The influence of animation on physical science learning in a grade 10 rural classroom

A thesis of limited scope submitted by

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of the Faculty of Education

University of Pretoria

Supervisor: Dr Pamela Ann Miller

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CLEARANCE CERTIFICATE

ANNEXURE D

UNIVERSITY OF PRETORIA

FACULTY OF EDUCATION

RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE	**CLEARANCE NUMBER : CS08/03/01**
DEGREE AND PROJECT	MEd. Computer Integrated Education The influence of animation on physical science learning in a grade 10 rural classroom.
INVESTIGATOR(S)	A. Carolus - 25415931
DEPARTMENT	Curriculum Studies
DATE CONSIDERED	27 October 2008
DECISION OF THE COMMITTEE	APPROVED

This ethical clearance is valid until 31 March 2009.

CHAIRPERSON OF ETHICS COMMITTEE Dr Salomé Human-Vogel

DATE 29 January 2009

CC Prof. W Fraser
Dr. P Miller
Student Administration

This ethical clearance certificate is issued subject to the following conditions:

1. A signed personal declaration of responsibility
2. If the research question changes significantly so as to alter the nature of the study, a new application for ethical clearance must be submitted
3. It remains the students' responsibility to ensure that all the necessary forms for informed consent are kept for future queries.

Please quote the clearance number in all enquiries.

ABSTRACT

This research study investigates how English First Additional Language learners respond to animation in Physical Science learning in a rural Further Education and Training (FET) Grade 10 class.

A study was implemented to find answers to the main question: "How do learners respond to animation in the learning environment?"

The sub questions are:
In an interactive learning environment with animations …

1. what learning takes place from a cognitive, affective and psychomotor perspective and how?
2. what language problems do the learners experience and how do they deal with them?

The study employed a computer program with which learners engaged for an average of 40 - 45 minutes. The animation elicited numerous cognitive, affective and psychomotor behaviours in the learners.

The observations describe cognitive activities, such as a progressive decrease in times taken to complete games successfully, a controlled display of information for brief periods, patterns of buttons pressed varied amongst the groups, and the learners' proficiency as game playing increased.

Results pointing to affective activities included the learners' perseverance to master the game and a wide range of emotions that were displayed during the execution of the animation.

The results showed the following:

- little time was spent on reading instructions with learners merely giving them a cursory glance;
- learners interacted with the learning activity in different ways both during the learning phase and the assessment phase;
- learners managed to reach the objective of the learning activity irrespective of how they approached the activity; and

- a wide range of other psychomotor activities were displayed during the course of the animation.

The study recommends minor changes to the program in order to improve it, and concludes that learners do respond positively to animation in a learning environment.

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KEY WORDS

Affective behaviour; animation; cognitive behaviour; computer program; education; multimedia; perseverance; physical science learning; psychomotor behaviour; rural school.

ACRONYMS

AS	Assessment Standard
CAT	Computer Applications Technology
FET	Further Education and Training
GET	General Education and Training
ICT	Information Communications Technology
ILE	Interactive learning environment
ILEs	Interactive learning environments
LO	Learning Outcome
LOLT	Language of Teaching and Learning
NCS	National Curriculum Statement
OBE	Outcomes Based Education
WCED	Western Cape Education Department
Z	Atomic number

GLOSSARY

Assessment standards	Assessment Standards are criteria that collectively describe what a learner should know and be able to demonstrate in a specific grade. They embody the knowledge, skills and values required to achieve the Learning Outcomes. Assessment Standards within each Learning Outcome collectively show how conceptual progression occurs from grade to grade.
Audit trail	Accurate, chronological, time-stamped recording of events recorded during animation execution.
Coding revision	Revising the coding/programming that underlies the animation.
Curriculum 2005	The first version (1997) of the post-apartheid National Curriculum Statement in South Africa to be implemented fully by 2005.
Drag and drop	A feature that is common to computer graphical interfaces that allow users to select a virtual object in the interface, drag it around and drop it over/on an object.
Game	Interactive drill and practice with some features of games that engages learners in practice that repeats material under study or learning content until it is mastered.
Extrasentential code-switching	The insertion of a tag from one language into an utterance entirely in another language.
Feedback	Feedback is regarded as information given by software to a learner about the appropriateness of his or her response.
First Additional Language Learners	Learners who receive instruction and learn in a language other than their mother tongue.
Further Education and Training.	Training band that covers Grades 10 –12 in schools and equivalent levels in FET colleges, namely NQF levels 2 - 4 and National Technical Certificates 1 - 3.
Interactive learning environment	A learning environment that provides students with opportunities to develop a range of skills and competencies along with the knowledge base to support them.
Intersentential code-switching	A clause or sentence is spoken in one language and the next clause or sentence is in yet another language.

Intrasentential code-switching	Intrasentential code-switching takes place within the clause boundary.
Learner	In South Africa a school going young person is called a learner, whereas in other countries he/she may be called a student
Learning outcome	A Learning Outcome is a broad statement of an intended result of learning and teaching. It describes knowledge, skills and values that learners should acquire by the end of the Further Education and Training band.
Motion tween	Changes the onscreen position and/or rotation of an object. At the same time it allows for modification of brightness, tint (colour) and alpha (transparency) levels.
Motivational messages	Messages that motivate and encourage the learners. The messages affect the learners positively and encourage learners not to give up and/or to improve on what they have acquired.
National Curriculum Statement	The policy document for Grades 10 - 12 that replaces the Core Curriculum, Curriculum 2005, Report 550 and the Transitional Guidelines.
Outcomes Based Education	A learner-centred methodology and activity-based approach that allows learners to pace their own learning in order to acquire knowledge, skills and attitudes.
Participant observer	An observer who participates in the experiment by assisting the subjects during animation execution.
Playhead	Represented by the small, red rectangle above the main timeline (in Flash MX 2004), indicating what appears on stage at a specific moment.
Revised National Curriculum Statement	The improved and revised form of Curriculum 2005 for Grades R - 9.
Second Language learners	Same as First Additional Language Learners.
Shape tween	In Flash MX 2004, it changes the shape and colour properties of a simple shape.
Tweening scale and "ease"	In Flash MX 2004, the tweening scale allows for an animation to start out quickly (positive ease) while negative ease slows the animation down towards the end.

NOTE

First Additional Language learners

In this study, learners were taught in English whilst their mother tongue is isiXhosa; therefore, English is their First Additional Language.

Use of the term "black"

The use of the term "black" when referring to a particular race group is not intended to be racist and should not be construed as such. It merely serves to draw the attention of researchers in the scholarly community to the background of the school as it may have implications for the replicability of this study.

Game

In this study the term "game" refers to a drill and practice game as described in the glossary (see Appendix Table 16 for the features of games).

SOFTWARE USED FOR DATA COLLECTION AND ANALYSIS

1. Flash MX 2004, Macromedia, Inc.
2. MS Excel, Microsoft Corporation.
3. MS Word, Microsoft Corporation.

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CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

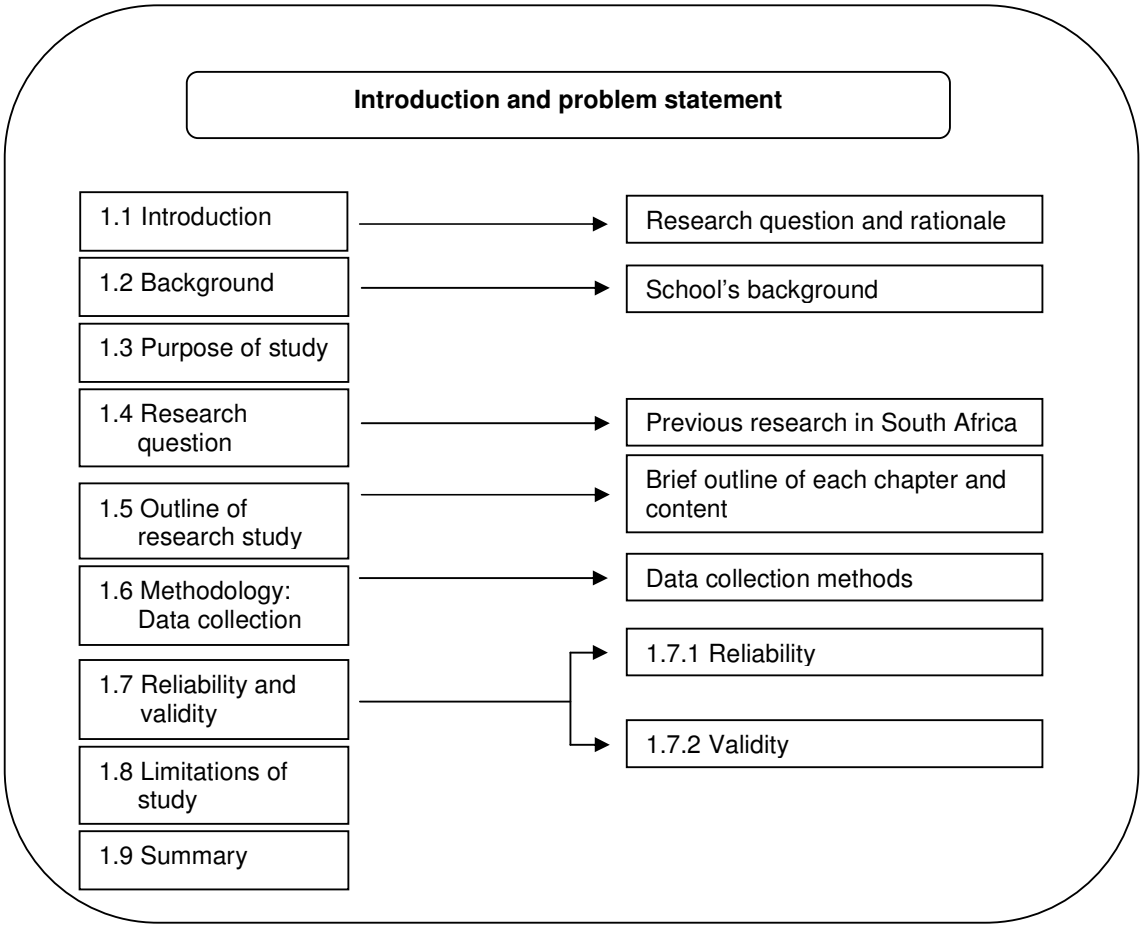

Figure 1 Overview of Chapter 1 indicating the content discussed

1.1 INTRODUCTION

This study describes research undertaken to establish how learners respond to animation in Physical Science learning.

The main research question is: "How do learners respond to animation in the learning environment?"

The sub questions are:
In an interactive learning environment with animations …

1. what learning takes place from a cognitive, affective and psychomotor perspective and how?
2. what language problems do the learners experience and how do they deal with them?

Physical Science is a moderate to difficult subject (McDermott, 1993; Teodoro, 2005) and is more so for English First Additional Language learners. I have found that learners in Grades 10 - 12 often have difficulty in visualizing problems in Physical Science, be it in exams, tests, tutorials or when subject matter is presented. Animations for educational purposes were considered for the following reasons:

- they can help to explain particular Physical Science concepts or facts;
- they gain learners' attention;
- they motivate students;
- they serve as visual tools in maintaining awareness;
- they highlight key information;
- they heighten student interest; and
- they facilitate information recall.

1.2 BACKGROUND

The research was done at a school situated in a small, rural settlement in the Western Cape, where the inhabitants are predominantly black people. In 2001, the school received twenty refurbished computers from the Telkom Foundation. The school broadened its curriculum by offering Computyping (now Computer Applications Technology or CAT) and elementary computer classes. Two years later, the school became a Khanya school, which translated into twenty new computers, a server, printer, etc. The availability of computers created an opportunity to circumvent the shortages in scientific equipment by designing animation(s) and multimedia learning environments instead.

1.3 PURPOSE OF THE STUDY

The purpose of the study was to establish the cognitive, affective and psychomotor effects of animation on Physical Science learning in a rural, Grade 10, English First Additional Language learner class.

1.4 RESEARCH QUESTION

The main research question is: "How do learners respond to animation in the learning environment?"

The sub questions are:
In an interactive learning environment with animations …

1. what learning takes place from a cognitive, affective and psychomotor perspective and how?

2. what language problems do the learners experience and how do they deal with them?

These critical questions are at the heart of the research problem. Research on the use of animations in Physical Science in schools in South Africa, to the best of my knowledge, is non-existent. Two searches of the Nexus Database yielded no results with regard to animations at school level, animations in school Physical Science or velocity animations in school Physical Science, or the effects of attention-gaining and elaboration strategies in South Africa.

Various studies show different results. Rieber, Boyce, & Assah (1989) found that animations do not facilitate learning for adults, while Mayton (1991) suggested that animations in computer-based tutorials for adults could be beneficial. It therefore needs to be established what kind of influence, if any, animations have on Physical Science learning.

1.5 OUTLINE OF RESEARCH STUDY

This thesis is organised into six chapters, described in Table 1.

Table 1 Outline of the research study

Chapter	Content
1. Introduction and problem statement	Introduction to study, purpose and research questions.
2. Literature review	An extensive literature study was done to collect information on what animation is, what an interactive learning environment is and to answer the following critical questions pertaining to an interactive learning with animations: 1. What learning takes place from a cognitive, affective and psychomotor perspective and how? 2. What language problems do the learners experience and how do they deal with them?
3. Animation	A description of the animation and coding used.
4. Research methodology	A description of the different research methods used to provide answers to the critical questions.
5. Results	Findings of critical questions described.
6. Synthesis and recommendations	Summary of study and recommendations.

1.6 METHODOLOGY: DATA COLLECTION

This investigation is a case study to determine how English First Additional Language learners interact with animation in a Physical Science interactive learning environment (ILE). In order to reach the objective of the research study, the researcher largely used qualitative data collection methods. In order to conduct a proper investigation, data was obtained, as set out in Table 2.

Table 2 Data collection methods to answer the research questions

Critical question	Data collection method
1. What learning takes place from a cognitive, affective and psychomotor perspective, and how?	Observations Interviews Questionnaire Audit trail
2. What language problems do the learners experience and how do they deal with them?	Observations Interviews Questionnaire

Observations: - By participant observers.
Interviews: - Formal, semi-structured interview with learners.
Questionnaire: - Specific questions to test cognitive, affective and psychomotor responses.
Audit trail: - Data collected by animation.

Data was collected using the following methods:

- Observations - Notes of the observers were typed and the data coded as cognitive, affective and psychomotor
- Interviews – Were transcribed and coded
- Questionnaire - Questions were designed to elicit responses indicative of cognitive, affective and psychomotor effects during the execution of the animation
- Audit trail - Data was collected by the animation and harvested after the 30 - 45 minute period. The data was transferred to a word processor to be chronologically split. The data was subsequently transferred to a spreadsheet for further analysis.

1.7 RELIABILITY AND VALIDITY

1.7.1 Reliability

Reliability was ensured by applying the following methods:

- training of observers;
- observation by multiple observers;
- data recording;

- data collection;
- and analysis and data interpretation.

1.7.2 Validity

Internal validity

Internal validity refers to the extent to which data can be confidently and accurately interpreted. The strategies used to defend internal validity in this research study are member checks, respondent validation, program coding revision and awareness of the researcher's bias.

External validity

External validity refers to "the degree to which scientific explanations of phenomena, match the realities of the world" (Schumacher and Macmillan, 1993, p. 157) and describes the extent to which a research study is applicable and generalisable to other.

To increase the usefulness of this study, issues of comparability (adequate description of the research design to extend the findings to other studies) and translatability (the use of theoretical frameworks and research strategies understood by other researchers) were addressed (Schumacher and Macmillan, 1993, p. 394). The following aspects were described:

- demographic variables;
- the venue where the research was done;
- the subjects' computer experience;
- the linguistic capabilities of English First Additional Language learners; and
- a pilot study.

1.8 LIMITATIONS OF THE STUDY

Whilst aware of the limitations of the research study, the researcher nonetheless strived towards a research study that was beyond reproach in terms of validity and reliability. The limitations were as follows:

- it was conducted with a very small sample (12 learners);
- it was conducted in the learners' First Additional Language;
- the study was concluded over a 40 - 45 minute period; and
- the animation was designed by the teacher to suit the purpose of the topic under study.

1.9 SUMMARY

This chapter briefly described the background, purpose and outline of the study, as well as data collection methods, validity and reliability and the limitations of this research study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this study is to determine how learners respond to animation in Physical Science learning. The study focused on English First Additional Language, Grade 10 learners in a rural South African school.

Figure 2 presents a layout of Chapter 2 and shows content discussed under the different headings.

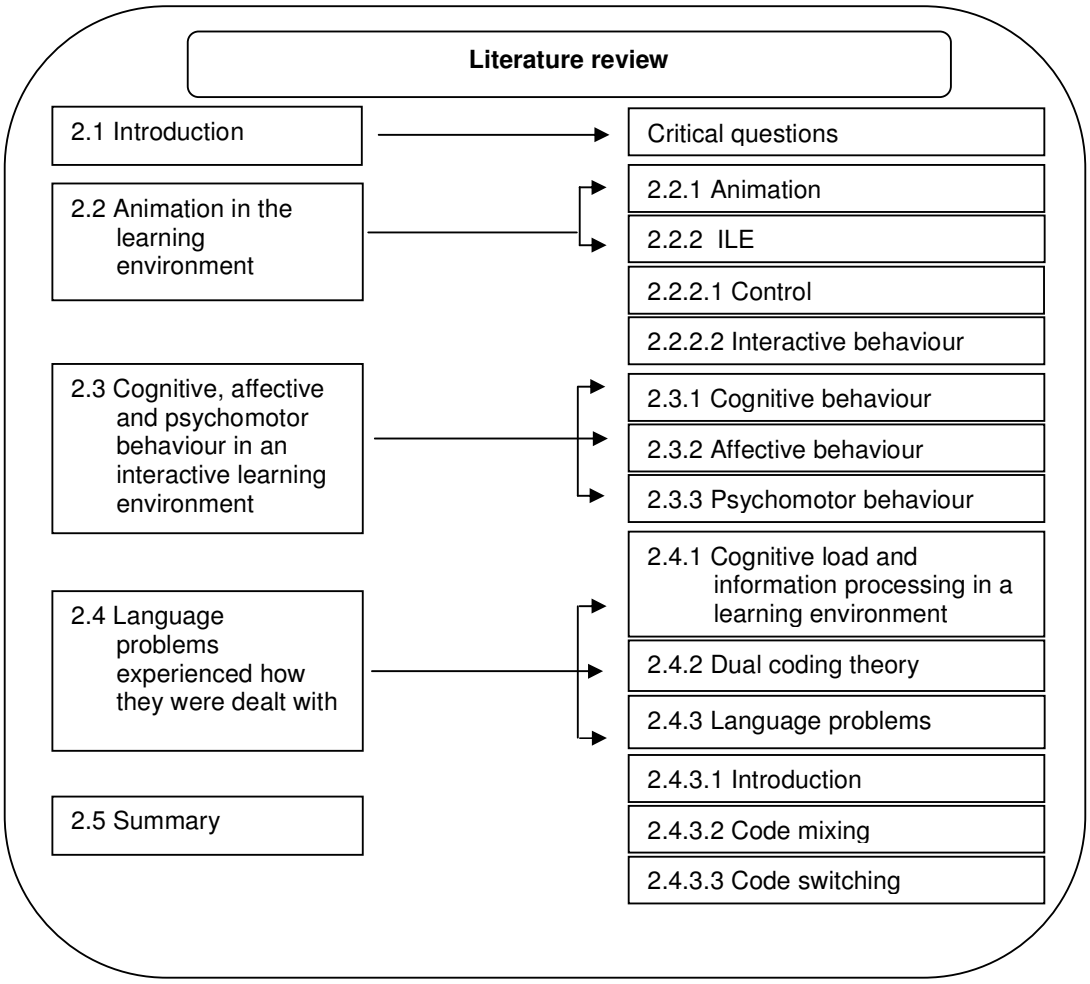

Figure 2 Overview of Chapter 2 indicating the content discussed

This chapter comprises a literature study in order to answer the critical questions.

The main research question is: "How do learners respond to animation in the learning environment?"

The sub questions are:

In an interactive learning environment with animations …

1. what learning takes place from a cognitive, affective and psychomotor perspective and how?
2. what language problems do the learners experience and how do they deal with them?

2.2 ANIMATION IN THE LEARNING ENVIRONMENT

Interaction with the animation in the learning environment could best be explained by clarifying the terms "animation" and "interactive learning environment" since the learners worked with animations in an interactive learning environment.

2.2.1 Animation

Various authors defined or described animations in different ways, as set out in table 3 below.

Table 3 Different descriptions of the term "animation"

Author	Description
Ainsworth & VanLabeke (2004)	A series of frames with each subsequent frame being an alteration of the previous frame.
Cameron et al. (1997), Izani, Aishah, Eshaq & Norham (2003)	An illusion of life
McGregor, et al. (2004)	A series of still computer-generated pictures presented in succession to develop the illusion of motion.
Millar, Hanna & Kealy (1999)	Bring to life.
Peters (2006)	To impart motion or activity to.
Price (2002)	A sequence of fleeting images occurring in the same place but distributed across time such that an event denoted by an earlier set of images occurs before an event denoted by a later set of images.

Animations may involve changes over time, for example, dynamic visualizations and spoken text (Scheiter, Gerjets & Catrambone, 2006). Ainsworth & VanLabeke (2004) and Lowe (2003) indicated that these changes over time may include:

- translations (position changes, e.g. which move objects from one place to another);
- transformations (form changes, e.g. which change properties of an object such as size, shape and colour); and
- transitions (inclusion changes, e.g. which make objects appear and disappear) (Stith, 2004; Khalil, Paas, Johnson & Payer, 2005).

Dancy & Beichner (2006) stated that animation will "offer the potential for increased learning when there is a need for external visualization and when the contents depend on

an understanding of motion". This statement underlined Stone's (1999) point of view that computer-based lessons "must add a dimension that would otherwise be absent".

In this investigation, Grade 10 learners studied a translation as animation since:

- they had to move the element(s) to their correct zone(s) on the Periodic Table; or
- the program moved the element(s) to their correct zone(s) if learners made correct selection(s) from the combo box (see Figure 6).

Table 4 gives a brief overview of the various types of animation with a short description of the unique features of each type. The table briefly states the unique features of various types of animation that may be grouped within the three forms of animation. It should be noted that this list is by no means comprehensive. A Flash MX 2004 animation was designed and used in this study.

Table 4 Types of animation and their unique features

No	Type of animation	Form of animation	Unique feature
1	Audio Video Interleaved	Translation	Indicates a task in progress, e.g. the Copy routine of Windows.
2	Motion guide	Translation	Allows for an object, numbers or letters to follow a predetermined path on the screen.
3	Motion tweening	Translation	Changes the onscreen position and/or rotation of an object. At the same time it allows for modification of brightness, tint (colour) and alpha (transparency) levels.
4	Tweening scale and "ease" (in or out)	Translation	Allows for an animation to start out quickly while negative ease slows the animation down towards the end.
5	Frame-by-frame	Translation and/or transformation	Main picture frame is created and then copied. Changes are made to subsequent frames, if necessary.
6	Graphics interchange format (GIF)	Translation and/or transformation	Basically frame-by-frame animation, compiled into a GIF file.
7	JavaScript	Translation and/or transformation	Different frames loaded into an array and a script written to play the frames as they are loaded into the array.
8	Shape tweening	Transformation	Changes the shape and colour properties of a simple shape.
9	Flash MX 2004	Includes translation, transformation or transition	Allows for a single frame to be created, whilst subsequent frames are created with suitable action scripts (coding or programming).
10	Timer controlled animations	Includes translation, transformation or transition	Sequence of events placed inside the timer's event procedure. The timer's prior settings execute the sequence of events.

(Kerman, 2004; Peters, 2006; Siler & Spotts, 1998; Stroo, 1998; Types of animations, n.d.)

2.2.2 Interactive learning environment

This study took place in an interactive learning environment (ILE). From a constructivist's point of view (Rieber, 1994, p. 226), computers are ILEs, viewed as a "source of rich, computational, cognitive tools with which the user can explore and experience many concepts and principles". Petford & Scott (1998) equate an interactive computer program with an ILE. De Bruyn (2004) offered another perspective, by describing an ILE as one that provides students with opportunities to develop a range of skills and competencies along with the knowledge base to support them. Aleven *et al*. (2003) and Forcheri *et al*. (2000) described ILEs as computer-based instructional systems that provide help and support to novices, enabling them to acquire learning skills and concepts pertaining to a particular task.

Betrancourt (2005) recognized two kinds of interactivity in animations. These are control and interactive behaviour.

2.2.2.1 Control

Control refers to the capacity of the learner to act upon the pace and direction of the succession of frames in an animation. Lai (2001) identified three types of control, namely, program, linear and learner control. *Program control* allows the learner to follow an instructional path predetermined by the instructional designer, in other words the designer decides the sequence for the learners. They are only required to follow the instructional path and can, thus, focus on the content to complete the task at hand whilst the animation plays through at its own rate. *Linear control* allows the learners to work through a sequenced or structured body of work or content. The learners are allowed to proceed to the next step when they are ready to do so. *Learner control* allows learners to control the context, content, sequence and pacing. This enables them to control the animation via start, stop, rewind, pause (or stop), next (step-by-step), previous and continue buttons (Mayer & Chandler, 2001; Syrjakow, Szczerbicka & Berdux, 2000), also known as hot keys (Stith, 2004). Naps *et al*. (2003) confirmed that learners who were *actively* engaged with visualization studies outperformed learners who simply watched or observed visualizations. This was in line with O'Day's 2006 statement that even minimal interactivity enhanced the value of learning.

Pridemore & Klein (1994) reported that learner control positively influences the retention of information and student interest.

This research study used learner control for the reasons mentioned above.

2.2.2.2 Interactive behaviour

Narayanan and Hegarty (2002, p. 281) defined interactivity as follows: "By interactivity we mean a facility by which the user acts on a computer presentation, which in turn interprets the user's action and produces an appropriate response". Mayer and Chandler (2001, p. 390) defined user interactivity as "user control over words and pictures that are presented in the multimedia explanation". Interactivity offers some advantages to the learning environment.

Instructional designers consider interactivity as a design principle as it fosters deep learning as opposed to the recall of factual information (Evans & Gibbons, 2007). Narayanan & Hegarty (2002) cited hyperlinks, entering data (Snelson, 2005), or adjusting the speed, velocity or acceleration of an animation as suitable examples of interactive behaviour. Other examples of interactivity include dragging-and-dropping (Inkpen, 2001), throwing

objects or using sliders to increase or decrease velocity or gravity (Peters, 2006), entering data via textboxes and interactive questioning (Byrne, Catrambone & Stasko, 1999).

According to Dalgarno (1998), learning primarily occurs through activity, rather than through passively receiving information. Students learn in various ways, which include seeing and hearing, reflecting and reacting (logically and intuitively), or by memorizing and visualizing information (Felder & Henriques, 1995, p. 22).

Table 5 summarizes the influence of animation on learning, showing how it is beneficial. Interactivity in this research study was accomplished by using drag and drop behaviour.

Table 5 Ways in which interactivity influence learning

No	Advantages of interaction with animation
1	Learning is more meaningful.
2	Learners remember more.
3	Helps to deliver concept knowledge and content
4	Assists in the construction of mental models.
5	Leads the learner to make predictions that can improve understanding.
6	Leads to better comprehension performance.
7	Makes learning material more enjoyable.
8	Assists in overcoming perceptual limitations.
9	Increases motivation and active learning.
10	Provides an effective way to deepen and increase knowledge.
11	Allows for self-paced learning and studying.
12	Focuses learners' attention.
13	Offers learners an opportunity to decide if they grasped the information presented, or whether the animation should be replayed.
14	Enhances understanding of exploratory data analysis.
15	Offers learners some choice of action.
16	Allows active participation.
17	Permits adjustment of presentation speed.

(Bele & Rugelj, 2006; Betrancourt, 2005, p. 290; Betrancourt, 2005, p. 291; Chan & Black, 2006; Doolittle, 2001; Dörner & Ware, 2004; Garcia *et al.*, 2005; Hsieh, Chen & Lu, 2005; Kraemer, Reed, Rhodes & Hamilton-Taylor, 2007; Large, 1996; Lauer, Muller & Ottman, 2001; Madej, 2003; Mayer & Chandler, 2001; Ong & Mannan, 2004; Scaife & Rogers, 2001; Scheiter *et al.*, 2006; Schmidt-Weigand, 2005, p. 83; Syrjakow, Szczerbicka & Berdux, 2000;)

2.3 COGNITIVE, AFFECTIVE AND PSYCHOMOTOR BEHAVIOUR IN AN INTERACTIVE LEARNING ENVIRONMENT

This section will examine the cognitive, affective and psychomotor behaviour of learners in an interactive learning environment (as described in Chapter 2, Section 2.2.2).

2.3.1 Cognitive behaviour

Cognitive behaviour refers to mental activities that occur during the learning process. This may include the recall or recognition of specific facts, procedures and concepts that serve in the development of intellectual abilities and skills as the learners acquire, recall, process (Price, 2002) and even present information (Miller, 2003).

Table 6 outlines cognitive behaviours, such as problem-solving, identification of steps, skills application, processing, reasoning and processes pertaining to cognition. The table summarizes the cognitive behaviour or activities with regard to problem-solving, identification of steps, processing, reasoning and memory that learners may experience during the learning in an interactive learning environment.

Table 6 Cognitive behaviours in an interactive learning environment

Process	Effects
Problem-solving	• Making inferences or deductions. • Observing and gathering data through the senses. • Classifying the types of subject matter. • Comparing information, analogical and schematic illustrations, and their own performance to others. • Analyzing delivered information. • Generalizing by searching the animation in order to learn. • Modelling from concrete to abstract.
Identification of steps	• Identifying learning steps to read and understand information from animation on a visual graphical level, an interpretation level, an assimilation level and a conceptual understanding level.
Skills application	• Extracting relevant information. • Using constrained spatial interrogation strategies to limit the proportion of total display area searched. • Applying extracted information in new situations. • Engaging in exploration and discovery. • Visualizing: graphical change, transformation and translation. • Searching for relevant information and detecting relationships.
Processing	• Engaging germane processing because animations create interests that motivate learners to exert more effort. • Reducing extraneous processing because animations require less effort to create mental pictorial representations.
Reasoning	• Using reasoning skills while working with multimedia, such as transforming an object from one sign system and recasting it in terms of the content and expression of another sign system, or transmediation. • Using authentic language as part of the reasoning process in collaboration with peers.
Memory	• Memory may be enhanced under some conditions. • Building: ▪ connections between words and images (pictures); ▪ connections that organize words; ▪ connections between the abstract and concrete domains; ▪ mental representations for comprehension; ▪ high-quality mental models from animations; and ▪ coherent mental representations of verbal material and visual material. • Transferring knowledge from one situation to the next. • Remembering the positions of objects before and after a change on the screen. • Extending knowledge from a known representation to an unknown representation without reorganization of knowledge. • Associating two known representations (relational understanding) without reorganization of that knowledge. • Recalling of information. • Extracting thematically relevant information from animations. • Emphasizing important information. • Directing attention to specific information. • Helping students to acquire a better understanding of targeted information.

(Ainsworth & VanLabeke, 2004; Forcheri, Molfino & Quarati, 2000; Lai, 2001; Large, 1996; Lowe, 2003; Lowe, 2004; Mayer & Anderson, 1992; Mayer & Moreno, 2002; Mayer, Moreno, Boire & Vagge, 1999; Mayer *et al.*, 2005; Miller, 2003; Price, 2002; Ragan & Smith, 1994; Scaife & Rogers, 1996; Szabo & Schlender, 1996; Su, 2007; Thomas & Demczuk, 2002; Zhu & Grabowski, 2005)

2.3.2 Affective behaviour

Affective behaviour refers to activities displayed by learners with reference to their motivation, the influence of their peers, management of time and the learners' mental state (Miller, 2003).

Paris (2004) posits that educators have long known that learner attitudes (affective behaviour) and responses are interconnected and that a positive correlation exists between the two. He indicated that "attitudes are evaluated beliefs which predispose the individual to respond in a preferential way" (Paris, 2004, p. 101). Afzal (2007) concurred by emphasizing the importance emotion has in learning and that emotion provides a basis for healthy cognitive functioning. Anolli *et al*. (2005) shared this opinion by indicating that the affective does indeed play a critical role in decision making and learning performance as it influences cognitive processes. Motivation is the key to learning and emotions play an important role in motivation (Dehn & Mulken, 2000).

Massoud (1991) indicated that an interconnection does indeed exist between attitudes and responses in information and communications technology (ICT). Desmet said (2007, p. 2):

> "Knowledge of the process of emotion, i.e. how emotions are evoked, can change our understanding of what makes us enjoy interacting with a computer or, for that matter, with any kind of product."

This quotation underlines the importance of a well designed animation to capture the attention of the learners, motivate them to work with the animation and to enjoy it. Animation increases learners' motivation (Rieber, 1991; Velazquez-Iturbide *et al.,* 2006). It is therefore important for learners to develop a positive attitude towards the animation whilst executing the animation.

Table 7 lists the different processes with their affective learner behaviour in an educational environment, grouped by motivation, spirit of the community, enjoyment, confidence, attention, satisfaction, behavioural attitudes, feedback and learning attitude.

Table 7 Affective behaviour in an interactive learning environment

Process	Effects
Motivation	• Improving extrinsic motivation in information processing, i.e. learning and better marks. • Attending to information. • Unceasing effort, perseverance, a sense of empowerment, confidence, excitement and on-task engagement. • Providing learners with opportunities to determine their own learning strategy.
Spirit of community	• Collaborating or cooperating and group ownership of work. • Transforming conventional communication patterns; learners teach and learn from each other. • Dominating of peer-to-peer discussion with more honesty, less fear, less shyness and less aggressiveness. • Rating animations as enjoyable.
Enjoyment	• Enjoying learning with animations.
Confidence	• Creating mental images of animations with confidence for the purpose of recalling information.
Attention	• Focusing attention on specific parts of the animation.
Satisfaction	• Displaying high levels of satisfaction with animations.
Behavioural attitudes	• Showing flexibility, adaptability and self-regulation. • Developing attitudes towards animation. • Concentrating or being bored by animations, i.e. mood of the learners.
Feedback	• Attitude towards feedback.
Learning attitude	• Developing a positive attitude. • Developing of meaningful understanding of higher-level concepts.

(Ainsworth & VanLabeke, 2004; Akay, Durmaz & Feyzioglu, 2006; Dehn, 2000; McGregor, Griffeth, Wheat & Byrd, 2004; Miller, 2003; Naps *et al.,* 2003b; Petford & Scott, 1998; Pridemore & Klein, 1994; Szabo & Schlender, 1996; Su, 2007; Velazquez-Iturbide, Paraeja-Flores & Urquiza-Fuentes, 2006; Weiss, Knowlton & Morrison, 2002; Zhang, 2000)

2.3.3 Psychomotor behaviour

Hands-on experiential activities add value to instruction and require various degrees of psychomotor or physical behaviour (Henke, 1997). Children learn through their senses and physical activities (Kritzenberger, Winkler & Herczeg, 2002).

Table 8 lists the various physical behaviours found when learners interact with information in an interactive environment, based on the literature.

Table 8 Psychomotor behaviour in an interactive learning environment

Process	Activity
Click	• Clicking the mouse, clicking on buttons, continuously active.
Communicate	• Communicating with other learners, showing and sharing work.
Examine	• Examining animated images, sound, instructions and images before reading text.
Lose sight of time	• Time management.
Move	• Moving quickly onto the next graphic or screen, looking for the elusive piece of information, not processing what is there, moving an object to a new position by dragging it.
Talk	• Discussing information, thereby processing information.
Focus	• Focusing on perceptual events. • Looking at the computer monitor and interacting with fellow learners.
Verbal and gestured explanations	• Making gestures to each other. • Forming verbalizations of subjects. • Explaining to each other.
Change	• Changing parameters via dynamic textboxes.
Observe	• Observing changes as a result of changes made in parameters.
Read	• Reading text and observing onscreen graphics, making drawings/marks, writing down facts.
Touch	• Touching a screen.

(Demetriadis, Triantfillou & Pombortsis, 2003; Lowe, 2004; Miller, 2003; Petford & Scott, 1998; Schwier, 1993; Thomas & Demczuk, 2002; Yeo *et al.*, 1998)

2.4 LANGUAGE PROBLEMS AND HOW THEY WERE DEALT WITH

This section describes information processing in a learning environment, briefly outlining the dual coding theory and discussing the language problems experienced.

2.4.1 Cognitive load and information processing in a learning environment

Lin & Chen (2006) defines cognitive load as the mental effort that a specific task imposes on a learner's cognitive system during learning. Mayer & Moreno (2003) states by that meaningful learning can only occur when learners engage in substantial cognitive processing during the learning process; this cognitive processing is generally referred to as the cognitive load. Cognitive load is also defined as "a multidimensional construct that represents the load that performing a particular task imposes on the cognitive system" (Paas, Tuovinen, Tabbers & Van Gerven, 2003, p. 353). Chalmers (2003) uses the term cognitive load to describe the amount of information that can be actively processed by working memory at a specific time. Guttormsen, Schar & Zimmerman (2007) concurs by stating that cognitive load is linked to human information-processing capacity. All these descriptions or definitions address the issue of information-processing and the load that it imposes on learners during the learning process.

Information processing is an active process that requires five cognitive processes: selecting words, selecting images (including animation), organizing words, organizing images (animation included), and integration (Mayer & Moreno, 2003). These processes place demands on the cognitive capacity of the information-processing system (Mayer & Moreno, 2003). It is, therefore, reasonable to address the issue as to how information processing via animation occurs, especially since the researcher used text, sound and animation in the research study. Paivio's dual coding theory lends itself to an explanation of information-processing with respect to the use of text, sound and animation (Ma & Kelly, 2006).

2.4.2 Dual coding theory

Dual coding theory posits that the human information-processing system consists of two separate channels - an auditory/verbal channel for processing auditory input and verbal representations and a visual/pictorial channel for processing visual input and pictorial representations in the memory system (Mayer & Moreno, 2003). In this context, the three main storage structures in the memory system are the sensory memory, the short-term memory or working memory (STM) and long-term memory (LTM). The sensory memory or register registers external stimuli (see Figure 3). STM consists of shallow working memory (sounds or images attended to by the learner) and deep working memory (verbal and pictorial models constructed by the learner).

Long-term memory stores permanent information and is regarded as the learner's relevant prior knowledge (Mayer & Moreno, 2003).

