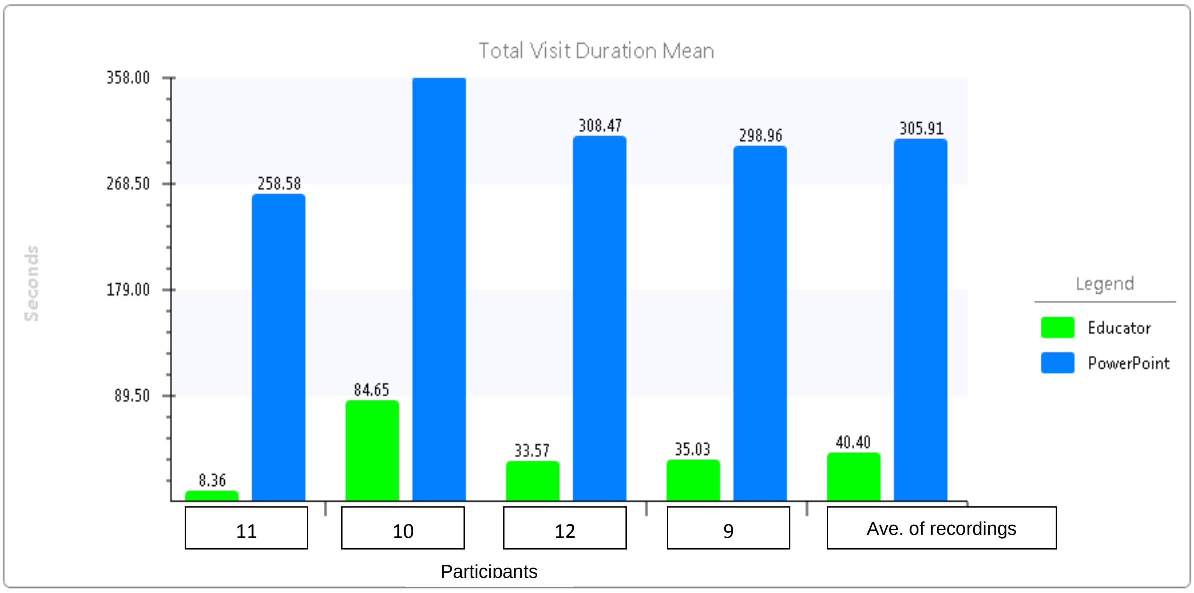



**Figure 5.15: TVD for the individual participants and the average of participants combined: the under-performing group**

Participant 10 had the longest TVD on the PowerPoint (358.00s) and the longest TVD on the educator (84.65s). Participant 10 achieved only 30% in the MCQ test (cf. Table 5.5). Participant 11 had the shortest TVD on the PowerPoint (258.58s) and the shortest TVD on the educator (8.36s). Participant 11 also achieved 30% in the MCQ test (cf. Table. 5.5.). These results are inconclusive and require additional information about the participants' learning experience which could be obtained in an interview (Tobii Technology, 2010:11).

Figure 5.15 indicates that the average TVD on the PowerPoint of all the participants in the under-performing group was 305.91s. The average TVD on the educator was 40.40s. The average TVD was calculated by adding the score for each individual participant in the group on the PowerPoint and the educator respectively and dividing it by the number of participants (4).

### 5.6.4 Comparison of the ability groups

Table 5.4 summarises the average TVD in seconds that each ability group spent looking at each AOI, the PowerPoint and the educator (Tobii Technology, 2008:17) and this finding as a percentage of total viewing time. By way of example, the attention percentage for the top-performing group on the PowerPoint was calculated as follows: 326.38s / 594s x 100 = 54.9%.

**Table 5.4: Comparison of TVD per ability group**

| **Ability Group** | **PowerPoint** | **Educator** |
|---|---|---|
| Top performing natural science learners (N=4) | 326.38s (54.9%) | 37.73s (0.40%) |
| Average performing natural science learners (N=3) | 398.51s (67.08%) | 58.61s (9.86%) |
| Under-performing natural science learners (N=4) | 305.91s (51.5%) | 40.40s (6.80%) |

TVD = Total visit duration

Figures 5.13-5.15 (see y-axes) indicate that the visits to the AOIs of the top-performing group occurred at intervals of 57s. Visits to the AOIs of the average-performing group occurred at intervals of 79s. Visits to the AOIs of the under-performing group occurred at intervals of 89.50s. This is summarised in Table 5.5.

**Table 5.5**: Intervals per group

| **Ability group** | **Intervals** |
|---|---|
| Top performing group | 57s |
| Average performing group | 79s |
| Under-performing group | 89.50s |

The Tobii Technology (2010:6) indicates that most people need between 50 - 60ms (0.05-0.06s) looking at a word to perceive it. When looking at a picture or illustration, people need to look at it for more than 150 ms (0.15s) before being able to interpret what they saw. According to Table 5.5, the top performing group perceived lesson information in intervals of 57s (intervals 22s shorter than the average-performing group and 32.50s shorter than the under-performing group). The average-performing group perceived the lesson information in intervals of 79s and the under-performing group perceived it in intervals of 89.50s. Thus, the average-performing natural science learners perceived lesson information in intervals that were 10.50s shorter than the under-performing natural science learners who used the longest intervals looking at the lesson in order to perceive the information. Although each participant watched the lesson presentation (slides 1-13) for the exact same length of time (9m54s), the different ability groups accessed the information in varying intervals and thus at a different tempo. The top-performing group accessed the information more quickly (in shorter intervals) than the other groups, and this could have influenced the efficiency with which they accessed the information. Mabila et al.'s (2014) study on eye-tracking also indicated differences in the user-performance among different skilled groups which was influenced by the effectiveness and efficiency with which each group was able to access online learning.

## 5.7 FINDINGS: MCQ AND THINK-ALOUD QUESTIONS

Table 5.6 summarises the results of the MCQ test given to indicate the learners' concept gains after the presentation of the lesson on the cell (slides 1-13) and the responses to the first think-aloud question which required from the participant to evaluate the difficulty of the material presented.

