

PHENOMENOLOGY: PRECONCEPTIONS AND EXPERIENCES OF NON-CHEMISTS AT RHODES UNIVERSITY USING MILK PAINT

A thesis submitted in fulfillment of the requirements for
the degree of
MASTERS IN CHEMISTRY
of
RHODES UNIVERSITY

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November 2016

Abstract

There exists an ever-increasing crisis in science education where students experience disinterest because of an inability to grasp true understanding of scientific subjects, and therefore there should be a call to increase the research of phenomenology in combination with science education. A rebalance and paradigm shift in the focus of the modes of teaching could result in a great improvement in the learning, comprehension, and intellectual self-confidence of students interested in the sciences. To study this, three research questions were established: How is chemistry perceived by non-chemists; what is the experience of the participants' during the chemistry practical in a laboratory and; do the participants' perspectives about chemistry change during the experience. The performed study consisted of a chemistry practical, two art works and, in some cases, an interview. Nine participants were asked to create the art under specific instructions of points of focus, namely their preconceptions prior to the practical (Artwork 1) and their lived experience during the practical (Artwork 2). Participants' artworks were examined using methods of visual semiotics and classical art analysis techniques, looking at line, shape, and colour choice. The iterative analysis of the interviews from participants 1, 2, 7, and 9 coded with ATLAS.ti 7 software, led to the emergence of themes that constitute the core of the participants' experience. This phenomenological study presents a path to engage the non-chemist with processes taking place in the laboratory by using 'Kitchen Chemistry' and illustrates how a phenomenological engagement with chemistry can make the subject more applicable to the general population of non-chemists.

Keywords: Phenomenology, Visual Semiotics, Visual Arts, Milk Paint, Chemistry Education, Lived Experience

Acknowledgements

My gratitude and initial acknowledgments go towards my two supervisors, Mrs Joyce Sewry and Dr Kevin Lobb. Through their support, I could start and complete this study.

“Thank you” does not begin to show my appreciation.

Thanks go to Dr Kenneth Mlungisi Ngoza and Mr Kavish Jawar. Their insight into science education, and specifically Dr Ngoza’s research workshop, started the journey into the foreign realms of science education, and for that I am grateful.

For allowing me the opportunity to work with Fine Arts students and attend several lectures, my thanks go to Ms Lindi Lombard. I only wish I could do more work within the arts.

To my family, whom has supported me through these long years, I thank you. Without your influence, none of what has been accomplished would have been possible.

To my darling partner, who has supported me though these years of anguish and has been my pillar of encouragement, I treasure you my fishy.

To Chris Rafael, thank you for all the distracting coffees and conversations.

To the National Research Foundation who have enabled my research during my Rhodes University career, thank you.

“Don't be afraid to use all the colours in the crayon box” – RuPaul

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Chapter 1 – Introduction

In recent years, many studies have been conducted that present a negative picture with respect to the learning of the sciences, with a key claim being that science education – particularly physics and chemistry – remains unpopular among students (Eilks & Hofstein, 2015 citing Dillon, 2009; Gilbert, 2006; Hofstein, Eilks, & Bybee, 2011; Holbrook, 2008; Osborne & Dillon, 2008). It is suggested that science teachers should make science education “more relevant” in order to better motivate and interest students in the science subjects (Eilks & Hofstein, 2015). However it is often unclear what this would actually entail (Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013). Many publications emphasize the relevance of science education in order to maintain the economic wealth of modern societies, thus justifying science skills among the young generation as essential for the continued prosperity in our future (Eilks & Hofstein, 2015).

This thesis comprises of 7 chapters. Chapter 1 deals with the aims, motivation, and the research questions. Chapter 2 is the literature review dealing with the various phenomenology theories with a comparison to constructivism. It also highlights perceptions and attitudes of science education and the differences in educator, student, and the education institution, concluding with everyday chemistry. Chapter 3 deals with Theoretical frameworks of Colour Theory, looking at colour, line, and shape. It also looks at Psychology of Visual arts using a backbone of semiotics. Chapter 4 is the chemistry of milk paint and takes the reader through its composition, history, and biology. It mentions milk paints many applications, its atomic structure, and the various methods of extraction of the proteins – Heat and acid proving to be the best technique. Chapter 5 details the research methodology of the experiments, the artworks, and the method of validation. Chapter 6 looks at the results, its analysis of the laboratory experiments and art works, and discussion. Finally, Chapter 7 concludes the thesis, addressing its limitations and suggesting some future work that could be done.