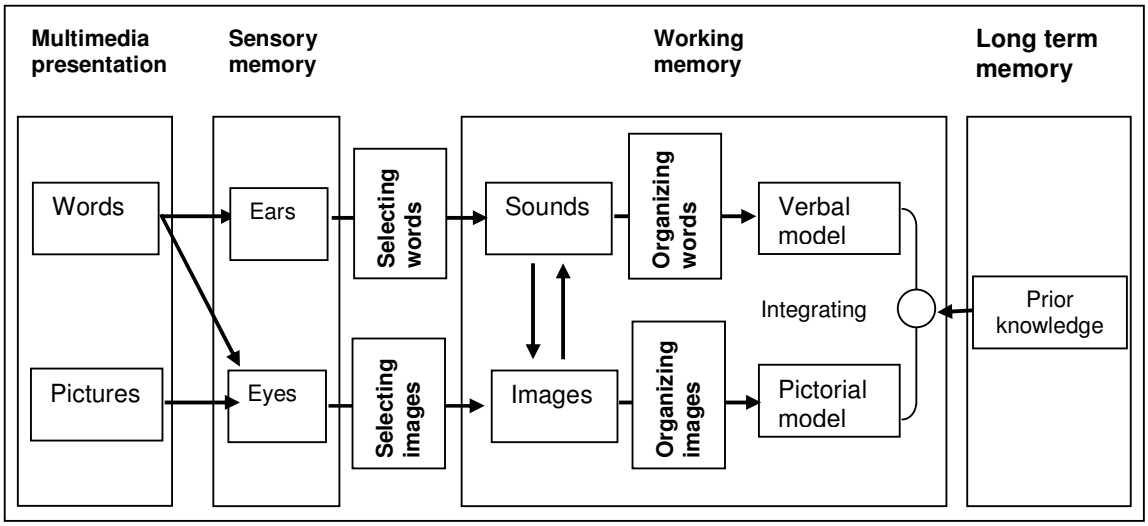

Figure 3 Paivio's dual coding theory (adapted from Doolittle, 2002)

Paivio's dual coding theory further suggests that pictures or graphics are superior to word or text for remembering concrete concepts. The verbal system is concerned with language

or linguistic-like processing, while the non-verbal system process all non-verbal processes, including emotions. Dual coding theory predicts three levels of processing within and between the verbal and the visual (non-verbal) systems. These are the representational, associative and the referential levels of processing.

The representational level of processing describes the interactions between the incoming stimuli from the environment and either the verbal or visual systems (Mayer & Anderson, 1992). The associative level of processing refers to the activation of informational units within either the verbal and visual systems, whilst the referential level of processing handles the building of connections between the verbal and visual systems (Rieber, 1994, p. 127).

Dual coding theory predicts that words and pictures provided during presentations will affect the coding systems in various ways. The dual coding system also explains the superior effect of pictures on the basis of two assumptions. Firstly, it commonly believes that verbal and visual effects produce additive effects. In terms of this assumption, if information is coded both verbally and visually, the chance of retrieving the information is doubled. Felder & Solomon (n.d., Visual and verbal learner, para. 1) agrees by indicating: "Everyone learns more when information is presented both visually and verbally." Secondly, the assumption is made that words and pictures activate mental processing in different ways. Pictures are more likely to be coded visually and verbally, while words are less like to be coded visually.

The primary theoretical support for the use of animations and illustration and their effects on learning, comes from dual coding theory (McGregor *et al.,* 2004). According to Rieber (1991), dually coded information increases the probability of retrieval because if one memory trace is lost, another is still available.

2.4.3 Language problems experienced

2.4.3.1 Introduction

First Additional Language learners refer to learners who receive instruction in a language other than their mother tongue (Uys, van der Walt, van den Berg & Botha, 2007). In this study, learners are taught in English, while their mother tongue is isiXhosa; therefore, English is their second language of instruction (ibid.), or First Additional Language (South African Government, 2006).

Many learners experience problems with English First Additional Language. "They normally cannot say their sentences properly. They struggle to say what they are thinking.

They want to speak English, but find it difficult" (Schlebusch & Thobedi, 2004, p. 42). The learners may appear ready to be taught in English First Additional Language but they fail to engage in higher order cognitive processes, such as synthesis, discussion, analysis, evaluation and interpretation (Pillay, 2004; Uys *et al*., 2005).

Learners often overcome these language problems by code mixing and code switching. Code mixing and code switching take place in bilingual and multicultural communities in South Africa, (Malaza, Martins, Roux & Niesler, 2005; Ncoko *et al.;* 2000; Pretorius, 2005), China (Gibbons, 1988; Ho, 2007), France (Jisa, 2000), Germany (Auer, 2005), India (Viswamohan, 2004) and the United States (Clachar, 2000), to name but a few countries.

2.4.3.2 Code mixing

The linguistic concepts intrasentential and intersentential (Pretorius, 2005) are used to differentiate between code mixing and code switching. Intrasentential code mixing occurs within the same sentence, i.e. insertion of a different language at the end of the clause or within the clause boundary. Examples of code mixing are as follows:

> Ngomhla we-ten ku-August. (Xhosa) - English at the end of the clause.
> [On the 10th of August.] (Malaza *et al.,* 2005)

and

> Wamkelekile, kuse-Central Hotel Reservations apha. (Xhosa) - English within the clause boundary.
> [Welcome, this is Central Hotel Reservations] (Malaza *et al*., 2005)

2.4.3.3 Code switching

Intersentential code switching occurs when an individual changes **between** sentences, from one language to the next (Pretorius, 2005; Alejandro, 2000). Learners and teachers regularly interact with information socially and in the classroom via code switching (Rose & van Dulm, 2006). Code switching occurs, orally or written (Ho, 2007) whenever learners alternate between two or more languages (Setati, 2002, p. 13) within a single utterance or conversation (van Dulm, 2005) but does not include borrowing words from another language into the lexical system of a language (van der Walt & Mabule, 2001). Heredia & Altarriba (2001, p. 164) define code switching as the substitution of a word or phrase in one language, for a word or phrase in a different language.

According to Ncoko *et al*. (2000), code switching facilitates both communication and learning of the First Additional Language in several ways. Firstly, code switching provides a natural shortcut to content and knowledge acquisition. Secondly, it improves the

acquisition of the First Additional Language and, lastly, it is proposed that there is a strong relationship between learning style and code switching (ibid.).
According to Rose & van Dulm (2006), code switching is widespread in South Africa's multilingual and multicultural society. It was documented in primary schools (Ncoko, Osman & Cockroft, 2000, p. 225), secondary schools (Rose & van Dulm, 2006, p. 1) and even at university level (Van Dulm, 2005, p. 4). Rose & van Dulm (2006) posit that code switching exists in predominantly black schools but conceded that code switching also occur in schools where the First Additional Language is Afrikaans (the primary language is English).

Intersentential code switching occurs at the **sentential boundaries** where one clause or sentence is spoken in one language and the next clause or sentence is in yet another language. This is illustrated in the following English/Afrikaans examples. Note the example of insertion of **sentences** in different languages.

Who is eating? *Vreet is mos eet né?* So who is eating?
[gorge is indeed eat hey?]

and

The caterpillars, so the caterpillars, that is your subject.
Vet ruspers is jou onderwerp.
[fat caterpillars is your subject] (Rose & van Dulm, 2006, p. 7)

The following is an example of a **clause** in one language following a clause in a different language:

I love Horlicks *maar hier's niks.*
[I love Horlicks but there's none here.] (van Dulm, 2005, p. 1)

Interaction with information via code switching seems to be common practice, depending on the institutions (school or university) and languages (primary and the First Additional Language).

Felder and Henriques (1995) proposed various ways in which foreign and second language learners (or First Additional Language learners in the South African context) interact with information in a learning environment. Mayer and Chandler (2001) posited that interactivity usually improved learning understanding when used in a way consistent with how people learn. These interactions with the learning material depend on the learning style of the learners and can be accomplished in several ways.

Oxford (2003, Introduction, para. 1) posited "Language learning styles and strategies are among the main factors that help determine how - and how well - our students learn a second or foreign language". Learning styles manifest themselves by the learning

strategies (learning behaviours or actions) (Ehrman, Lou Leaver & Oxford, 2003). Felder and Henriques (1995) proposed that the instructional methods need to be balanced to accommodate all learning styles simultaneously or at least sequentially. Wallace (n.d., p. 1) described a learning style as "the conditions under which a student begins to concentrate on, absorb, process, and retain new or difficult information or skills". Wallace (n.d.) and Kerman (2004) recognized four types of learners based on the way in which they interact with information. These were auditory learners (learners who prefer to use their voices and to listen), visual learners (learners who prefer to process information by seeing it), tactile learners (learners who prefer to touch or manipulate) and kinesthetic learners (who learn best through whole body involvement and direct experience). Fleming and Mills (1992) showed a slightly different classification, namely visual, aural, read/write and kinesthetic learners. Unlike Wallace (n.d.) and Kerman (2004), their visual category excludes words, and is instead included in the read/write category.

2.5 CONCLUSION

This chapter provided a theoretical underpinning to the research. Animations were examined and defined, as well as an interactive learning environment. How learners behave in an ILE were described from cognitive, affective and psychomotor perspectives. The language usage of First Additional Language learners was discussed.

Chapter 3 will discuss the animation that was developed and used in this study by English First Additional Language learners in an interactive learning environment and Chapter 4 will discuss the methodology used in this research. Chapter 5 will explore the results of the research and discusses how and what learning took place from a cognitive, affective and psychomotor perspective, as well as the language problems experienced by the learners.

CHAPTER 3

ANIMATION

3.1 INTRODUCTION

The purpose of this chapter is to describe the animation and its user interface.

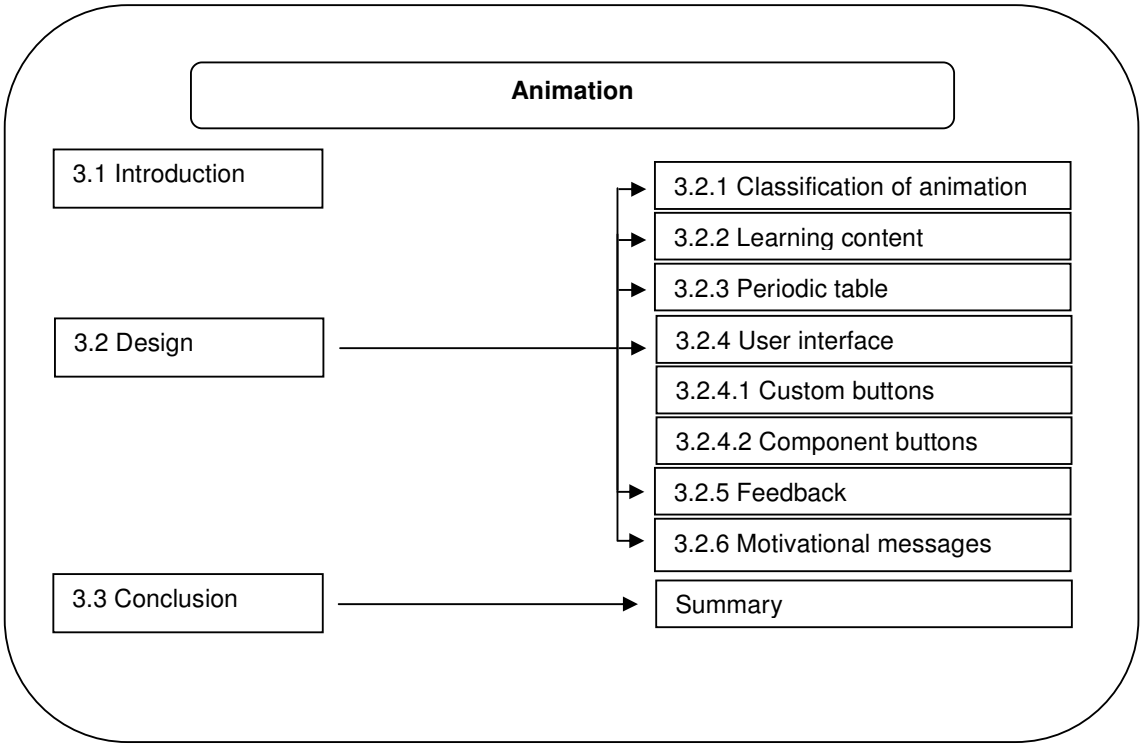

Figure 4 Overview of Chapter 3 indicating the content to be discussed

Figure 4 presents a layout of Chapter 3 and shows content discussed under the different headings.

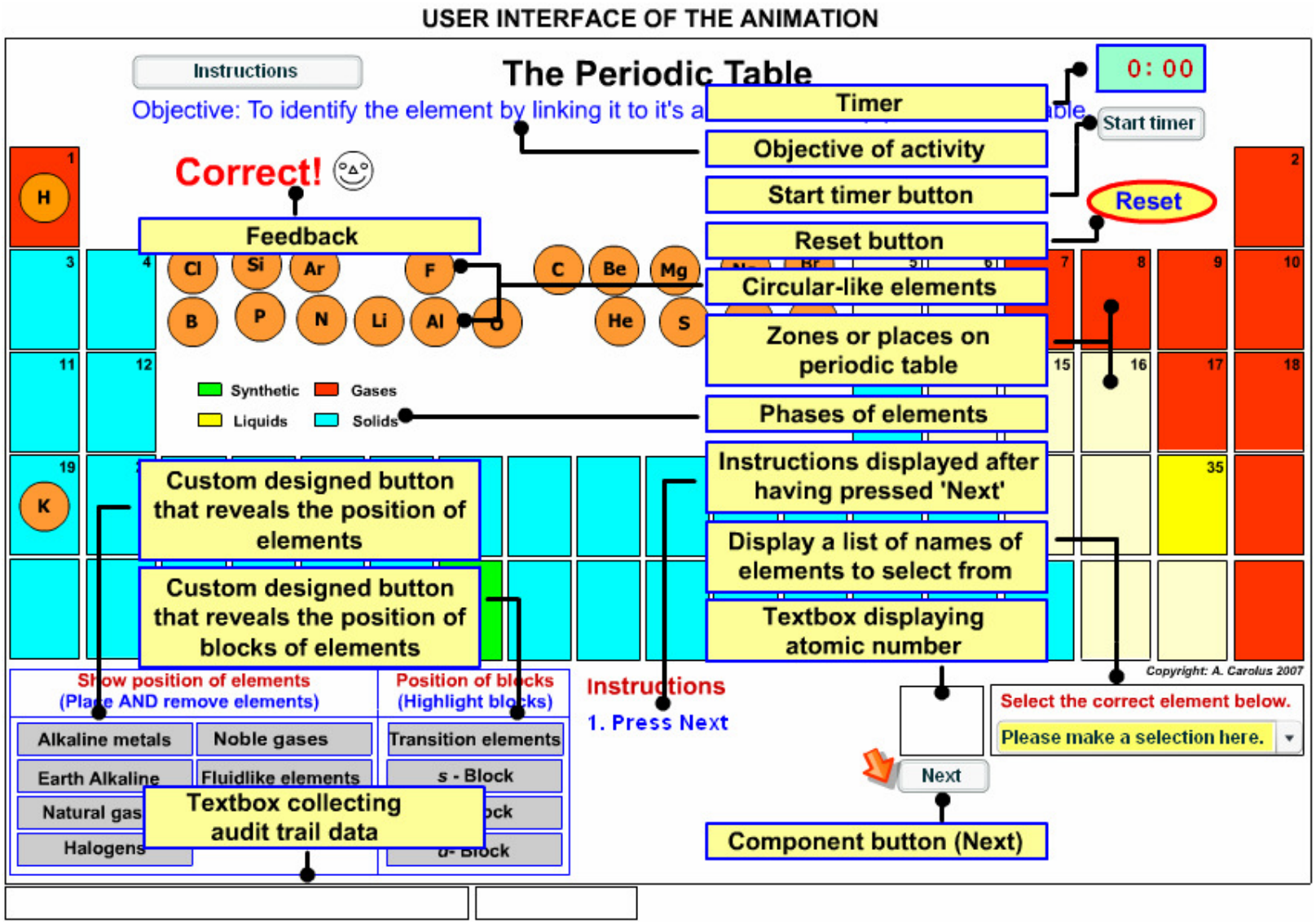

Figure 5 User interface of the animation

3.2 DESIGN

The following explains the type of animation (Periodic Table), the user interface, custom designed buttons and component buttons (see Figure 5).

3.2.1 Classification of animation

Alessi & Trollip's (2001; p. 7) model for effective and efficient learning provides for four phases of instruction. These phases include presenting information, guiding the learner, practicing and assessing the learner. These four steps can be applied to various interactive multimedia to facilitate learning [ibid]. Based on these four steps, Alessi & Trollip's (2001; p. 11) distinguish between four methodologies of interactive multimedia and its capabilities to facilitate learning. The four interactive multimedias include tutorials, drills and practices, simulations and games.

Tutorials

Tutorials are interactive multimedia that engages learners by presenting information and guiding learners through this information.

Simulations

Simulations can be viewed as open-ended interactive learning environments. A simulation may at most address three of the four phases of instruction of Alessi & Trollip's (2001, p. 11) model and rarely cover all four phases of instruction.

Both games and drills and practices characteristically engage learners in assisting them to "practice for fluency and retention" (Alessi & Trollip, 2001, p. 11). Games and drills and practices are often also combined to appeal to the emotions of the learners or to draw on the affective aspect of learning. For example, this study used feedback to motivate learners when they moved elements to correct places or made correct selections from a combobox.

Drill and practices

This interactive multimedia engages learners in practice that repeats material or content to be learnt until it is mastered (Alessi & Trollip, p.7, 2001).

Games

Games are interactive multimedia that conveys information in a non-repetitive manner, or it may serve as environment where information (content) is discovered.

Hogle (1996) and George, Harvey, & Wheeler (1985) laid down criteria for games in terms of which this animation does not qualify. This animation guided the learners (via the instructions), allowed practice to master the content and allowed for self assessment. As a result, the animation can be defined as a drill and practice game. Squire (2006) described the goal of a drill and practice game as the effective transmission of information to "train" a set of desired responses, e.g. to memorize atomic numbers like in this research study. Chang, Yang, & Yu (2003) used a quiz drill and practice game that allowed participants to memorize knowledge.

3.2.1 Learning content

The learning content for this interactive learning courseware resorted under Learning Outcomes (LO's) 1 and 2 and the specific Assessment Standards (AS's) for Physical Sciences (FET phase) as set out in Table 9 below.

Table 9 Learning Outcomes and Assessment Standards of the learning content

Objective and Learning Outcomes			
Objective: To identify the element by linking it to its atomic number (Z) on the periodic table.			
Learning Outcome 1		**Learning Outcome 2**	
Use practical scientific inquiry and problem solving skills.		Construct and apply scientific knowledge.	
AS 1.2	Interpret data to understand the organization of elements on the periodic table.	AS 2.1	Recalling, stating and discussing prescribed concepts.
Learner activity 1		**Learner activity 2**	
Drag element symbols or select names from combo box.		Discuss in groups/pairs.	

The objective of the learning activity was the identification of the element by linking it to its atomic number (Z) on the Periodic Table by:

- dragging the symbol of the element to its correct zone (atomic number) on the periodic table; or
- selecting the correct element (corresponding to its displayed atomic number) from a combo box after which the animation places the element correctly.

Table 9 briefly stated the objective, Learning Outcomes and Assessment Standards for the content studied during the execution of the animation.

3.2.2 Periodic Table

The purpose of the activity was to enable learners to identify the elements by linking them to their atomic numbers. The activity opens up with the first 22 elements placed at random above the Periodic Table (see Figure 6) which the learners must drag and drop on the correct places or zones on the Periodic Table, marked with their atomic number.

3.2.3 User interface

Different kinds of buttons were placed on the Periodic Table, each with a specific function. These included custom designed and component buttons.

3.2.3.1 Custom designed buttons

The custom designed buttons are of two types. The first type shows the position of a particular grouping of elements during the learning phase. On pressing, it places the element in the correct place or zone on the Periodic Table. On releasing the button, the element returns to its original position above the Periodic Table. These buttons are labelled 

(Alkaline metals), 

(Earth alkaline elements), 

(Natural gases), 

(Halogens), 

(Noble gases), 

(Fluidlike elements) and 

(All elements) (see Figure 6).

The second type of custom designed button simply highlights the positions of different blocks of elements. These buttons are marked 

(Transition elements), 

(s-block), 

(p-block) and 

(d-block) (see Figure 6). These buttons can be used prior to placing the elements (not during the game) or after the elements are placed on the Periodic Table. Using these buttons after having placed the elements has added value since it also identifies the elements, for example belonging to Alkaline, Earth alkaline groups of elements, etc., provided the elements are placed correctly.

The Reset button 

returns (all) elements to their original positions on the periodic table during the learning phase and after an abandoned or completed game.

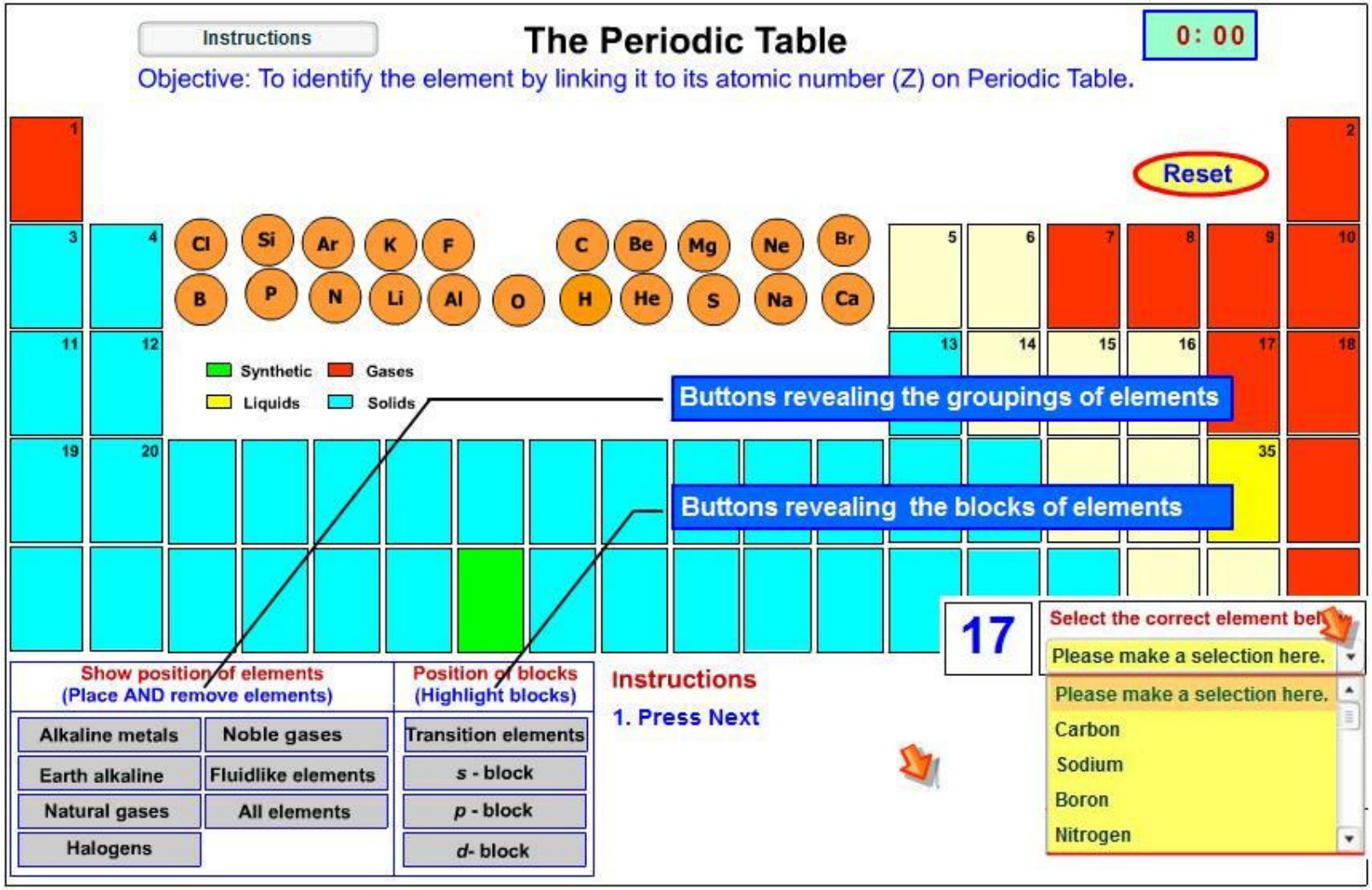

Figure 6 Start-up screen for the drag and drop animation activity. Note the visible timer and customized buttons above, on the right-hand side; and customized buttons below, on the left-hand side, at the bottom of the screen. The component buttons are the "Next" and "Instructions" buttons. The circular elements are randomly placed on the periodic table.

3.2.3.2 Component buttons

The second type of button, namely the component buttons, are labelled 

(Start timer), 

(Stop timer), 

(Instructions), 

(Remove instructions) and 

(Next). The game starts once the learner presses the 'Start timer' button. All the buttons in the animation are disabled (custom designed and component buttons), with the concomitant enabling of the 'Stop timer' button. The 'Start timer' button marks the start of the game and dynamically displays the time in a text box just above the 'Start' button (see Figure 8). It was important for the learners to note the time as they were "playing" against time.

Once the learner had placed the elements (all) in their (correct) places or zones, the 'Stop timer' button had to be pressed and a motivational message appeared (see Figures 11 - 13), the 'Stop timer' button was disabled and the 'Reset' button was enabled (all other buttons were still disabled).

The 'Instructions' button brings up the instructions (see Figure 7). The instructions consist of a movie clip that loads into level two of the animation and is, therefore, always present and overlays the Periodic Table. The movie clip consists of two frames labelled 'none' and 'info'. The frame labelled 'none' is empty (devoid of information), transparent and the playhead never moves beyond frame 1 as it is prevented from doing so by a `Stop();` command on the 'none' frame. The 'Instructions' button instructs the playhead to move to frame 2 of the instructions movie clip that contains and shows the instructions. The instructions consist of a learning phase and a self assessment phase. The learning phase spells out the two ways in which the elements may be placed on the periodic table while the self assessment phase explains how the game works and how the circular elements can be dragged in the animation.

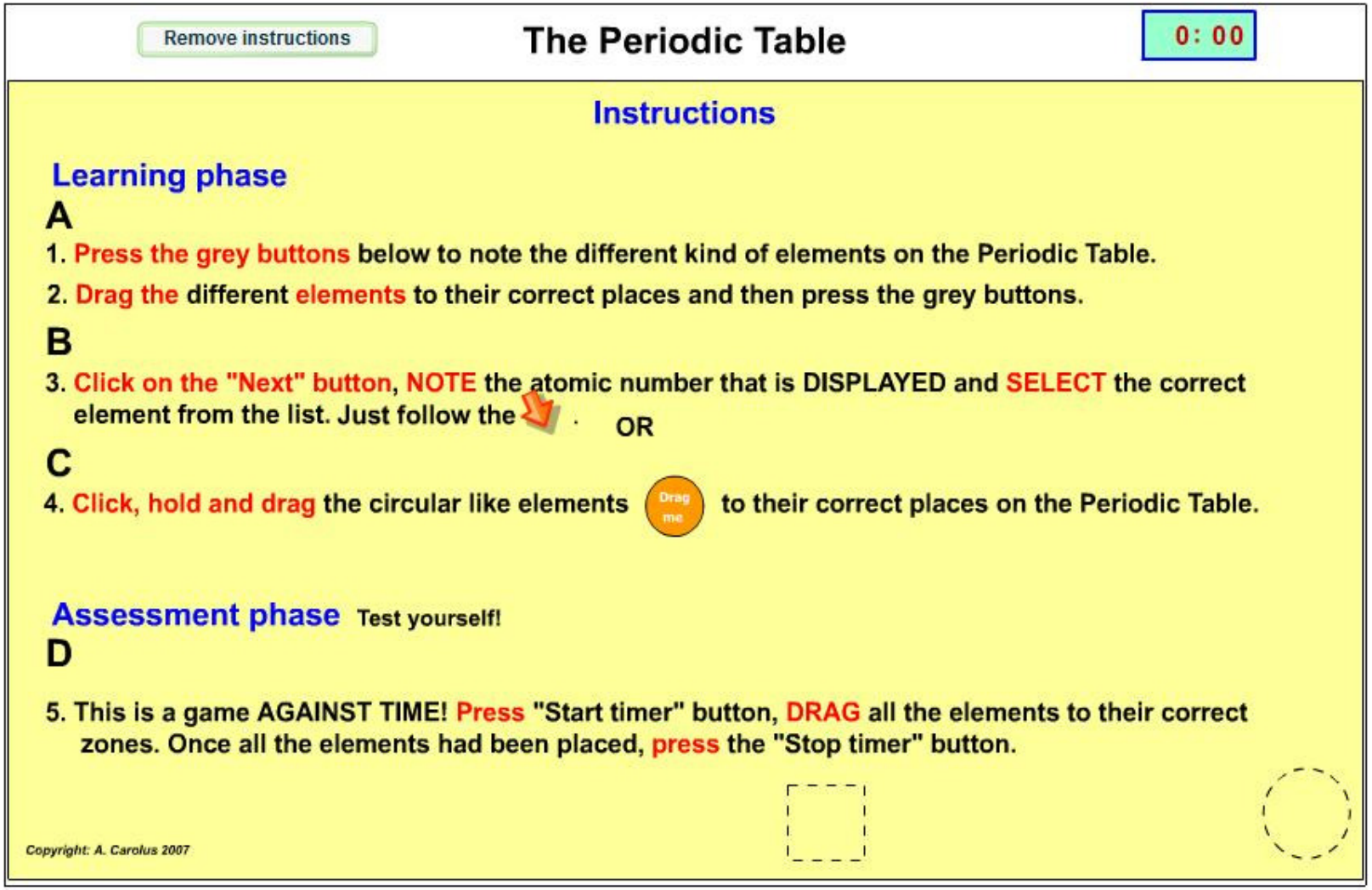

Figure 7 Instructions placed in level 2 of the animation overlaying the periodic table. Note the circular clip marked "Drag Me" that can be dragged around whilst observing the instructions.

In addition, the dragging process in the instructions is live in that the movie clip labelled 'Drag me', can be dragged around. Finally, the label of the 'Instructions' button changes to 'Remove instructions' once pressed.

The 'Remove instructions' button removes the instructions by moving the playhead of the movie clip from the frame labelled 'info' to the frame labelled 'none' resulting in an empty movie clip (totally transparent) overlaying the Periodic Table.

The 'Next' button works in conjunction with the combo box. Once the 'Next' button is pressed, an atomic number is randomly selected from an underlying array containing the atomic numbers of the elements. The 'Next' button becomes invisible and the orange arrow jumps to the combo box from where the name of the corresponding element needs to be selected. If the chosen element corresponds to the atomic number, the circular element will automatically be placed (by the animation) in the correct position or zone on the Periodic Table and the word 'Correct' with a smiling face next to it appears. If incorrectly placed, the word 'Sorry' appears with a sad face next to it (see Figure 9, below). The event log is compiled in the background while the learner works the program.

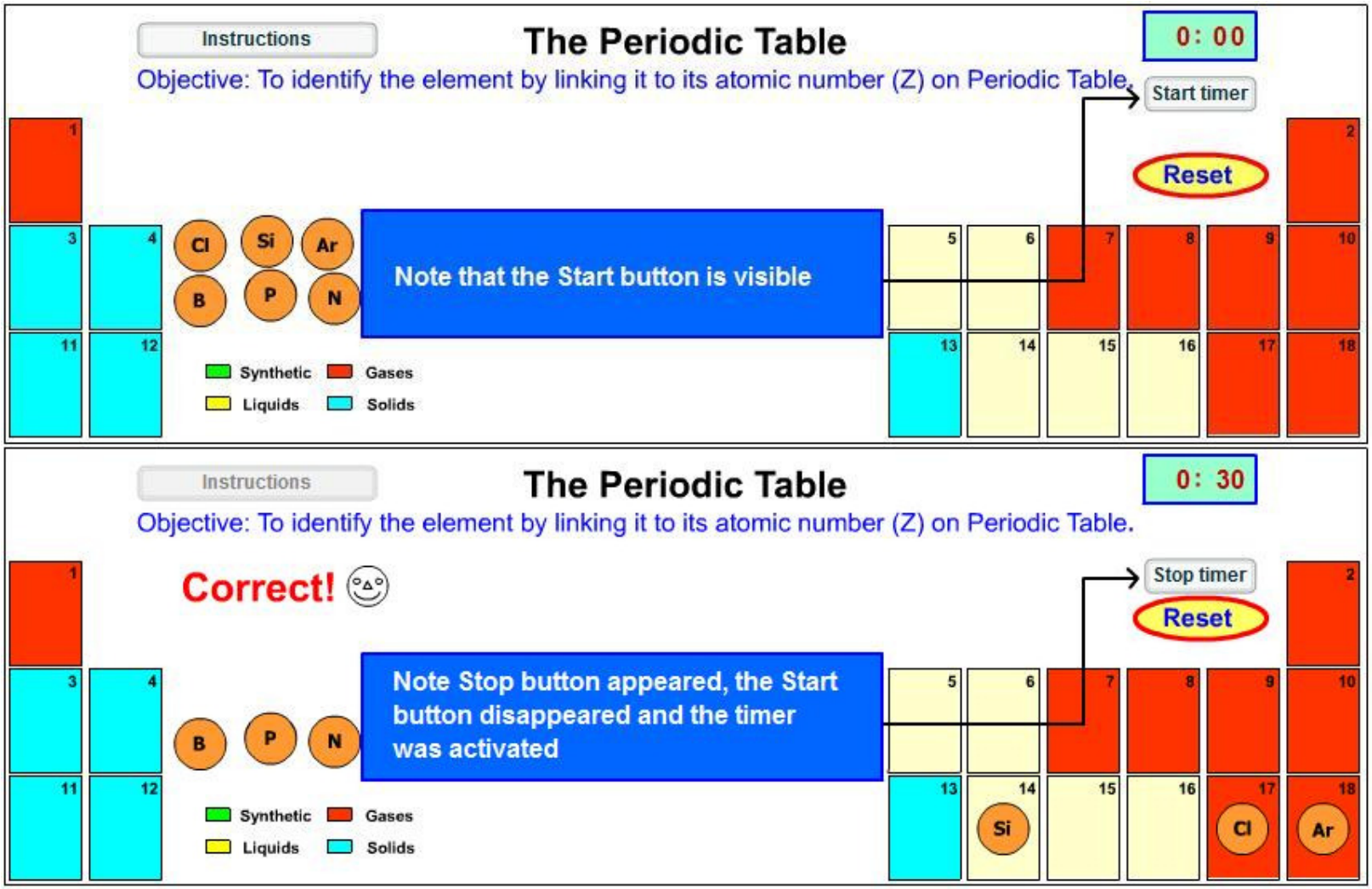

Figure 8 Note the Start button is visible in the figure (above) and once pressed, it disappears, the Stop button appears (below) and the timer is activated. Note that a few elements have been dragged to zones on the Periodic Table.

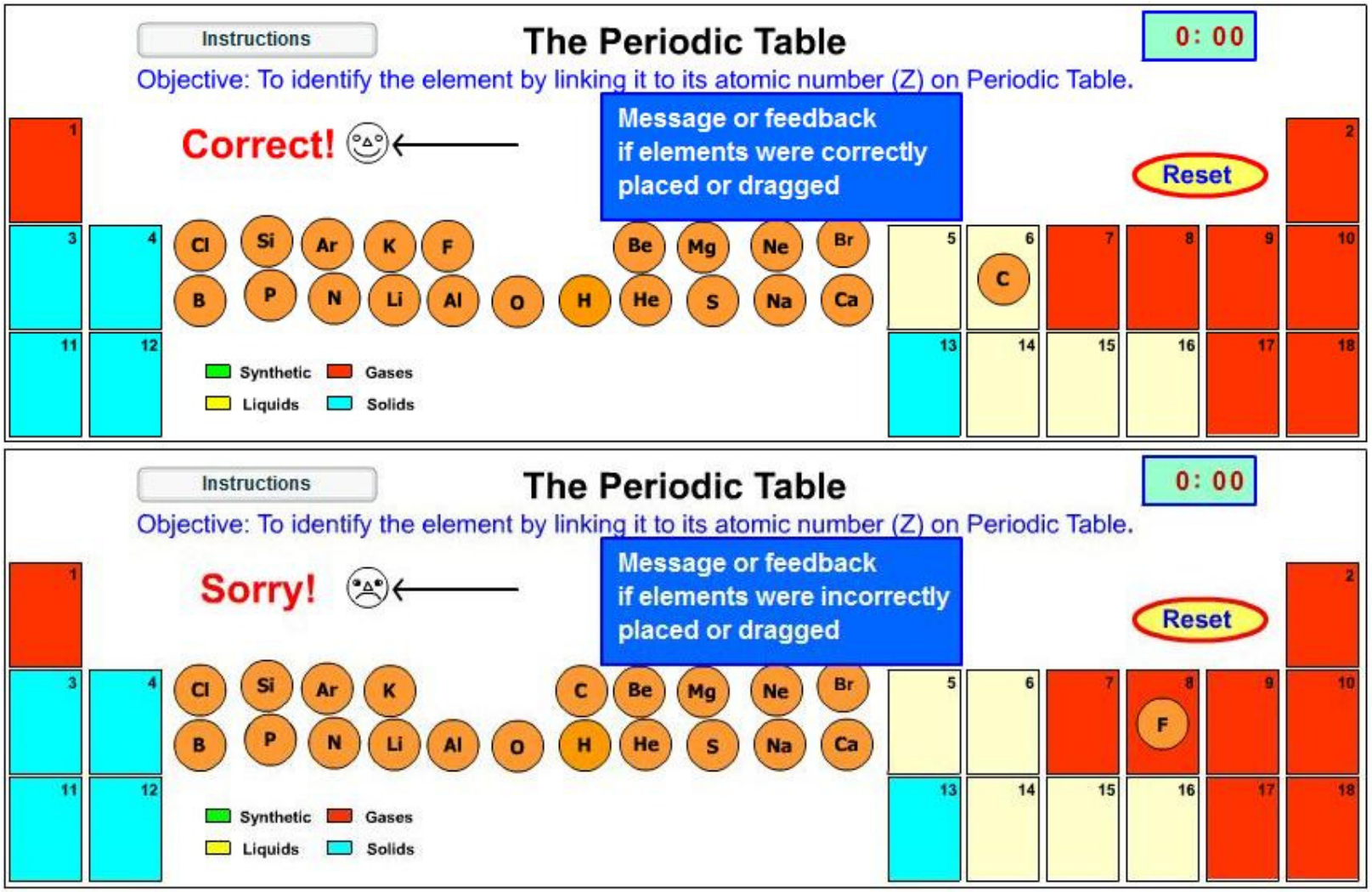

Figure 9 Feedback messages when a learner makes a correct selection from the combo box according to the atomic number or drags an element to the correct zone (above) and when an incorrect selection is made from the combo box or the element is dragged to the wrong zone (below).

3.3.3 Feedback

Feedback is regarded as information given by software to a learner about the appropriateness of his or her response (Poncelet & Proctor, 1993) or phrased differently; feedback provides information about the success or the quality of a response (Stemler, 1997). Feedback may serve several purposes, such as answer correctness, learning guidance, timeliness, motivational messages and learning focus (Varol & Colburn, 2007). In addition, Rieber (1994) added feedback as reinforcement and informational feedback. Feedback as reinforcement is a tenet of behavioural learning theory, whilst constructivism underlies informational feedback. Pridemore & Klein (1994) also recognize two categories of feedback, namely verification and elaboration, similar to the various types of feedback described by Mory (2003).