**Table 5.6:** Results of the MCQ and the first think-aloud question

| Participant | Score for MCQ | Rating of the difficulty of the material (first think-aloud question) |
|---|---|---|
| **Participant 1** | 80% | Easy |
| **Participant 2** | 40% | Difficult |
| **Participant 3** | 80% | Difficult |
| **Participant 4** | 80% | Easy |
| **Participant 5** | 50% | Difficult |
| **Participant 6** | 80% | Easy |
| **Participant 7** | 0% | Easy |
| **Participant 8** | Missing | Missing |
| **Participant 9** | 70% | Difficult |
| **Participant 10** | 30% | Easy |
| **Participant 11** | 30% | Difficult |
| **Participant 12** | 40% | Easy |

The results of the MCQ test gives an indication of the participants' concept gains accrued as a result of their viewing of the lesson presented during the video-recording. The MCQ covered information presented on all thirteen slides and was not based only on Slide 13. Table 5.6 indicates that the mean score in the MCQ for the top-performing natural science learners was 70%. The mean score in the MCQ for the average-performing natural science learners was 65%. The mean score in the MCQ for the under-performing natural science learners was 42.5%.

The scores in the MCQ are congruent with the grades obtained for each of the groups as also indicated in Table 5.7.

**Table 5.7: The mean for the MCQ and for the NS First semester, 2014 per ability group**

| Participants | Mean for MCQ | Mean for NS for first semester, 2014 |
|---|---|---|
| Top-performing NS learners | 70% | 88% |
| Average-performing learners | 65% | 55% |
| Under-performing leaners | 42.5% | 28,5% |

The mean for the first semester in natural science for the three groups is based on the data provided in chapter 4, Table 4.1. Participant 7, however, obtained zero for the test although she answered all the questions and indicated that the content was ‘easy’.

Furthermore, after the completion of the online MCQ test, I asked the participants a second think-aloud question and made field notes of their responses. The second think-aloud question was formulated as follows, “Were you satisfied with the manner in which the educator conveyed the subject matter?” State a reason for your answer.

**Table 5.8: Summary of the responses to the second think-aloud question**

| **Participant** | **Response to second think aloud question** |
|---|---|
| **Participant 1** | Yes. The educator spoke at a good pace and did not drift off the topic. I liked the pictures and felt that overall it was good. |
| **Participant 2** | I felt that the lines on the PowerPoint were a bit distracting. I felt that the lesson was good but there were “some stuff” that I did not understand. |
| **Participant 3** | Yes. The educator went back to remind the learners about the subject matter taught earlier in the lesson. |

| | |
|---|---|
| **Participant 4** | I found the situation too static. The lesson progressed too slowly. |
| **Participant 5** | Yes, the topics were properly explained and made it possible to easily understand. |
| **Participant 6** | Yes. Everything was well organised and that I was able to understand everything. |
| **Participant 7** | Yes. The lesson was “basic and simple”. It was easy to concentrate since the educator stood still as movement distracts me. |
| **Participant 8** | Missing |
| **Participant 9** | Yes. I wanted “more repetition” since “some information was difficult”. |
| **Participant 10** | No. I prefer the lesson to “be real”. Looking at the computer monitor makes my eyes “sore”. |
| **Participant 11** | Yes. The explanation of the lesson went well and made it easier. |
| **Participant 12** | Yes, “everything was clearly explained”. |

Table 5.9 suggests that seven of the eleven participants were satisfied with the way in which the educator conveyed the subject matter. Two participants (2 and 9) felt that the technical presentation of the PowerPoint was distracting, and that more repetition of the “difficult” subject matter was needed in the narration. Two participants (4 and 10) preferred a live classroom situation, since watching the video-recorded lesson was a strain on the eyes and “too static”. The latter objection was an obvious limitation of the study, but this concern relating to the choice of the eye-tracking technology is explained in paragraph 5.9.1.

## 5.8 FINDINGS: OBSERVATION

A brief description is given of general observations of each participant during the data-gathering as recoded in my field notes, and enriched by the video-recording (Chapter 4). The time of day of the data-gathering is indicated and the score in the MCQ is given.

**Participant 1** (Monday, Lesson 7: 2.15pm-2.30pm)
Participant 1 was very enthusiastic and lively, despite it being the last lesson of the day, and noises generated by workers on the roof.

**Video footage of Participant 1:**
Eye movements back and forth between the educator and the PowerPoint. Refers to PowerPoint when the educator mentions a fact that can be found on the PowerPoint and when the educator points at the PowerPoint. Participant 1 seems to be constantly looking at the educator. Eye movements are smooth and not haphazard.

**Score for MCQ: 80%**

**Participant 2** (Tuesday, Lesson 6: 12.30pm-12.50pm)
Participant 2 found it difficult to sit still, and was moving forward and backward, trying to get comfortable.

**Video footage of Participant 2:**
Participant 2 watched the lesson intently, focussing on the educator and also on the PowerPoint. The participant's eye movements did not always end in fixations. The participant fixated where the educator pointed to the PowerPoint.
**Score for MCQ: 40%**

**Participant 3** (Tuesday, Lesson 2, 9.00am-9.20am)
Participant 3 watched the lesson very intently.

**Video footage of Participant 3:**

Participant 3 watched intently, looking mainly at the PowerPoint, and glancing intermittently at the educator.

**Score for MCQ: 80%**

**Participant 4** (Monday, Lesson 5, 12.25pm-12.40pm)
Participant 4 appeared very relaxed.

**Video footage of Participant 4:**
Participant 4 seldom looked at the educator and focused more on the PowerPoint. In the response to the second think-aloud question, she expressed that the educator was "too static" and that she prefers the educator to move while teaching.

**Score for MCQ: 80%**

**Participant 5** (Monday, Lesson 2, 8.50am-9.10am)
Participant 5 engaged in the uninterrupted viewing of the lesson.

**Video footage of participant 5:**
The participant focused and fixated on the text on the PowerPoint mentioned by the educator. Saccadic pathways slightly erratic: the participant looked back and forth rapidly without fixating on anything. She focused mainly on the PowerPoint and very seldom looked at the educator. When the participant did eventually look at the educator, she looked mainly above the educator's head and very fleetingly at the educator's eyes.

**Score for MCQ: 50%**

**Participant 6** (Monday, Lesson 3, 9.35am-9.55am)
Participant 6 watched the lesson calmly and was focused.

**Video footage of Participant 6:**

He constantly looked at the face of the educator and focused on what the educator was saying. He looked at the PowerPoint but looked twice as much at the educator. His saccadic path was a bit erratic at times. At times he just listened and did not look at either the PowerPoint or the educator.