With regards to the context of the thesis, research was done on volunteering Rhodes University students in South Africa (Ages between 18 and 24). Documented in the thesis are experiences of the participants, some were used to the environment of an undergraduate laboratory, and some who had never experienced a pre-university laboratory. They were taken through an experiment to synthesize milk paint from kitchen materials at a Rhodes University Chemistry laboratory, for safety purposes. Participants created two artworks with the intention of portraying their perceptions of chemistry in artwork 1 and their perceptions of chemistry after the laboratory experiment. This analysis was done using visual art analysis techniques, psychology of colours, line, and shape, as well as applying visual semiotics.

1.1 Research Motivation

Every developed and emerging country needs more scientists to achieve additional scientific knowledge and technological developments and to maintain future economic standards of living (Eilks & Hofstein, 2015). It is therefore of importance to understand how non-chemists perceive the relevance of science so that we may establish ways to make science education applicable.

Students' disinterest in science subjects combined with their inability to achieve true understanding of these subjects has led to a call of increased research in phenomenology and science education (Edvin Østergaard, Dahlin, & Hugo, 2008).

With a rebalance and paradigm shift in the focus of the modes of teaching, there could be an improvement in the learning, comprehension, and intellectual self-confidence (Arons, 1982) of students interested in the sciences. The traditional aspect of teaching is confusing for some learners. Often little attempt is made to make the lessons more applicable to the students' life worlds, creating a disconnect and driving the students into an increasingly disinterested state – the eventuality being that students are dissuaded from studying the

sciences. Therefore a rebalancing of the pedagogical approach is important for the entire spectrum of students (Arons, 1982).

1.2 Research Aims and Objectives

The aim of this study was to explore the phenomenology or lived experience of non-chemistry students at Rhodes University. In this study, non-chemist participants have either not studied chemistry at any level, or have studied chemistry till matric qualification, up to and including an undergraduate who has not had good experience of a basic first year undergraduate chemistry course. This includes participants who are on a science-based degree.

Using visual art as a method of self-reflection and analysis, the participants' perspectives of chemistry during a laboratory experiment making paint from milk were studied. Through this method, the aim was to understand why many students prefer to avoid the sciences.

This study is focused around the perspectives of non-chemists at Rhodes University, their experiences or phenomena within a traditional laboratory setting with an emphasis on kitchen chemistry, and the possibility that these individual perspectives may change during this experience. In this way, we can start opening discussions about the aim and core content of chemistry curricula.

1.3 Research Questions

To evaluate the perceptions and experiences of the participants, three research questions were established:

- a) What are the perceptions of chemistry held by Rhodes University students who do not study chemistry?
- b) What is the experience of the practical work of the participants during chemistry practical in a laboratory?

- c) How do the participants' perspectives about chemistry change during the experience?

1.4 Significance of the Research

In this study, we use kitchen chemistry to show, using visual artistic expression, the perspectives and change of perspectives of non-chemists of chemistry. Participants take part in a laboratory practical session creating paint from casein using traditional methods of laboratory instruction. This is done to make chemistry more relevant and establish an interest of chemistry. The contribution of this qualitative research study is with its unorthodox approach to laboratory methods – the generation of a paint formulation from milk – and the use of visual arts to evaluate the preconceived ideas of chemistry and the lived experience of the phenomena (milk paint) of the participants involved.

Current teaching methods do not place emphasis on the phenomena under study and little attention is paid to those students who might be interested in the sciences but lack the capability to study within the bounds of the traditional pedagogy. The research focuses on the individuals and on their lived experience, through which we understand their perspectives. Through this collaboration of artistic expression and chemistry education, I believe that students will not only find chemistry more enjoyable to learn, but also promote chemistry as applicable in everyday life. Applicable knowledge is useful knowledge, and it is my hope that the results of this research will impact chemists, especially those in education, and non-chemists alike.

Chapter 2 – Literature Review

This chapter looks at and compares various phenomenology theories to constructivism. These strands of information come from a variety of researchers including Heidegger, Merleau-Ponty, and Sartre and their views on phenomenology and its impact on the arts as well as sciences, Edvin Østergaard who looked at phenomenology IN, OF, and AND science education. Hilbing and Barke (2000) was also an influence in this research as they looked at perceptions and attitudes of chemistry and how these preconceptions are brought in by students at a young age and influence their outlook and reaction to chemistry and science education. Hoffman (2011) compared chemistry diagrams of molecular structures to artworks, with chemistry being the craft of substances and their transformations.