Mory (2003) cited various types of feedback: these are no-feedback (no response is given to the learner's response), simple verification feedback (informs learner of a correct of incorrect response), correct response feedback (informs learner what the correct response should be), elaborated feedback (provides information as to why a response is correct or incorrect) and try-again feedback (informs a learner when a response is incorrect and provides additional opportunities for the learner to try again). The same author further suggested that feedback significantly facilitates learning if the learner must respond before the feedback is visible.

Timing of feedback is also an important factor. Feedback may be immediate or delayed (Mark, Lehman & Herring, 2003). These authors posit that immediate feedback promotes the acquisition and retention of information as do Brosvic, Epstein & Cook (2004).

This study employed simple verification feedback or knowledge of results, to inform learners of a correct or incorrect response (see Figure 9). It also provided learners with the opportunity to answer until correct. Additionally, both graphical and textual feedback was given during the dragging and selection events, unlike Rieber *et al's*. (1996) study where either graphical or textual feedback was given.

3.3.4 Motivational messages

Motivation is important as it affects the affective state of learners whilst learning. Felder and Silverman (1988) concluded that learners need motivation for learning, whilst Chalmers (2003) agreed by stating that motivation is an important aspect to consider when researching and developing user interfaces for computer-assisted instruction.

If a learner drops an element in the wrong zone or place, the element will be accepted at the zone or place where it was dropped (see Figure 9; correct atomic number is 9). In fact, any element will be accepted if dropped in any zone or place on the Periodic Table. This reduces the element of chance or guessing by the learners. This activity obliges learners to know the correct atomic number before dropping the circular elements. Once an element is dropped in any particular spot, it will remain there unless the learner drags it to another zone (correct or incorrect) where it will be accepted or else the element will return to its original place above the Periodic Table. If a learner drops an element in a particular zone or place, the chronological sequence and event are recorded in the event log or audit trail (see description in Glossary or Section 4.3.1.5.1) as shown in Figure 10, in the left hand bottom corner of the diagram. Note how Boron was incorrectly dropped in the Nazone during event 3 yet was accepted here (//3/B/:07/XNazone). Event 4 shows that after 11 seconds into the animation, Mg was correctly dropped in the Mgzone (//4/Mg/0:11/Mgzone).

Learners are motivated by a number of messages depending on how they complete and how fast they play the game. If the learner places all the elements correctly within 60 seconds, the message: “You have done it!” appears (see Figures 11 and 12). If the learner places all the elements correctly in more than 60 seconds, the message: “You have done it in 60+ seconds!” appears (see Figure 13). If the learner places all the elements, some correctly and others incorrectly in less than 60 seconds or more than 60 seconds, a motivational message: “Check and try again, please!” appears (see Figure 14, below). If the learner abandons the game, a different motivational message: “Try again, you can do it!” appears (see Figure 14, above).

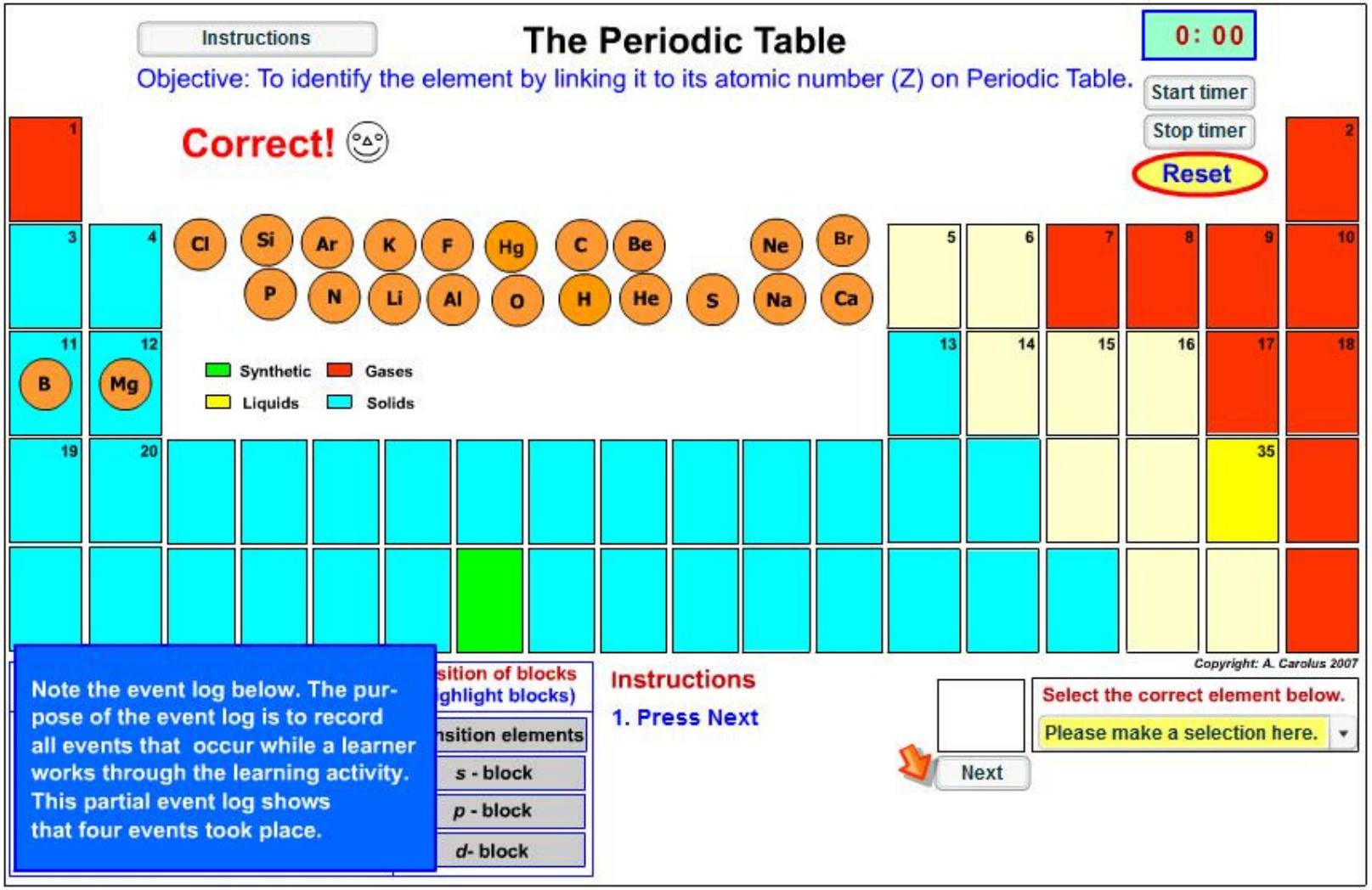

Figure 10 Partial event log or audit trail showing four events that occurred and that two elements were dropped, correctly or incorrectly and yet accepted by the zones.

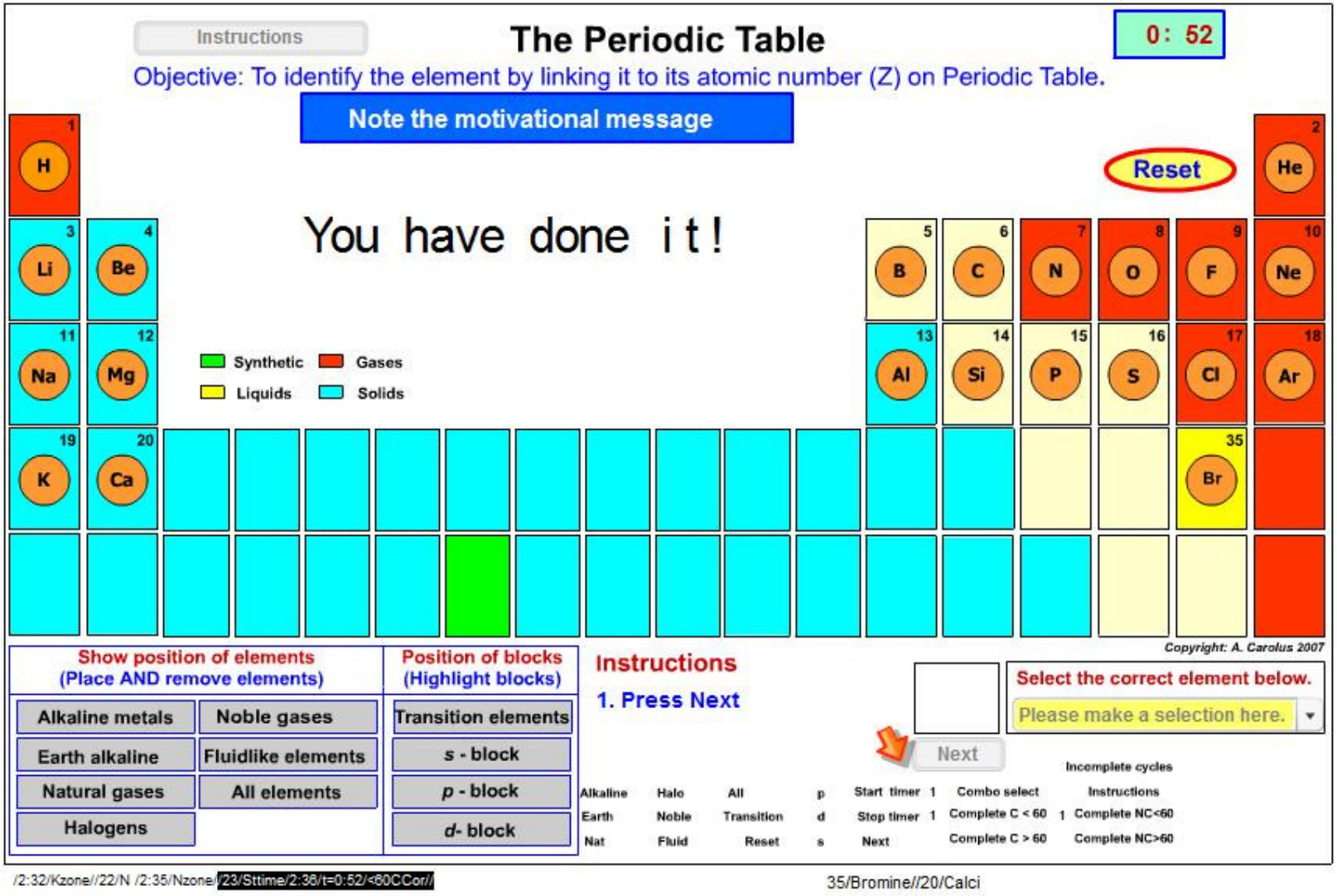

Figure 11 All the elements had been placed correctly within 60 seconds. This is illustrated by the last entry in event log with t = 52, <60C and the message: "You have done it!"

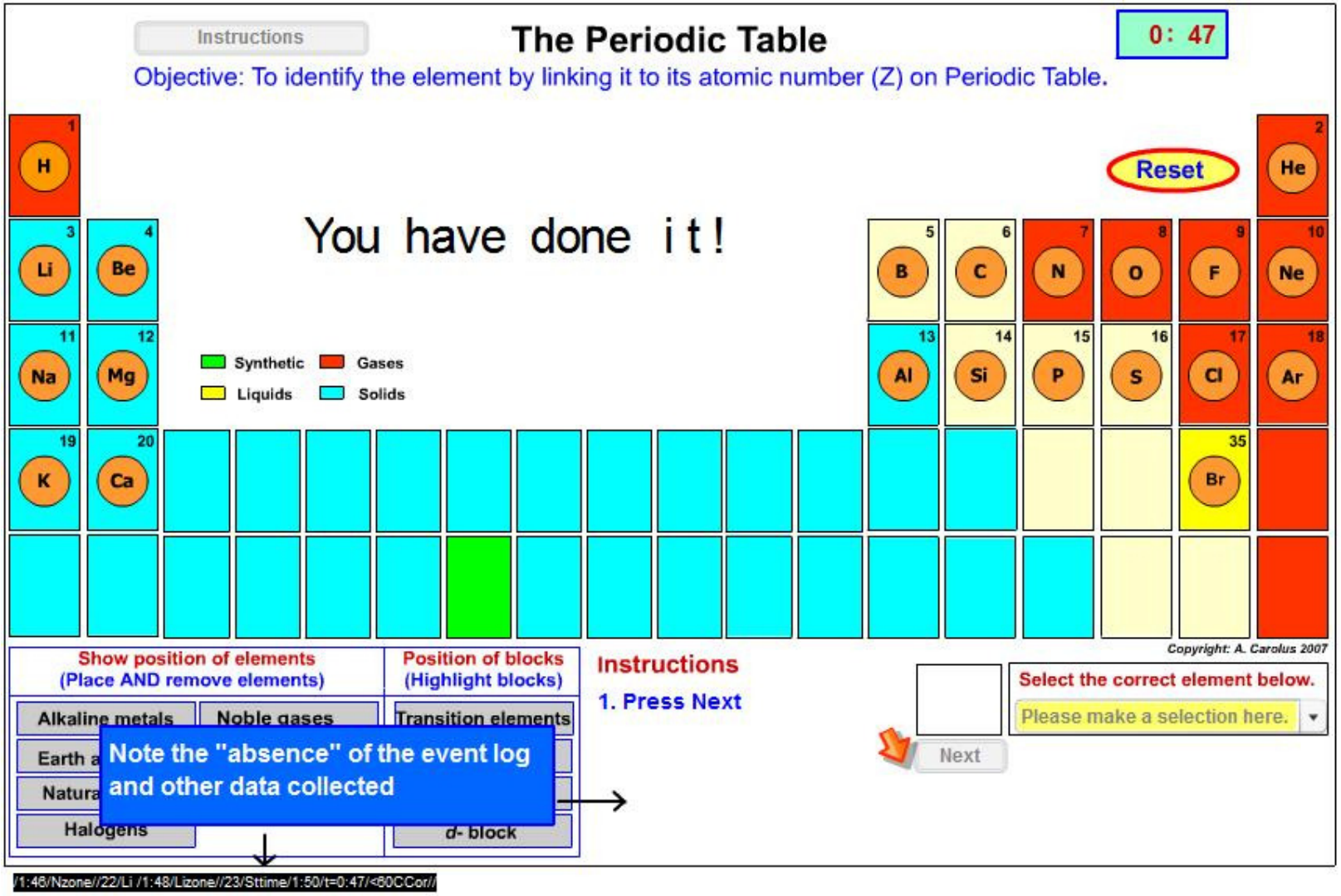

Figure 12 Figure shows the "absence" of the event log and data collected compared to Figure 9. The event log was highlighted to be visible. Learners were unaware of the event log and even if they discovered it, could not change the data collected.

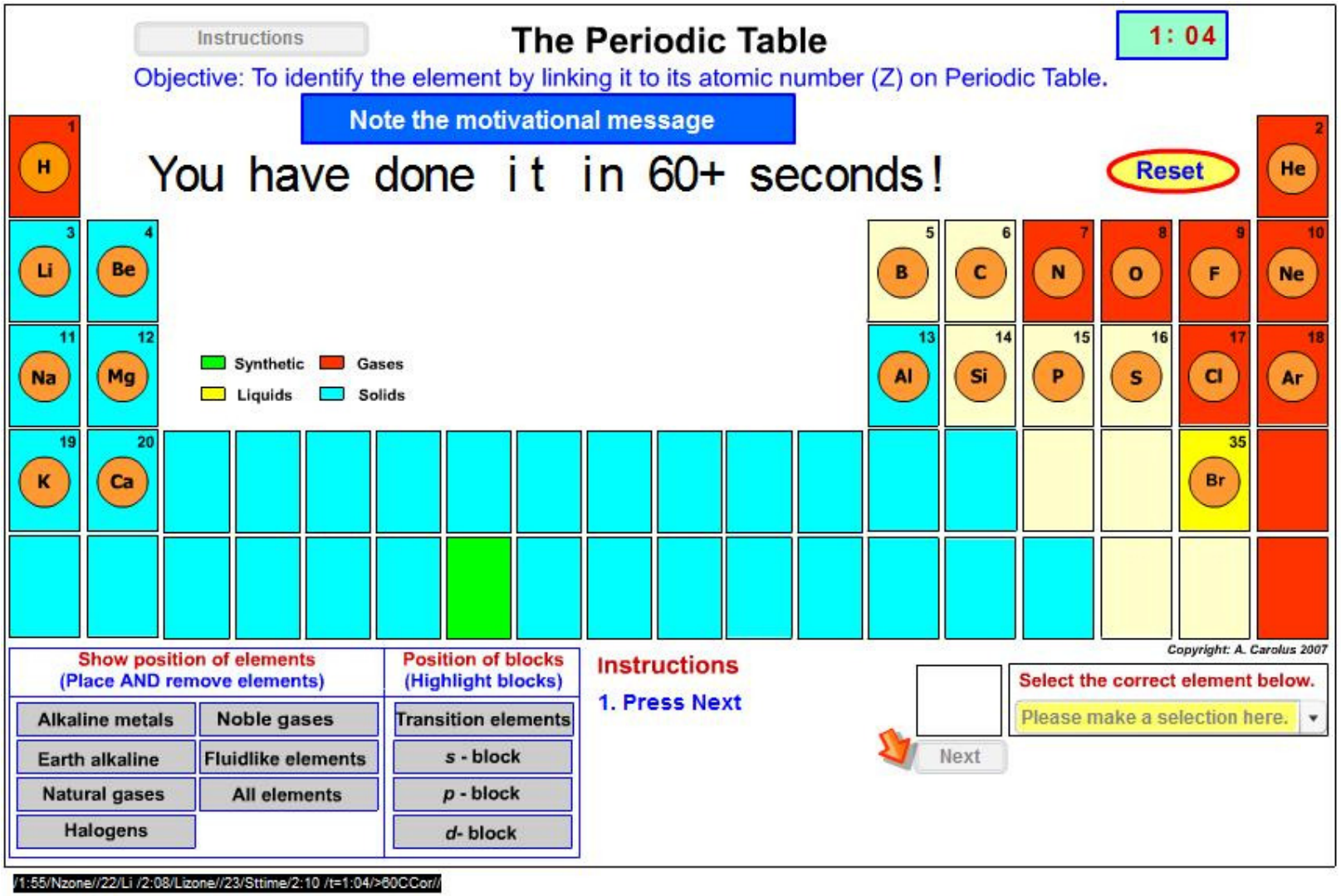

Figure 13 This game was completed in more than 60 seconds. Note that the event log entry at the bottom of the diagram confirmed the time (timer) and the motivational message above.

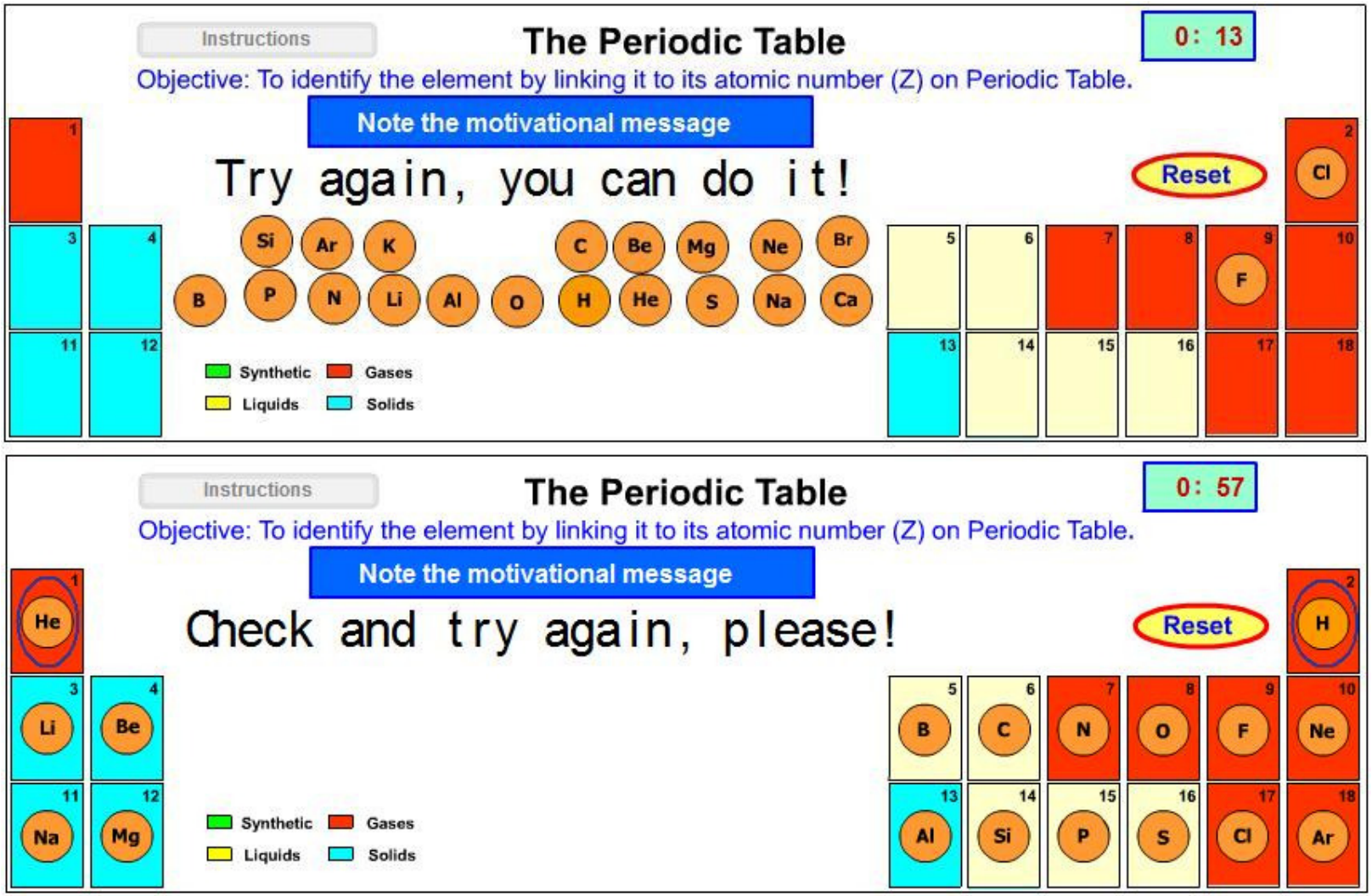

Figure 14 Diagram shows partial views of two Periodic Tables. The diagram on top shows an abandoned game with its motivational message. The diagram below shows an incorrect, yet completed game. The two circled elements should exchange places.

3.3 CONCLUSION

This chapter described the animation and the user interface. It also showed the feedback that appeared for dragging or placing an element correctly or incorrectly and the motivational messages that appeared whenever a learner engaged in a game.

The methodology used in the research is discussed in Chapter 4.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 INTRODUCTION

This chapter describes the methodology, research and measures taken to ensure validity and reliability in this study in order to answer the critical questions below. Observations, questionnaires, interviews and an audit trail were used to collect data about the program and cognitive, affective and psychomotor behaviour of the learners.

Critical questions

The main research question is: "How do learners respond to animation in the learning environment?"

The sub questions are:
In an interactive learning environment with animations …

1. what learning takes place from a cognitive, affective and psychomotor perspective and how?
2. what language problems do the learners experience and how do they deal with them?

Figure 15 presents a layout of Chapter 4 and shows the content discussed under the different headings.

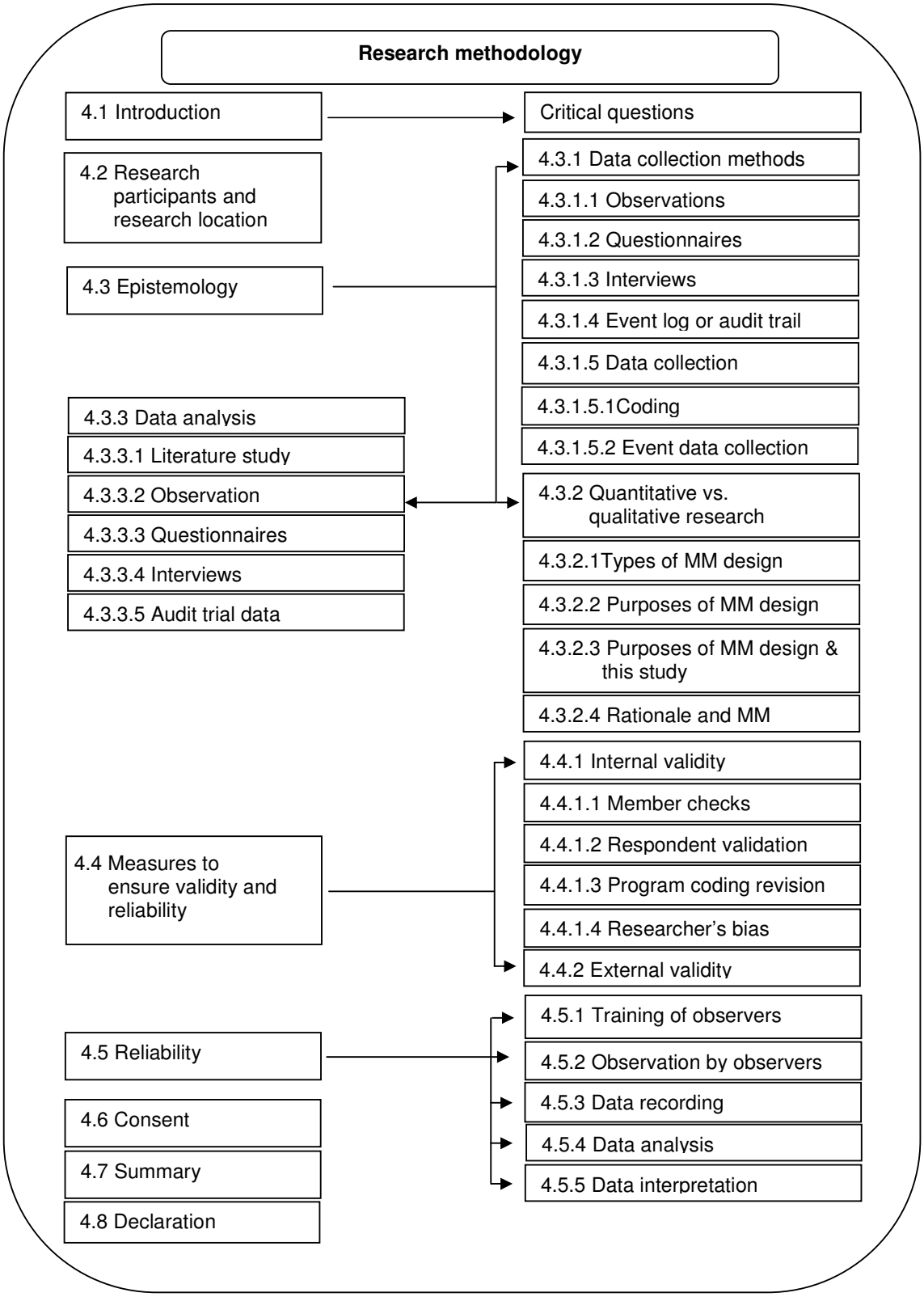

Figure 15 Overview of Chapter 4 indicating the content discussed

4.2 RESEARCH PARTICIPANTS AND RESEARCH LOCATION

The target population is described by a number of contributing features discussed below. All the Grade 10 learners were from a predominantly black, previously disadvantaged community, isiXhosa home language speakers and taught in English, i.e. they were English First Additional Language learners. The class consisted of twelve learners, both male and female, ranging in age from 16 to 18 years of age.

The participants in the research were twelve Grade 10 English First Additional Language learners. The research was done at a rural, black school resorting under the Western Cape Education Department. Learners worked with the animation (that collected data in the background), completed the questionnaires, took part in interviews (three randomly selected learners), checked the data collected and verified the interpretations of the data. Some of the learners studied Computer Applications Technology (CAT) as a subject and, therefore, had good computer experience. Some learners had taken computer literacy classes since Grade 9 and three learners had joined the school in Grade 10 and, therefore, had little experience except for occasionally game playing on the computer.

The Grade 10 class initially consisted of seventeen learners of different linguistic and academic ability, all studying Physical Science. The learners varied in linguistic ability from those who could barely speak English to those who could express themselves quite well. By the time the research study commenced, the class comprised of twelve learners only. All twelve learners were invited to take part in the study.

The animation was loaded onto a central server in the Khanya computer laboratory at the school where the research was conducted. Twenty four workstations were connected to the server from where learners (in groups of two) could access the animation via their individual workstations. Only six workstations were used for the research. The participant-observers either sat next to the Grade 10 learners or stood behind them in a position from which to observe them.

Learners were taught the basics of the Periodic Table in a normal class period during the course of the day. The research was conducted in a 45 minute period immediately after school with the observers in attendance. The research had to be conducted after school hours as the Khanya laboratory was not available during the course of the normal school day and the observers (Grade 11 learners) attended their own classes during the day.

The animation was piloted by Grade 11 learners. The reasons for the pilot study are as follows:

- to familiarize the Grade 11 learners with the animations and for them to be able to assist the Grade 10 learners during the subsequent research;
- to prevent the Grade 11 learners from being distracted by the animations instead of observing the Grade 10 learners;
- to test the physical setup in the laboratory;
- to test the audit trail data collection for obvious mistakes; and
- to locate and correct programming mistakes.

4.3 EPISTEMOLOGY

The research followed a case study methodology. A case study approach is a specific instance that is often designed to illustrate a more general principle or, alternatively, it is a study of an instance in action, one in which the case is studied in depth as it occurs in a real situation, studying real people (Cohen, Manion & Morrison, 2005, p. 181). Leonard-Barton (1990) described a case study as “a history of a past or current phenomenon, drawn from multiple sources of evidence”.

Important is that case studies may be done using mixed methods (Ke, 2008; Yin, 1981) as in this research study. A common misconception is that case studies solely or largely rely on participant observations or ethnographies. This case study used observations, interviews, questionnaires and an audit trail. The various mixed methods (see Table 15) used in conjunction produced largely convergent and consistent results (Jick, 1979).

Types of case studies

A case study may be exploratory (as a pilot to other studies or research studies), descriptive (providing narrative accounts), explanatory (testing theories), interpretative (developing conceptual categories) or evaluative (explaining and judging) (Onwuegbuzie & Johnson, 2006).

This case study provided narrative (verbatim) accounts of interviews, was interpretative in nature (seeing the learning situation through the eyes of the participants and observers) and proved to be chronological (audit trail provided certain happenings in a certain order). This tied in with the fact that the observation method lies at the heart of a case study.

Strength of case studies

The strengths of case studies outweigh their weaknesses. The strengths include, amongst others:

- Results that are more readily understood by a wide audience;
- Results that speak for themselves, i.e. self evident;
- Unique features that may be easily being lost in a large scale study are caught;
- Strong realities are displayed by case studies;
- The fact that it can be undertaken by a single researcher instead of a team;
- Case studies examine issues in real contexts (Cohen, Manion, & Morrison, 2005, p. 184).

Reasons for using a case study and this research study

Generally case studies display several features (Cohen, Manion, & Morrison, 2005). These include:

- Clear descriptions of events related to the case (language usage; actions of learners toward each other; learners' display of emotions towards each other);
- Provision of a chronological sequence of events (the sequence in which buttons were pressed);
- Focusing on individuals or groups of people (6 groups/pairs of learners took part);
- Highlighting specific events that pertain to a case (timer malfunction; negative case sampling; duration of games, times when drills were started versus duration of drills; sequence in which buttons were pressed; duration of displayed information; times spent observing positions, groups and blocks of elements; patterns or occurrences of buttons pressed; distribution of drills);
- Integrally involvement of researcher or his/her aides in the study (participant observations; interviews done by researcher);
- When writing up the report an attempt is made portray the richness of the study (comments of observers and interviewer were written down verbatim; cognitive, affective and psychomotor of animation of learning were recorded; quantitative and qualitative methods were used; descriptions of how learners dragged and selected elements were included; detailed descriptions of how learners approached the learning activity were given);
- Examining issues in real contexts (research done in a physics period; content covered formed part of syllabus; groups were learners offering the subject physical science);
- Attesting to the dynamic and unfolding interactions of events, human relationships (sequence of buttons pressed; duration of displayed information; occurrences of buttons

pressed; different ways of dragging elements; explaining to each other; disagreeing with each other).

4.3.1 Data collection methods

Several methods were used to collect data during this study to provide the depth of information necessary. These methods were used to triangulate, verify data, disprove data and for negative case sampling. Data was collected by:

- observation;
- a questionnaire;
- an interview; and
- an audit trail.

Data collection by the different data collection methods was as follows: the observation was done according to Borg & Gall (1979, p. 464); the questionnaire according to Schumacher and Macmillan (1993, p. 238) and the interview according to Schumacher and Macmillan (1993, p. 250). Reasons for conducting research according to these authors' research methods are separately discussed under each data collection method. Audit trail data was collected by a custom designed, Flash MX 2004 coded program.

Table 10 shows the five different methods of data collection to answer the main research question. It further tabulates the data collection methods used to investigate the main research questions in this study.

Table 10 Data collection matrix of methods used to answer the sub questions

No	Research question	Literature study	Observation	Questionnaires	Interviews	Audit trail data
1	What learning takes place from a					
1.1	cognitive	✓	✓	✓	✓	-
1.2	affective and	✓	✓	✓	✓	✓
1.3	psychomotor perspective	✓	✓	✓	✓	✓
	and how?	-	✓	✓	✓	-
2	What language problems do learners experience and how do they deal with them?	✓	✓	✓	✓	-

4.3.1.1 Observations

Observation was used as a research method to gain an insight into the learners' cognitive, affective and psychomotor behaviour in a natural or real class setting (Ary *et al.,* 2006). Observation was done by participant-observers for the following reasons:

- to gain rapport and develop relationships with the group;
- to assist the learners during animation execution;
- to gather low-inference data, that normally yields reliable data and
- to obtain independent perspectives of the learners' cognitive, affective and psychomotor behaviour during the execution of the animation.

Six Grade 11 learners were trained as participant-observers and the observation checklist explained to them (see Appendix A). These learners were taught Physical Science by the researcher in Grade 10 and in his opinion had a sound knowledge of the subject. It was also required that the observers give guidance and assistance to the Grade 10 learners.

A total of twenty two questions were compiled with respect to language usage and cognitive, affective and psychomotor behaviour during the execution of the experiment. Questions were posed (as opposed to statements) to what participant-observers should look for during observation. These questions served as a guide as to what observers should look for and compelled the observers to be specific. With the use of statements, as opposed to questions, there was the possibility that observers could simply write down the given statement. The Grade 10 learners (who worked in pairs) were observed for all actions and utterances and duly recorded by observers.

Observations were recorded during the research activity to avoid biased recall and afterwards the observers were given an opportunity to amend their notes. The researcher also discussed the notes with each observer (where applicable) to clarify points that did not make sense in order to increase the reliability of the study.

4.3.1.2 Questionnaires

A directly administered questionnaire was used for the following reasons:

- questionnaires can be produced at low cost;
- they yield a high response rate; and
- the researcher was present during the administration of the questionnaire.

Questionnaire data was collected to investigate the cognitive, affective and psychomotor behaviour of the learners whilst working and viewing the animation. Twenty two questions (see Appendix Table 1) were designed to match the research objectives and to gauge the learners' cognitive processing, emotions and physical activities indicative of their cognitive, affective and psychomotor behaviour respectively. The questions on psychomotor behaviour focused on the learners' actions, whilst the questions on affective behaviour focused on the emotions of the learners. The questions on cognitive behaviour were aimed at determining if the learners' knowledge improved during execution of the animation.

4.3.1.3 Interviews

Personal interviews were conducted for the following reasons:

- the researcher can establish a rapport with the interviewee;
- a high response rate is obtained;
- fewer incomplete answers are given;
- ample time can be allowed for thoughtful answers; and
- the researcher is present to clarify uncertainties.

Three randomly selected learners were interviewed after the 30 - 45 minute session of interaction with the animation. Ten carefully compiled questions (see Appendix B) were used to probe the learners' thoughts to gain an insight into the cognitive, affective and psychomotor behaviour and to find out how English First Additional Language learners interact with animation in an interactive learning environment. Interviews were recorded (lasting 5 - 10 minutes per learner) and transcribed. The data from the interviews was used to verify the data from the questionnaire responses.

4.3.1.4 Event log or audit trail

An audit trail is the automated data collection of all transactions (events) by the operating system on a stand alone computer or behavioural event recording that occurs while students interact with different educational programs, by specialized programs or by custom designed event capturing programs (Kennedy and Judd, 2003). According to these authors, audit trails refer to a sequence or chronological order of events or activities within a technology environment, often called the "history". It may also include a record of user inputs, text entries and responses to fixed questions, instructional activities and tasks (ibid.). These event histories, in which time plays an important role, are often stored in databases or flat files and, in the case of this study, within the animation.

This study used an audit trail for the following reasons:

- to determine how the learners interacted with the learning unit;
- to establish how often elements were dragged, as opposed to selected;
- to establish the sequence in which buttons were pressed;
- to determine the number of times buttons were pressed;
- to determine how many games were played;
- to determine how many games were abandoned;
- to determine how many games were correctly and incorrectly completed in less than 60 seconds;
- to determine how many games were correctly and incorrectly completed in more than 60 seconds:
- to find out how many times elements were dragged (correctly and incorrectly) and in which zones these elements were placed;
- to triangulate; and
- to establish responses of learners.

The data was obtained by scripting the Flash MX 2004 animation to record the learners' interactivity with the animation and by storing the data in the animation. After the 30 - 45 minute session of interaction with the animation, the data was harvested, copied to a word processor, delimited and analyzed in a spreadsheet.

4.3.1.5 Data collection

This section describes the coding used to collect data for:

- dragging and dropping elements;
- selecting elements from the combo box;
- game playing; and
- buttons pressed.

Where applicable, these codes were used for data collection during the learning and assessment phases and subsequent data analysis.

4.3.1.5.1 Coding

Various codes were written to characterize events that occurred in order to log all learner activities for subsequent data analysis. These codes are descriptive of the customized button events, component button events, instructional events and elements dragged or selected. Table 11 shows the symbols or characters that are common to all events in the

program. These symbols do not describe the events per se, but rather mark the end of any event, show how long an event took and the chronological sequence of events. The table also shows the different codes used when dragging an element. Almost all the event coding shows the following format: Number/time/letter code//.

Table 11 Codes or symbols for the different events with an explanation of each symbol

No	Code or Symbol	Explanation
1	Number	Indicates the chronological order of events
2	/	Delimits the parameters in an event entry
3	0:01	When, after the start of an activity, the event occurs
4	//	Delimiter indicates the end of an event

Table 12 shows the symbols the animation uses to record an event whenever an element is dragged around or placed using the 'Next' button.

Table 12 Codes or symbols for the different elements dragged or placed with an explanation of each symbol

No	Code or Symbol	Elements dragged or placed - X…zone
1	Number	Indicates the chronological order of events
2	Symbol	Symbol of element
3	time	Time since the program started
4	X..	Wrong zone or place

Table 13 describes the codes for different games against time. It shows codes indicating if the game is abandoned, if it is completed correctly in less than 60 seconds, if it is completed correctly in more that 60 seconds, if it is completed incorrectly in less than 60 seconds and if it is completed incorrectly in more than 60 seconds.