**Score for MCQ: 80%**

**Participant 7** (Monday, Lesson 4, 11.35am-12.00pm: after first break)

Participant 7 appeared to watch the lesson intently

.

**Video footage of Participant 7:**

No video footage was recorded due to technical problems.

**Score for MCQ: 0%**

**Participant 8** (Tuesday, Lesson 8, 2.25pm-2.45pm): Missing data

**Participant 9** (Tuesday, Lesson 4, 11.00am-11.15am)

Participant 9 was very restless and coughed periodically while watching the lesson.

**Video footage of participant 9:**

Eye movements were erratic. Very little attention to the educator’s pointing on the PowerPoint. Focused on the educator but rubbed his eyes and scratched his face; appeared distracted.

**Score for MCQ: 70%**

**Participant 10** (Tuesday, Lesson 5, 11.45am-12.00pm)

Participant 10 watched the lesson intently.

**Video footage of participant 10:**

Minimal interaction with the PowerPoint and the educator. Fixated extensively on the diagrams.

**Score for MCQ: 30%**

**Participant 11** (Monday, Lesson 4, 12.00pm-12.15pm)

Participant 11 was very fidgety throughout the viewing and took a while to settle to watch sporadically.

**Video footage of participant 11:**

Did not look at the educator or the PowerPoint. Eye movements were haphazard. Did not follow on the PowerPoint with what the educator was saying and pointing to. No prolonged fixations. Seemed disinterested.

**Score for MCQ: 30%**

**Participant 12** (Monday, Lesson 1, 8.05am-8.20am)

Participant 12 watched the lesson intently while making slight shuffling movements.

**Video footage of participant 12:**

Eye movements were haphazard and erratic. Her fixations did not match up with what was being spoken of or pointed at by the educator. Her saccadic pathways were extremely erratic. Her eye movements or saccadic pathways did not necessarily end in fixations. She appeared fidgety and on occasion touched her head.

**Score for MCQ: 40%**

## 5.9 DISCUSSION OF THE PROCESS AND FINDINGS

In this section attention is firstly given to the findings which relate to the procedures and the process of the research (5.9.1 and 5.9.2). I deem these useful for further eye-tracking studies. Thereafter, I give attention to the general findings as represented in the gaze-plots, heat-maps and bar graphs.

### 5.9.1 Usefulness of the Tobii X2-60 eye-tracker

Chosen from a wide variety of eye-tracking equipment (cf. Chaper 3), the Tobii X2-60 eye-tracker was used in this study for the following reasons. The Tobii X2-60 is suitable for detailed research of natural behaviour (cf. par. 3.3.1.1). It is a small, portable eye-tracking lab and easy to transport. In this case the Tobii X2-60 was easily transported by the technician from Pretoria to Cape Town, the location of the study. Furthermore, this eye-tracker allows a considerable amount of head movement without affecting accuracy and precision (Tobii Technology, 2010). Due to its size the Tobii X2-60 eye-tracker could also be comfortably housed in the small private booth prepared for the study (cf. Figure 4.2) and this prevented visual disturbances, such as glare or reflections, as well as any other distractions, such as noise or interruptions. Finally, I knew that the participants would feel comfortable with a computer and video-recording as they work with personal computers frequently, since the school is well-resourced with IT equipment. Thus, this finding emanating from the process forms an important practical recommendation for further studies where a researcher has to select suitable eye-tracking equipment from a wide range. Its limitations are, however, acknowledged (cf.; par. 5.9.2)

### 5.9.2 Calibration concerns

As has been discussed fully in chapter 4, calibration procedures are an important and integral part of any eye-tracking research. In this study, in spite of careful planning, participant 8 could not be eye-tracked. The technician followed a friendly, professional and disciplined process with each participant (cf. par. 4.3.3.3). Once the participant was successfully calibrated, he would move out of the participant’s sight to the side of the booth, where the two chairs can be seen on the side (cf. Figure 4.2). At this point in time the participant would press the space bar and the lesson would start on the monitor. Participant 8 subsequently slid down into the chair to watch the lesson. Since

Participant 8 was slouching, the eye-tracker could not pick up the eye movements. Problems with calibration in eye-tracking research are, however, not unknown. Granka et al. (2004) discovered that the data of 10 participants of a total of 36 participants could not be used in a study due to calibration problems (cf. par 3.4.7).

A head-mounted eye-tracking device (cf. Figure 3.4) was used successfully by Rosengrant et al. (2009) in a study with eleven university science students to compare expert and novice's eye-gaze patterns (cf. par. 3.4.4). Also eye-tracking glasses (cf. Figure 3.3) were used by Chen (2012) to eye-track eight university science students in a natural setting, as well as by Little (2012) who observed eight college students wearing eye-tracking glasses in a natural setting (cf. par 3.4.4). However, I decided against using eye-tracking glasses in a natural setting so as to exclude as many variables that could possibly have an adverse effect on the study. While the eye-tracking glasses may have been successfully implemented at university level, the participants in my study were 14-15 years of age, and I felt the equipment would prove cumbersome for a secondary school learner. Head-mounted equipment is also expensive, it carries the risk of damage by the users, and in a secondary school classroom the novelty of head-mounted equipment may also create an overall disruption of the lesson. Therefore the booth (cf. Figure 4.2), together with the participation of individuals, was the best for my study.

### 5.9.3 The educator and the PowerPoint as AOIs

Bringham et al. (2001) emphasise the role of visual attention to comprehend text, pictures and reading in education (cf. par 2.4.2). Ayesha et al. (2011) state that when teachers endorse eye contact, it enhances the learner's attention and contributes to favourable academic results (cf. par 2.4.2). These studies suggest the importance of visual attention to pictures, diagrams and text, in contrast to attention given to the educator during teaching and learning. The question posed in this exploratory study was to determine how the learners' visual attention was distributed during the natural science lesson on a visual presentation (PowerPoint) and the educator. The study showed that the PowerPoint as an AOI received more visual attention in comparison to the educator as an AOI (cf. Figures 5.5; 5.6 and 5.12 and Table 5.2; 5.3). These findings are corroborated by the following studies. Rosengrant et al (2011) investigated the gaze patterns of undergraduate students attending a physical science lecture using the Tobii eye-tracking glasses. They found that students mostly paid attention to the PowerPoint slides and very little attention was given to the lecturer. Yang et al., (2013) considered what held university learners' attention during a multimedia PowerPoint presentation of dinosaurs by using the faceLab eye-tracking system. The 21 science students who were eye-tracked individually showed a great preference for diagrams and texts. In their eye-tracking study of mathematical representations, Bolden et al. (2015) found that young children preferred the picture representations of the number line in maths more than the symbolic representations. Slykhuis et al., (2005) also found that pre-service science educators who were eye-tracked while viewing PowerPoint slides with a mix of relevant and irrelevant slides devoted more visual attention to relevant slides. This finding has implications for classroom instruction, as mentioned in 5.5.2 and in the recommendations emanating from the study.