Table 13 Codes or symbols for the game with an explanation of each code or symbol

No	Code or Symbol	Events pertaining to the game
1	Number	Indicates the chronological order of events
2	Stime	Timer started
3	Time	Time when the game was started
4	t =	Duration of the game
5	Aban	Game is abandoned
6	<60Ccor	Game is complete, correct in less than 60 s
7	>60Ccor	Game is complete, correct in more than 60 s
8	<60CNCor	Game is complete, not correct in less than 60 s
9	>60CNCor	Game is complete, not correct in more than 60 s
10	Sstime	Timer stopped

Table 13 summarizes the codes used by the animation to record the events occurring when the learners played the assessment game.

Whenever buttons are pressed, a different set of codes are used to record the events. Table 14 summarizes the codes used by the animation to record the events when the learners pressed different buttons.

Table 14 Codes or symbols for the different buttons pressed, with an explanation of each code or symbol

No	Code or Symbol	Button presses
1	All & AllD	All button pressed and released
2	Alk & AlD	All button released and released
3	Clip	Drag circular element in instructions
4	Co	Indicates a combo box selection
5	db & dbD	d - block button pressed and released
6	dbIP & dbIPD	Elements placed, d - block button pressed and released
7	Earth & EarthD	Earth alkaline button pressed and released
8	Fluid & FluidD	Fluid-like button was pressed and released
9	Halo & HaloD	Halogen button was pressed and released
10	Inert & InertD	Inert gases button was pressed and released
11	Inst	View instructions
12	N	Next button pressed
13	Ngas & NgasD	Natural gas button pressed and released
14	pb & pbD	p - block button pressed and released
15	pbIP & pbIPD	Elements placed, p - block button pressed and released
16	Re	Resets the timer and elements to original position
17	ReInst	Removes the instructions
18	sb & sbD	s - block button pressed and released
19	sbIP & sbIPD	Elements placed, s - block button pressed and released
20	Trans & TransD	Transition element button pressed and released

4.3.1.5.2 Event data collection

Event data is collected by the animation as the learner interacts with the animation. The data is collected in six text boxes below the animation. The first text box collects all the data in chronological order; the second text box collects data of elements incorrectly dragged and selected from the combo box; the third text box collects data of elements incorrectly dragged; the fourth text box collects data of elements dragged to correct zones; the fifth text box collects data of elements selected incorrectly from the combo box and the sixth text box collects data of elements selected correctly from the combo box (see Figure 16).

A second set of data is collected directly on the animation. This data includes the button clicks, the number of abandoned games; correctly completed games (in less and more than 60 seconds) and the number of incorrectly completed games (in less and more than 60 seconds) (see Figure 16). This data forms part of the event log but is collected separately as it lends itself to descriptive analysis. The event log was not visible to the learners whilst

they were busy with the activity (see Figure 16). Compare Figures 6 and 16 for the absence and presence respectively of the event log.

4.3.2 Quantitative and qualitative research

This study employed a mixed method of data collection and analysis as some of the data lent itself to quantitative analysis and other data lent itself to qualitative analysis. Salomon (1991) posited that quantitative and qualitative methodologies are not in competition but, instead, compliment each other. The different methods and the rationale for using these methods are described below.

4.3.3 Mixed methods

Johnson & Onwuegbuzie (2004) formally defines mixed method research (designs) as: "the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or languages into a single study". Hanson, Creswell, Plano Clark, Petska, & Creswell (2005) concurred by clearly stating that mixed method designs involve collection, analysis and integration of qualitative and quantitative data in a single (case) study. An even better, all inclusive definition of mixed methods research is that of (Creswell, Plano Clark, Gutman, & Hanson, 2003, p.212) that defined it as:" the collection or analysis of both quantitative and qualitative data in a single study in which the data are collected concurrently or sequentially, are given a priority, and involve the integration of data at one or more stages in the process of research". Kaplan & Duchon (1988) posited that there has been a move in other fields toward combining qualitative and quantitative methods to provide a richer, contextual basis for interpreting and validating results.

According to the **fundamental principle** of mixed method research (Johnson, et al., 2007; Johnson and Onwuegbuzie, 2004; Onwuegbuzie and Johnson, 2006; Onwuegbuzie and Leech, 2004), quantitative and qualitative research methods, approaches, and concepts that have complementary strengths and non-overlapping weaknesses, are used in conjunction to address the same research question. Mingers (2001) concurred by stating that:" research results will be richer and more reliable if different research methods, preferably from different (existing) paradigms, are routinely combined together."

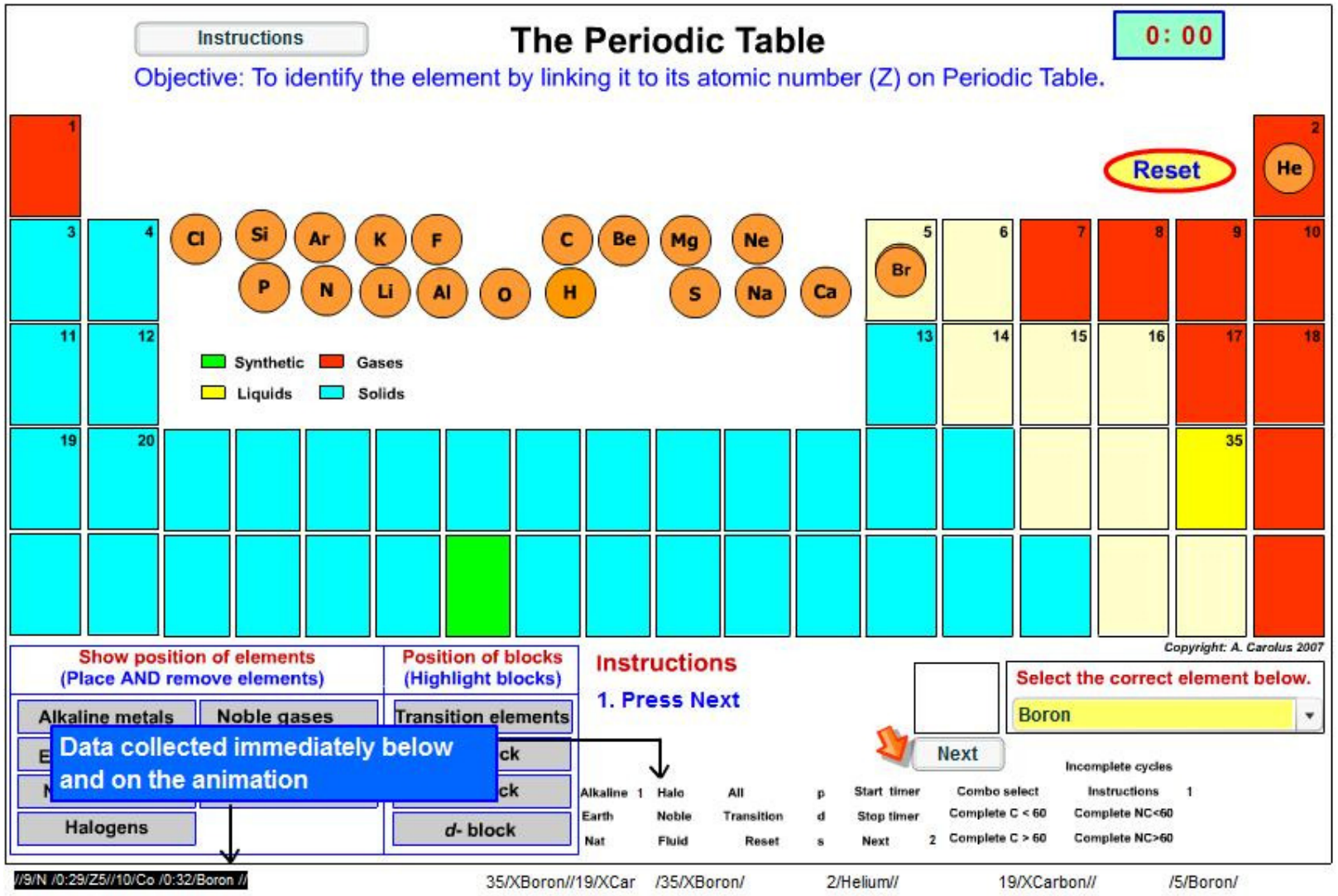

Figure 16 Data collected directly on and immediately below the animation. The data on the animation formed part of the event logs.

The qualitative case study was selected as the dominant paradigm to investigate the influence of animation on physical science learning. Wherever possible and applicable, the quantitative research methods were used to extend the predominantly qualitative approach.

4.3.3.1 Types of mixed methods design

Teddlie & Tashakkori (2006) and Onwuegbuzie & Johnson (2006) listed five types of mix methods design. These are concurrent mixed design, parallel mixed design, sequential mixed design; conversion mixed design and fully integrated mixed design.

In concurrent mixed design (Onwuegbuzie & Johnson, 2006; Teddlie & Tashakkori, 2006) the quantitative and qualitative data are collected separately at approximately the same point in time, neither the qualitative nor quantitative analysis build onto each other and after collection and interpretation of data from the quantitative and qualitative components, a meta-inference is drawn based on the inferences made from each component.

In parallel mixed designs (Onwuegbuzie & Leech, 2004; Rocco, et al., 2003), the data are collected and analyzed separately. In this respect it is similar to concurrent designs. However, while inferences are made in concurrent designs on both sources of data in an integrated manner, in parallel mixed designs, each data source leads to its own set of inferences.

Sequential mixed designs (Onwuegbuzie & Johnson, 2006; Teddlie & Tashakkori, 2006) are characterized by quantitative/qualitative data collection and analysis from one phase of a study informing another phase of a research study or investigation. Typically the data analysis must start before all data is collected, in order to inform another phase of a study. The approaches to data collection, analysis and inference making are therefore carefully sequenced to inform successive phases of study.

Conversion mixed design is characterized by the conversion of quantitative data to qualitative data called qualitizing (Onwuegbuzie & Johnson, 2006; Onwuegbuzie & Leech, 2004; Sandelowski, 2000; Teddlie & Tashakkori, 2006) and conversion of qualitative data to quantitative data called quantitizing or scaling (Jick, 1979) and subsequently analyzed and inferences made on both sets of data.

Fully mixed research design is also known as fully integrated mixed research designs (Teddlie & Tashakkori, 2006). Quantitative and qualitative approaches are interactively mixed at all stages of the investigation (i.e., research objective, type of data/operations,

type of analysis/inference; Onwuegbuzie & Johnson, 2004) such that at each stage, one approach (e.g., quantitative) influences the formulation of the other approach (e.g., qualitative).

4.3.3.2 Purposes of mixed method research

A research project may be exploratory (without a priori hypotheses) or confirmatory with a priori hypotheses (Rocco, et al., 2003). This research project was exploratory in nature as it sought to investigate the effects of animation on physical science learning. This project therefore lent itself to the use of multiple methods to obtain answers to main and sub questions of this research topic.

Greene, Caracelli, and Graham (1989) and Rocco, Bliss, Gallagher, & Perez-Prado, (2003) listed five general purposes of mixed method research studies. The complementary strengths include triangulation (seeks convergence of findings or to corroborate data (Sandelowski, 2000), expansion (seeking to expand the scope, breadth and range of inquiry by using different methods for different inquiry components), complementarity (different methods are used to assess different study components or phenomena or to clarify, explain, or elaborate the results of analyses), development (using the findings from one method to help inform the other method, or to guide the use of additional sampling, and data collection and analysis techniques), initiation (discovering paradoxes and contradictions that lead to reframing of the research question).

4.3.3.3 Purposes of mixed method research and this research study

Triangulation

Triangulation seeks to converge findings or to corroborate data. Observation (qualitative data collection method that generated qualitative, verbatim descriptions (results)), showed that the learners managed to complete drill and practice games. The audit trail data (quantitative research method that generated quantitative data that indicated the frequency of completed drill and practice games), questionnaires (qualitative data collection method that yielded responses that were quantitatively transformed (quantitizing (Sandelowski, 2000)) to indicate how many learners completed games.

Expansion

Expansion serves to widen the scope of the study. This could have been accomplished by the open-ended questions (the interview is qualitative research method that yielded qualitative data) posed by the interviewer. None of the groups dragged (all, some, most) of

the alkaline or earth alkaline elements to their respective zones and followed up by pressing the alkaline or earth alkaline buttons. This provided a reason to expand the study although it was not done.

Additionally, 67% of all learners indicated that they dragged the instructions movieclip around whilst reading the instructions. Audit trail data proved that only one group (at most 2 learners) dragged the instructions movieclip. Further investigation of this issue could have broadened the scope (expansion) of this study.

An observation by one observer that some learners “cheated” warranted further investigation. Although a new research question was not formulated, enough interest was kindled to expand on this phenomenon by discussing the issue with the observer.

Complementarity

Complementarity was demonstrated several ways. Two independent observation results (qualitative research method that yielded qualitative results) indicated that learners were “playing” with the timer. Audit trail data (quantitative research method) indicated that the Start button were pressed successively, resulting in timer malfunction. Attempts by learners to restart the games, were construed as playing with the timer.

Complementarity was also demonstrated by the completion of games. The observers (qualitative research method that yielded qualitative results) indicated that some drill and practice games were completed correctly in progressively smaller time intervals as time went by. The questionnaire data (qualitative research method that yielded quantitized results) confirmed the completion of the drill and practice games. The audit trail data (quantitative research method) gave more detail (quantitative results) as to how long it took to complete drill and practice games and how the learners went about completing the drill and practice games.

Development

Development uses the findings of one method to inform another method. Observation (qualitative research method) data that indicated learners were playing with the timer were informed by the audit trail data (quantitative research method). The audit trail showed that learners pressed the Start button successively, bringing about timer malfunction.

Initiation

Initiation deals with the discovery of paradoxes and contradictions that calls for the reframing of research questions. Initiation did not occur in this research study.

4.3.3.4 Rationale and mixed methods used in this study

Sandelowski (2000) posited that mixed method research is may be affected at the sampling, data collection and data analysis levels. This in keeping with the numerous definitions of mixed methods research put forward by various authors (Creswell, Plano Clark, Gutman, & Hanson, 2003, p .212; Hanson, Creswell, Plano Clark, Petska, & Creswell, 2005; Johnson & Onwuegbuzie; 2004; Kaplan & Duchon, 1988).

The main research question in this research study was written as an overarching mixed research question (Tashakkori & Creswell, 2007), namely: “How do learners respond to animation in the learning environment?” with the sub questions:

In an interactive learning environment with animations …

1. what learning takes place from a cognitive, affective and psychomotor perspective and how?
2. what language problems do the learners experience and how do they deal with them?

Table 15 briefly stated the data collection methods, sampling techniques (if any), how the data was analyzed and the data output in order to answer these questions.

Sub question one refers to human nature of mankind and therefore would seem to be strictly qualitative in nature. However, the observation and the audit trail data collection that occurred simultaneously, was indicative of a **parallel mixed design** (during the observation, the interactive animation collected data in the background and the data sets were analyzed separately; see Table 15). A qualitative data collection method and a quantitative data collection method were employed, whilst the data was also qualitatively (descriptions) and quantitatively (frequencies, sequencing, average times) analyzed.

Conversion mixed design (see Table 15) also took place during this research study. In answering sub question one questionnaire data (closed questions) that yielded responses to cognitive, affective and psychomotor questions were counted as per yes/no category. The cognitive (see Figure 34), affective (see Appendix Figure 1) and psychomotor (see Appendix Figure 2) data were quantitized. This quantitized data indicated to the researcher

Table 15 Combinations of data sampling, data collection and data analysis methods used

MM design		Data sampling	Data collection method	Perspective	Data analysis	Data output
	Parallel mixed design	Per group of two learners (six groups)	Audit trail data	Cognitive	Quantitative	Line and bar graphs, extracts from original data
					Qualitative	Description, screen dumps
				Affective	Quantitative	Table and bar graphs
				Psychomotor	Quantitative	Tables, extracts from original data
Fully integrated design & sequential mixed design		Per group of two learners (six groups)	Observations	Cognitive	Qualitative	Descriptions
				Affective	Qualitative	Descriptions in table
				Psychomotor	Qualitative	Descriptions
	Conversion mixed design	All learners	Questionnaires	Cognitive	Quantitizing	Bar graphs
				Affective	Quantitizing	Table (perseverance), bar graph affective behaviour
				Psychomotor	Quantitizing	Bar graph psychomotor behaviour
					Qualitative	Descriptions in table
		Three randomly chosen learners	Interviews	Cognitive	Qualitative	Verbatim responses relayed
				Affective	Qualitative	Descriptions in table
				Psychomotor	Qualitative	-

MM = Mixed methods. Read the mixed designs opposite the data collection method(s).

how many participants managed to accomplish some or other task while the observation (qualitative description) indicated how wide the range of accomplishments was.

Fully mixed research designs (Johnson & Onwuegbuzie, 2004; Onwuegbuzie & Johnson, 2006), is also known as fully integrated mixed research designs (Onwuegbuzie & Johnson, 2006) involve the mixing of quantitative and qualitative approaches in an interactive way at all stages of the investigation (i.e., research objective, type of data/operations, type of analysis/inference (see Table 15).

Sequential mixed design describes the use of quantitative and qualitative methods in chronological order with results from one method feeding into the other (Mingers, 2001). Greene, et al. (1989) describes sequential mixed methods data collection via quantitative and qualitative methods as a chronological process, with the first method informing the development of the second method (see Table 15).

Sub question two was mostly answered by collecting data via a qualitative collection method (observation) by verbatim reports of the observers (qualitative analysis).

4.3.4 Data analysis

The following section describes the data analysis for each data collection method, looking at observation, questionnaire, interviews and audit trail data.

4.3.4.1 Literature study

The literature study consisted of an analysis of the literature to answer the research sub questions, namely:

In an interactive learning environment with animations …

1. what learning takes place from a cognitive, affective and psychomotor perspective and how?
2. what language problems do the learners experience and how do they deal with them?

The literature study formed the theoretical underpinning of the investigation.

4.3.4.2 Observation

The observation was done in order to establish how responses displayed by the learners were in line with cognitive, affective and psychomotor behaviour. The observers' notes

were typed (per group) into a spreadsheet and responses marked as cognitive, affective and psychomotor behaviour. The observers' notes were compared for consistencies in physical, affective and cognitive behaviour, according to the observation checklist (see Appendix A) to verify the occurrence or non-occurrence of events per group. Finally, groups were compared to see which behaviours occurred in all groups, or which behaviours were limited to some or specific groups.

4.3.4.3 Questionnaires

The questionnaire (see Appendix Table 1) consisted of three categories of questions specifically drawn up in line with cognitive, affective and psychomotor behaviour. These questions were drawn up to test if learners responded in ways that were indicative of cognitive, affective and psychomotor behaviour. The learners were simply required to answer yes or no to the questions that were pre-coded in line with the research questions. The first category (questions 1 - 13) was labelled C for cognitive behaviour; the second category (questions 14 - 18) labelled A for affective behaviour and the third category (questions 19 - 22) labelled P for psychomotor behaviour. Some questions elicited responses in more than one category. The questionnaire questions (with answers, i.e. yes or no) of all groups were typed in a spreadsheet and the data was collated in order to do a content analysis.

4.3.4.4 Interviews

The interviews (see Appendix B) were qualitative and standardized semi open-ended in nature. The interviews of each participant were transcribed verbatim to avoid bias on the part of the researcher. Non-verbal cues were also included in the transcript. A general thematic approach of data analysis followed and the data coded, reduced and organized according to Wiersma and Jurs (2005, p. 206).

4.3.4.5 Audit trail data

The audit trail was used to determine the frequency and duration of significant user activities or user interface events.

The Flash MX 2004 animation compiled an audit trail (or event log) in the background as the learners were interacting with the animation. Delimiters marking the start and end of events (//), were built into the collected data in order to facilitate subsequent text data analysis (see Table 11). The data was subsequently copied to Microsoft Word and split into segments as per event using a Microsoft Word macro. The data was subsequently

copied to Microsoft Excel, delimited to different columns and, finally, specific columns were concatenated depending on the nature of the information required (see Appendix D).

4.4 MEASURES TO ENSURE VALIDITY AND RELIABILITY

The research study showed the attempts made to produce valid, authentic and reliable meaning and knowledge about the cognitive, affective and psychomotor affects of animations on Physical Science learning in a Grade 10 classroom. For this purpose, various methods of data collection were used; the researcher conferred with the observers whenever their notes were not clear, interviews were transcribed verbatim, the learning unit was tested continuously and upgraded to ensure that it functioned properly and the learning unit was piloted by the Grade 11 learners prior to use with the subjects of the study.

4.4.1 Internal validity

The strategies used to defend internal validity in this research study are member checks, respondent validation, program coding revision and taking cognizance of the researcher's biases.

4.4.1.1 Member checks

The subjects of the research were given ample opportunity to study the research as it was written up. Grade 11 observers were allowed to amend their observations immediately after the observation study. Interviewees were allowed to study the transcripts of their interviews and check it against their own interviews.

4.4.1.2 Respondent validation

In this research study, the observations of the participant-observers were returned to them for clarity whenever notes were not explicit.

4.4.1.3 Program coding revision

The animation's ability to record events sequentially and correctly was tested continuously prior to use with the subjects. This was done to ensure that *all* events were recorded and that events were recorded correctly as failure to record all data and incorrectly recorded data could render the audit trail data useless. Additionally, some event data was recorded separately from the main audit trail to be corroborated or checked against the main audit trail (see Section 4.3.1.5.2; Event data collection).

4.4.1.4 Researcher's bias

As the researcher, I was biased. I had my own preconceived ideas about how the learners should use the program. However, by using reflexivity (critically reflecting on your own potential biases and predispositions) and negative-case sampling (looking for examples that disconfirm expectations) (Johnson and Christensen, 2004, p. 249 - 250), random selection of interviewees, accurate recording of observation data and confirming or clarifying it with the observers and accurate reporting, the data refuted or lessened the researcher's bias. However, the subjects showed various ways of interaction with the animation and it was recorded as such in the event log.

4.4.2 External validity

Validity refers to "the degree to which scientific explanations of phenomena, match the realities of the world" (Schumacher and Macmillan, 1993, p. 157) and describes the extent to which a research study is applicable and generalisable to other situations (Miller, 2003).

To increase the usefulness of this study, issues of comparability (adequate description of the research design to extend the findings to other studies) and translatability (the use of theoretical frameworks and research strategies understood by other researchers) had to be addressed.

4.5 RELIABILITY

Reliability was ensured by applying the following methods:

- training of observers;
- observation by multiple observers;
- data recording;
- data collection and analysis; and
- data interpretation.

4.5.1 Training of observers

Observers were trained to enhance consistency in observation.

4.5.2 Observation by multiple observers

Observations were done by multiple observers. Observers conferred and checked each others' data.

4.5.3 Data recording

Interviews were transcribed and transcriptions presented to interviewees to be checked against the audio tapes. Observations were typed out and presented to observers for correctness and observations were clarified with them where necessary. The animation was tested extensively and programming mistakes were also corrected prior to the research study.

4.5.4 Data analysis

The data analysis is described in the study and subjects checked the data. Transcriptions of interview data were compared to the actual interviews after transcription. Observation data was computerized as is, the spelling corrected and then presented to the observers for their verification.

4.5.5 Data interpretation

Data interpretation was checked by the subjects after the findings were written up.

4.6 CONSENT

Permission to conduct the study was obtained from the Western Cape Education Department, the School Governing Body (SGB) and the parents of the participants. Each participant filled out a form that was signed by him/herself and the parent/guardian of each participant. It was clearly spelt out that no participants would be harmed in any way and that the data was confidential (see Appendix C).

4.7 SUMMARY

This chapter described the different codes used to log each activity as the learners worked through the animation. Additionally, it showed where the activities were recorded. These codes were critical for subsequent data analysis. This chapter also described the research methodology followed and the measures taken to ensure validity and reliability. Measures taken to ensure anonymity were also described.

The results of the research study are discussed in Chapter 5.

4.8 DECLARATION

Learners who took part in the research study were not informed that they may withdraw from the research study whenever they wished to do so without facing penalization. The

reason for this was that the material covered in the study formed part of the syllabus for Grade 10 Physical Science. This was ruled unethical and the researcher was advised to bring this to the attention of the academic community. Subsequent to discussing the results of the study with the learners, they were informed by an assistant that they could withdraw their results if they wished to do so. Learners signed a form to indicate their preferences and these forms were duly submitted to the relevant authorities.

CHAPTER 5

RESULTS

5.1 INTRODUCTION

This chapter discusses the results collected during execution of the animation to find out how English First Additional Language learners interact with animation in an interactive learning environment. The results are presented under the headings cognitive, affective and psychomotor behaviour. The results are presented logically, starting with the most striking findings first. In addition, results are verified by drawing on evidence from all data collection methods, wherever applicable.

Figure 17 presents a layout of Chapter 5 and shows content discussed under the different headings.

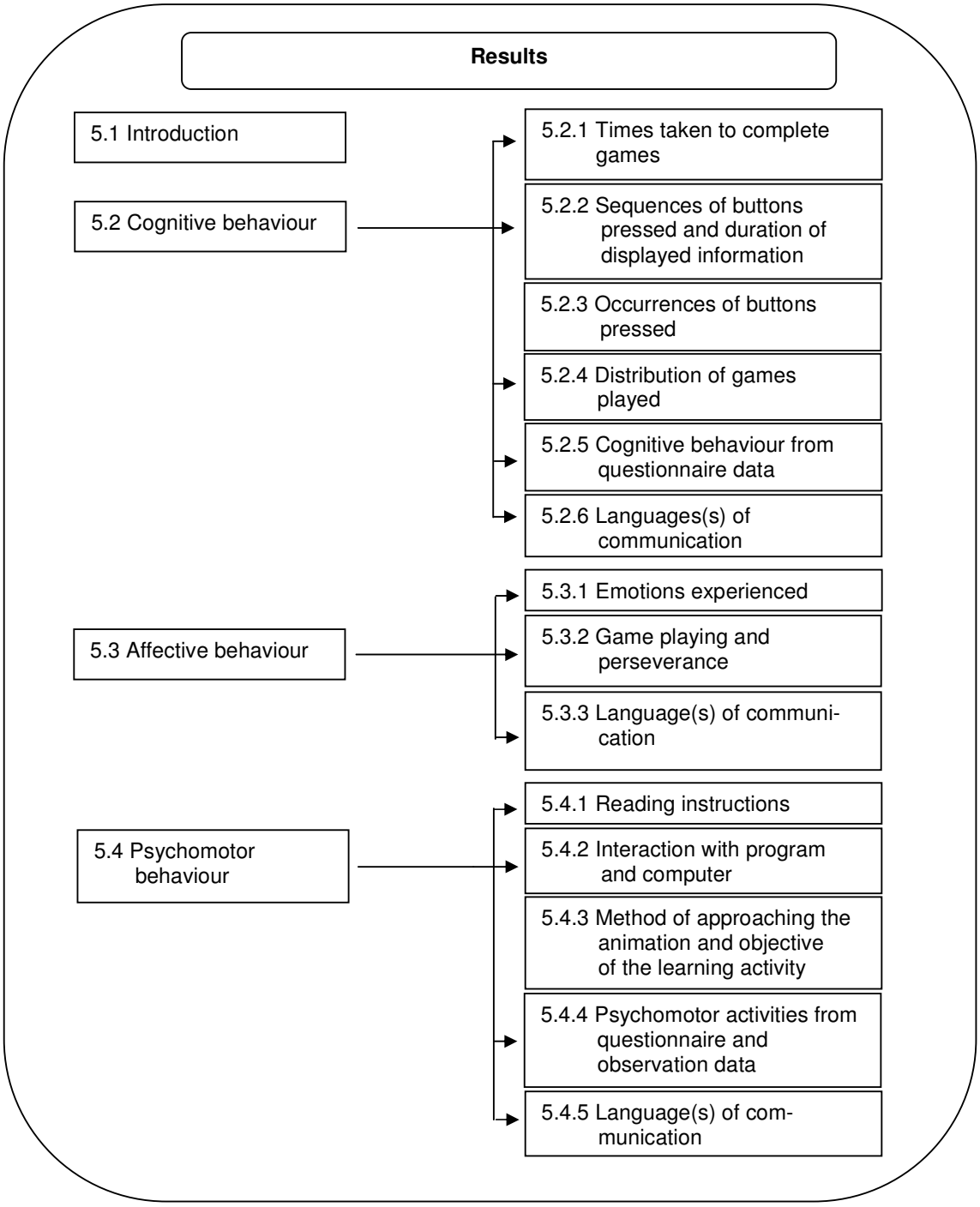

Figure 17 Overview of Chapter 5 indicating the content discussed

5.2 COGNITIVE BEHAVIOUR

This section discusses and summarizes the cognitive behaviour displayed by the subjects in terms of all the data collection methods. The topics included are:

- the times taken to complete games;
- the sequence of the buttons pressed and duration of displayed information;
- occurrences of buttons pressed;
- distribution of games played;
- cognitive behaviour from questionnaire data; and
- language(s) of communication.

5.2.1 Times taken to complete games

Times taken by the different groups (1, 2, 4, 5 and 6) to complete games correctly, decreased progressively as time went by.

Figures 18, 19, 20, 21 and 22 graphically display the different groups' times taken to complete the games. A graph for group 3 was not included as a timer malfunction occurred. A linear trend line was added to the rest of the graphs and it displayed a decrease in times taken to complete the games over time. This suggested that learners became better at game playing.

The trend line for group 4 showed an incline to the right, suggesting an increase in time to complete the games (see Figure 20). Data for only eight games was used to obtain a graphical display as timer malfunction occurred and all subsequent data was discarded. If the two correctly played games that took over 2 minutes are discarded, then a downward sloping trend line would be obtained.

Subsequent to timer malfunction, group 3 resorted to placing the elements via the combo box, whilst intermittently resetting the game and trying to stop the timer. Group 4 continued to play games whilst the timer was malfunctioning.

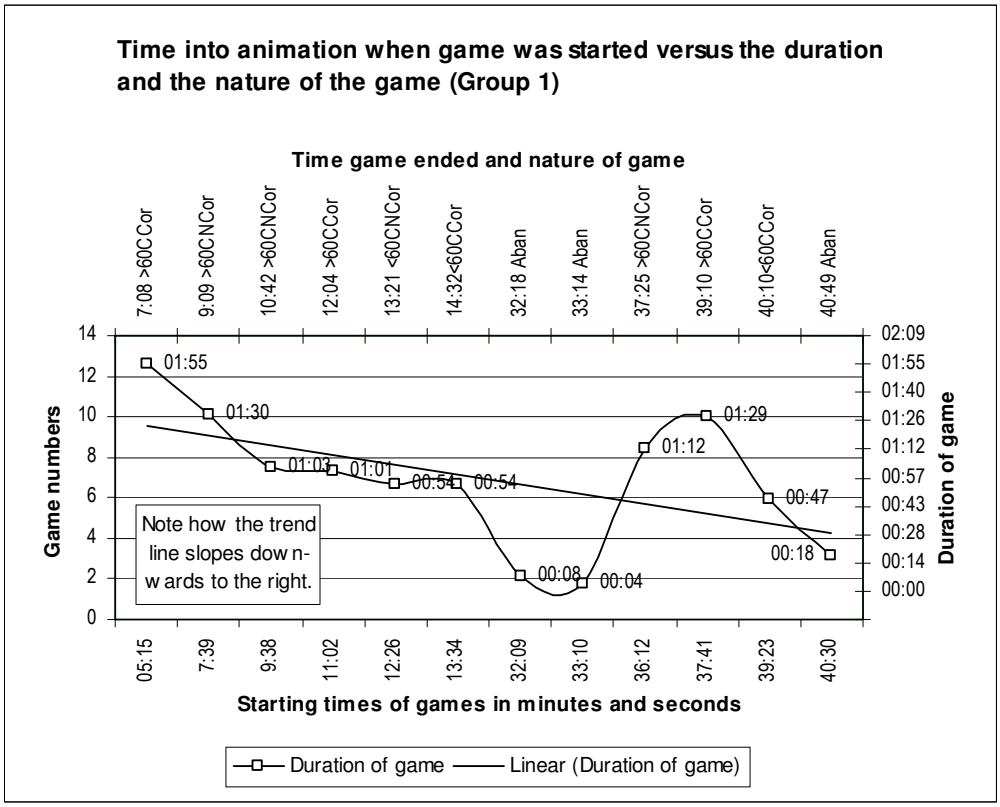

Figure 18 Times taken by group 1 to complete games correctly

(Aban = Abandoned games; >60CNCor = Completed incorrectly in more than 60 seconds; <60CNCor = Completed incorrectly in less than 60 seconds; >60CCor = Completed correctly in more than 60 seconds; <60CCor = Completed correctly in less than 60 seconds)

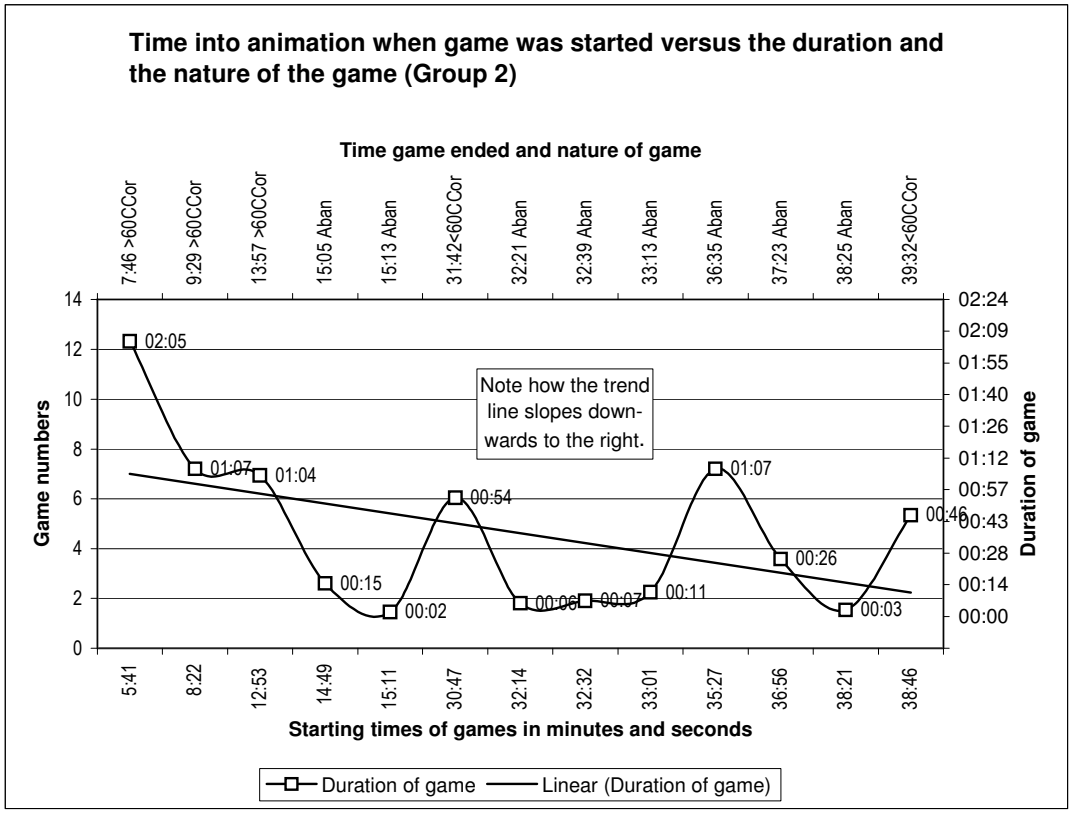

Figure 19 Times taken by group 2 to complete games correctly

(Aban = Abandoned games; >60CNCor = Completed incorrectly in more than 60 seconds; <60CNCor = Completed incorrectly in less than 60 seconds; >60CCor = Completed correctly in more than 60 seconds; <60CCor = Completed correctly in less than 60 seconds)

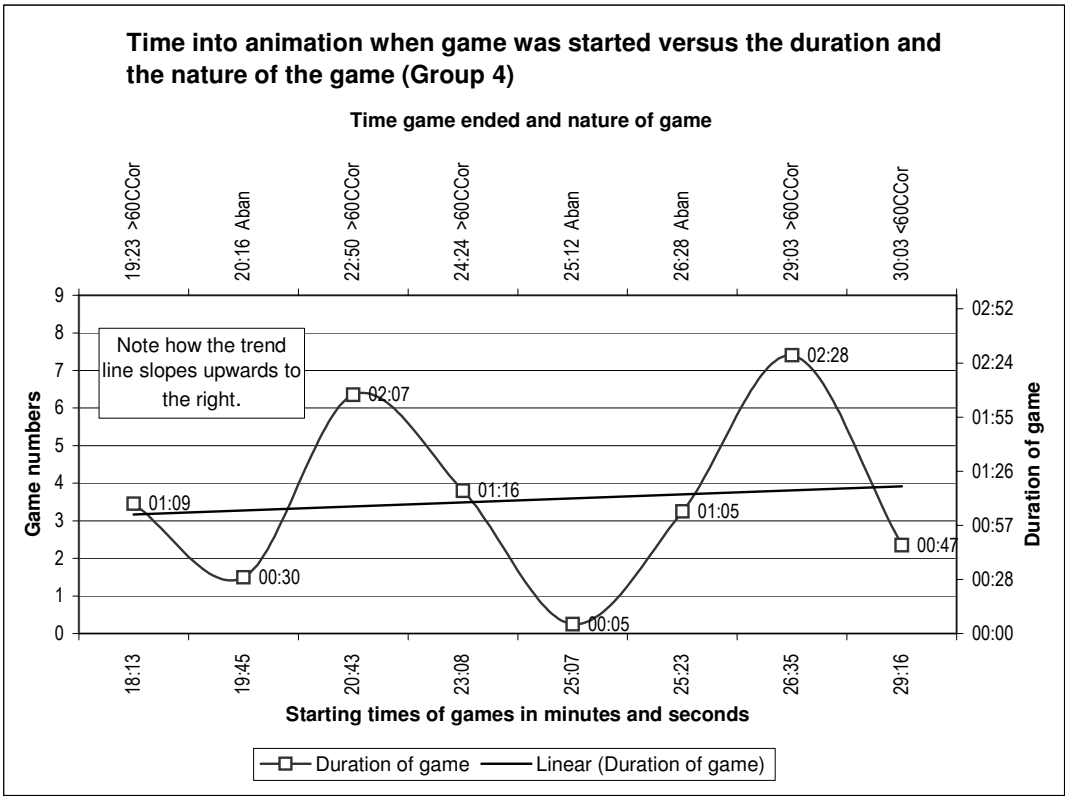

Figure 20 Times taken by group 4 to complete games correctly

(Aban = Abandoned games; >60CNCor = Completed incorrectly in more than 60 seconds; <60CNCor = Completed incorrectly in less than 60 seconds; >60CCor = Completed correctly in more than 60 seconds; <60CCor = Completed correctly in less than 60 seconds)

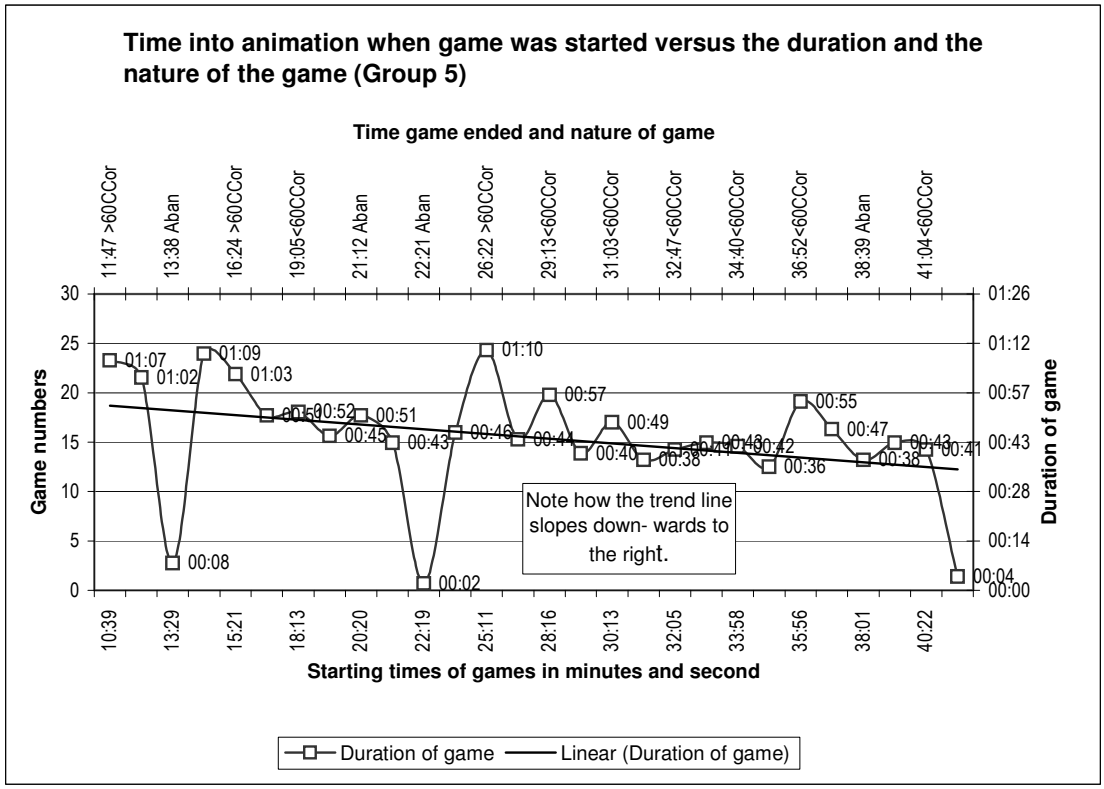

Figure 21 Times taken by group 5 to complete games correctly

(Aban = Abandoned games; >60CNCor = Completed incorrectly in more than 60 seconds; <60CNCor = Completed incorrectly in less than 60 seconds; >60CCor = Completed correctly in more than 60 seconds; <60CCor = Completed correctly in less than 60 seconds)

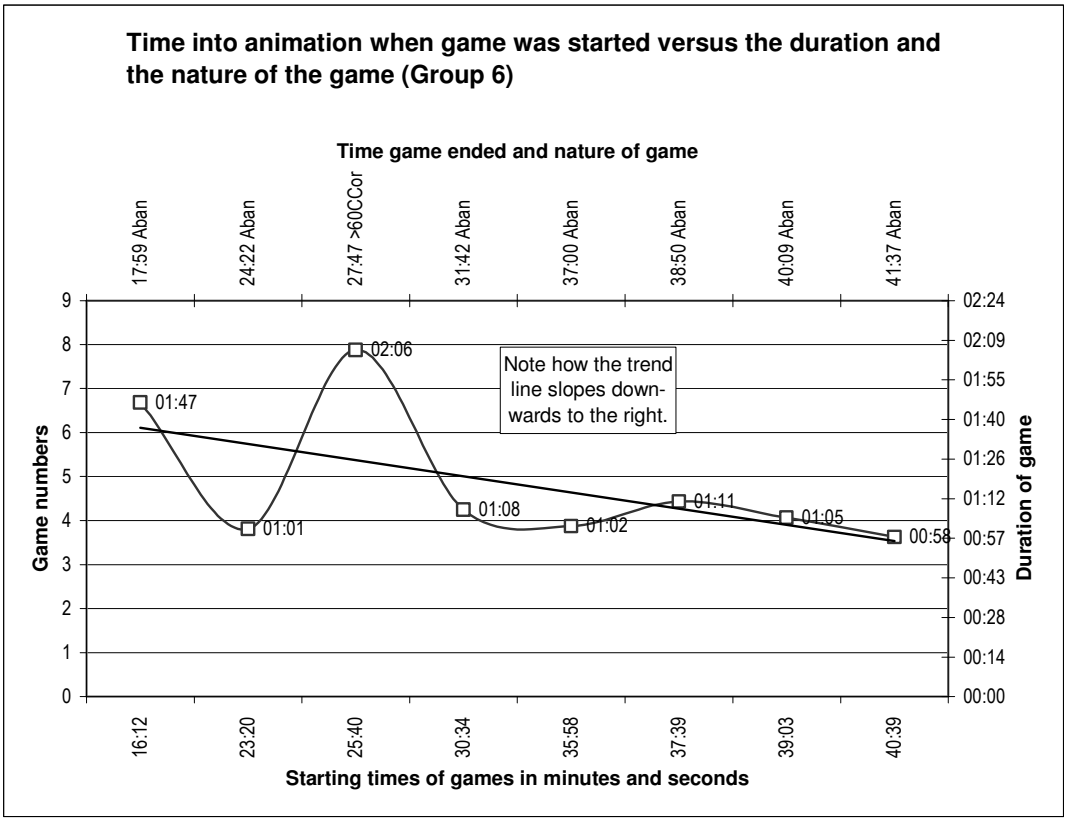

Figure 22 Times taken by group 6 to complete games correctly

(Aban = Abandoned games; >60CNCor = Completed incorrectly in more than 60 seconds; <60CNCor = Completed incorrectly in less than 60 seconds; >60CCor = Completed correctly in more than 60 seconds; <60CCor = Completed correctly in less than 60 seconds)

5.2.2 Sequence of buttons pressed and duration of displayed information

Some groups started out pressing the buttons in sequence as it appeared on the user interface while other groups approached the buttons in a different manner.

Groups 1, 2, 3 and 5 (see Figures 24, 25, 26 and 28 respectively) pressed the informational buttons from top to bottom and from left to right. In other words, they pressed the 'Instructions' button, followed by buttons indicating the position of groups of elements and, finally, buttons indicating blocks of elements (information presenting buttons). Group 4 read the instructions after having pressed the information presenting buttons, whilst group 6 never read the instructions. For the most part, the learners pressed the buttons in the sequence as they appeared on the user interface (see Figure 23 from top to bottom and from left to right) and then as they found it necessary when they searched for information.

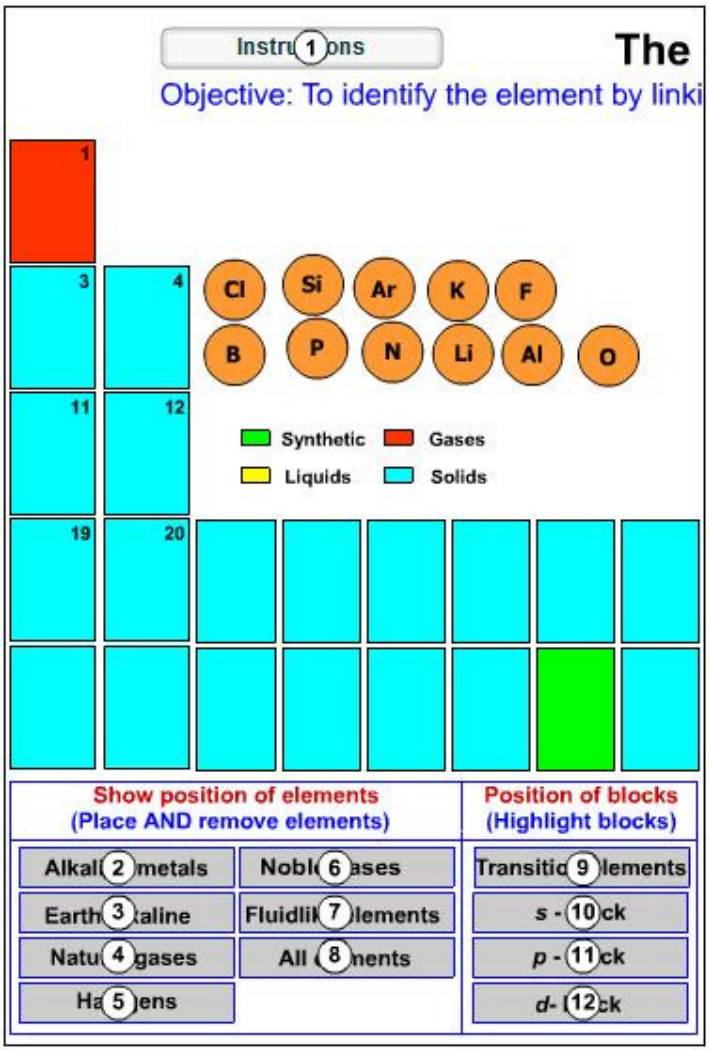

Figure 23 Partial view of the user interface showing the sequence (top to bottom and left to right) in which informational buttons were pressed interface

The instructions were observed or read for an average of 28 seconds, excluding group 6 who did not read the instructions at all (see Table 18). Some groups (1 - 3) pressed all the buttons (though only once) whilst groups 5 and 6 pressed all buttons an average of 4 and 8 times respectively. Group 4 failed to look at the information presented by 7 of the buttons.

Duration of displayed information

The times recorded and displayed on the graphs (see Figures 24 - 29) indicate the actual times that informational buttons were pressed and released. Times were recorded on the MouseDown event and subsequent MouseUp events. MouseDown event times were plotted on the x-axis while MouseUp events were plotted on the secondary x-axis. The time difference (in square brackets) between corresponding MouseDown and MouseUp events was also plotted on the secondary x-axis showing how long learners observed the information presented (positions of groups and blocks of elements). In many cases the time differences were zero, indicating a button was pressed and released in the same second. This means that learners observed the presented information for less than *one* second only or consumed important information.

Firstly, all the groups, except for group 6, pressed all buttons that display information, within 10 minutes into the animation (see Figures 24 - 29). These groups then resorted to game playing, dragging and the selection of elements from the combo box. Secondly, all the groups except for group 6 pressed almost all buttons for less than a second to view information. This suggested that these groups relied on memory recall during dragging, next/selection and game playing.

Group 6 did not conform to the pattern and the researcher concluded that this group failed to master the content as the group regularly pressed the ‘All elements’ buttons to observe the positions of all the elements. This group did not read the instructions (see Figure 29 and Appendix Table 15).

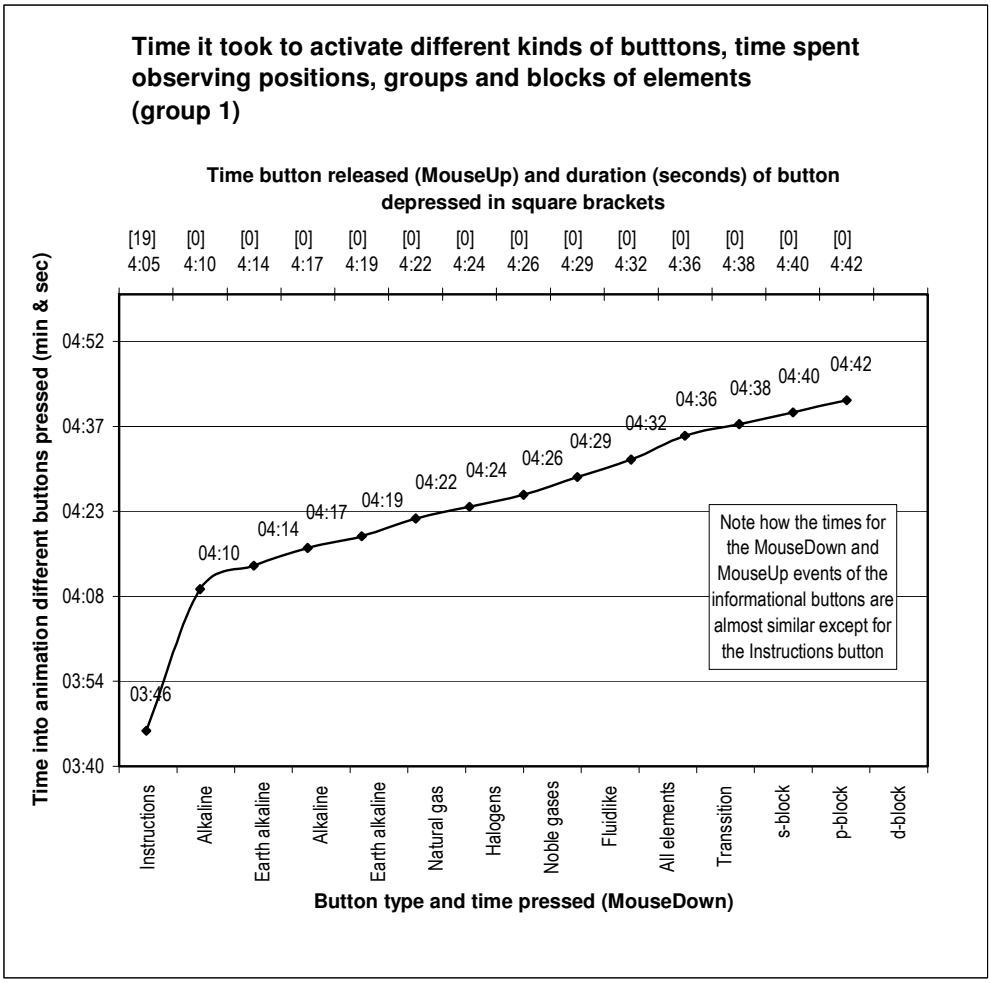

Figure 24 Sequence and times (minutes and seconds) into animation of buttons pressed and length of time (seconds) these buttons were pressed

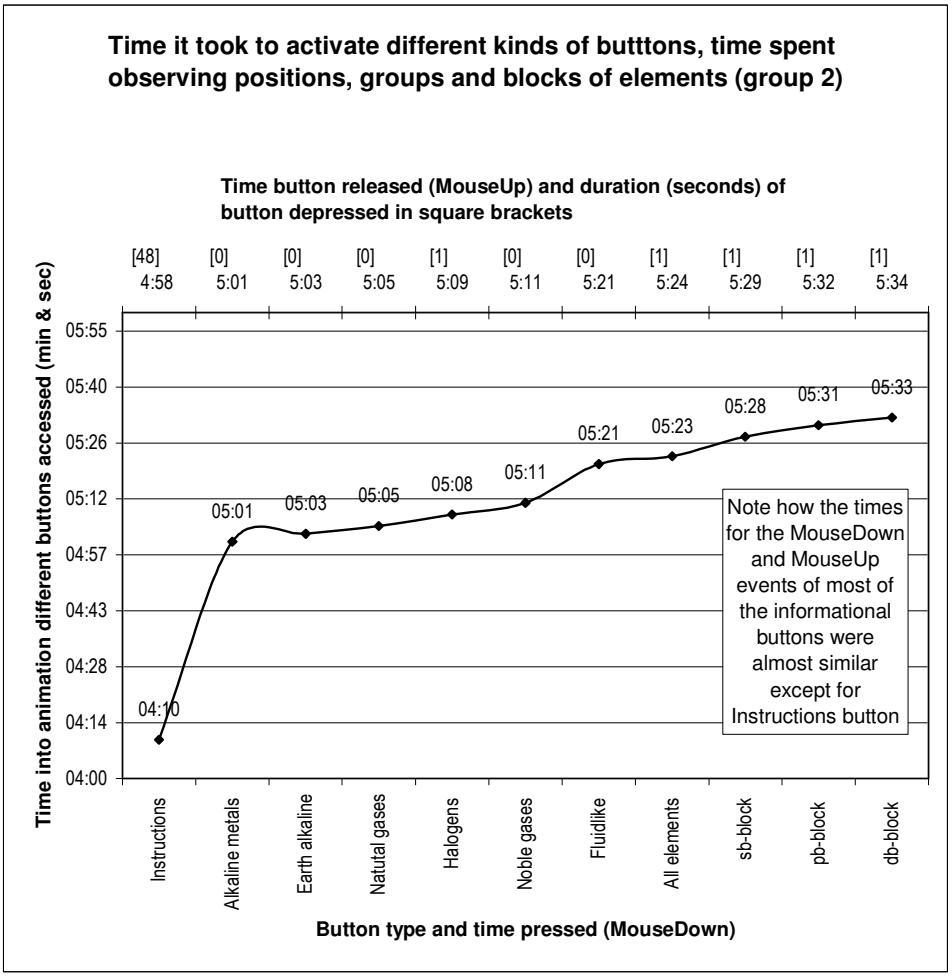

Figure 25 Sequence and times (minutes and seconds) into animation of buttons pressed and length of time (seconds) these buttons were pressed

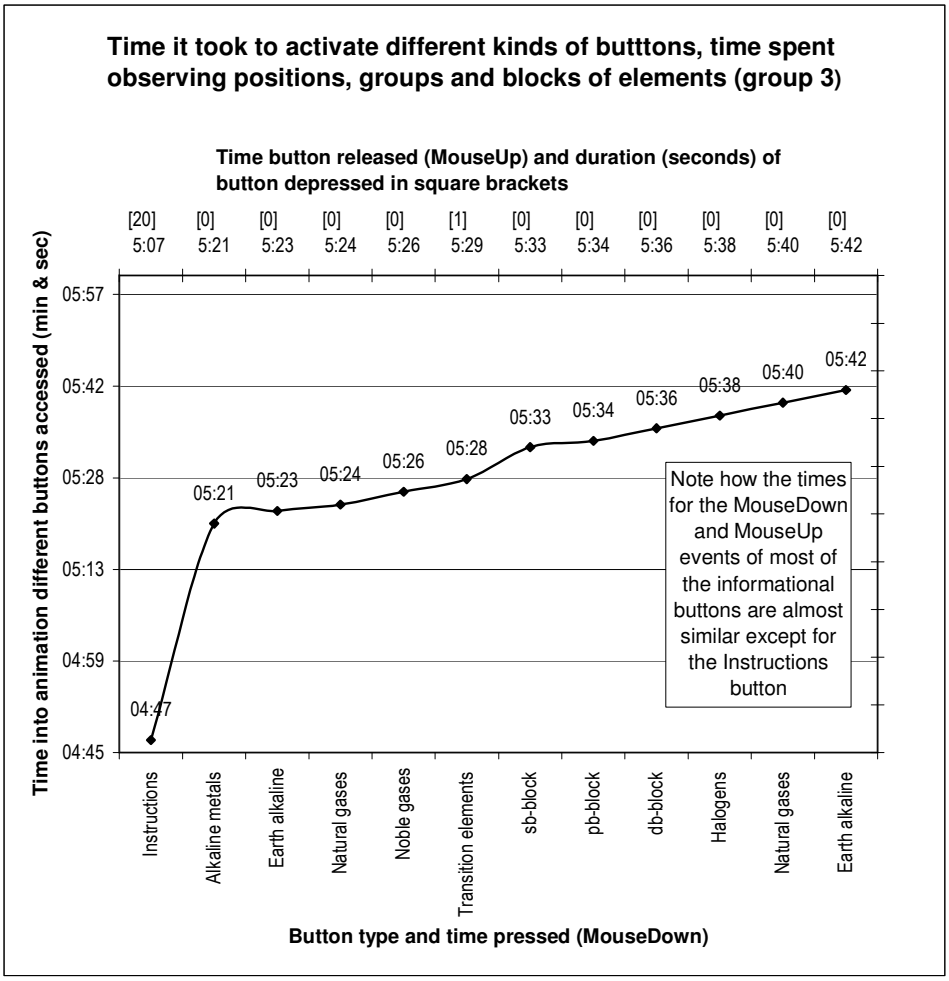

Figure 26 Sequence and times (minutes and seconds) into animation of buttons pressed and length of time (seconds) these buttons were pressed

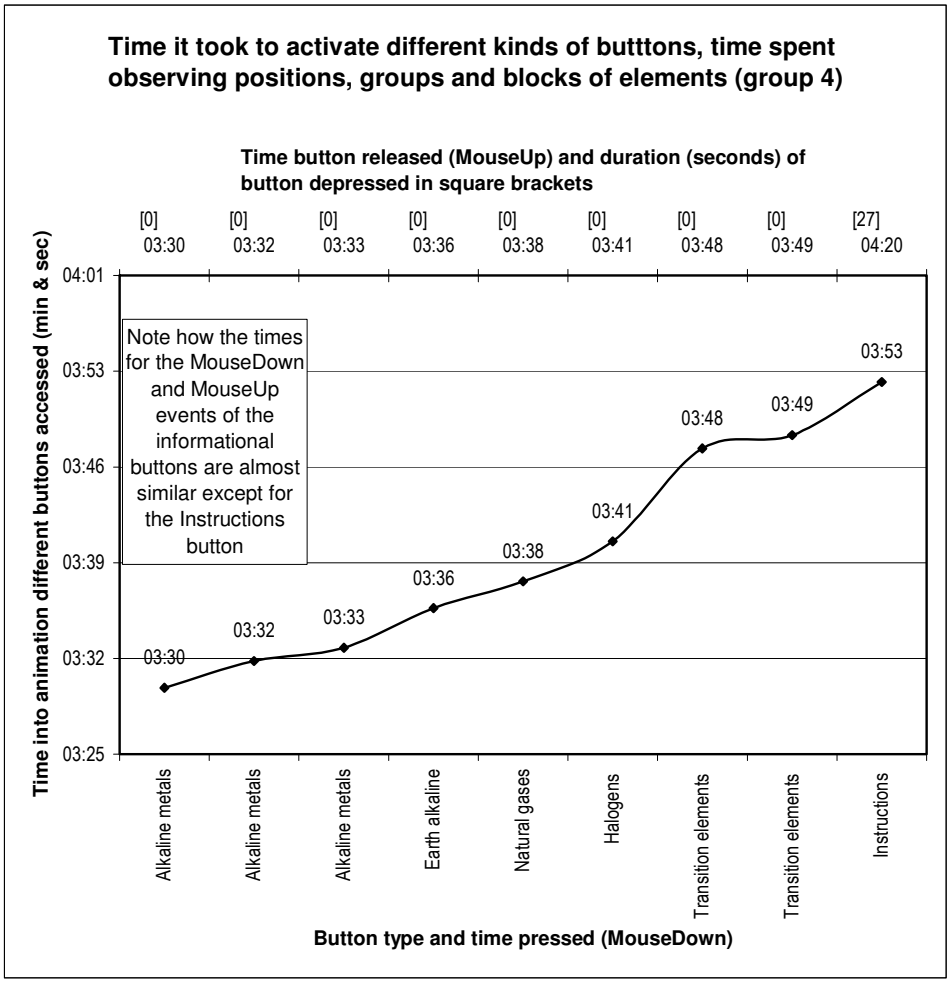

Figure 27 Sequence and times (minutes and seconds) into animation of buttons pressed and length of time (seconds) these buttons were pressed

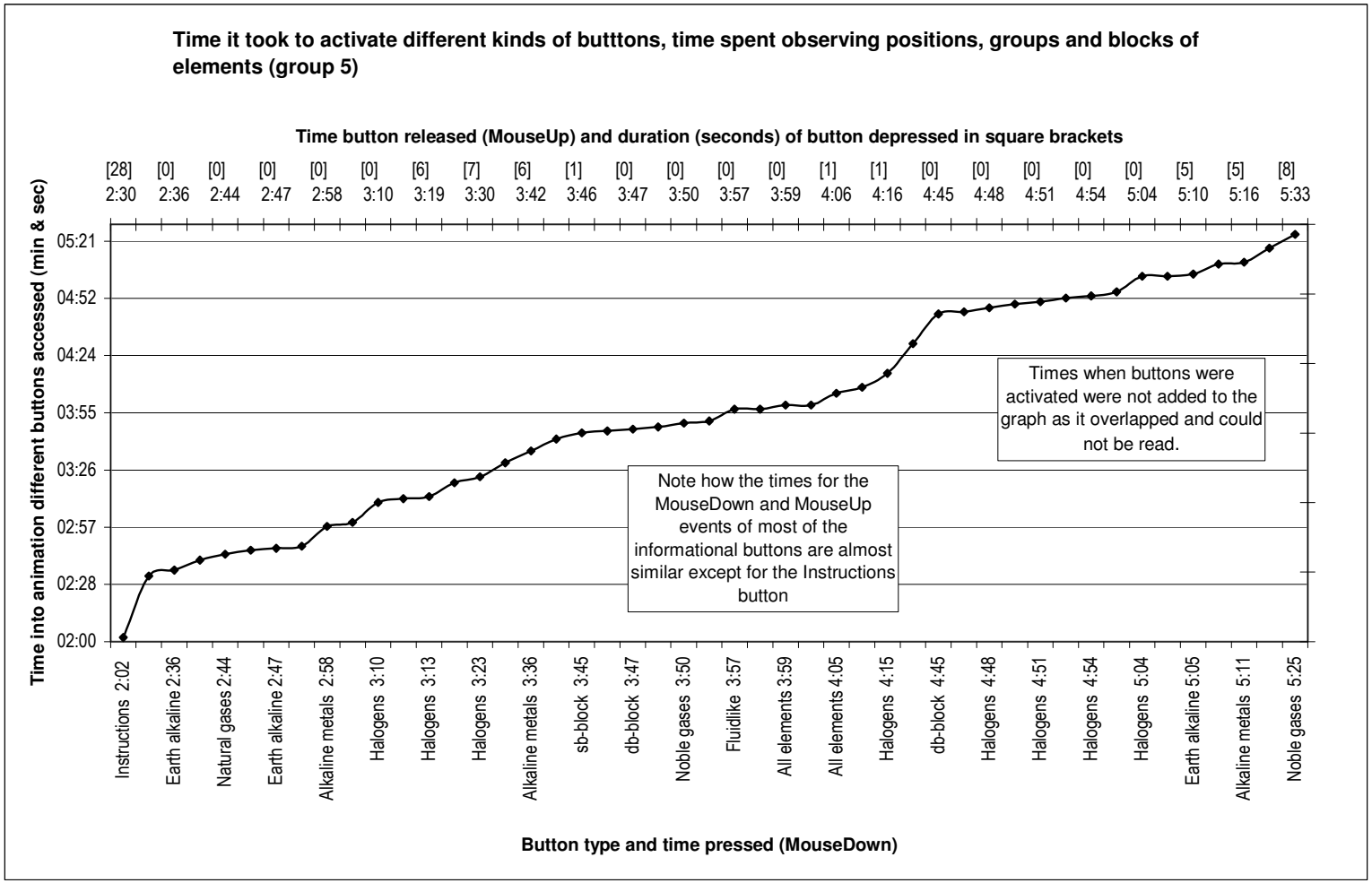

Figure 28 Sequence and times (minutes and seconds) into animation of buttons pressed and length of time (seconds) these buttons were pressed. Note: Every other data value was plotted for this group.

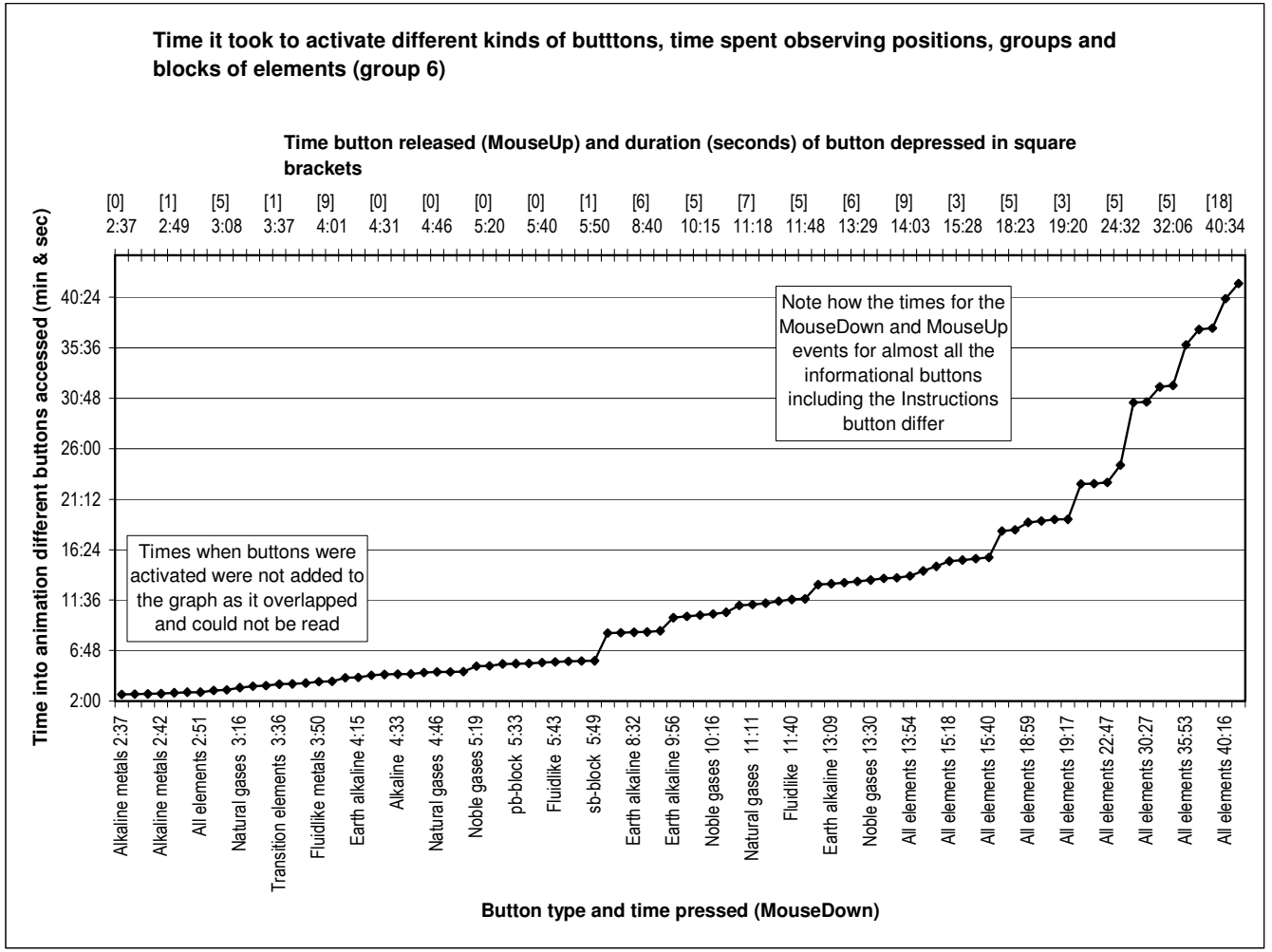

Figure 29 Sequence and times (minutes and seconds) into animation of buttons pressed and length of time (seconds) these buttons were pressed. The group failed to press the 'Instructions' button. Note: Every fourth data value was plotted for this group.

5.2.3 Occurrences of buttons pressed

Patterns or occurrences of buttons pressed during execution of the animation were remarkably different.

The actual number of times different buttons were pressed by the class, varied (see Figure 30 and Figure 31). This excluded the buttons pressed during game playing. The buttons pressed showing the instructions and position of certain blocks of elements (buttons numbered 1 - 4) were not used extensively as these blocks did not show the actual positions of elements. The buttons showing the actual positions of elements (buttons numbered 6 - 12) were, on average, pressed three times more than the buttons showing the position of groups of elements.

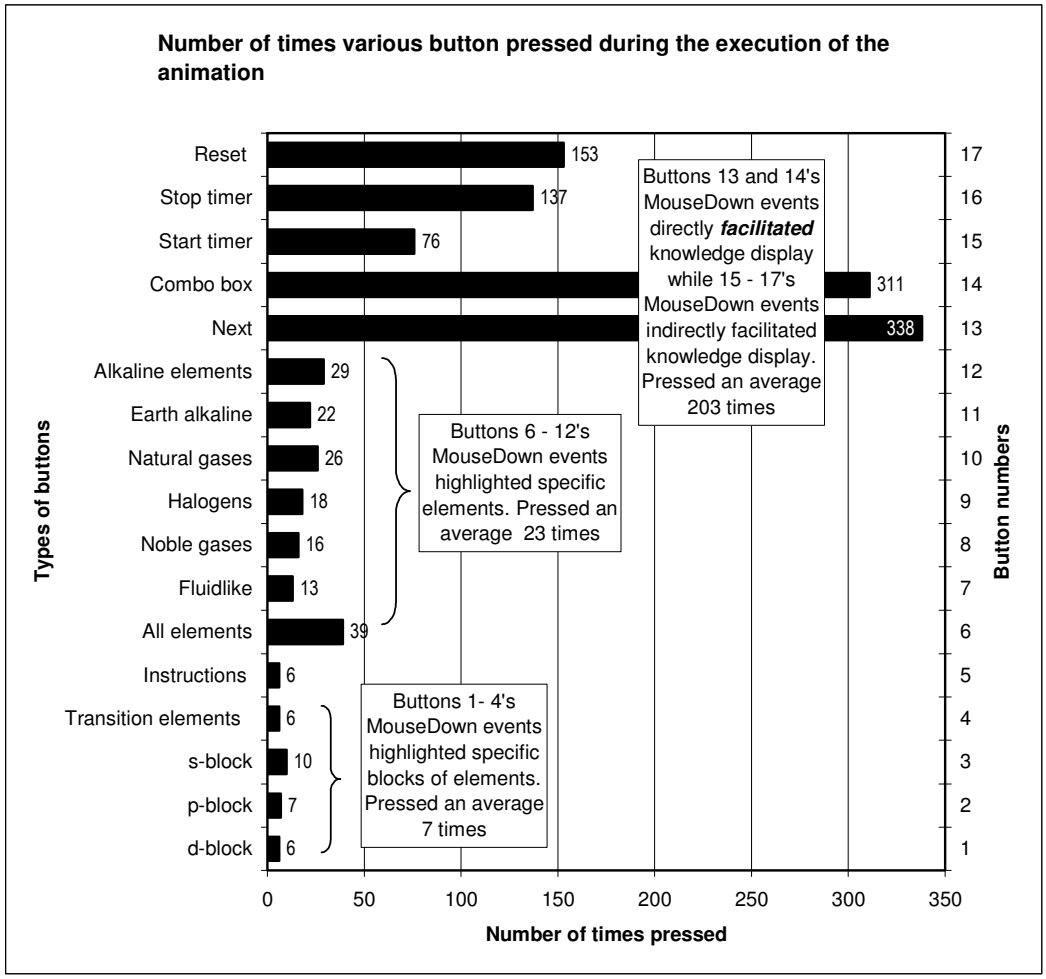

Figure 30 Actual numbers of times buttons were pressed during the execution of the animation

The 'Next' button, selection from the combo box, 'Stop timer' and 'Reset' buttons, on average, were used 203 times more than the buttons showing the positions of the elements (see Figure 30).

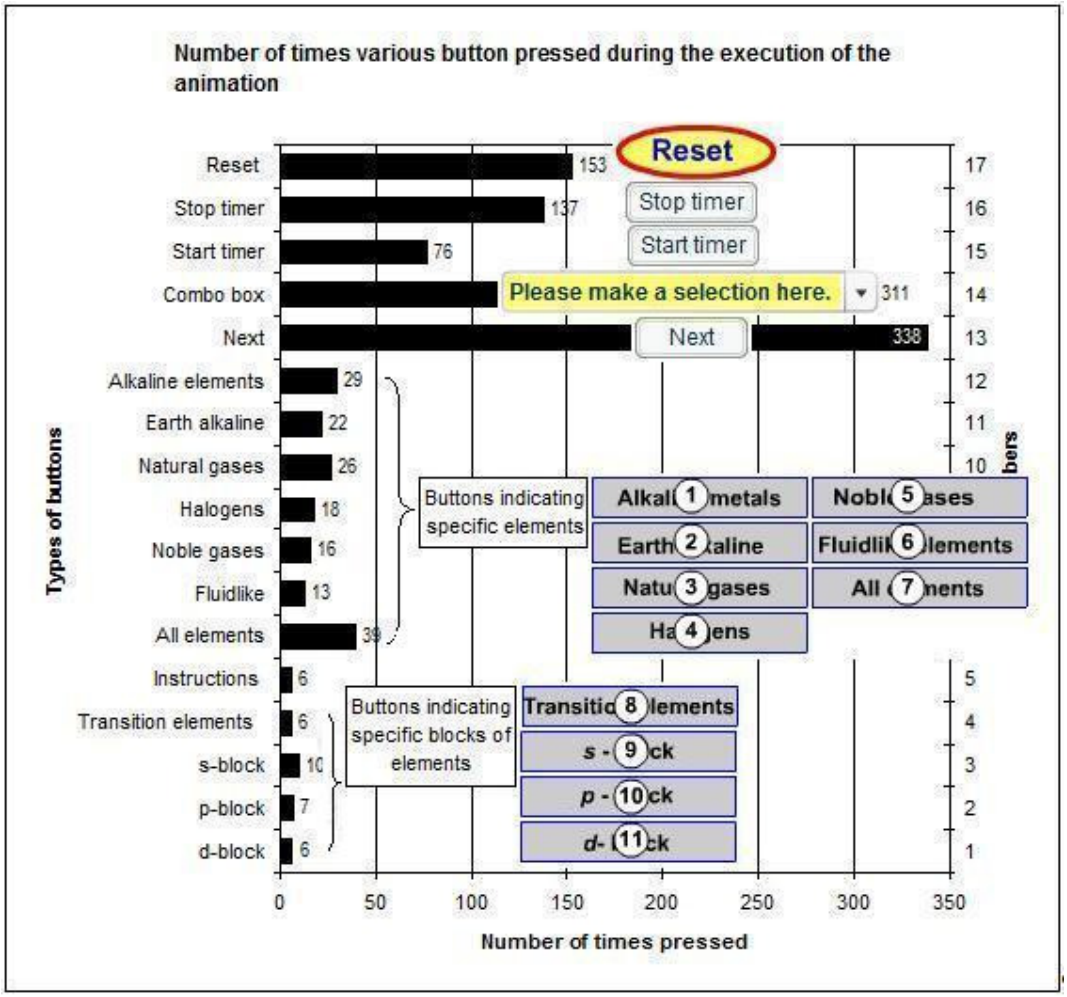

Figure 31 Number of times buttons were pressed during the execution of the animation and the sequence in which buttons were pressed

5.2.4 Distribution of games played

Learners became more skilful at game playing as time went by or learners' proficiency at game playing increased.

The total number of games and the nature of the games played by each group varied considerably. The data showed a total of 72 games (excluding games subsequent to timer malfunction) were played by the whole class (see Figure 32). The total number of games played per group varied from 3 - 28 (see Figure 33 and Table 17). Evident from the graphical displays of each group are the initial abandonment of games and the progression from abandonment to correct completion/playing of games (see Figure 32).

Figure 32 illustrates skills improvement for the whole class. Initially, large numbers of games were abandoned (29), then the trend reflected incorrect completion of games in more than 60 seconds (5), incorrect completion of games in less than 60 seconds (2), correct completion of games in more than 60 seconds (15) and, finally, correct completion of games in less than 60 seconds (21).