### 5.9.4 Eye-tracking as indicator of cognitive processing and performance

The Tobii Technology (2010) cautions that care must be taken to make assumptions about the relation between visual attention (as revealed by fixations and eye movements) and what subjects are thinking about. The interpretation of visual attention and its link to cognitive processes and performance (also interest and motivation) should thus be done with care. To obtain a clearer picture of the relationship between visual attention patterns and cognitive processes during eye-tracking and their possible effect on performance, eye-tracking could be followed up by participant interviews which explore the thinking processes, or the eye-tracking should be accompanied by think-aloud protocols where the participants describe what they are thinking about as they view an object or scene (Tobii Technology, 2010).

While giving due consideration to the above, the findings of this study showed interesting differences per ability group. Although all three groups of participants focused primarily on the PowerPoint as AOI, their results differed in terms of the attention given to both the PowerPoint and the educator based on the findings of the gaze-plot (cf. 5.3.3), the heat-map (cf. 5.4.3) and fixations (cf. 5.5.1). The under-performing group consistently focused less visual attention on the AOIs in comparison to the average- and top-performing natural science learners. Moreover, their performance in the MCQ was also the least successful (cf. Table 5.7) in comparison to the other two groups. This suggests some link between visual attention and performance, which has also been indicated by other eye-tracking studies. For example, Rosengrant et al. (2009) established differences in eye-gaze patterns of experts and novices regarding electrical circuits. The novices' eye-gaze patterns went back and forth whereas the experts' eye-gaze patterns followed a definite path and were more controlled (cf. par. 3.4.4). Van Rooy and Pretorius (2013) found that patterns of visual attention based on eye-tracking were linked to significant differences in the reading ability of strong, average and weak Grade 4-learners in a multilingual setting (cf. par 1.1). Finally, Duchowski (2002:455) stressed the diagnostic role of eye tracking in providing objective and quantitative evidence of a participant's visual and overt (attentional) processes which can be linked to performance. This has implications for the use of slide presentations and of other visuals which may compete for attention with the educator during learning. In this regard, Bolden et al. (2015) argue that teachers should be aware that children with a low performance in maths require greater focus on picture representations rather than on symbolic representations in order to improve their performance. Furthermore, the speed with which the three groups accessed information on the AOIs differed. The under-performing groups accessed information more slowly that the other two groups. This implies that the tempo at which instruction takes place in a mixed-ability class should be adjusted to accommodate all the learners.

## 5.10 CONCLUDING REMARKS

In this chapter the findings of the exploratory eye-tracking study were indicated.

The final chapter, chapter 6, provides a summary of the research, recommendations for practice and areas for future study.

# CHAPTER SIX

# SUMMARY OF THE RESEARCH, FINAL CONCLUSIONS AND RECOMMENDATIONS

## 6.1 INTRODUCTION

The aim of this study was to address the role of eye contact in promoting the effective learning of natural science in a secondary school (cf. par 1.2). In chapter one I discussed the background to eye contact as a means of non-verbal communication in the classroom, formulated the problem and the aims, and described the method of an exploratory, descriptive study, using eye-tracking technology.

In this concluding chapter I will present a summary of the literature study and the empirical investigation in the light of the problem formulation and the aims. I will again refer to the key findings, and will make recommendations for the improvement of practice. I will also propose areas for future research, note the limitations of the study, and outline the final conclusions.

## 6.2 OVERVIEW OF THE STUDY

The aims of the study were indicated in 1.3, and were presented to address the main research question, namely “What is the role of eye contact in promoting effective learning in natural science in the secondary school? This research question was sub-divided into the following research questions:

This study aims to address the main research question, namely what is the role of eye contact using eye-tracking technology in promoting effective learning in natural science in the secondary school? This research question is sub-divided into the following research questions:

i) What theoretical perspectives and relevant extant findings in the literature inform the use of eye contact, its relationship to attention, and its role in teaching and learning? (Chapter 2).

ii) What is the current state of the research concerning eye-tracking technology in the learning situation with particular reference to science learning as a means of determining visual attention, and to identify the gaps in the current research? (Chapter 3).

iii) How does a mixed-ability group of selected Grade 9-learners (natural science) distribute visual attention as measured by a Tobii X2-60 eye-tracker during the viewing of a video recording of a natural science lesson on the structure of the cell, with special reference to the educator and the PowerPoint as the two Areas of Interest (AOIs)? (Chapters 4 and 5).

iv) Based on the findings of the literature and the exploratory inquiry, what recommendations can be made for the improvement of classroom practice regarding the use of eye contact to effect optimal learning in the secondary school classroom, with particular reference to natural science? (Chapter 6).

The overview of the exploratory study highlighted the literature review and the empirical enquiry in the following sections.

### 6.2.1 The literature review

The literature review was discussed in chapters 2 and 3. Chapter 2 highlighted the theoretical perspectives that inform the role of eye contact, its relationship to attention, and its role in teaching and learning. Chapter 3 focused on the current state the research in respect of eye-tracking technology in the learning situation, as well as the limitations of eye-tracking.

Chapter 2 addressed the following research question: What theoretical perspectives and relevant extant findings in the literature inform the use of eye contact, its relationship to attention, and its role in teaching and learning? The role of eye contact as a vital aspect in the teaching and learning environment is underpinned by the learning theories of the prominent psychologists, Vygotsky, Piaget and Bandura. Their overarching premise is that, among others, cognitive development takes place during social interaction (cf. par. 2.2.1 Vygotsky's sociocultural view of development - cf. par 2.2.2; Piaget's theory of cognitive development - cf. par. 2.2.3; Bandura's social learning theory). Building upon these learning theories, a number of studies were reviewed stressing the importance of eye contact during teaching and learning. Dhu (2011) maintains that good eye contact is imperative to social interaction (cf. par. 2.3) so that learning can take place. Bringham et al. (2001) contend that eye movement for comprehension and reading is essential in learning (cf. par. 2.4.2). According to Zhang (2006), educators are able to assess whether more or less explanation is required by observing the learners' eye contact, and that eye contact is able to draw out responses from hesitant learners. Ellen (2000) cautions educators to make appropriate eye contact with their learners so that the classroom may be a place of acceptance and physical and emotional safety (cf. par. 2.3). Three studies strongly leant in favour of eye contact in a learning environment: Haskins (2000), Benzer (2012) and Hains-Wesson (2011) (cf. par. 2.4.2). Haskins (2000) instructs educators to maintain eye contact; Benzer (2012) identifies the eyes as being important to body language; and Hains-Wesson (2011) discovered that 91% of the students attribute eye contact to helping them to pay attention, while 74% of the students said that eye contact encouraged their interest in the topic being discussed. The key areas in which eye contact plays a vital role were discussed which included, cooperative learning (cf. the essential role of eye contact in 2.4.3); classroom discipline (cf. 2.4.4); and technologically-based learning (2.4.5). The important role of eye contact in special needs education was highlight with regard to autism (cf. 2.4.6.1), ADHD (cf. 2.4.6.2), the Fragile X Syndrome (cf. 2.4.6.3) and TBI (2.4.6.4).

Chapter 3 addressed the following research question: What is the current state of the research concerning eye-tracking technology in the learning situation with particular reference to science learning as a means of determining visual attention, and to identify the gaps in the current research? The current state of eye-tracking methodology to determine eye contact in general, as well as in educational and other settings was presented. Poole and Ball (2005) define *eye-tracking* as the measuring of an individual's eye movements so that a researcher knows where a person is looking at any given time, as well as the sequence in which the individual's eyes shift from one location to another (cf. par. 3.2). An eye-tracker measures eye positions and eye movements (cf. par. 3.2.1). Several providers produce eye-tracking technology. Tobii technology is the leading eye-tracking device in the world (cf. par. 3.3.1). The Tobii X2-60 Eye-tracker (used in my study), an unobtrusive eye-tracker embedded in the computer, can be used for detailed research (cf. par. 3.3.1.1). Another Tobii eye-tracker also used in research is the Tobii T120 Desktop Eye-tracker (cf. 3.3.1.2) which has replaced the Tobii 1750 Eye-tracker (3.3.1.3). There are also a number of eye-tracking devices, including a head-mounted apparatus and related eye-tracking software, such as ERICA (cf. 3.3.2), Noldus (cf. 3.3.3), Traktext (cf. 3.3.4), SMI (cf. 3.3.5), RED 250 (cf. 3.3.6), HED (3.3.7), faceLAB (3.3.8). The use of eye-tracking studies in eye-tracking technologyare extensive in the study of infants (cf. 3.4.1), the understanding of mathematics (cf. 3.4.2), online learning (cf. 3.4.3), specific learning programmes such as Schoolrooms (cf. 3.4.3.1) and MetaTutor (3.4.3.2), science education in schools and at university (cf. 3.4.4), textual research (3.4.5), the assessment of special-needs children (3.4.6), computer interfaces (3.4.7), marketing and consumer behaviour (3.4.8), gender research (3.4.9), and faked responses (3.4.10). Finally, the limitations of eye-tracking were outlined (cf. 3.5).

### 6.2.2 The exploratory study

The empirical inquiry addressed the third research questions: How does a mixed-ability group of selected Grade 9-learners (natural science) distribute visual attention as measured by a Tobii X2-60 eye-tracker during the viewing of a video recording of a natural science lesson on the structure of the cell, with special reference to the educator and the PowerPoint as the two Areas of Interest (AOIs)? (Chapters 4 and 5). The research design of the exploratory study undertaken was outlined in a summary in 1.4.2 and fully described in chapter 4. The findings were presented in Chapter 5. An exploratory inquiry was used to obtain preliminary descriptive data regarding the learners' eye contact during a video presentation of a natural science lesson, using Tobii eye-tracking methodology. The study was carried out at a public secondary school in

Cape Town administered by the Western Cape Education Department (WCED), selected by means of convenience and purposive sampling. The aim of the empirical study was to identify and analyse patterns of visual attention of the participants according to their gaze on a PowerPoint presentation (cf. 4.3.3.4) and the educator as the two designated AOIs. The Tobii X2-60 eye-tracker was used (cf. 4.3.3.1). The description of the research design included a discussion of sampling in 4.3.2. Twelve (12) Grade 9 natural science learners were purposefully selected by means of maximum variation sampling (McMillan & Schumacher, 2010), to provide a group of mixed ability: four learners with an overall score of 80% or above (top performing learners), four learners with an overall score of 54% - 55% (average performing learners), and four learners with an overall score of 24% - 37% (under-performing learners). The grades were based on the first semester, 2014, scores in natural science as provided by the Head of the Department (natural science). During the calibration process (cf. 4.3.3) participant 8 was not adequately calibrated, and her data were excluded. Thus, the final sample comprised eleven (11) participants (average performing group = 3 learners), and the data-analysis was carried out on the two designated AOIs. The Tobii X2-60 Eye-tracker was described (cf. 4.3.3.1); the research setting (cf. 4.3.3.2) and procedures (cf. 4.3.3.3); the recorded lesson (cf. 4.3.3.4); the MCQ used to assess their recall of the instructional content (cf. 4.3.3.5); reliability and validity (cf. 4.4); the limitations of eye-tracking, also with particular reference to the study (cf. 4.4.3); and the ethical measures taken by means of institutional and departmental permission, permission from the school and the parents of the learners, and the assent of the learners (cf. 4.5). The data were analysed by the expert technician using Tobii software. The findings were presented in Chapter 5.