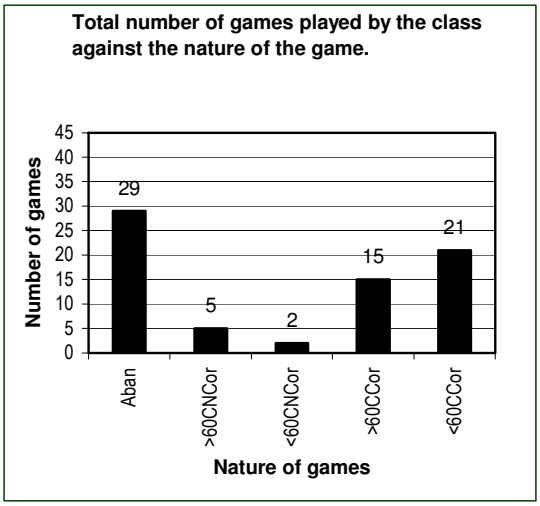

Figure 32 Number of games played by the whole class

This tendency of abandonment of games, completion of a greater number of games in more than 60 seconds to completion of a lesser number of games in less than 60 seconds, was expected by the researcher. All the groups displayed this tendency, with the exception of group 5 (see Figure 33). Group 5 showed a remarkable difference between games completed in more than 60 seconds (3 games) as opposed to games completed in less than 60 seconds (16 games).

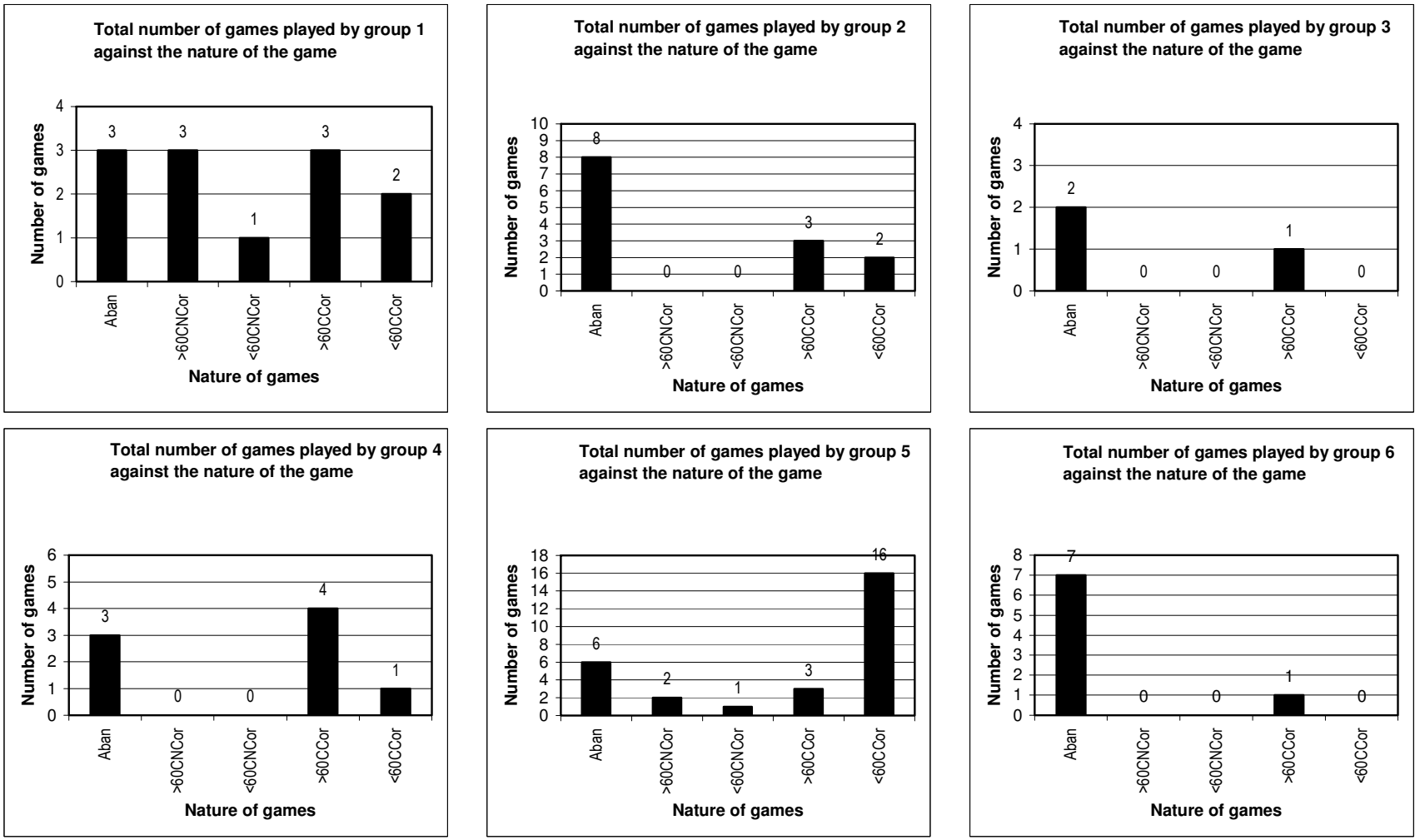

Figure 33 Number of games played by groups 1, 2, 3, 4, 5 and 6

The questionnaire data (see Figure 34) verified that one hundred percent (100%) of all learners played games while seventy five percent (75%) of all learners managed to complete a game(s). Correctly completed games were also corroborated by the observers as illustrated below:

> The second time one min seven seconds which mean [*sic*] they cooperated.
>
> In 54 seconds they have all the elements correct [*sic*].
>
> 46 seconds without cheating.
>
> Done the task in 60s +++++ (not good).
>
> They finished in 60 sec +++ the first time.
>
> They place the elements correctly and they are finishing in 51 sec.

5.2.5 Cognitive behaviour from questionnaire data

One hundred percent (100%) of all learners indicated that the animations assisted them in getting to know the atomic numbers (Z) of all the elements.

Seventy five percent (75%) of all learners indicated verbal comments (audible when buttons were pressed) assisted them with the learning activity.

Thirty three percent (33%) of the learners indicated that they knew the atomic numbers (all) prior to the execution of the animation.

A total of eighty three percent (83%) of all learners confirmed that they knew the atomic numbers of the elements after having worked with the animation. This meant the groups could work through the learning phase in two ways: firstly, groups could drag and drop elements directly and, secondly, they could use the 'Next/Select' sequences, in which case the animation placed the elements. Subsequent to these actions, the learners could assess themselves by playing games against time. The eighty three percent (83%) total of learners referred to those learners who played the games (assessment) after having worked through the learning phase.

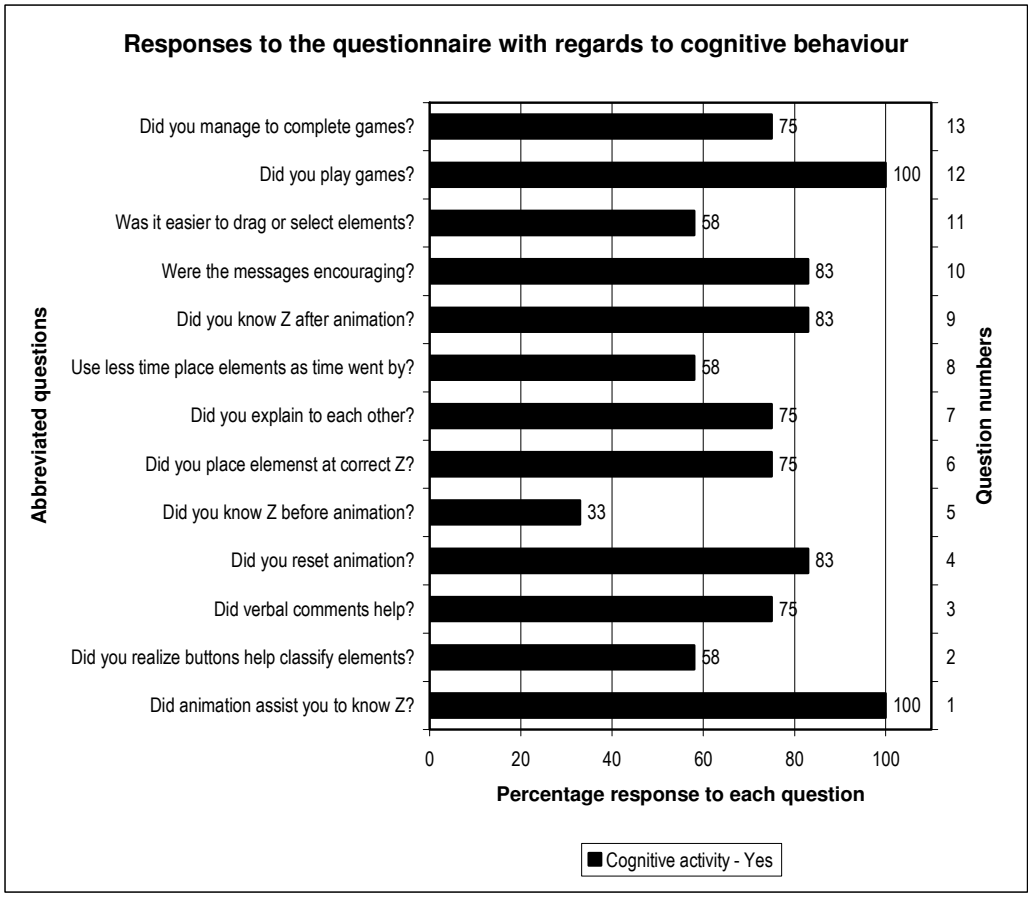

Figure 34 A graphical representation of responses to the questionnaire with regards to cognitive behaviour

5.2.6 Language(s) of communication

Observer data showed that the learners in all groups communicated with each other in isiXhosa, as well as English First Additional Language, the language of learning and teaching.

> Language used Xhosa [sic].
> The language speaking Xhosa [*sic*].
> They are using Xhosa to communicate with each other.
> Responding in Xhosa.
> Xhosa is the language they use.
> They respond in Xhosa only.

The language use was subsequently confirmed when the results were discussed with the learners. English was interspersed with isiXhosa quite often as the learners engaged with the animation.

5.3 AFFECTIVE BEHAVIOUR

This section deals with the emotions experienced by the learners, game playing and perseverance and language(s) of communication.

5.3.1 Emotions experienced

The learners experienced and/or displayed a wide range of emotions while interacting with the animation.

The learners experienced a wide range of emotions whilst executing the animation. It needs to be pointed out that the emotions listed here were displayed by the class as a whole and not confined to one particular group. Table 16 show the emotions displayed and the observers' notes and/or questionnaire data to verify these emotions.

Table 16 Emotions experienced, description and verification by questionnaire and/or observation

Emotion	Description(s)	Observer notes
Confusion	Observers initially noted confusion in some learners.	Firstly they are confused.
Doubt, uncertainty and disinterest	Some learners doubted and were uncertain about the positions of the elements and how to approach the animation. Others seemed disinterested.	Doubtful on [*sic*] placing the elements. They are not sure about the elements. Unsure what they must do. Don't [*sic*] know exactly what to do. They seem not interested [*sic*].
Boredom, interest and positive attitude.	Interest in the learning activity ranked from boredom to complete immersion in the animation. Initially, some learners appeared to be bored. As time went by, the learners became more interested and developed a more positive attitude.	They were like bored. The one learner was getting bored and started to eat [*sic*] the wires of the earphones. They are interested. They are becoming more interested. They are becoming more interested [*sic*] and they are now sure about the element that makes them to complete the periodic table. Less than 60 seconds.
Enjoyment	Learners also enjoyed the animation as they laughed and giggled.	Giggled and shouted. They laugh [*sic*]. The learner was laughing while the other was missing [*sic*] one element. They are also one another a chance also laughing [*sic*]. (shows enjoyment).
Impatience and nervousness	Some of the observers' notes indicated impatience in some learners and nervousness in others.	Unpatient [*sic*] to finish the activity. Nerves [sic] (both of them).
Annoyance	Some learners were annoyed for various reasons.	Raised their voices to each other. They were annoyed with each other for placing the elements the partner was too slow [*sic*]. The other girl was starting to think about the time and she raised her voice.
Disagreement	Often group members disagreed with each other.	Their second try they just started to place the elements and they helped each other and they also disagree at some point. [*sic*]. Disagree on some points.
Respect	Some observers reported that learners acted respectfully towards each other.	Responding in a respectful way and language both of them [*sic*].

Table 16 Continued

Emotion	Description(s) from interview, observation and questionnaire data
Liking	Eighty three percent (83%) of all learners indicated that they liked dragging the elements better, as opposed to elements being placed by the animation (see Appendix Figure 1, Question 15). This was corroborated by the audit trail data that showed eighty four percent (84%) or 1639 of all events by the class as a whole were drag and drop events (see Appendix Table 11). Dragging elements were also considered easier by the interviewees as illustrated by the following quotes: Interviewee 1: Easier to do than Next/select Interviewee 2: Less time to do it. Interviewee 3: Easier to drag and drop A mere fifty eight percent (58%) of the learners expressed a liking of the instructions. The only interactivity presented by the instructions the dragging of a small movie clip embedded in the instructions. Learners also liked the elements being placed correctly as they received feedback from the animation. The instructions were not well liked or received. This was corroborated by failure of some groups to read the instructions, the short time spent on reading the instructions when actually read and some groups reading the instructions way after they had started the animation (see Table 18). The overall impression is that the animation was liked and received well by the learners. This was corroborated by the three interviewees (see Appendixes E - G) who answered affirmatively that they liked the animations. Correct placements of elements by the animation were well received. These correct placements were verified from questionnaire data (see Appendix Figure 1, Question 14).
Memorable	An even split was observed as to finding the animations memorable.
Anxiety	Observation data revealed that only forty two percent (42%) of the learners were anxious when they saw the animation for the first time (see Appendix Figure 1, Question 18). This in itself was encouraging as it indicated that most of the learners were comfortable with the animations. The anxiety was confirmed by the observers who noted: • Biting nails. • The other learner was getting bored and started to eat the wires of the earphones.
Motivation	Eighty three percent (83%) of learners indicated that they found the messages encouraging or motivational. Interview data corroborated that these messages were found to be encouraging or motivational (Appendix E to G). Two types of messages were displayed: One type that informed learners about the correctness of their answers (elements dragged or selected), the second type served to motivate the learners. Depending on the nature of games played, certain messages were displayed. Even when learners abandoned a game, they were motivated to try again.

5.3.2 Game playing and perseverance

Learners persevered to master the game in the assessment phase.

Game playing proved to be popular amongst all the groups, irrespective of whether the groups managed to complete the games correctly (see Appendix Tables 13 - 15). Questionnaire data revealed that one hundred percent (100%) of the learners played the assessment game, although only seventy five percent (75%) of all learners managed to complete a game (see Figure 34, Question 13).

Table 17 shows the average time (calculated, in seconds) that it took for each kind of game, with the number of games in brackets for each group.

Table 17 Average calculated times (in seconds) of various games played by different groups, with the number of games in brackets

Average times (in seconds) of various games played by groups						
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Nature of	Total number of games					
the game	12	13	3	8	28	8
Aban	10 (3)	17 (8)	**85 (2)**	33(3)	24(6)	**70(7)**
>60CNCor	75 (3)	0	**0**	0	66(2)	**0**
<60CNCor	54 (1)	0	**0**	0	43(1)	**0**
>60CCor	88 (3)	85(3)	**159 (1)**	105 (4)	67(3)	**126(1)**
<60CCor	53 (2)	50 (2)	**0**	47 (1)	46(16)	**0**

Numbers in brackets indicate the number of games

The results indicated that some groups abandoned games as quickly as ten seconds after the onset of the game (see Table 17). Other groups persevered and took as long as seventy to eighty five seconds before they abandoned their games (groups 3 and 6 respectively). In comparison, these two groups fared the same with respect to all subsequent games in terms of type and number completed (see Table 17, depicted in bold type). The data suggests that these two groups spent time in pursuance of playing the games correctly. Even the games completed correctly, in more than sixty seconds, indicate a rather long duration and perhaps explain why so few games were completed, either correctly or incorrectly.

Groups 1 and 2 were relatively quick to abandon games compared to groups 4 and 5. Compared to group 1, group 2 invested more time before abandoning games, however, despite abandoning games more quickly, group 1 managed to complete four more games, although incorrectly. These two groups were also quicker than the other groups to

complete games correctly, except for group 5. These two groups compare favourably as far as the last, correctly completed games were concerned with respect to average time and number of games (circled on Table 17).

The average time taken by all groups to complete games correctly, in less that 60 seconds, were remarkably similar and ranged from 46 seconds for group 5, to 53 seconds for group 1 (see Table 17 and Figure 35).

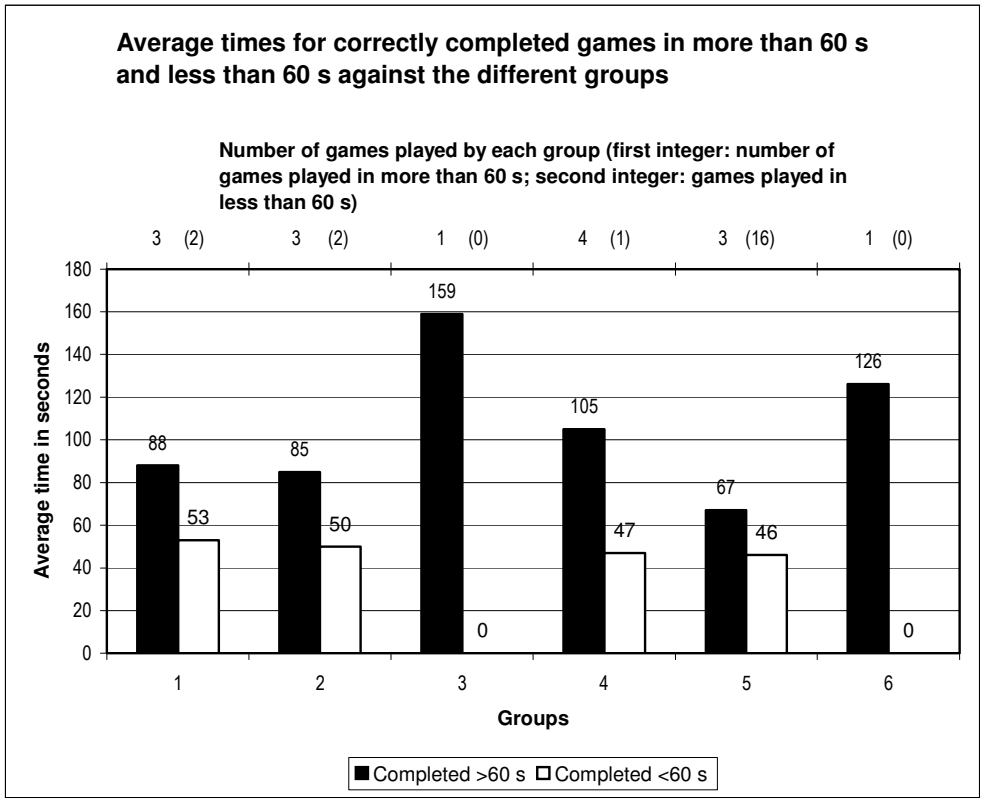

Figure 35 Average times taken per group for correctly completed games in more than 60 s and less than 60 s.

5.3.3 Language(s) of communication

In all groups, observers noted that learners used both English First Additional Language and isiXhosa to communicate with each other. It is possible that the learners felt more comfortable expressing themselves in their mother tongue, isiXhosa, when they spoke to each other.

5.4 PSYCHOMOTOR AFFECTS

This section deals with the following:

- time spent reading the instructions;

- interaction with the program and the computer;
- approach to the animation and the objective of the learning activity;
- psychomotor activities from questionnaire and observation data; and
- language(s) of communication.

5.4.1 Reading instructions

The results suggest that learners spent very little time on reading the instructions or merely gave them a cursory glance.

The results indicated that only five groups pressed the 'Instructions' button (see Table 18). Of these five groups, only four groups pressed the 'Instructions' button at the onset of the animation, i.e. as the first event. The fourth group only pressed the 'Instructions' button as the seventeenth event into execution of the animation (**17/Inst** /3:53). Additionally, the elapsed times prior to engagement with the animation varied amongst the groups. This suggests that the learners familiarized themselves with the user interface before they attended to the instructions. The time spent reading the instructions also varied. While group 6 did not read the instructions at all, they spent 2 minutes and 37 seconds familiarizing themselves with the user interface.

Table 18 Time spent by various groups on reading the instructions

Group	Activity and time started	Activity and time ended	Time elapsed before engaging animation (minutes and seconds)	Time spent on instructions (seconds)
1	1/Inst /3:46	2/ReInst /4:05	3:46	19 s
2	1/Inst /4:10	2/ReInst /4:58	4:10	48 s
3	**1/Inst /4:47**	**6/ReInst /5:07**	4:47	**20 s**
4	17/Inst /3:53	18/ReInst /4:20	3:53	27 s
5	1/Inst /2:02	2/ReInst /2:30	2:02	28 s
6	1/Alk /2:37	2/AlkD /2:37	2:37	-

Two of the three interviewees indicated that it was not difficult to understand the instructions while one indicated that the instructions were initially difficult:

> Interviewee 1: First its difficult but if you going on and going on we understand better but now I think its not that difficult anymore *[sic]*.
>
> Interviewee 2: Because they was *[sic]* straight forward.
>
> Interviewee 3: No, no, no it was not difficult *[sic]*.

This perhaps explains why the learners spent so little time on reading the instructions. In a separate experiment the researcher read the instructions and recorded the times the animation started and ended (this included moving the clip embedded in the instructions around). It took an average of 38 seconds (results not shown) to read the instructions and move the embedded clip.

Sixty seven percent (67%) of all learners indicated that they **dragged** the movie clip embedded in the instructions. This was simply *not true* since the audit trail data showed that *only* group 3 moved the instructions movie clip. In addition, while group 3 actually moved the clip around, the entire process took a mere 20 seconds (see Table 18). This was illustrated by the following sequence of events from group 3 audit trail data:

1/Inst /4:47
2**Clip** /4:52
3OrigPos /4:54
4**Clip** /4:57
5OrigPos /5:00
6/ReInst /5:07

The movement of the clip was indicated by the word clip in events 2 and 4. This is indicated by the fact that the Instructions were brought up during the first event **1/Inst** /4:47 and only removed during the sixth **6/ReInst** /5:07 event (see Table 17). This data suggests that the learners did not read the instructions but perhaps gave them a cursory glance or merely scanned them.

5.4.2 Interaction with the program and the computer

Learners interacted with the animation in a number of ways during dragging activities, both during the learning phase and gaming.

Dragging elements

a. Some learners initially dragged an element to incorrect zone(s), received feedback that it was the wrong zone(s) and then dragged it around until they found the correct zone. Note the examples below of argon (Ar) during the learning phase and fluorine (F) during the assessment phase.

Learning phase	Game playing
245/Ar /21:38/XCazone	377/Stime /30:34
246/Ar /21:40/XNazone	……
247/Ar /21:42/XAlzone	383/F /30:56/XNzone
248/Ar /21:43/XAlzone	384/F /30:57/XCzone
249/Ar /21:45/Arzone	385/F /30:59/Fzone
	……
	397/Sttime /31:42 /t=1:08/Aban

b. Some cases were also found where learners dragged an element to an incorrect zone(s) and, finally, returned it to the original position. Note the examples of phosphorous (P) and chlorine (Cl) below. The dotted line in case of Cl implies that some events were omitted.

Learning phase	Game playing
360/P /29:44/XLizone	297/Stime /25:40
361/P /29:47/XAlzone	……
362/P /29:48/OrigPos	319/Cl/27:07/XPzone
	320/Cl/27:09/XBzone
	321/Cl/27:10/XCzone
	322/Cl/27:11/OrigPos
	……..
	335/Sttime/27:47 /t=2:06/>60CCor

c. In some cases learners even dragged two elements to the same zone. This is illustrated by the following extract (below) from the raw data. Note how helium (He) was dragged to the incorrect Nezone (event 242) and Neon subsequently dragged to the same zone (event 243). Event numbers 244 and onwards show how the group tried to move the two elements to their respective (correct) zones.

242/He /24:11/XNezone
243/Ne /24:11/Nezone
244/He /24:11/XNezone
245/Ne /24:11/Nezone
246/He /24:12/XNezone
247/Ne /24:12/Nezone
248/He /24:13/XNezone
249/Ne /24:13/Nezone
250/Ne /24:16/OrigPos
251/He /24:18/Hezone
252/Ne /24:19/Nezone
253/Ne /24:21/Nezone

Missed events

Evidence also indicates that learners missed some MouseUp events as they moved the cursor to other buttons whilst holding down the mouse button. These were found in two groups and are illustrated below. Note event 15 and event 16. Event 16 should have been 16/EarthD /2:58. Event 41 and 42 show a pattern similar to events 15 and 16.

13/Earth /2:47
14/EarthD /2:47
15/Earth /2:48
16/Alk /2:58
17/AlkD /2:58

38/EarthD /4:15
39/Earth /4:26
40/EarthD /4:26
41/Earth /4:27
42/Ngas /4:31
43/NgasD /4:31

Selection of elements

Method 1

Learners also resorted to selection of elements from the combo box. Selection of elements from the combo box proved not to be very popular among the learners. The following sequences extracted from the data shows the selection of elements:

123/N /15:43/Z11
124/Co /15:57/Sodium
125/N /15:59/Z12
126/Co /16:16/Magnesium
127/N /16:18/Z35
128/Co /16:33/Bromine
129/N /16:35/Z10
130/Co /16:58/XBoron
131/N /17:05/Z4

The data shows that sodium's atomic number was displayed (Z11, event 123). The learner responded by selecting the name sodium from the combo box (event 124 from Co, sodium). This group pressed 'Next' and in the subsequent event made a selection from the combo box. Note the pattern of N (Next) being pressed, followed by Co (combo box) selection.

Method 2

Group 6 selected elements from the combo box in an entirely different way. Event 79 shows the display of fluorine's atomic number (Z9) in the text box. Instead of selecting an element's name from the combo box (correct or otherwise), this group resorted to pressing various buttons to establish the atomic number of fluorine. Having pressed the button that displays the natural gases (event 89), the atomic number of fluorine was revealed. The

learner(s) subsequently selected the correct element (fluorine) from the combo box (event 90). This group repeated this kind of behaviour (events 91 through 103).

79/N /7:57/Z9	**79/N /7:57/Z9**
80/Alk /8:27	80/Alk /8:27
81/AlkD /8:27	81/AlkD /8:27
82/Alk /8:30	82/Alk /8:30
83/AlkD /8:30	83/AlkD /8:30
84/Earth /8:32	84/Earth /8:32
85/EarthD /8:33	85/EarthD /8:33
86/Earth /8:34	86/Earth /8:34
87/EarthD /8:40	87/EarthD /8:40
88/Ngas /8:40	88/Ngas /8:40
89/NgasD /8:48	89/NgasD /8:48
90/Co /9:41/Fluorine	**90/Co /9:41/Fluorine**
91/N /9:47/Z10	**91/N /9:47/Z10**

Playing with the timer

Observers noted that some learners were playing with the timer. After consultation with the observers, it was established that learners clicked the 'Start' button in rapid succession with far reaching consequences. An observer's note:

> They are playing with the timer.

This resulted in timer malfunction and incorrectly recorded times for subsequent games.

Timer malfunction was confirmed by audit trail data:

113/Stime /15:04
114/Stime /15:04
115/Ca /15:06/OrigPos
116/Na /15:06/OrigPos
117/Na /15:07/OrigPos
118/Ca /15:09/Cazone
119/K /15:25/Kzone
120/Na /15:32/Nazone
121/Sttime /15:37 /t=1:04/Aban

Timer malfunction resulted as a consequence of a double start (events 113 and 114). This caused the timer to operate twice as fast, thus, recording incorrect times. Note the time that the game started (15 minutes and 4 seconds into the animation) and when the game ended (15 minutes and 37 seconds). The actual time between starting and end times should be 33 seconds, while the timer read 1 minute and 4 seconds.

"Cheating"

The researcher had preconceived ideas as to how the learners would engage with the learning activity. However, some learners played the game far differently to what was expected. One observer noted that learners were cheating while working the learning activity. This turned out to be learners writing down the atomic numbers from a book and entering these atomic numbers when required by the animation. This was verified by the notes made by the observers:

> She is writing all the elements down.
> They are checking on a book the number of elements [*sic*].
> Some of the element numbers are written down.
> They are writing down numbers of elements.
> They are writing the elements down and point [sic].
> They are writing elements down to make it easier for themselves.
> They are help [*sic*] each other by saying the element in a paper (chitting) [*sic*].
> 46 seconds without chitting [*sic*].

"Cheating" or not, learners played and completed the game.

Negative case sampling

The researcher expected learners to handle the dragging and selection during the learning phase, in two ways:

- conventional pressing of buttons to highlight the positions of certain blocks of elements; and
- dragging and selecting (all) elements to their (correct) zones and only *then* using the buttons to indicate the position of certain blocks of elements.

Negative case sampling showed that none of the groups approached the animation in the second way, as mentioned above (see Figure 36). Instances of events marked and sblPD, as well as pblP and pblPD would have indicated that the s-block and p-block elements respectively were *in place* and that the s-block and p-block buttons were *pressed afterwards*. Not a single occurrence of these events could be found in data analyzed for all of the groups.

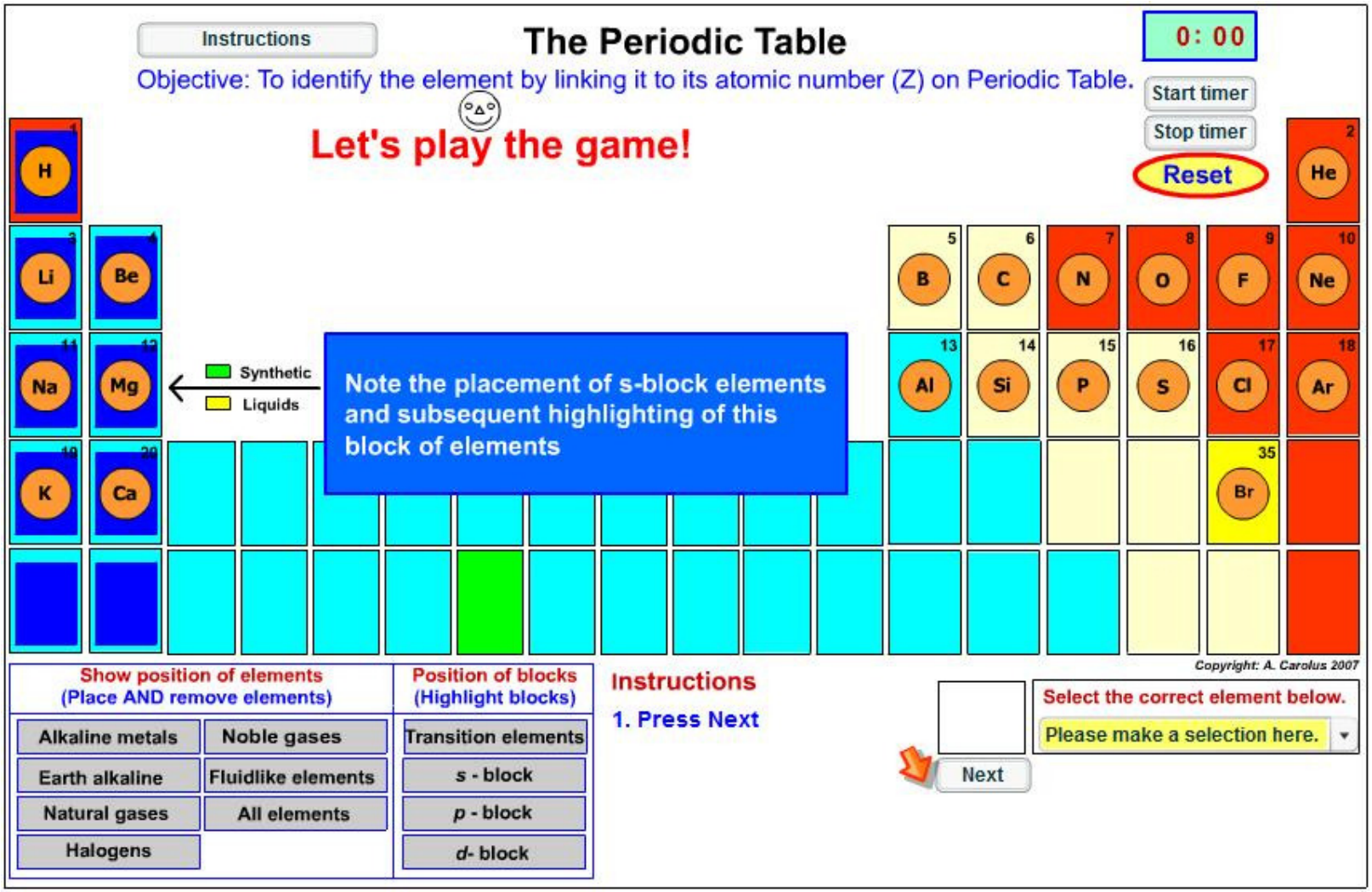

Figure 36 Example of negative case sampling where learners were expected to place (any, all, most of) the elements by dragging or selection from the combo box and then press the buttons(s) showing the position of blocks of elements. None of the groups worked the animation in this way. Note that the animation is ready for game playing.

5.4.3 Method of approaching the animation and the objective of the learning activity

Regardless of how they approached the learning activity, all the groups managed to reach the objective of the learning activity.

'Buttons' refers to the different buttons (customized) that were pressed during the course of the animation. The researcher expected learners to read the instructions first, press the buttons showing the positions of elements and positions of blocks of elements (as this would assist them in selection from the combo box and dragging elements to correct zones), then proceed to the learning phase (dragging and selection from the combo box or the other way round) and, finally, to play the game against time. Approaching the learning activity in this way would have assisted the learners in mastering the game faster.

Appendix Tables 13 - 15 are shortened versions of sequences of events extracted from the original data. The first event (1/Inst /3:46) indicated when the instructions were activated and the second event (2/ReInst /4:05) indicated when the instructions were removed. 'Buttons' were denoted by the first button press event (not necessarily chronological event 1), in this case 3/Alk /4:10, to the last event 28/dbD /4:42 (see Appendix Table 13, group 1). Table 19 indicates the way the groups were expected to approach the animation versus how they actually approached the animation.

Table 19 Summary of buttons and sequences of buttons pressed by the different groups during execution of the animation

Expected way/steps to approach animation and ways in which groups approached the animation					
	Expected steps in approach to animation				
Steps	Instructions	Buttons	Dragging/ Selection	Selection/ Dragging	Gaming
Groups	**Steps taken by groups in approach to animation**				
1	Instructions	Buttons	**Gaming**	Selection	Gaming
2	Instructions	Buttons	**Gaming**	Buttons	Gaming
3	Instructions	Buttons	Selection	**Gaming**	Selection
4	**Buttons**	**Instructions**	Dragging	Selection	Dragging
5	Instructions	Buttons	Selection	**Gaming**	Dragging
6	**Buttons**	**Selection**	**Buttons**	**Selection**	**Buttons**

Note: Buttons refer to all the informational buttons, excluding the instructions button

Most of the groups (1, 2, 3, and 5) pressed the 'Instructions' button first and then pressed the different customized buttons (see Tables 18 and 19). Group 4 pressed the buttons and then viewed the instructions. Group 6 predominantly pressed (12 out of 15 times) the 'All elements' button (see Appendix Table 15). Table 19 may create the impression that group 4 and 6 did not play games; however, this is not the case. These groups played their games much later. This was corroborated by Appendix Tables 14 and 15.

In summary, whilst the groups went about interacting with the animation in different ways, all of the groups managed to successfully attain the objective of the activity. Some groups were more successful than others but they all reached their goal nonetheless.

5.4.4 Psychomotor activities from questionnaire and observation data

Questionnaire and observation data revealed a host of other psychomotor activities displayed during the execution of the animation.

A variety of psychomotor behaviours were observed during the execution of the animation. Virtually all categories of psychomotor behaviour found in the literature (see Table 8) took place during this study, namely clicking, communicating, examining, moving, pointing, verbal and gestural explanations, changing, reading/writing, touching, laughing and listening (see Appendix Table 5 and Table 20). Instances of occurrences of the above-mentioned psychomotor behaviours are cited in context and, wherever possible, corroborated.

Table 20 Psychomotor behaviour displayed and verified by questionnaire and/or observation data

Behaviour	Description(s)	Observer notes
Clicked	Numerous types of button ***clicks*** were recorded. Some of the learners ***clicked*** the buttons that indicated the position of elements and the position of blocks of elements. This was confirmed by the questionnaire data where sixty seven percent (67%) of the class indicated they ***pressed*** all buttons (see Appendix Figure 2, Question 19). They often started the timer (button ***click*** to start a game), placed a few elements and then abandoned (stopped) the game. The questionnaire data confirmed that ninety two percent (92%) of all learners used (**clicked**) the 'start/stop' buttons (see Appendix Figure 2, Question 21). It must be noted that all activities between the start timer and stop timer events were drag and drop events as all other buttons were inactivated. A large number of dragging activities occurred, 1639 in total, as confirmed by the audit trail data (see Appendix Table 11).	They just clicked on other places. …he only use the mouse when click [*sic*] on the help block. They start the timer and place 3 elements and reset it again. …in this game before they stat [*sic*] the click. They started the timer but they did not do anything. Pressing in wrong places where he's not suppose to press/click [*sic*].
Communicated	Communication was demonstrated in a number of ways. Observers explicitly indicated that communication occurred. Learners ***instructed*** each other and often *asked* questions. Group members often ***talked*** to each other and members of other groups.	They were communications [*sic*] with each other. They communicate in Xhosa. One instructed the other. Telling the partner what to do. Ask observer for instructions. Only one student knew which element knew which element goes where; the other kept asking for help Asking each other questions. Looked at other the group members and talked to them. They talk while looking at the work. Pointing the screen and talking Xhosa Pointing screen and talking at the same timer [*sic*]. They talk while they are working.
Argued	Sometimes arguments **took place** about the placement of the elements.	They argued about, about [*sic*] which elements to place where.

Table 20 Continued

Behaviour	Description(s)	Observer notes
Explained and discussed	The learning environment encouraged learners to explain and discuss the learning content. Questionnaire data confirmed that seventy five percent (75%) of all learners responded that they ***explained*** to each other whilst working through the learning activity (see Figure 34, Question 7).	They are explaining to one another. They are discussing the work before they do the work.
Moved	In their endeavours to complete the game(s) successfully, learners often **moved** the elements to different positions correctly or incorrectly.	Moving elements in wrong places [*sic*]. The movement of elements had been confirmed by audit trail data (section 5.4.2).
Pointed	Numerous instances were reported where learners ***pointed*** to the screen, perhaps to focus or highlight points(s) in the learning activity.	Pointing the screen and talking Xhosa. Pointing screen and talking at the same timer *[sic].* They are showing one another (pointing). They are pointing the ones they know to correct themselves *[sic].* When one respond to other one's question he respond by pointing to the monitor. They use the guide to know [*sic*] were to point. …he also use fingers to point [*sic*]. …both of them use Xhosa and they use their fingers to point.
Read and wrote	Numerous read and write observations were made. These included ***reading*** the instructions, ***writing*** down symbols of elements and writing down atomic numbers.	Writing down elements. They are reading the instructions. They are writing down numbers of elements. They are writing the elements down and point. They are writing elements down to make it easier for themselves.
Touched	Only one instance where learner(s) ***touched*** the screen was recorded.	They are touching the screen of the computer and finished in 2:15 and they tryed [*sic*] again.
Laughed	All the observers indicated that the groups ***laughed*** for different reasons.	They laugh. Giggled and shouted. They are also one another [*sic*] a chance also laughing (shows enjoyment). They were laughing. The learner was laughing while the other was missing one element. …and they were laughing.