## 6.3 KEY FINDINGS

The findings of this exploratory study of the role of eye contact using eye-tracking methodology during the teaching of a Grade 9 natural science lesson were presented in Chapter 5. The findings were presented according to gaze-plots (cf. 1.5.6), heat-maps (cf. 1.5.5) and bar graphs to illustrate the distribution of the visual attention. The heat-maps and gaze-plots were based on the eye-tracking of the participants’ visual attention on Slide 13, related to The Cytoplasm (cf. Figure 5.3). The gaze-plots and heat-maps provided an overall picture of the participants' visual attention with regard to the educator and PowerPoint, and also indicated attention to certain zones on the PowerPoint (the diagram of the cell and the term, ectoplasm). The combined gaze-plot in Figure 5.4 indicates that the participants focused predominantly on the face of the educator (making virtual eye contact) and the diagram of the cell (Slide 13). Figure 5.4 also indicates that the learners looked specifically to where the educator pointed with a pointer on Slide 13 while she was teaching the Cytoplasm: the term, Ectoplasm (cf. par. 4.3.3.4; Figure 5.3). The heat-map in Figure 5.8 indicates that the educator's face, particularly her eyes, received considerable attention, as indicated by the red area over her right eye. This suggests that although the participants were looking at a video-recording, which did not allow direct social interaction, they still fixated on the eyes of the educator, thus making 'virtual' eye contact (cf. par. 2.4.5). Further discussion of the following results can be found as indicated, regarding a comparison of gaze-plots per ability group (cf. 5.3.2), and a comparison of the combined heat-maps per ability groups (cf. 5.4.2). A number of tables served to summarise the following information, namely the calibration of the participants (Table 5.1), the TFD per ability group (see Table 5.2), the MCQ and the first think-aloud question, and the responses to the second think-aloud question (Table 5.6). The general observations of each participant were given during the data gathering (cf. 5.8), followed by the general discussion of the procedures and findings (cf. 5.9). Bar graphs were used to indicate the durations of the fixation and the visit (Fig. 12-15). The latter findings confirmed that the participants' primary attention was focussed on the PowerPoint rather than on the educator, and differences emerged for the three ability groups. The under-performing group showed the shortest fixation on both AOIs. These findings have implications for teaching and learning in the presentation of a natural science lesson.

## 6.4 RECOMMENDATIONS FOR THE IMPROVEMENT OF PRACTICE

The final research question: Based on the findings of the literature and the exploratory inquiry, what recommendations can be made for the improvement of classroom practice regarding the use of eye contact to effect optimal learning in the secondary school classroom, with particular reference to natural science? Guided by the literature review and empirical inquiry, recommendations to improve how eye contact functions and can promote effective learning in natural science in a secondary school are suggested. The recommendations are based on the findings of the literature review and the exploratory study. They are as follows:

(a) During their pre-service training and professional development the teachers should be informed of effective strategies to incorporate eye contact in social environments, such as in the classroom, since meaningful learning takes place in social settings (cf. 2.2.1 to 2.3). Eye contact can be used to motivate the learners, to maintain positive classroom discipline, and to promote positive teacher-learner relationships. It is a particularly important strategy in large classes, or during the teaching of the so-called 'difficult subjects', such as natural science (Sedibe, Maema, Fourie & Peter, 2014), in order to keep all learners on task.

(b) Different cultures demand and attach value to varying types of non-verbal communication, such as eye contact. Educators should be made aware of the various preferences represented in culturally-diverse classrooms in order to engage with each learner in a meaningful manner.

(c) Since gender is also a factor in how eye contact is used within various cultures, the educators should be fully aware of the vital aspect of the role of eye contact and gender. This is of importance in natural science classrooms where there is traditionally an under-representation of girls, and where the girls should be made to feel secure and accepted, in order to pursue further studies in natural science (Tennenbaum & Leaper, 2003).

(d) Appropriate eye contact between the educator and the learner assists in creating an environment of acceptance and emotional safety for the learner. When teaching natural science, which is perceived as a difficult subject by both teachers and learners (Sedibe et al., 2014), a secure environment in which the learners are encouraged to take cognitive 'risks' to achieve success is of great importance.

(e) Careful observation of the avoidance of eye contact by the learner with the educator may be an indication of a lack of interest in the natural science subject matter, or that the learner may be struggling with the comprehension of the subject matter, which should alert the educator to possibly move at a slower pace, or that more repetition of the subject matter is needed.

(f) When teaching a lesson using a PowerPoint presentation, the educator has to be mindful that the PowerPoint will attract more attention, particularly when a slide is first presented. The learners need to be given sufficient time to scan the visual information to first obtain an overall picture, and then to read the text. Learners of different abilities may need different lengths of time to access the information (cf. 5.9; Smith et al., 2012) and this has implications for meeting the needs of a mixed-ability natural science class.

Diagrams and pictures require more time for information processing (cf.5.9; Yang et al., 2013) by learners. Therefore, diagrams and pictures (e.g., in PowerPoint presentations, also print, illustrations, maps or charts) should be presented in such a way that the learners have sufficient time to combine information accessed from these visuals with the teacher's narration of the lesson. Bolden et al. (2015) state that educators need to be clear about the possible drawbacks of representations for lower-attaining children, and that the progression in their understanding of the representation needs to be taken into account by the educator.

(g) The educators should be aware that they will receive less visual attention while the students are gazing back and forth at them from a PowerPoint presentation (or other visuals). A possible strategy is to allow the learners sufficient time to look at a PowerPoint slide and then block the slide while a further explanation is given. PowerPoint slides should not be left on indiscriminately throughout the duration of the lesson while the educator moves on to new content, as they will serve as distractors (Yang et al., 2013). Furthermore, educators should be aware that a PowerPoint presentation, albeit its many advantages as a teaching aid, is a distractor (Rosengrant et al., 2009), and it should be used judiciously. Its use should always be justified in terms of the aims of the lesson. Yang et al., (2013) advise that when using multimedia material such as a PowerPoint in the classroom, a written text or note is essential as supplementary to the PowerPoint. It is recommended that the learners receive a printout of the PowerPoint slides, such as those used in this study, as notes to keep and to refer to when doing revision.

Educators should be aware that signals, such as pointing at a particular term on a PowerPoint presentation (or any other visual) with a pointer, may help the learners (particularly the under-performing learners) to locate important information quickly and easily. Natural science is rich in complex difficult terminology which the students often find challenging to access (Abimbola, 1988) and the teacher's cues are important for effective instruction, particularly with novice learners (Yang et al., 2013).

## 6.5 AREAS FOR FURTHER RESEARCH

The findings of this study in respect of the role of eye contact in promoting effective learning in natural science in the secondary school indicate the following areas of priority in the quest for further knowledge:

Similar studies involving eye-tracking during a multimedia lesson could be carried out in a classroom using head-mounted eye-tracking equipment.