Table 20 Continued

Behaviour	Description(s)	Observer notes
Placed elements	During the activity, learners dragged the elements to different zones on the Periodic Table. They ***placed*** the elements in different zones or affected changes.	Placed the elements incorrectly at the second time [*sic*]. Placed the elements incorrectly again. Placed the elements incorrectly, but at the end they tried to place the elements correct and they done to 55 seconds only [*sic*]. They place the elements correctly and they are finishing in 51 sec. …they place one two or more time in different places.
Managed time	Observers for various groups indicated that learners also tried to ***manage their time*** as they tried to finish the game in sixty seconds. This was evident as learners often looked at the timer.	…keep on doing at looking if it pass timer. (They checked the timer to see if it still read less than sixty seconds.) The other girl was starting [*sic*] to think about the time and raised her voice.

5.4.5 Language(s) of communication

Observers of all groups indicated that learners expressed themselves in both isiXhosa and English First Additional Language whilst communicating with their partners during execution of the animation. The observers' notes did not indicate if the use of isiXhosa was a regular occurrence or if isiXhosa language usage was sporadic. All observers indicated at least once that isiXhosa was used to communicate (see Section 5.2.6).

In summary, this chapter reported on the results of this study. The synthesis and recommendations are discussed in Chapter 6.

CHAPTER 6

SYNTHESIS AND RECOMMENDATIONS

6.1 INTRODUCTION

The purpose of this study was to determine the cognitive, affective and psychomotor affects of animation on Physical Science learning. In order to achieve this goal, the following critical questions were answered:

Critical questions

The main research question is: "How do learners respond to animation in the learning environment?"

The sub questions are:
In an interactive learning environment with animations …

1. what learning takes place from a cognitive, affective and psychomotor perspective and how?
2. what language problems do the learners experience and how do they deal with them?

This chapter will synthesize the findings of the study.

Figure 37 presents a layout of Chapter 6 and shows content discussed under the different headings.

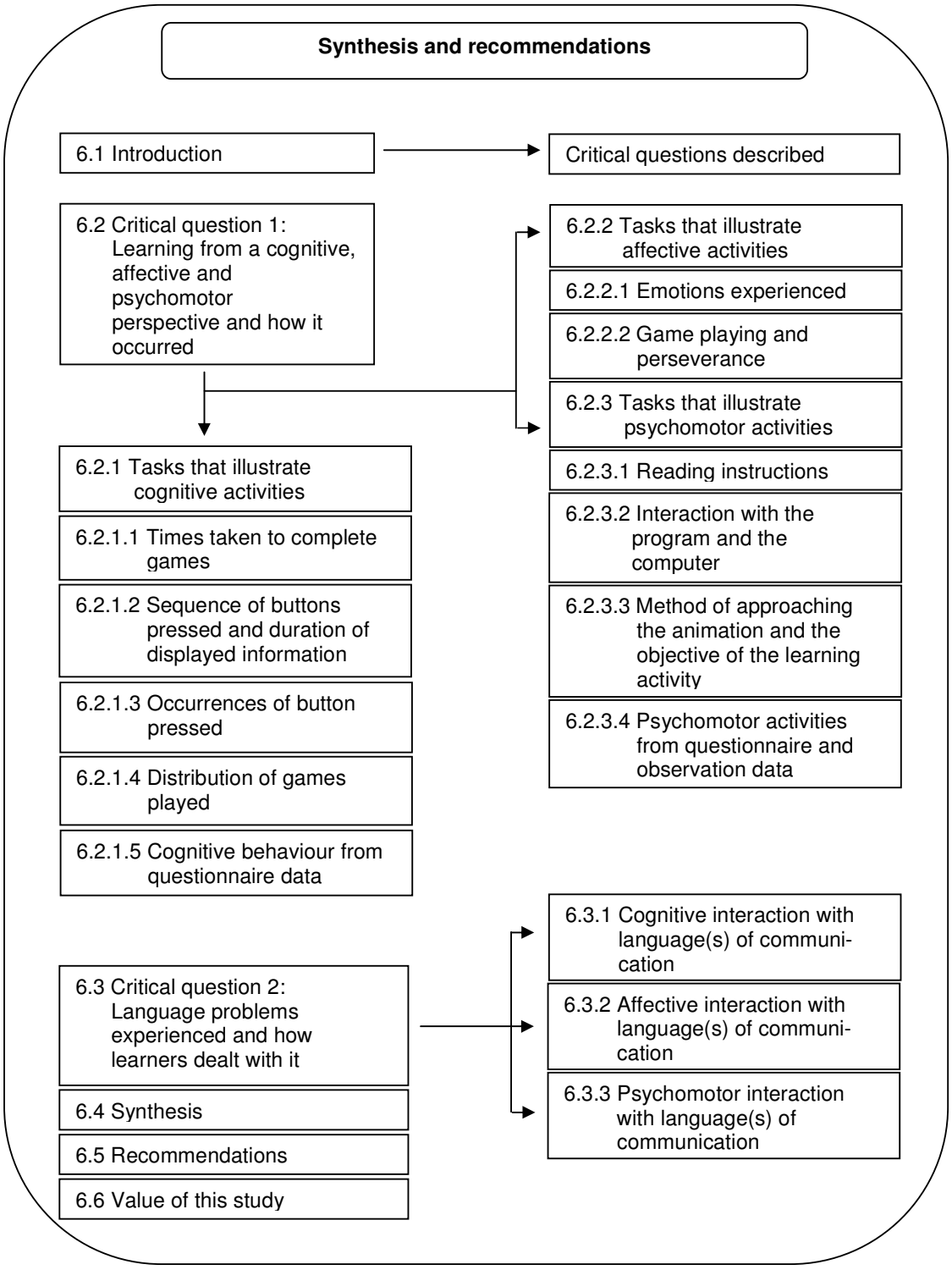

Figure 37 Overview of Chapter 6 indicating the content discussed

6.2 CRITICAL QUESTION 1: LEARNING FROM A COGNITIVE, AFFECTIVE AND PSYCHOMOTOR PERSPECTIVE

6.2.1 Tasks that illustrate cognitive perspective

In this study, cognitive activity was demonstrated in a number of ways. Cognitive activities such as enhancement of children's memory capacity, attention span and problem solving strategies can affect academic performance via computer games. The type of activity used in both this study and that of Pillay (2003) was a linear cause and effect game for both the learning and assessment phases. This meant that for every action the learner took, he/she would be informed of whether it was correct or incorrect.

Cognitive activity was demonstrated in a number of ways in this study. These included times taken to complete the games; the sequence of buttons pressed and the duration of information displayed; occurrences of buttons pressed; distribution of games played; and cognitive behaviour from questionnaire data.

6.2.1.1 Times taken to complete games

Times taken by the different groups (1, 2, 5 and 6) to complete games correctly decreased progressively as time passed.

In this study, learners were evaluated by establishing if they became proficient at game playing if they played the game over and over. Proficiency was demonstrated if learners managed to complete (play) the games correctly in progressively shorter time intervals.

Ko's 2002 study with children playing a board game (computer and paper version) aimed to find out if learners became more proficient in inference-making during game playing if they played the game over and over. This game expected learners to complete the games in progressively fewer moves as time passed. His studies found that learners had indeed managed to complete the games in fewer moves as time passed, by making inferences from game rules.

In this study the results indicated that successive time intervals to complete the games correctly decreased over time. While this study showed that games were completed quicker, Ko's 2002 study showed that games were completed in fewer moves as time went by. This study therefore does not concur with the literature and needs further investigation.

6.2.1.2 Sequence of buttons pressed and duration of displayed information

Some groups started out pressing the buttons in sequence as they appeared on the user interface while other groups approached the buttons in a different manner.

In this study, learners familiarized or acquainted themselves with the instructions, positions of blocks of elements and the positions of specific elements by pressing various buttons on the user interface. This familiarization was important and took place during the learning phase as was required for subsequent successful game playing during the assessment phase. Learners were keen to familiarize themselves with the elements as all groups (except group 6) pressed all the informational buttons within the first 6 minutes of activating the learning activity (see Appendix Tables 13 - 15).

Table 18 presents an overall picture of the way in which learners approached the learning activity. The stepwise approach showed that groups, 1, 2, 3 and 5 pressed the 'Instructions' button first and then the informational buttons. This way of approaching the learning activity suggested that the learners wanted to ensure that they pressed all informational buttons in order to derive maximum benefit once they started gaming. Group 4 pressed the informational buttons and then the 'Instructions' button. Of importance is the fact that these groups (1 - 5) did not press the informational buttons again but resorted to game playing or selection from the combo box.

Group 6 behaved in a completely different manner to the other groups. This group:

- did not read the instructions at all;
- continuously pressed various informational buttons (mostly the 'All elements' button) during the learning activity; and
- **only** pressed the 'All elements' button from 13 minutes and 43 seconds to 41 minutes and 42 seconds into the animation.

It is possible that this group had a short attention span or that the group failed to retain knowledge or could not adequately recall information and, therefore, constantly referred to the positions of all elements. In my opinion, this group imposed a huge cognitive load on themselves by continuously pressing the 'All elements' button. This meant they had to remember the position of twenty elements whenever they pressed this button. If instead they pressed the other informational buttons that revealed less information at a time (3 - 4 items), the cognitive load would have been lower as the information would have been presented in small chunks. This group only completed one correct game, 25 minutes and 40 seconds into the learning activity and still took longer than sixty seconds to accomplish this.

This aspect of the study definitely needs further research as the literature is silent on the order in which informational buttons need to be pressed to derive maximum benefit for learning.

Duration of displayed information

In this research study, learners pressed informational buttons to display information. Learners, therefore, decided how long they wanted to display the information. This suggested that while learners pressed these informational buttons for relatively short periods of time, they managed to remember and recall this information during game playing.

Sperling's 1960 study investigated the availability of information during brief visual presentations. Ten symbols (letters) were exposed for brief periods ranging from 0.015 to 0.5 seconds. Report-backs of what was seen revealed that the subjects, on average, managed to recall up to four letters correctly. An important finding was that the duration of exposure did not play a role in the amount of information recalled.

In this study, informational buttons displayed a number of pieces of information on their MouseDown events. These were the 'Alkaline' (4); 'Earth alkaline' (3), 'Natural gases' (4), 'Halogens' (3), 'Noble gases' (3), 'Fluidlike' (2) and 'All elements' (22) buttons. With the exception of the 'All elements' button that displayed twenty two pieces of information, all other informational buttons displayed considerably less information. In addition, the duration that information was displayed was not as short as in Sperling's 1960 study and learners controlled the duration of information display.

In conclusion then, although learners may have looked briefly at the displayed information (for less than 1 second in many cases) or simply glanced at it, it is the researcher's contention that the duration of information display was long enough to enable them to recall the information that was used in the gaming phase of the activity.

This part of this study concurs with the literature. The only difference was that the learners in this study controlled the duration of information display which was an advantage compared to Sperling's 1960 study in which duration of exposure was predetermined.

6.2.1.3 Occurrences of buttons pressed

Patterns or occurrences of buttons pressed during execution of the animation were remarkably different.

Informational buttons 1 - 4 and 6 - 12 (see Figures 30 and 31) served to display information vital to learning and reaching the goal of the learning activity. Buttons 6 - 12 were pressed an average of 23 times compared to buttons 1 - 5. The informational buttons 6 - 12 assisted the learners in familiarizing or acquainting themselves with the positions and atomic numbers of elements during the learning phase (Kozielska, 2000; Teodoro, 2005). Buttons 13 - 17 mainly served to operationalize the learning activity.

The relatively high number of button presses with respect to the 'Next' button and selection from the combo box, as opposed to the 'Start timer' and Stop timer' buttons could be misleading. The 'Next' button and selection from the combo box were pressed (or could be pressed) for each element, whereas the 'Start timer' and 'Stop timer' veiled the number of button presses between them.

A possible reason for the discrepancy between the number of 'Next' button presses and the combo box selections is that the learners could easily abandon their dragging activities for the 'Next/combo box' selection sequence of events and vice versa. Surprisingly, not a single group interacted with the animation in this way. Whenever learners started a sequence of dragging activities, or 'Next/combo box 'selection sequence, irrespective of whether they dragged or selected some or all elements, they diligently hit the 'Reset' button. Some of the groups, however, followed the 'Next/combo box' selection sequence of events and then reset the animation, resulting in the discrepancy between the 'Next' button presses and the combo box selection.

Learners often used the 'Reset' button (83%). Resetting the animation allowed learner control of the learning content, afforded learners opportunities to interact with the information in ways they saw fit and allowed for pacing and sequencing via numerous informational buttons. Manipulation and exploration allowed the learners to construct their own knowledge and learners took responsibility for their own learning. This was in line with Mayer & Gallini's 1990 proposal that animation should be manipulated and controlled to assist learners in keeping them focused on relevant information.

Whilst occurrences of buttons pressed imply psychomotor behaviour, the sequence in which the buttons were pressed may be indicative of the learners directing their own

learning. Since linear and program control were non-existent, learner control enabled learners to manipulate and explore the program in any way they wanted to in order to increase their own opportunities for learning.

While this study focused on the patterns or occurrences of buttons pressed, the literature is silent on it. This part of the study therefore warrants further investigation.

6.2.1.4 Distribution of games played

Learners became more skilled at game playing as time went by or learners' proficiency at game playing improved.

The games in this study were played against time. Learners became better at game playing as time passed. As more and more games were played, or as games were played over and over, times to complete the games successfully gradually decreased. Figure 32 shows how large numbers of games were initially abandoned, then how some games were incorrectly completed (in more and less than sixty seconds), followed by correctly completed games in more than sixty seconds and, finally ,even more completed in less than 60 seconds. This trend in game playing suggests that the learners became more proficient at game playing. Figures 18, 19, 21 and 22 confirmed learners' proficiency at game playing. These correctly played games (in less than sixty seconds) were confirmed by the observers. Some groups performed better than others in terms of the number of correctly completed games in less and more than sixty seconds. This suggested that some groups became skilled faster than other groups and this perhaps accounted for the huge difference in games correctly played within the allotted time.

While this study reports on the progressive decrease in time for successful game completion, Ko's 2002 study reported on completion of games in progressively fewer and fewer moves as indicators of learner proficiency. This part of the study, therefore, concurs with the literature, though the parameters to demonstrate proficiency differed.

6.2.1.5 Cognitive behaviour from questionnaire data

A hundred percent (100%) of all learners indicated that the animations assisted them in getting to know the atomic numbers of all the elements. It is fairly accurate to assume that these learners had a low level of prior knowledge as the content covered in the activity was new to them. Most of the groups managed to complete the games in more than 60 seconds and subsequent games were completed in less than 60 seconds. This suggested

that the learners' retention of information and the subsequent recall of information improved. This animation allowed for the control of animated, graphical information. Pridemore and Klein (1994) reported that control influences retention and student interest positively and this could have lead to improved retention of information.

A mere thirty three percent (33%) of learners indicated that they initially knew the atomic numbers (prior to their interaction with the learning activity) while eighty three percent (83%) of learners indicated that they knew the atomic numbers after playing the game. Again, this could be a result of improved retention of information and corrective feedback given (after each dragging and selection event) that confirmed to the learners that they achieved their goal or that they were not successful. It is therefore, fair to make the assumption that learners' knowledge increased as a result of their interaction with the animation.

Whilst the literature indicates that control of (an) animation influences information retention, subsequent recall of that information and student interest positively, this study did not prove beyond doubt that learner control improved information retention, recall of (that) information and, therefore, further investigation is required.

6.2.1 Tasks that illustrate affective activities

Picard *et al.* (2004) and Anolli *et al.* (2005) contend that the roles of cognitive and affective behaviour are "inextricably integrated" with one another as does). Anolli *et al.* (2005, p. 1) stated: "Students who are anxious, angry or depressed don't learn: people who are caught in these states do not take information efficiently or deal with it very well".

The topics to be discussed include the emotions experienced by the learners, game playing and perseverance.

6.2.2.1 Emotions experienced

The learners experienced and/or displayed a wide range of emotions while interacting with the animation.

Various emotions were displayed by the learners. The emotions ranged from boredom to complete immersion in the learning activity. They laughed and giggled to show enjoyment. Some learners were annoyed if their partners were too slow when placing elements and some learners showed their dissatisfaction by raising their voices. Initially, some of the learners were anxious and nervous. Although some learners seemed to be bored at first,

they became interested in the animation and developed a more positive attitude as time passed. Initially, some learners were confused, not knowing where to place the elements. ChanLin (2001) posited learners with low prior knowledge often find animations too demanding and hence the confusion.

Eighty three percent (83%) of the learners indicated that they found the messages during game playing encouraging or motivational. This was precisely what the activity set out to do as it motivated learners upon completion of a game(s) or even if they abandoned games. The highly interactive activity also provided continued motivation to the learners.

Hao (2004) indicated that while content-related feedback was important, emotional and motivational support was equally important. This author further contended that motivational factors contribute to educational effectiveness at cognitive and social levels. A high level of learner control (interactivity) also provided continued motivation and sustained willingness to learn (ibid).

This study concurs with the literature (as cited above) as it shows, that content related feedback was important and that motivational messages affected learners positively.

Learners persevered to master the game in the assessment phase.

Perseverance is defined as the amount of time that a student is willing to actively engage with a specific learning unit of instruction or a task (Carroll, 1989; Gettinger, 1984). Time spent in learning is regarded as an important indicator of achievement (Caldwell, Huitt & Graeber, 1982; Gettinger, 1984; Karweit & Slavin, 1981).

Learners with different academic abilities took part in this research study. The learners required different amounts of time to master the learning activity (Periodic Table). Although none of the groups managed to complete the activity (game) correctly in less than sixty seconds on their first attempts, they played the game over and over until they managed to play the game correctly in less than sixty seconds. Figure 33 illustrates how all groups (except 3 and 6) managed to play the games correctly in progressively shorter time periods (and finally in less than sixty seconds). This suggests that the learners were willing to actively engage with the game until they were satisfied that they had completed the game in less than sixty seconds.

The learners' motivation was sustained by verification feedback messages after having moved an element and encouraging messages upon having completed a game or even

after abandoning a game. Compared to the studies of Carroll (1989) and Gettinger (1984), this study showed that learners spent time until they mastered the activity, that is, they persevered. This study therefore concurred with the literature as far as perseverance is concerned.

6.2.3 Tasks that illustrate psychomotor activities

According to Henke (1997), hands-on activities add value to instruction. Kritzenberger *et al*. (2002) concurred by stating that children learn through their senses and physical activities. In an interactive learning environment such as this research study, physical or psychomotor activities include touching the screen, reading (aloud), changing parameters onscreen, verbal and gestural explanations, focusing, talking, moving objects, examining, communicating, clicking and surfing, to name a few.

The movement of circular elements on screen was remarkably similar to Verenikina & Herrington's 2008 study in which the physical presence of the elements was not real and yet learners could move a "concrete" round element that represented the real element.

The topics to be discussed include the reading of instructions, interaction with the program and the computer, method of approaching the animation and the objective of the learning activity and psychomotor activities from questionnaire and observation data.

6.2.3.1 Reading instructions

The results suggest that learners spent very little time on reading the instructions or merely gave them a cursory glance.

Only five groups spent time (albeit very little) reading the instructions, while one group did not read the instructions at all. Group 6 who did not read the instructions fared the worst at game playing. Carroll, Mack, Lewis, Grischkowsky & Robertson (1985) posited that users do not like to read instructions and, if they read instructions, it's only superficially processed.

According to Roussou (2004) and Spannagel, Girwidz, Lothe, Zendler & Schroeder (2008) learners want to learn by "doing", that is, instead of reading instructions, it was more fun to put the instructions into practice. Pillay, Brownlee & Wilss (1999) asserted that learners enjoy playing computer games as this is their way of putting instructions into practice.

This phenomenon of playing the game as opposed to reading the instructions first was demonstrated by this study. This was confirmed by affective questionnaire Question 16 that indicated as few as fifty eight percent (58%) of the learners liked the instructions (see Appendix Figure 1).

The instructions were important in guiding the learners to reach the goal of the learning activity. The instructions were kept short and only included procedural information.

This study concurred with Carroll et. al's (1983) study that instructions are not well liked and that users do not like to read instructions.

6.2.3.2 Interaction with the program and the computer

Learners interacted with the animation in a number of ways, both during the learning phase and gaming.

The program lent itself to trial and error and experimenting during the learning and assessment phases. This afforded learners ample opportunities to pace, explore, direct and control their own learning. Only one correct solution was available for each element moved. The game, therefore, encouraged low-level associations to be made between element symbol and atomic number. In some cases learners resorted to trial and error by dragging the elements to various zones until the verification feedback "Correct" was displayed.

Inkpen (2001) showed that learners preferred drag and drop activities as the learners were more familiar with it since they often used computer programs that involved drag and drop activities.

This study explained the preference of drag and drop activities as did the study of Ikpen (2001). This study, therefore, concurs with the literature.

6.2.3.3 Method of approaching the animation and the objective of the learning activity

Regardless of how they approached the learning activity, all the groups managed to reach the objective of the learning activity.

The game used for this study was a linear, sequential cause-and-effect game with a clear goal. This game might have been simplistic but it tied in with its objective to link the

elements to their atomic numbers. For each element moved, there was only one correct solution. Even though the game encouraged or lent itself to low-level associations being made using trial and error, learning in this study was intentional, i.e. the learning objective was closely aligned with the content to be mastered.

Learners approached the learning activity in ways contrary to what was expected and yet ample evidence suggested that the learners reached the objective of this activity. This was demonstrated by the number of games played (correctly versus incorrectly) (see Figure 33 and Appendix Table 10), an overall decrease in times to play games correctly (see Figure 33; Appendix Tables 6, 7 and 8) and an increase in the percentage of learners who indicated that they knew the atomic numbers of the elements (from thirty three percent [33%] prior to interaction with the learning activity to eighty five percent [85%] after having played the assessment game).

It is the contention of the researcher that learners managed to reach the objective of the learning activity, despite the fact that they employed different ways to do so.

6.2.3.4 Psychomotor activities from questionnaire and observation data

Questionnaire and observation data revealed a host of other psychomotor activities displayed during the execution of the animation.

Communication forms part of an interactive learning environment According to Sun, Williams, Ousmanou & Lubega (2003), active learners have the tendency to retain and understand information best by working with it. These authors also contended that tactile learners would be satisfied with drag and drop activities by moving objects on screen as part of their learning experiences. Inkpen (2001, p. 21) posited that kinesthetic connectivity (pressing down the mouse button) can actually help to “reinforce conceptual connectivity”.

Seventy five percent (75%) of all learners indicated verbal comments (audible when buttons were pressed) assisted them with the learning activity. The narration was personalized, i.e. some words were changed into the first and second person to describe the position of certain elements and blocks of elements. Coupled to this, animation and narration were presented simultaneously, thereby avoiding cognitive overload and possibly resulted in improved memory and retention of facts.

Learners often used the ‘Reset’ button (83%). This allowed learner control and afforded them opportunities to interact with the information as they saw fit. By manipulating and

exploring, the learners constructed their own knowledge and took responsibility for their own learning.

Seventy five percent (75%) of the learners indicated that they explained to each other. According to Sun *et al*. (2003), active learners understand information best by communicating information, discussing it, self-explaining it or explaining it to others.

All groups played the assessment game. Learners had total control over the animation and ample opportunities existed to manipulate and explore the learning activity. Learners were free to manipulate objects directly (by dragging elements) or indirectly (by pressing a button to display information). Learners could move in any direction and, therefore, directed their own learning. Some learners played the game in a manner different to what was expected (cheating as described by some observers).

This study, therefore, concurred with the literature in many aspects.

6.3 CRITICAL QUESTION 2: LANGUAGE PROBLEMS EXPERIENCED AND HOW LEARNERS DEALT WITH THEM

6.3.1 Cognitive interaction with language(s) of communication

It often happens that learners fail to make a cognitive connection with the learning content in the language of instruction and, therefore, learners switch to their mother tongue. This was emphasized by Mpofu (2006, p. 25) who indicated that the home language (mother tongue) is important as it serves as a “mediator of thought”. Learners may seem ready to be taught in English First Additional Language but they struggle cognitively to grasp concepts and find it difficult to express themselves in the First Additional Language.

Except for one observer, all other observers’ first written note referred to the use of isiXhosa as the language of communication. This suggested that the learners probably felt more comfortable expressing themselves in their mother tongue, isiXhosa, when they spoke to each other. This observation appears to verify Schlebusch and Thobedis’ 2004 statement that they struggle to say what they are thinking (in English First Additional Language), or as Snow, Met & Genesee (1989) concurred that the First Additional Language often tends to dissociate learning from cognitive or academic development.

This part of the study concurs with the literature and, while all indications are that the learners code switched whist interacting with the animations, further investigation is

required to establish just how prevalent code switching is in the Physical Science classroom.

6.3.2 Affective interaction with language(s) of communication

Learners used isiXhosa, their mother tongue and English First Additional Language to communicate whilst interacting with the learning activity. This was accomplished via code-switching and code mixing. It may have been that learners liked talking to each in their mother tongue and by doing so they exhibited strong loyalty to their own first language or each other during the conversation.

It is the researcher's contention that these learners code-switched because they liked their mother tongue, that they were able to convey information about the content of the learning activity more accurately and that they simply expressed themselves spontaneously in isiXhosa.

The literature mentions various reasons relating to the affective aspect of using the mother tongue during learning and other situations. This study cannot adequately explain the affective aspect of mother tongue usage whilst learners interacted with the animation. Whilst this study does concur with the literature, further research is required.

6.3.3 Psychomotor interaction with the language(s) of communication

In all groups isiXhosa was used as the language of communication while the groups worked with the animation. The observers' notes did not indicate if the use of isiXhosa was a regular occurrence or if isiXhosa language usage was sporadic. In addition, it could not be said with certainty whether the learners code-mixed or code-switched or did both. All observers indicated at least once that isiXhosa was used to communicate, as noted by the following:

> Xhosa is the language they use.

And yet another observer noted:

> They are using Xhosa to communicate with each other.

A subsequent discussion of the results with the learners revealed that switching between isiXhosa and English was done continuously while they worked with the learning activity.

More research is required to examine the extent to which code-switching and code-mixing occurs in a Physical Science, English First Additional Language classroom.

6.4 SYNTHESIS

Times taken by learners to play the games correctly decreased progressively over time. This meant that learners had to play the games over and over, indicating that meaningful engagement with the material enabled learners become skilled or proficient.

Guidance is needed to inform learners how to use the buttons or in what order the buttons need to be used. Essential talking or communication took place during the execution of the animation via code-switching and proved to be a valuable component of the learning process.

6.5 RECOMMENDATIONS

The following recommendations are suggested:

- an investigation into code-switching (English to isiXhosa) in Physical Science learning and
- minor adjustments to the program to improve selection of elements.

The limitations of this research study were as follows:

- it was conducted with a small sample (12 learners studying Physical Science);
- the study was conducted over a short 40 - 45 minute period;
- the animation was designed by the teacher to suit the purpose of the topic.

Despite the aforementioned limitations, my contribution to the field of knowledge of computer use in education and Physical Science learning proved that animation can be utilized purposefully in an interactive learning environment with English First Additional Language learners.

6.7 VALUE OF THIS STUDY

According to my findings, animations can enhance learning in an educational environment with English First Additional Language learners. This study illustrated that learning can be made fun and interesting without losing sight of the objective of the learning activity. This study also provided a methodology to investigate how English First Additional Language learners interact cognitively, affectively and psychomotorically with animation during

Physical Science learning. The study further showed that time is required for learners to become skilled or proficient at game playing.

Additionally, it was found that code-switching occurred during Physical Science learning and it proved to be a valuable communications tool. In my view, educators should accept code-switching as a means of communication in the classroom. As a corollary, the teacher should be able to speak both languages in order to correct or add to conversations and explanations between learners.

The abovementioned research is my contribution to the field of knowledge regarding computer use in education.

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APPENDICES

Appendix A Observation checklist

While the learners operate and watch the animation, notes will be made about:

Language

1) In what language do they respond to each other? (English or Xhosa or both together)

Emotions

2) How did they respond (emotionally and/or verbally, e.g. bored, interested, disgusted, excited, etc.) to the animations?
3) How did they respond to each others' questions?
4) Did they laugh?
5) Did they appear excited?
6) Were they apprehensive at first?
7) How did they react to the sound? (laugh, imitate, excited, bored)

Physical

8) Do they communicate with each other, verbally? (yes/no)
9) Do they talk while looking at the work? (yes/no)
10) Were learners making any sounds? (Giggle, laughed, agreement, disagreement, confirmation).
11) How do they physically respond to each others' questions? (look at each other, at screen, are they pointing, gestures, bumping, touching, laughing)
12) Did they try to gain control of the mouse?
13) Did they adjust the volume?
14) Did they write down anything?
15) Did they argue about handling the mouse?
16) Did they write anything down?

Cognitive

17) Did they actually discuss the work?
18) Was there any uncertainty about what to do in the animation (observer)?
19) What was the first button they pressed?
20) Did they spend some time studying or observing the animation before starting out?
21) Did they confer or argue about the work?
22) Did they disagree on some points?

Appendix B Interview questions

PERIODIC TABLE

1) Did you like the animation? Why?

2) Was it difficult to understand the instructions? Why?

3) Would you like to see animations being used more frequently in future?

4) How did you go about working through the activity on the Periodic Table?

5) What did you like best: Placing the elements directly or using the 'Next' button and then selecting from the combo box? (and Why?)

6) Did it become easier to place the elements on the Periodic Table as time went by?

7) Did you like some of the messages that appeared after you placed all the elements? (Why?)

8) Did you like the feedback after having placed an element correctly?

9) Did you feel motivated after having received an encouraging message?

10) Drag and drop: Did this activity assist you in getting to know the atomic numbers of the elements?

The interviews will be taped.

Appendix C Informed Consent Form

I will be participating in a research study conducted by A. Carolus as part of his Master's dissertation. The purpose of the research is to study the cognitive, affective and psychomotor effects of animations on physical science learning in a grade 10 physical science classroom. The research will be conducted in the school's Khanya Laboratory during the third term, from 13 August of 2007 till the end of the term.

I understand that the experimental design will require that I attend 1 (ONE) experimental session and that I will work with a fellow learner during these sessions. During/after the session I will be required to perform the following tasks:

1. Log onto the computer and work with an animation for approximately 30 minutes.
2. Complete a questionnaire (paper-based) after the session on the computer.
3. Answer questions in an interview after the questionnaire.

I understand that my participation in this study is also completely voluntary and that I stand to benefit from it as material to be covered forms part of the school's physical science curriculum for Grade 10. If I take part in the study I will have access to all the animations used in the study for revision and studying purposes.

I have been informed and understand that an event log of all my actions will be compiled whilst working with the animations and that all data collected will be kept strictly confidential. I understand that my name will not appear in any publication or that I will not be identified in any way. All data will be stored in a secure location to ensure complete confidentiality. This research study has been reviewed and approved by the Western Cape Education Department and can be confirmed at any time by calling Dr R.S. Cornelissen at (021) – 467 2286. The study also has the approval of the Governing Body of Masakheke Combined School.

I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntary agree to participate in this study.

I have been given a copy of this consent form.

……..	……	……
(Name of Learner)	**Signature of Learner**	**Date**
……..	……	……
(Name of Parent/Guardian)	**Signature of Parent/Guardian**	**Date**
A. Carolus	……	……
(Name of researcher)	**Signature of researcher**	**Date**

Appendix D Outline of audit trail data collection and analysis

1. Data collected by the Flash MX 2004™ animation

Group One
Data (All) Sequential
1/Inst /3:46 //2/ReInst /4:05 //3/Alk /4:10//4/AlkD /4:10//5/Earth /4:14//6/EarthD /4:14//7/Alk /4:17//8/AlkD /4:17//9/Earth /4:19//10/EarthD /4:19//11/Ngas /4:22//12/NgasD /4:22//13/Halo /4:24//14/HaloD /4:24//15/Noble /4:26//16/NobleD /4:26//17/Fluid /4:29//18/FluidD /4:29//19/All /4:32//20/AllD /4:32//

2. Data copied to Word to be split by a macro

Split Data

1/Inst /3:46 //2/ReInst /4:05 //3/Alk /4:10//4/AlkD /4:10//5/Earth /4:14//6/EarthD /4:14//7/Alk /4:17//8/AlkD /4:17//9/Earth /4:19//10/EarthD /4:19//11/Ngas /4:22//12/NgasD /4:22//13/Halo /4:24//14/HaloD /4:24//15/Noble /4:26//16/NobleD /4:26//17/Fluid /4:29//18/FluidD /4:29//19/All /4:32//20/AllD /4:32//

3. Data was split according to events by a Word macro

Data Splitted

1/Inst /3:46
2/ReInst /4:05
3/Alk /4:10
4/AlkD /4:10
5/Earth /4:14
6/EarthD /4:14
7/Alk /4:17
8/AlkD /4:17
9/Earth /4:19
10/EarthD /4:19
11/Ngas /4:22
12/NgasD /4:22
13/Halo /4:24
14/HaloD /4:24
15/Noble /4:26
16/NobleD /4:26
17/Fluid /4:29
18/FluidD /4:29
19/All /4:32
20/AllD /4:32

4. Data subsequently copied to Excel

1/Inst/3:46
2/ReInst /4:05
3/Alk /4:10
4/AlkD /4:10
5/Earth /4:14
6/EarthD /4:14
7/Alk /4:17
8/AlkD /4:17
9/Earth /4:19
10/EarthD /4:19
11/Ngas /4:22
12/NgasD /4:22
13/Halo /4:24
14/HaloD /4:24
15/Noble /4:26
16/NobleD /4:26
17/Fluid /4:29
18/FluidD /4:29
19/All /4:32
20/AllD /4:32

Appendix D (Continued)

5. Text to column delimited data and subsequent concatenation, depending on the type of data required

Column C	Column D	Column E	Column F	
Number	Buttons	Time (minutes & seconds)	Conatenated E & D	
1	Inst	3:46	Inst	3:46
2	ReInst	4:05	ReInst	4:05
3	Alk	4:10	Alk	4:10
4	AlkD	4:10	AlkD	4:10
5	Earth	4:14	Earth	4:14
6	EarthD	4:14	EarthD	4:14
7	Alk	4:17	Alk	4:17
8	AlkD	4:17	AlkD	4:17
9	Earth	4:19	Earth	4:19
10	EarthD	4:19	EarthD	4:19
11	Ngas	4:22	Ngas	4:22
12	NgasD	4:22	NgasD	4:22
13	Halo	4:24	Halo	4:24
14	HaloD	4:24	HaloD	4:24
15	Noble	4:26	Noble	4:26
16	NobleD	4:26	NobleD	4:26
17	Fluid	4:29	Fluid	4:29
18	FluidD	4:29	FluidD	4:29
19	All	4:32	All	4:32
20	AllD	4:32	AllD	4:32

Note: The type of data in the far right-hand side column was used in Figures 28 and 29.

Appendix E Interview questionnaire (Student 1)

Periodic Table

1) **Interviewer:** Did you like the animation? Why?
Student 1: Yes, I liked it because it is easy to learn the element to put in place.

2) **Interviewer:** Was it difficult to understand the instructions? Why?
Student 1: First it's difficult but if you going on and going on we understand better but now I think its not that difficult anymore and I enjoy it.

3) **Interviewer:** Would you like to see animations, I repeat, would you like to see animations being used more frequently in future?
Student 1: Yes because I, I think because within my own opinion it teach the learners to know the elements better than in terms of teaching and if you do things in computer, it is easy to understand.
Interviewer: Ok

4) **Interviewer:** How did you go about working through the activity on the periodic table?
Student 1:

5) **Interviewer:** What did you like best: Placing the elements directly or using the Next button and then **s**electing from the combo box? (and Why?)
Student 1: Using to placing directly.
Interviewer: Why?
Student 1: Because it's to easy if you do that than to select an element.

6) **Interviewer:** Did it become easier to place the elements on the periodic table as time went by?
Student 1: Yes, because one time you know that you must run with the time. That's why I think so.

7) **Interviewer:** Did you like some of the messages that appeared after you placed all the elements? (Why).

8) **Interviewer:** Did you like the feedback after having placed an element correctly?
Student 1: Yes encourage, yes because encourage me the feedback. I do it well.

9) **Interviewer:** Did you feel motivated after having received an encouraging message?
Student 1: Yes because, yes because the message insured that I can do it, that's why I feel encouraging.

10) **Interviewer:** Drag and drop: Did this activity assist you in getting to know the atomic numbers of the elements?
Student 1: Yes because if you didn't' put in the correct way, it show you and today I know it.

Appendix F Interview questionnaire (Student 2)

Periodic Table

1) **Interviewer:** Did you like the animation? Why?
Student 2: Yes I, I did like the animations. Because it is colorful and it makes me interested in doing it.

2) **Interviewer:** Was it difficult to understand the instructions? Why?
Student 2: No.
Interviewer: Why not?
Student 2: Because they was [sic] straight forward.

3) **Interviewer:** Would you like to see animations being used more frequently in future?
Student 2: Yes
Interviewer: Why?
Student 2: Because it is going to make people easier to work with animations; makes their jobs easier.

4) **Interviewer:** How did you go about working through the activity on the periodic table?
Student 2: Firstly I, I looked at the elements and looked at the numbers and try to memorize everything I know and then I started doing it.

5) **Interviewer:** What did you like best: Placing the elements directly or using the Next button and then selecting it from the combo box? (and Why?)
Student 2: I liked placing the elements directly; its because of it, it took less time and it allows you to use your memory.
Interviewer: Okay

6) **Interviewer:** Did it become easier to place the elements on the periodic table as time went by?
Student 2: Yes, it did become easier.
Interviewer: Why?
Student 2: Because you, you see when you place the element wrong and then you correct it.

7) **Interviewer:** Did you like some of the messages that appeared after you placed all the elements? (Why).
Student 2: Yes I did.
Interviewer: Why did you like it?
Student 2: Because of they were encouraging.
Interviewer: Ok?

8) **Interviewer:** Did you like the feedback after having placed an element correctly?

9) **Interviewer:** Did you like, I repeat, Did you feel motivated after having received an encouraging message?
Student 2: Yes, I felt motivated

10) **Interviewer:** Drag and drop: Did this activity assist you in getting to know the atomic numbers of the elements?
Student 2: Yes it did.
Interviewer: Why?
Student 2: Because you could drag and drop it and then if you didn't drag drop it correctly, it will correct you.
Interviewer: Okay.

Appendix G Interview questionnaire (Student 3)

Periodic Table

1) **Interviewer:** Did you like the animation? Why?
Student 3: Yes, I liked it because they, they teach they us more about elements and how to place the elements.

2) **Interviewer:** Was it difficult to understand the instructions? Why?
Student 3: Yeah, it was, it was difficult.
Interviewer: Why?
Student 3: Because, because of the time; the time is sixty, sixty seconds and ….[Pause]…. it is difficult because you have to place all 20 elements
Interviewer: I think you've got it wrong. I am just asking if it was difficult to understand the instructions, not placing the elements.
Student 3: No, no, no it was not difficult.

3) **Interviewer:** Would you like to see animations being used more frequently in future?
Student 3: Yes
Interviewer: Why?
Student 3: Because, because ……[Long Pause]… because, because ……. They motivate us. They motivate us.
Interviewer: Ok

4) **Interviewer:** How did you go about working through the activity on the periodic table?
Student 3: [Long Pause] [No response]
Interviewer: I repeat the question**:** How did you go about working through the activity on the periodic table?
Student 3: I started to, to practice….[Pause]…. to practice to go how to, to manage my time**.**
Interviewer: OK, but what did you do first? Did you drag and drop first or did you play the game first or did you use the Next and select?
Student 3: I used Next and Select
Interviewer: You didn't drag and drop or where did you start, you start with drag and drop and then with select or what did you do?
Student 3: I started to drag and drop and ….[Pause]…. and to select.

5) **Interviewer:** What did you like best: Placing the elements directly or using the Next button and then selecting it from the combo box? (and Why?)
Student 3: Placing elements directly
Interviewer: Why?
Student 3: Because its easier when you drag the elements directly

6) **Interviewer:** Did it become easier to place the elements on the periodic table as time went by?
Student 3: Yes
Interviewer: Why?
Student 3: Because you, you already experienced... uh…to manage your time and …… [Long Pause] ….. to, ..[Pause]..to be more far *[sic],* to be more faster than when, when you started to ……...
Interviewer: Ok

7) **Interviewer:** Did you like some of the messages that appeared after you placed all the elements? (Why).
Student 3: Yes
Interviewer: Why?
Interviewer: Because they, they give, they give me hope that you try next time?

8) **Interviewer:** Did you like the feedback after having placed an element correctly?
Student 3: Yes
Interviewer: Why?
Student 3: Because, they make me excited because … [Pause] … because I placed ……. correctly.

9) **Interviewer:** Did you feel, did you feel motivated after having received an encouraging message?
Student 3: Yes
Interviewer: Why was that?
Student 3: [long Pause, no answer]
Interviewer: Ok

10) **Interviewer:** Last question. Drag and drop: Did this activity assist you in getting to know the atomic numbers of the elements?
Student 3: Yes
Interviewer: Why? And how did it assist you?
Student 3: Because … [Long Pause]
Interviewer: Ok. …… Thank you.

Appendix Table 1 Questionnaire on Periodic Table

Fill out the form as accurately and honestly as possible by ticking in the correct block (in your opinion) opposite each question or statement. You do not have to put your name on the form.

No		Questions	Yes	No
1	C	Did the animation assist you in getting to know the atomic numbers of the elements?		
2	C	Did you realize the buttons below, on the left-hand side, helped classify the different elements?		
3	C	Did the verbal comments help you to understand in what you were doing?		
4	C	Was it helpful to be able to reset the animation?		
5	C	Did you know the atomic numbers of all the elements before the animation?		
6	C	If you were given a test after the animation, would you be able to place element each opposite its correct atomic number?		
7	C	Did you or your partner explain or try to explain to each other sections of the animation?		
8	C	As time went by, did you gradually use less time to place the elements correctly?		
9	C	Do you **NOW** know the atomic numbers of the elements?		
10	C	Did the message(s) encourage you to do better?		
11	C	Was it easier to drag the element to its correct place, than clicking the “Next” button and selecting the correct element from the list?		
12	C	Did you play the game?		
13	C	Did you manage to complete the game?		
14	A	Did you like the elements being placed correctly by the animation?		
15	A	Did you like dragging the elements?		
16	A	Did you like the instructions in the yellow box?		
17	A	Did you find the animations memorable?		
18	A	Were you anxious when you observed the Periodic Table for the first time?		
19	P	Did you press all the different buttons to look at all the different groupings of elements on the Periodic Table?		
20	P	Did you drag the round element (in the instruction box)?		
21	P	Did you use the “Start timer” and “Stop timer” often?		
22	P	Did you often use the “Next” button and selected the correct element from the drop down box?		

Note: This table was presented to the learners without the column indicating A, C or P.

Appendix Table 2 Use of the audit trail to indicate cognitive activity

	Research Question	How do English First Additional Language learners interact with information	cognitively,	affectively and	psychomotorically	in an interactive learning environment?
	Purpose					
1	Number of times of each element dragged and selected correctly & incorrectly and in which zone.		✓		✓	
2	Number of:					
	abandoned games		✓			
	incorrectly completed games in less than 60 seconds		✓		✓	
	incorrectly completed games in more than 60 seconds		✓		✓	
	correctly completed games in more than 60 seconds		✓		✓	
	correctly completed games in less than 60 seconds.		✓		✓	
3	Time taken to complete the games.		✓		✓	
4	Occurrences of different buttons pressed during learning phase.		✓		✓	
5	The sequence in which the buttons were pressed.		✓		✓	
6	How often elements were dragged as opposed to placed.			✓	✓	

Appendix Table 3 Cognitive - comments by observers

Groups	1	Working together.. They argued about, about w hich elements to place w here. They w ere uncertain at some points. They had difficulties w ith the second phase. Only one student knew w hich element knew w hich element goes w here; the other kept asking for help.
	2	They tried again. The second time one min seven seconds w hich mean they cooperated. They are explaining to one another. They are pointing the ones they know to correct themselves. They decide w hich elements they w ill start w ith first. They talk w hile looking at the w ork. Only one number of a element they have not got it correct. In 54 seconds they have all the elements correct. They are w riting elements dow n to make it easier for themselves. They are help each other by saying the element in a paper chiting *[sic].* 46 seconds w ithout cheating. The other one w as too slow and the other w as very fast but they w ere co-operating w ith one another.
	3	Their second try they just started to place the elements and they helped each other and they also disagree at some point. They started the timer but they did not do anything. They start the timer and place 3 elements and reset it again. They did not know w hay to do w ith the paper the principal gave them.
	4	Putting elements incorrect. Only one person is participating. No communication betw een partners. Don't do the activity by his self. Getting help from his partner. Did'nt set the timer at first. Done the task in 60s +++++ (not good) Don't communicate w ell during the activity. Asking each other questions. Not concestrating-*[sic]* on w hat they are doing. Doubtfull on placing elements. Unsure w hat they must do. One partner is excellent. They are playing w ith the timer.
	5	They are w orking together. Firstly they are confused. They are not sure about the elements. They finished in 60 sec +++ the first time. They place the elements correctly and they are finishing in 51 sec. They are becoming more intrested *[sic]* and they are now sure about the element that makes them to complete the periodic table. Less than 60 seconds. They are w orking w ell w ith each other and the are co-operating. They share information. They are agreeing w ith their w ork by w orking together. They are handling w ell the mouse *[sic]*. They don't w rite dow n annything except they are paying concentration to the monitor. They are discussing the w ork before they do the w ork. When one is asking a question the other is responding in the mother tongue. When one respond to other one's question he respond by pointing to the monitor. They w ere alw ays agree on their w ork and even agree to some points.
	6	...They don't know the w ork; .. they try it w ithout the timer

Appendix Table 4 Affective - comments by observers

Groups	1	Working together. They w ere interested. They laugh. Raised their voices to each other. They w ere annoyed w ith each other for placing the elements, the partner w as too slow . Giggled and shouted. They had difficulties w ith the second phase.
	2	They are also one another a chance also laughing (show s enjoyment). They are surprised by other elements. The other one w as too slow and the other w as very fast but they w ere co-operating w ith one another.
	3	They are interested but the first student started but the other one took over and they already started the timer. Their second try they just started to place the elements and they helped each other and they also disagree at some point. They have respect for each other. The other girl w as starting to think about the time and she raised her voice. The other learner w as getting bored and started to eat the w ires of the earphones.
	4	Nerves *[sic]* (both of them). Don't give each other a chance to place elements. Don't find it exciting. Depending to one another. Concerned about the invigilator. Laughing. Responding in a respectfull w ay and language both of them. The other refuses to try and do it on right. Biting nails. Unpatient *[sic]* to finish the activity. The other one is relaxing on the chair w aiting to go home. Too lazy to try again (both of them). Disagree on some points. One partner is excellent. Forgets to start the timer.
	5	They are intrested *[sic]*. They are becoming more intrested and they are now sure about the element that makes them to complete the periodic table. Less than 60 seconds. They are w orking w ell w ith each other and the are co-operating. They are going along w ith the completing the periodic table for less than 60 sec. The learner w as laughing w hile the other w as missing one element.
	6	they seem not interested in w hat they are doing. they w ere like bored. ….. Was intrested *[sic]* in groups's w ork, not in their w ork no intrest [sic] then they then get back intrested [sic] and the compitite [sic] to w ith each other he w as consened *[sic]* in w hat …. Was doing …… w as very bored. and ….. Was geusing *[sic].*

Appendix Table 5 Psychomotor - comments by observers

Groups	**1**	Ask observer for instructions They laugh Point at the screen They argued about, about *[sic]* which elements to place where. They were bumping each other. Only one member used mouse They were communications *[sic]* with each other One instructed the other Raised their voices to each other Took turns using the mouse Giggled and shouted Looked at other the group members and talked to them Writing down elements Took off the ear phones Only one student knew which element knew which element goes where; the other kept asking fo They looked at the screen most of he time and looked at each other when one does something
	2	They are reading the instructions. They set the timer and insert the elements. They are showing one another (pointing). They are explaining to one another. Presses Alkaline block and natural gases. They are pointing the ones they know to correct themselves. They are pointing the ones they know to correct themselves. They are checking on a book the number of elements. They talk while looking at the work. They talk while looking at the work. They are writing down numbers of elements. They are also one another a chance also laughing (shows enjoyment) They are writing the elements down and point. They are writing elements down to make it easier for themselves.
	3	They are interested but the first student started but the other one took over and they already started the timer. They are touching the screen of the computer and finished in 2:15 and they tried again. Their second try they just started to place the elements and they helped each other and they also disagree at some point. They are working slowly with the mouse that is why they don't finish early. Only one person worked with the mouse. They started the timer but they did not do anything. They just clicked on other places. They start the timer and place 3 elements and reset it again. She started but the other girl was putting her finger on her ear. Sometimes there was no communication between them if the other one was doing the work wron

Appendix Table 5 (Continued): Psychomotor - comments by observers

Groups	4	Working together. Putting elements incorrect. Only one person is participating. Pressing in w rong places w here he's not suppose to press/click. Pointing the screen and talking Xhosa. Show ing the other partner w hat to do. Don't do the activity by his self. Lots of incorrect placing. Moving elements in w rong places. Pointing screen and talking at the same timer. Too slow ly to place elements. Asking each other questions. Telling the partner w hat to do. Responding in a respectfull w ay and language both of them. Biting nails. Forgets to start the timer. They are playing w ith the timer.
	5	They w ere laughing. Placed the elements incorrectly at the second time. Placed the elelements incorrectly again. They talk w hile they are w orking. Placed the elelements incorrectly, but at the end they tried to place the elements correct and they done it to *[sic]* 55 seconds only. They place the elements correctly and they are finishing in 51 sec. They are handling w ell *[sic]* the mouse. They don't w rite dow n annything except they are paying concentration to the monitor. They are discussing the w ork before they do the w ork. When one is asking a question the other is responding in the mother tongue. When they heared the sound they w ere imitating. When one respond to other one's question he respond by pointing to the monitor. The learner w as laughing w hile the other w as missing one element.
	6	Xhosa is the language they use. The communicate in Xhosa. And they look in the other groups. And/But they w ere taking the earphones out and now nothing to do. They listen to other w hat they are doing. and do w hat they see in the others. and they w ere stragling *[sic]* but only one w as w orking. …. is just looking and tell and tell …... w ere to point. they use the guide to know *[sic]* w ere to point. .. only use head to .. to correct … and. he only use the mouse w hen click on the help block. he also use fingers to point. both of them use Xhosa and they use their fingers to point. the the mouse they start communicating. Pressed all element and try again. they place one tw o or more time in different places. and they w ere laughing. only question they asked is did you look respond yes. omlost *[sic]* every time the use the fingers. in this game before they stat *[sic]* the click. … keep on doing at looking if it pass timer *[sic]*.

Appendix Table 6 Nature of the games played, time started, time game ended and time taken to complete game (groups 1 and 2). Times are indicated in minutes and seconds.

Number	Game started	Game ended	Nature of game	Time
Group 1				
1	5:12	7:08	>60CCor	1:55
2	7:39	9:09	>60CNCor	1:30
3	9:38	10:42	>60CNCor	1:03
4	11:02	12:04	>60CCor	1:01
5	12:26	13:21	<60CNCor	0:54
6	13:34	14:32	<60CCor	0:58
7	32:09	32:18	Aban	0:08
8	33:10	33:14	Aban	0:04
9	36:12	37:25	>60CNCor	1:12
10	37:41	39:10	>60CCor	1:29
11	39:23	40:10	<60CCor	0:47
12	40:30	40:49	Aban	0:18

Number	Game started	Game ended	Nature of game	Time
Group 2				
1	5:41	7:46	>60CCor	2:05
2	8:22	9:29	>60CCor	1:07
3	12:53	13:57	>60CCor	1:04
4	14:49	15:05	Aban	0:15
5	15:11	15:13	Aban	0:02
6	30:47	31:42	<60CCor	0:54
7	32:14	32:21	Aban	0:06
8	32:32	32:39	Aban	0:07
9	33:01	33:13	Aban	0:11
10	35:27	36:35	Aban	1:07
11	36:56	37:23	Aban	0:26
12	38:21	38:25	Aban	0:03
13	38:46	39:32	<60CCor	0:46

Appendix Table 7 Nature of the games played, time started, time game ended and time taken to complete game (groups 3 and 4). Times are indicated in minutes and seconds.

Number	Game started	Game ended	Nature of game	Time
Group 3				
1	6:17	9:00	Aban	2:43
2	9:22	12:02	>60CCor	2:39
3	14:43	14:49	Aban	0:06

Number	Game started	Game ended	Nature of game	Time	Times wrongly recorded
Group 4					
1	18:13	**19:23**	>60CCor	1:09	
2	19:45	20:16	Aban	0:30	
3	20:43	22:50	>60CCor	2:07	
4	23:08	24:24	>60CCor	1:16	
5	25:07	25:12	Aban	0:05	
6	25:23	26:28	Aban	1:05	
7	26:35	29:03	>60CCor	2:28	
8	29:16	30:03	<60CCor	0:47	
9	31:33	32:29	>60CCor	**0:56**	**1:54**
10	32:47	33:36	<60CCor	**0:48**	0:52
11	34:13	34:57	<60CCor	**0:44**	0:47
12	36:05	36:59	<60CCor	**0:54**	0:56
13	38:34	39:36	>60CCor	**1:02**	1:04
14	41:15	42:13	>60CCor	**0:58**	**1:01**

Note that the data collected in Appendix Table 7 (group 4) includes both the data prior to timer malfunction (numbers 1 - 8) and thereafter (game numbers 9 - 14). Note how the times recorded for games 9 and 14 exceeded 1 minute and the nature of the games therefore recorded as >60CCor, whilst the nature of the game should have been recorded as <60CCor.

Appendix Table 8 Nature of the games played, time started, time game ended and time taken to complete game (groups 5 and 6). times are indicated in minutes and seconds.

Number	Game started	Game ended	Nature of game	Time
Group 5				
1	10:39	11:47	>60CCor	1:07
2	12:12	13:15	>60CNCor	1:02
3	13:29	13:38	Aban	0:08
4	13:55	15:05	>60CNCor	1:09
5	15:21	16:24	>60CCor	1:03
6	17:05	17:57	<60CCor	0:51
7	18:13	19:05	<60CCor	0:52
8	19:17	20:03	<60CCor	0:45
9	20:20	21:12	Aban	0:51
10	21:22	22:06	<60CCor	0:43
11	22:19	22:21	Aban	0:02
12	24:12	24:58	<60CCor	0:46
13	25:11	26:22	>60CCor	1:10
14	27:02	27:46	<60CCor	0:44
15	28:16	29:13	<60CCor	0:57
16	29:26	30:07	Aban	0:40
17	30:13	31:03	<60CCor	0:49
18	31:14	31:52	<60CCor	0:38
19	32:05	32:47	<60CCor	0:41
20	32:59	33:42	<60CNCor	0:43
21	33:58	34:40	<60CCor	0:42
22	35:03	35:39	<60CCor	0:36
23	35:56	36:52	<60CCor	0:55
24	36:59	37:47	<60CCor	0:47
25	38:01	38:39	Aban	0:38
26	39:29	40:12	<60CCor	0:43
27	40:22	41:04	<60CCor	0:41
28	41:15	41:20	Aban	0:04

Number	Game started	Game ended	Nature of game	Time
Group 6				
1	16:12	17:59	Aban	1:47
2	23:20	24:22	Aban	1:01
3	25:40	27:47	>60CCor	2:06
4	30:34	31:42	Aban	1:08
5	35:58	37:00	Aban	1:02
6	37:39	38:50	Aban	1:11
7	39:03	40:09	Aban	1:05
8	40:39	41:37	Aban	0:58

Appendix Table 9 Extract of the data collected to show timer malfunction (group 3)

113/Stime /15:04
114/Stime /15:04
115/Ca /15:06/OrigPos
116/Na /15:06/OrigPos
117/Na /15:07/OrigPos
118/Ca /15:09/Cazone
119/K /15:25/Kzone
120/Na /15:32/Nazone
121/Sttime /15:37 /t=1:04/Aban

Appendix Table 10 Nature of the games played by the class and different groups

Nature of game	Games							Percentage games
	Groups						Class	
	1	2	3	4	5	6		
Aban	3	8	2	3	6	7	29	40
>60CNCor	3	0	0	0	2	0	5	7
<60CNCor	1	0	0	0	1	0	2	3
>60CCor	3	3	1	1	3	1	15	21
<60CCor	2	2	0	0	16	0	21	29
Correct games (%)	5	5	1	1	19	1	36	50
Totals	12	13	3	8	28	8	72	100

Appendix Table 11 Occurrences of each element dragged per zone, correctly and incorrectly

	H	He	Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca	Br	Hg	Undefined	Total dropped	Correctly dropped	Wrongly dropped
H	77	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	78	77	1
He	1	73	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	1	0	0	0	0	83	73	10
Li	0	0	62	0	1	0	0	0	0	1	5	0	3	5	1	3	6	1	0	0	0	0	0	88	62	26
Be	0	1	3	67	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	1	0	0	77	67	10
B	0	0	1	2	70	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	75	70	5
C	0	0	0	0	3	70	3	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	79	70	9
N	0	0	1	0	0	2	65	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	72	65	7
O	0	0	0	0	0	1	7	67	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	77	67	10
F	0	1	0	0	1	1	3	1	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79	72	7
Ne	0	0	3	1	0	1	0	0	0	74	3	0	0	0	0	0	0	2	0	0	0	0	0	84	74	10
Na	0	0	1	0	0	0	0	0	0	0	62	0	2	0	0	0	0	0	5	3	0	0	0	73	62	11
Mg	0	0	0	0	0	0	0	0	0	0	0	72	0	0	0	0	0	0	0	0	0	0	0	72	72	0
Al	0	0	1	0	1	1	1	0	0	0	1	0	61	4	2	3	0	1	0	0	0	0	0	76	61	15
Si	0	0	0	0	3	0	0	0	0	0	0	0	5	61	5	6	0	0	0	0	0	0	0	80	61	19
P	0	0	1	1	0	0	1	0	0	1	1	0	3	2	59	6	1	1	0	0	0	0	0	77	59	18
S	0	0	0	0	2	2	2	0	0	2	1	0	2	4	12	57	3	0	0	0	0	0	0	87	57	30
Cl	0	1	1	0	1	2	1	0	3	2	4	0	2	2	3	4	64	1	0	4	0	0	0	95	64	31
Ar	0	0	0	0	0	1	1	1	0	2	1	0	5	1	1	1	0	63	0	2	0	0	0	79	63	16
K	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	67	0	0	0	0	69	67	2
Ca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	67	0	0	0	70	67	3
Br	0	0	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	64	0	0	69	64	5
Hg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total of all elements dragged and dropped																								**1639**	**1394**	**245**

The diagonal row of grey blocks shows the correctly dragged elements.

Appendix Table 12 Occurrences of each element selected from the combo box correctly and incorrectly

	H	He	Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca	Br	Hg	Undefined	Total selections	Correctly selected	Wrongly selected
H	14	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	14	2
He	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	14	0
Li	0	0	12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	12	1
Be	0	0	0	12	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	12	2
B	0	0	0	0	13	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	13	3
C	0	0	0	0	1	11	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	14	11	3
N	0	0	0	0	0	2	9	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	2	15	9	4
O	1	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	12	1
F	0	0	0	0	0	0	1	1	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	13	2
Ne	0	0	0	0	1	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	14	13	1
Na	0	0	0	0	0	1	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	13	12	1
Mg	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	1	0	0	0	0	0	0	0	15	14	1
Al	0	0	0	0	0	0	0	0	0	0	0	0	13	1	0	0	0	0	0	0	0	0	1	15	13	1
Si	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	3	0	0	0	0	0	0	0	13	10	3
P	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	4	0	0	0	0	0	0	0	12	7	5
S	0	0	0	0	0	0	1	0	1	0	0	0	0	1	5	8	0	0	0	0	0	0	0	16	8	8
Cl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	1	0	0	0	12	11	1
Ar	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	13	0	0	0	0	0	14	13	1
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	14	14	0
Ca	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	13	0	0	0	15	13	2
Br	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	16	15	1
Hg	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	10	0	12	10	2
Total selections of all elements																							3	**311**	**263**	**45**

The diagonal row of grey blocks shows the correctly selected elements.

Appendix Table 13 Trends in reading instructions, buttons clicked, selection from combo box, dragging and game playing

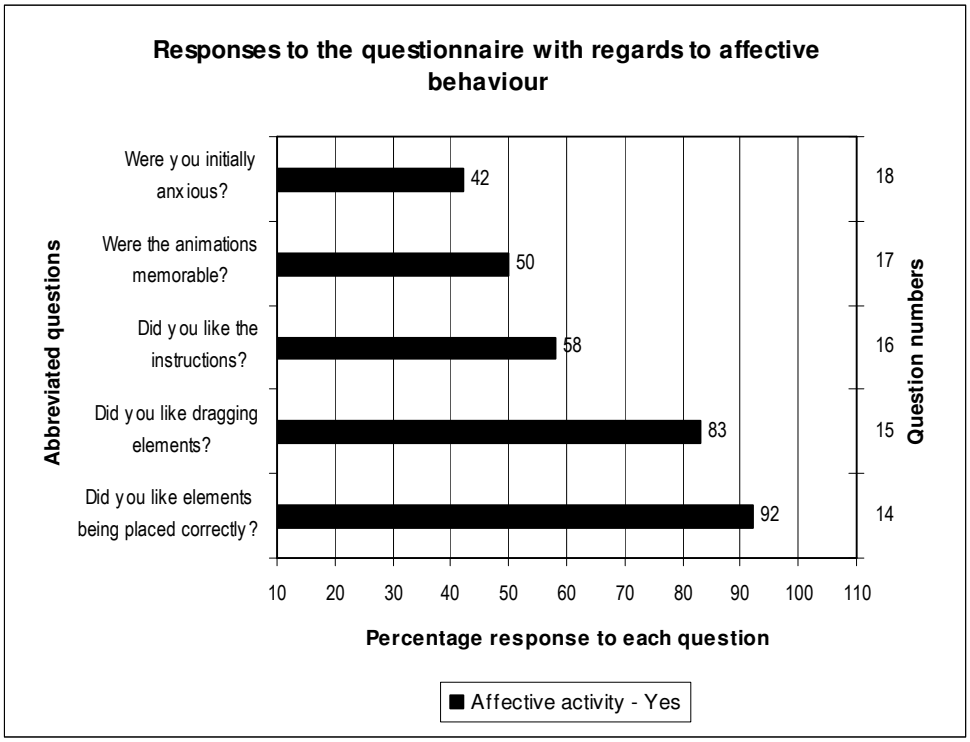
Group 1			Group 2		
Activity and time started	**Activity and time ended**	**Sequence**	**Activity and time started**	**Activity and time ended**	**Sequence**
1/Inst /3:46	2/ReInst /4:05	Instructions	1/Inst /4:10	2/ReInst /4:58	Instructions
3/Alk /4:10	28/dbD /4:42	Buttons	3/Alk /5:01	22/dbD /5:34	Buttons
29/Stime /5:12	51/Sttime/7:08 /t=1:55/>60CCor	Gaming	23/Stime /5:41	51/Sttime/7:46 /t=2:05/>60CCor	Gaming
53/Stime /7:39	78/Sttime /9:09 /t=1:30/>60CNCor	Gaming	53/Stime /8:22	78/Sttime/9:29 /t=1:07/>60CCor	Gaming
82/Stime /9:38	105/Sttime /10:42 /t=1:03/>60CNCor	Gaming	80/Halo /9:51	103/AllD /12:12	Buttons
107/Stime /11:02	130/Sttime/12:04 /t=1:01/>60CCor	Gaming	104/Stime /12:53	129/Sttime/13:57 /t=1:04/>60CCor	Gaming
132/Stime /12:26	154/Sttime /13:21 /t=0:54/<60CNCor	Gaming	131/N /14:42/Z1	131/N /14:42/Z1	Selection
156/Stime /13:34	178/Sttime/14:32/t=0:58/<60CCor	Gaming	132/Stime /14:49	133/Sttime /15:05 /t=0:15/Aban	Gaming
180/N /15:36/Z12	270/N /27:18/Zundefined	Selection	135/Stime /15:11	136/Sttime /15:13 /t=0:02/Aban	Gaming
272/N /27:26/Z3	318/N /31:42/Z80	Selection	139/N /15:37/Z20	183/N /20:36/Zundefined	Selection
319/Stime /32:09	320/Sttime /32:18 /t=0:08/Aban	Gaming	185/N /21:46/Z13	229/N /29:19/Zundefined	Selection
322/N /32:36/Z11	326/N /32:59/Z17	Selection	230/S /29:56/Szone	230/S /29:56/Szone	Dragging
328/Stime /33:10	329/Sttime /33:14 /t=0:04/Aban	Gaming	232/Stime /30:47	256/Sttime/31:42/t=0:54/<60CCor	Gaming
331/N /33:31/Z16	353/N /35:29/Z15	Selection	258/Stime /32:14	259/Sttime /32:21 /t=0:06/Aban	Gaming
355/Stime /36:12	378/Sttime /37:25 /t=1:12/>60CNCor	Gaming	261/N /32:29/Z14	261/N /32:29/Z14	Selection
380/Stime /37:41	404/Sttime/39:10 /t=1:29/>60CCor	Gaming	262/Stime /32:32	263/Sttime /32:39 /t=0:07/Aban	Gaming
406/Stime /39:23	428/Sttime/40:10/t=0:47/<60CCor	Gaming	265/Stime /33:01	268/Sttime /33:13 /t=0:11/Aban	Gaming
430/Stime /40:30	434/Sttime /40:49 /t=0:18/Aban	Gaming	270/Li /33:21/OrigPos	270/Li /33:21/OrigPos	Dragging
436/H /41:05/Hzone	442/B /41:27/Bzone	Dragging	271/Stime /35:27	286/Sttime /36:35 /t=1:07/Aban	Gaming
444/N /41:54/Z1	455/Co /42:58/XNitrogen	Selection	288/Stime /36:56	299/Sttime /37:23 /t=0:26/Aban	Gaming
			301/H /37:32/Hzone	321/Si /38:19/Sizone	Dragging
			322/Stime /38:21	323/Sttime /38:25 /t=0:03/Aban	Gaming
			325/Stime /38:46	349/Sttime/39:32/t=0:46/<60CCor	Gaming
			351/N /40:23/Z6	383/N /43:35/Z11	Selection

Appendix Table 14 Trends in reading in reading instructions, buttons clicked, selection from combo box, dragging and game playing

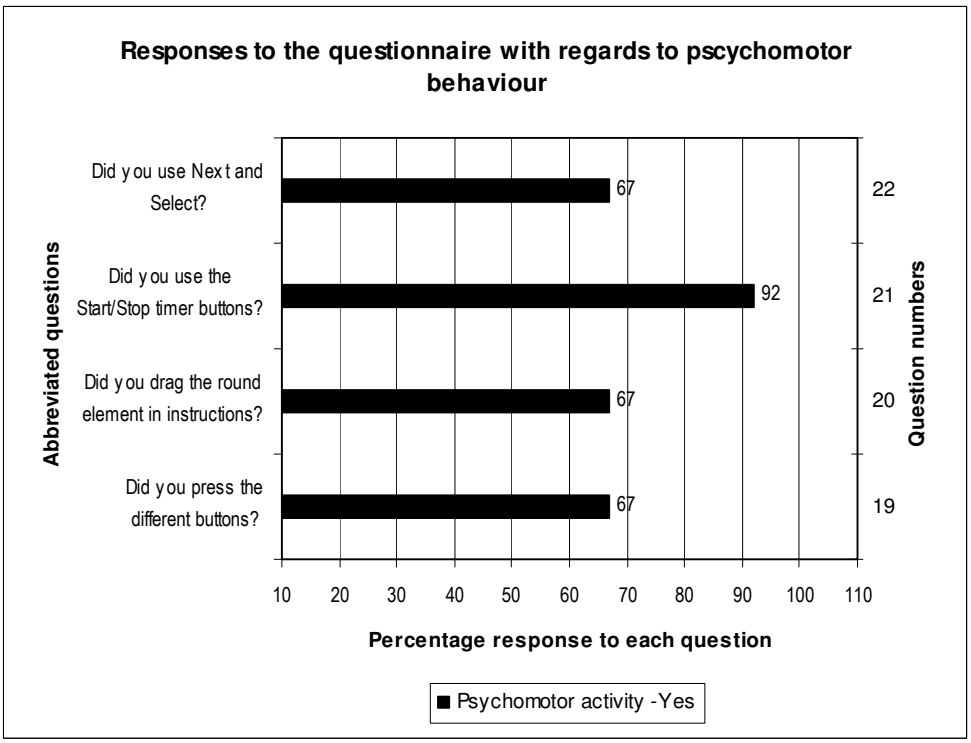
Group 3			Group 4		
Activity and time started	**Activity and time ended**	**Sequence**	**Activity and time started**	**Activity and time ended**	**Sequence**
1/Inst /4:47	6/RelInst /5:07	Instructions	1/Alk /3:30	16/TransD /3:49	Buttons
2Clip /4:52	5OrigPos /5:00	Clip	17/Inst /3:53	18/RelInst /4:20	Instructions
7/Alk /5:21	28/EarthD /5:42	Buttons	19/H /4:26/Hzone	47/Na /6:54/OrigPos	Dragging
29/N /6:09/Z6	29/N /6:09/Z6	Selection	48/N /7:07/Z9	48/N /7:07/Z9	Selection
30/Stime /6:17	65/Sttime /9:00 /t=2:43/Aban	Gaming	50/N /7:23/Z3	102/Al /14:21/Alzone	Selection
67/Stime /9:22	95/Sttime/12:02 /t=2:39/>60CCor	Gaming	104/Be /15:06/OrigPos	135/Br /17:42/Brzone	Dragging
97/N /12:29/Z20	108/N /14:15/Z4	Selection	137/Stime /18:13	163/Sttime/19:23 /t=1:09/>60CCor	Gaming
110/Stime /14:43	111/Sttime /14:49 /t=0:06/Aban	Gaming	165/Stime /19:45	169/Sttime /20:16 /t=0:30/Aban	Gaming
			171/Stime /20:43	212/Sttime/22:50 /t=2:07/>60CCor	Gaming
			214/Stime /23:08	254/Sttime/24:24 /t=1:16/>60CCor	Gaming
			256/Stime /25:07	257/Sttime /25:12 /t=0:05/Aban	Gaming
			259/Stime /25:23	279/Sttime /26:28 /t=1:05/Aban	Gaming
			281/Stime /26:35	327/Sttime/29:03 /t=2:28/>60CCor	Gaming
			329/Stime /29:16	351/Sttime/30:03/t=0:47/<60CCor	Gaming
			353/F /30:48/Fzone	371/H /31:23/Hzone	Dragging

Appendix Table 15 Trends in reading instructions, buttons clicked, selection from combo box, dragging and game playing

Group 5			Group 6		
Activity and time started	**Activity and time ended**	**Sequence**	**Activity and time started**	**Activity and time ended**	**Sequence**
1/Inst /2:02	2/Relnst /2:30	Instructions	1/Alk /2:37	75/sbD /5:50	Buttons
3/Alk /2:33	93/NobleD /5:33	Buttons	76/N /6:57/Z6	91/N /9:47/Z10	Selection
94/N /5:45/Z18	134/Co /10:14/Magnesium	Selection	92/Alk /9:49	117/AllD /11:48	Buttons
136/Stime /10:39	158/Sttime/11:47 /t=1:07/>60CCor	Gaming	118/Co /12:04/Aluminium	**123/N /12:51/Z16**	Selection
160/Stime /12:12	184/Sttime /13:15 /t=1:02/>60CNCor	Gaming	**124/Alk /13:04**	143/AllD /14:26	Buttons
186/Stime /13:29	188/Sttime /13:38 /t=0:08/Aban	Gaming	**144/Co /14:40/XNeon**	**145/N /14:45/Z2**	Selection
190/Stime /13:55	218/Sttime /15:05 /t=1:09/>60CNCor	Gaming	**146/All /14:48**	147/AllD /14:55	Buttons
220/Stime /15:21	242/Sttime/16:24 /t=1:03/>60CCor	Gaming	**148/He /14:58/OrigPos**	148/He /14:58/OrigPos	Dragging
244/Stime /17:05	270/Sttime/17:57/t=0:51/<60CCor	Gaming	149/All /15:18	157/All /15:49	Buttons
272/Stime /18:13	296/Sttime/19:05/t=0:52/<60CCor	Gaming	158/Stime /16:12	182/Sttime /17:59 /t=1:47/Aban	Gaming
298/Stime /19:17	322/Sttime/20:03/t=0:45/<60CCor	Gaming	184/All /18:11	187/AllD /18:23	Buttons
324/Stime /20:20	347/Sttime /21:12 /t=0:51/Aban	Gaming	188/K /18:26/Kzone	193/H /18:49/Hzone	Dragging
349/Ca /21:22/OrigPos	349/Ca /21:22/OrigPos	Dragging	195/All /18:59	202/AllD /19:20	Buttons
350/Stime /21:22	374/Sttime/22:06/t=0:43/<60CCor	Gaming	203/B /19:32/Bzone	266/Be /22:36/OrigPos	Dragging
376/Stime /22:19	377/Sttime /22:21 /t=0:02/Aban	Gaming	267/All /22:39	273/All /22:52	Buttons
379/N /22:27/Z9	393/N /23:54/Z2	Selection	274/Stime /23:20	292/Sttime /24:22 /t=1:01/Aban	Gaming
395/Stime /24:12	422/Sttime/24:58/t=0:46/<60CCor	Gaming	294/All /24:27	296/All /24:33	Buttons
424/Stime /25:11	450/Sttime/26:22 /t=1:10/>60CCor	Gaming	297/Stime /25:40	335/Sttime/27:47 /t=2:06/>60CCor	Gaming
452/Stime /27:02	476/Sttime/27:46/t=0:44/<60CCor	Gaming	337/C /28:16/Czone	372/Si /30:21/Sizone	Dragging
478/Cl/28:04/Clzone	482/K /28:12/OrigPos	Dragging	373/All /30:24	376/AllD /30:32	Buttons
484/Stime /28:16	509/Sttime/29:13/t=0:57/<60CCor	Gaming	377/Stime /30:34	397/Sttime /31:42 /t=1:08/Aban	Gaming
511/Stime /29:26	530/Sttime /30:07 /t=0:40/Aban	Gaming	399/All /31:53	402/AllD /32:06	Buttons
532/Stime /30:13	557/Sttime/31:03/t=0:49/<60CCor	Gaming	403/Mg /32:09/OrigPos	465/Ca /35:49/Cazone	Dragging
559/Stime /31:14	582/Sttime/31:52/t=0:38/<60CCor	Gaming	466/All /35:53	467/AllD /35:53	Buttons
584/Stime /32:05	607/Sttime/32:47/t=0:41/<60CCor	Gaming	468/Stime /35:58	496/Sttime /37:00 /t=1:02/Aban	Gaming
609/Stime /32:59	633/Sttime /33:42 /t=0:43/<60CNCor	Gaming	498/All /37:20	501/AllD /37:32	Buttons
635/Stime /33:58	657/Sttime/34:40/t=0:42/<60CCor	Gaming	502/Stime /37:39	528/Sttime /38:50 /t=1:11/Aban	Gaming
659/Stime /35:03	683/Sttime/35:39/t=0:36/<60CCor	Gaming	530/Stime /39:03	559/Sttime /40:09 /t=1:05/Aban	Gaming
685/Stime /35:56	712/Sttime/36:52/t=0:55/<60CCor	Gaming	561/All /40:16	562/AllD /40:34	Buttons
714/Stime /36:59	742/Sttime/37:47/t=0:47/<60CCor	Gaming	563/Stime /40:39	577/Sttime /41:37 /t=0:58/Aban	Gaming
744/Stime /38:01	767/Sttime /38:39 /t=0:38/Aban	Gaming	579/All /41:42	580/AllD /41:49	Buttons
769/Br /38:49/Brzone	790/C /39:28/Czone	Dragging			
791/Stime /39:29	815/Sttime/40:12/t=0:43/<60CCor	Gaming			
817/Stime /40:22	840/Sttime/41:04/t=0:41/<60CCor	Gaming			
842/Stime /41:15	845/Sttime /41:20 /t=0:04/Aban	Gaming			



Appendix Figure 1 Graphical representation of responses to the questionnaire with regard to affective behaviour



Appendix Figure 2 Graphical representations of responses to the questionnaire with regard to psychomotor behaviour

Appendix Table 16 Features of games and a drill and practice game as in this study

Features of games	Features of the drill and practice game used in this research study
• Game players must be able to engage freely in a game; • A challenge(s) are posed against a task or an opponent; • A game is governed by a definite set of rules; • A game can be complete in a finite set of moves or actions; • A game ends (George, Harvey, & Wheeler (1985); • Winning is usually based on knowledge or skills of players; • The game should address important concepts or content; • The game should consider the age and developmental level of the players; • Game players should not lose points for wrong answers; • Reinforcement in the form of advancement in the game for right answers (Gredler, 2004).	• Participants repeated (practiced) a particular action; • Challenge was to complete the activity within 60 seconds; • No set of rules, participants simply dragged elements to different zones; • Game could be complete in a number of finite moves as there were a finite number of elements; • The activity came to an end or could be aborted; • Content/knowledge, as opposed to skill was learnt; • The activity did not consider the age and developmental level of the participants; • The activity indicated right or wrong answers; • Motivation in the form of messages.