The limited number of participants used in this study necessitates comparative research with individuals of varying abilities in natural science in grade 9, as well as in other secondary school grades.

The possibilities of conducting this study at primary school level and at tertiary level exist in a variety of learning areas.

From an exploratory perspective, more data could be gathered regarding the length of fixations to address the question whether the duration of fixation indicates cognitive understanding or a lack thereof.

More information regarding PowerPoint presentations could be acquired via eye-tracking methodology with regard to which components of the PowerPoint and which layout holds the attention of the participant on the PowerPoint - whether it is font size, colour, illustrations, diagrams or the layout.

## 6.6 LIMITATIONS OF THE RESEARCH

This study was non-experimental, cross-sectional, and based on a small purposive sample. The aim was exploratory and descriptive, and the findings cannot be generalised to the larger population of Grade 9 natural science learners at the school where the study was conducted. Furthermore, eye-tracking research requires expensive equipment and technical assistance in its application and analysis. Thus, it is acknowledged that its usability in a study such as this is limited, the data-extraction is labour-intensive and there exist many difficulties in interpreting the data (Jacob & Karn, 2003). The prolific amount of data generated in this study could be overwhelming, and therefore I, together with the technician, overcame this difficulty by using only the data generated by Slide 13 of the PowerPoint in the heat-maps and gaze-plots, and primarily the AFD per ability group, and per combined group of all the participants. Individual data per participant were generated but not used, due to it being unmanageable. Finally, the limitations due to calibration were acknowledged and described in detail (cf. 4.3.3.3; 5.2).

## 6.7 FINAL CONCLUSIONS

The landscape of learning is on a course laden with change as we move towards a digital classroom. Future learners will thus engage in using more electronic media than traditional books. Eye-tracking in the virtual classroom produces information that can be used to support educators in their instruction in the emerging digital classroom of the future. This study formed a novel basis for further inquiries into how eye-tracking methodology can supply the educators with valuable information about the role of eye contact during teaching and learning.

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APPENDIX A

UNISA college of education

## Research Ethics Clearance Certificate

This is to certify that the application for ethical clearance submitted by

**LP Volmink [36041513]**

for a M Ed study entitled

**The role of eye contact in promoting effective learning in natural science in the secondary school**

has met the ethical requirements as specified by the University of South Africa College of Education Research Ethics Committee. This certificate is valid for two years from the date of issue.

Prof KP Dzvimbo
Executive Dean : CEDU

Dr M Claassens
CEDU REC (Chairperson)
mcdtc@netactive.co.za

Reference number: 2014 JUNE /36041513/MC

19 JUNE 2014

## APPENDIX B: PERMISSION FROM WCED

Western Cape Government
Education

Directorate: Research

Audrey.wyngaard2@pgwc.gov.za

tel: +27 021 467 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

wced.wcape.gov.za

**REFERENCE:** 20140319-26839

**ENQUIRIES:** Dr A T Wyngaard

Mrs Leonora Volmink
13 D. F. Malherbe Street
Goodwood
7460

**Dear Mrs Leonora Volmink**

**RESEARCH PROPOSAL: THE ROLE OF EYE CONTACT IN PROMOTING EFFECTIVE LEARNING IN NATURAL SCIENCE IN THE SECONDARY SCHOOL**

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **26 March 2014 till 30 September 2014**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

**The Director: Research Services**
**Western Cape Education Department**
**Private Bag X9114**
**CAPE TOWN**
**8000**

We wish you success in your research.

Kind regards.
Signed: Dr Audrey T Wyngaard
**Directorate: Research**
**DATE: 01 April 2014**

# APPENDIX C

## REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT HIGH SCHOOL

Dear Sir

I am currently busy with my MEd, (specialising in Natural Science), studies at UNISA. The Western Cape Department of Education (WCED) has approved my request to conduct research (see attached copy). I have special interest in the: **The role of eye contact in promoting effective learning in Natural Science in the Secondary School,** at the school site. The envisaged participants are 12 grade 9 Natural Science learners. Participating in the research will provide the educators with pertinent information regarding what holds a learners attention during learning. The learners will be expected to participate in an eye-tracking study and also to answer 10 Multiple Choice Questions, with 2 think-aloud questions. There will be no risks involved to any of the participants. Participation is entirely voluntary and all information will be kept confidential. The student's and school's name will not be revealed. No monetary rewards are given to participants. Participants are free to withdraw from the study at any point without being penalized. Participants are expected to indicate whether they agree or disagree to participate by completing a consent form. Permission will be obtained from learners' parents (see attached letter) and learners will also give assent to take part in the research (see attached letter). As required, the results of the study will be made available to the school. The results of the study will be discussed at school in a special information sharing session. The results of the research may be published in a scientific journal or presented at a scientific meeting.

This research is conducted under the supervision of Prof Eleanor Lemmer at UNISA (Department of Education). Prof Eleanor can be contacted on lemmeem@unisa.ac.za. Please feel free to contact me if you have any queries regarding the research or any other related matter.

Your support and willingness to allow the school to participate in this research is appreciated.

Thank you

Signature: ______________________ Date: _____

E-mail: Tel: Cell:
__________________________________________________________________

**INFORMED CONSENT FROM THE SCHOOL GOVERNING BODY (SGB)**

I have been given the chance to read this consent form. I understand the information about this study. Questions that I wanted to ask about this study have been answered. My signature (on behalf of the SGB) indicates our wholehearted support for the study.

______________________________________________ ____________________ PRINCIPAL

(NAME IN PRINT) SIGNATURE

DATE_____________________

# APPENDIX D

# PARENTAL PERMISSION FOR CHILDREN PARTICIPATION IN RESEARCH

**Title: The role of eye contact in promoting effective learning in Natural Science in the Secondary School.**

Dear parent

The purpose of this form is to provide you (as the parent of a prospective research study participant) information that may affect your decision as to whether or not to let your child participate in this research study. Read the information below permission for your child to take part. If you decide to let your child be involved in this study, this form will be used to record your permission.

If you agree, your child will be asked to participate in a research study regarding the role of eye contact in promoting effective learning in Natural Science. The purpose of this study is **to determine whether eye contact is necessary in order for the learner to acquire subject matter.**

If you allow your child to participate in this study, he or she will be asked to:

(1) Watch a 10 minute natural science lesson.

(2) Answer 10 multiple choice questions based on the lesson and 2 questions based on how they felt the lesson was presented and whether they thought the subject matter was difficult.

This study will take 30 minutes and there will be **a total** of 12 learners in this study. Each learner will watch the video one at a time. Your child's eye movements **will** be tracked by the Tobii eye-tracker which is embedded in the computer monitor. The equipment is unobtrusive and it will be operated by an expert technician, Mr Adriaan Pottas, Department of Computer Science, Unisa. Mr Pottas and I will be present throughout your child's participation.

There are no foreseeable risks to participating in this study. The possible benefits of participation are to establish how best a learner acquires subject matter and the best way for the educator to impart the subject matter. Your child's participation in this study is voluntary. Your child may decline to participate or to withdraw from participation at any time. You can agree to allow your child to be in the study now and change your mind later without any penalty.

In addition to your permission, your child must agree to participate in the study. If you child does not want to participate they will not be included in the study and there will be no penalty. If your child initially agrees to be in the study they can change their mind later without any penalty. Neither you nor your child will receive any type of payment participating in this study.

Your child's privacy and the confidentiality of his/her data will be protected by not using your child's name in the data collected as well as the report. The anonymous data will be allocated to participant one, two, etc. Only the researcher and the technician will have access to this data. The data resulting from your child's participation may be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate it with your child, or with your child's participation in any study.

The eye-tracking data only records your child's eye movements by showing this information as dots and colour coding. This will, once again be reported by using the term: participant one, two etc. In no way will your child's name be revealed.

Prior, during or after your participation you can contact the researcher, **Leonora Volmink** at **021 5916700** or send an email to **leonorav@vodamail.co.za** for any questions or the study supervisor: Prof EM Lemmer, email: lemmeem@unisa.ac.za. This study has been reviewed and approved by The Western Cape Education Department**.**

You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow them to participate in the study. If you later decide that you wish to withdraw your permission for your child to participate in the study you may discontinue his or her participation at any time. You will be given a copy of this document.

________________________________

Printed Name of Child

________________________________

Signature of Parent(s) or Legal Guardian Date: ____________

________________________________

Signature of Researcher Date: ____________

## APPENDIX E

## LEARNER ASSENT FORM

**Title of study: THE ROLE OF EYE CONTACT IN PROMOTING EFFECTIVE LEARNING IN NATURAL SCIENCE IN THE SECONDARY SCHOOL.**

Dear ___________________

I am doing a study on way you focus your attention by means of eye contact during a natural science lesson in order for you to better understand your lesson. This study is part of my studies at the University of South Africa. The principal has given me permission to do this in your school.

I would like to invite you to be a special part of my study. I am doing this study so that I can find ways your teachers can use to enable you to grasp natural science better. This form is to explain to you what I would like you to do. There may be some words you do not know in this form. Please ask someone to explain any words that you do not know. You may take home a copy of this form to think about and talk to your parents about this before you decide if you want to be in this study.

My assistant, Adriaan Pottas, from the University of South Africa, and I will show you a video recording of a Grade 9 natural science lesson on a computer monitor. An eye-tracking device which is inside the monitor of the computer will collect information about your eye movements. This device will not harm or disturb you in any way. It is similar to a video recorder but it only records your eye movements and nothing else.

After you have watched this video, I will ask you to answer 10 multiple choice questions, as well as 2 questions based on your opinion online. These questions are all about the lesson you will have watched. I will mark your test afterwards but your name will not be on the test and it will not count for any marks at school. I will not share your test results with your teachers or parents. I will be writing a report on the study but I will not use anyone's name in the report. Watching the science lesson and completing the test will take about 30 minutes. You may decide that you do not want to be part of this study at any time.

If you choose to be in the study, you may stop at any time. No one will blame or criticise you. If you have any other questions about this study, you can talk to me or you can have your parent or guardian call me or email me: Mrs Leonora Volmink Phone number: 0215916700 Email: leonorav@vodamail.co.za or my study supervisor: Prof EM Lemmer email: lemmeem@unisa.ac.za

If you decide to be part of my study, you will be asked to sign this form. Do not sign the form until you have all your questions answered and understand what will happen to you.

----------------------------------------------------------------------------------------------------

CONSENT:

I have read this form. I have understood the information about my study. I am willing to be in the study.

Learner's name (print) ___________________

Learner's signature ___________________ Date: ___________________

Witness name (print) _________________

Witness signature __________________ Date: ________________

(The witness is over 18 years older and present when signed).

# APPENDIX F

## MCQ TEST

1. The basic structure of a living, human cell consists of:
A. Cell wall, cell membrane and nucleus.
B. Cell wall, cell membrane and cytoplasm.
C. Cell membrane, cytoplasm and nucleus.
D. Cell wall, cytoplasm and nucleus.

2. The cell membrane consists of:
A. Cellulose, phospholipids and proteins.
B. Phospholipids, proteins and cutin.
C. Proteins, carbohydrates and cutin.
D. Phospholipids, proteins and carbohydrates.

3. Membranes that do not allow any substance to pass through are:
A. Impermeable.
B. Permeable.
C. Selectively permeable.
D. Semi permeable.

4. DNA molecules are found on…
A. The nucleolus.
B. The chromatin network.
C. The nuclear membrane.
D. The nucleopore.

5. RNA molecules are found on…
A. The nucleolus.
B. The chromatin network.
C. The nuclear membrane.
D. The nucleopore,

6. The cell membrane is NOT …
A. The plasmalemma.
B. The plasma membrane.
C. A semi permeable membrane.

D. Surrounding the cell.

7. The nuclear membrane is…
A. Impermeable.
B. Selectively permeable.
C. Semi permeable.
D. Permeable.

8. The cytoplasm does not…
A. Consist of an ectoplasm and endoplasm.
B. Consist of an ectoderm and endoderm.
C. Have many important organelles, like the mitochondrion.
D. Have a non-granular ectoplasm and a granular endoplasm.

9. The nucleoplasm is not…
A. The fluid found inside the nucleus.
B. A suspension for other organelles in the nucleus.
C. Maintains the shape of the nucleus.
D. Is the liquid substance

10. Membranes that allow solvents and solutes to pass across it are…
A. Impermeable.
B. Permeable.
C. Selectively permeable.
D. Semi permeable.

Did your find the subject matter presented in the lesson and in the test difficult or easy?

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Did you find it easy to follow the lesson presented on the video? Give a reason for your answer.

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