Diagrams of molecular structures are used frequently in chemical literature. Hoffman (2011) suggests that in these diagrams of molecular structures, there is more art in the “assemblages of symbols” than scientists would admit and artists would concede. This is because the shape and structure of molecules are critical to the chemist’s conception of chemistry. Every chemical, physical, and biological property depends on the three-dimensional arrangement of atoms in space. The creators of molecular drawings attempt to abstract the essence of the reality of what is happening molecularly, and then attempt at communicating this essence in a scientific orientated visual language (Hoffmann, 2011). An argument can be made that what is missing between this and visual arts is the aspect of artistic creation and the play of emotions in the process of communication.

To those privy to the code, the free floating diagrammatic representation of molecules can have tremendous emotional impact through the creation of something novel and beautiful (Hoffmann, 2011). Chemistry is thus the art, craft, and science of substances and their transformation. According to Hoffman (2011), the honesty and intensity of the aesthetic response of chemists, when they allow themselves to express it, must be taken positively to make connections with other aesthetic experiences. The beauty of these aesthetic objects resides in its structure and its incredible interplay of dimensionality.

“These products of our hands and minds, beautiful molecules, appeal directly to the mind. For a chemist, their line into the soul is direct, empowering, sometimes searing. They are natural, hemoglobin like a fern unfurling, like the cry of a duck on a winter lake. They are synthetic (or if you like artificial, man or woman-made, unnatural) – the catenane, Schrock’s tungsten epitome, like a Shaker tune “’tis a gift to be simple,” like Ogata Korin’s screens” – (Hoffmann, 2011, p. 291)

2.1 Phenomenology

One of the characteristic traits of the existential phenomenological tradition in philosophy is a serious engagement with the fine arts, be it literature, theatre, music, or plastic arts. Philosophers such as Heidegger, Merleau-Ponty, and Sartre believed that works of art are capable of showing us the phenomena under consideration more directly and powerfully than any other philosophical prose could (Wrathall, 2010).

“Every exhibiting of an entity in such a way that it shows itself in itself may, with formal legitimacy, be called “phenomenology” (Wrathall, 2010, p. 9).

Existential phenomenologists rely on art as a phenomenological demonstration, although just as it might take some verbal description to help point out what is decisive about the object, it also requires discussion to understand what it is that an object shows us. In essence art can “show us things which we couldn’t otherwise see” (Wrathall, 2010, p. 11). Heidegger further questions

“is art still an essential and necessary way in which that truth happens which is decisive for our historical existence, or is art no longer of this character?” (Kockelmans, 1985, p. 84)

This reflects his concern that we are losing our ability to experience art as “world disclosive” (Wrathall, 2010, p. 11). Merleau-Ponty’s central preoccupation is the lessons that art can teach us about the nature of our embodied perceptual engagement with the world. This has to do with the way artists are trained and practiced, for when an artist records what he sees on canvas, it allows us to also take part in his way of seeing the world (Wrathall, 2010). The artist is uniquely well qualified to help us understand our perceptual engagement with the world. This is because the artist is able to become attuned to the means

by which the world is composed for our visual perception and then is subsequently able to orientate us through the art work to the process of composition (Wrathall, 2010). The art works, thus, ‘performs a phenomenology’ insofar as it shows us something in such a way that we can understand it more perspicuously than we did before (Wrathall, 2010).

According to Merleau-Ponty (1993, p. 57), what art can reach that the sciences cannot, the thing that non-phenomenological philosophy often overlooks, is the “sensible and opened world such as it is in our life and for our body”. This specification is meant to direct us to our everyday ordinary and practical engagement with the things around us. When we look at things in such a way that we can make assertions and form judgments about them, we overlook the features of the world that move our pre-reflective, pre-conscious (associated with a part of the mind below the level of immediate conscious awareness) mode of being in the world (Wrathall, 2010). Expression, language, and symbolism are the keys to the theory of truth (phenomenology) and provide the foundation for a philosophy of history and “transcendental” humanity. Merleau-Ponty sees in the phenomenon of expression a positive ambiguity that “gathers the plurality of monads, the part and the present, nature and culture, into a single whole” (Toadvine, 2016, unpagged).

Artists foster special skills – that of learning to look at the world in such a way that they can discern its meanings. Some art might be more practical than reflective as the artist looks to the world in such a way to allow it to move his/her body rather than describe it. The work of art thus leads our eye through the painting on the canvas, and in the process, it exploits a set of bodily anticipations and dispositions to produce an experience. Art can produce the same effects as objects do only because seeing a picture is itself a temporal activity. Klee (1919) believed that we perceive because our bodies are attuned to resonate to features of the world in such a way that they signify beyond themselves and invite us to move beyond them and explore. We can see this with his description of what it feels like to create art:

“A certain fire, yet to come, revives, works its way along the hand, streams onto the board and, from the board, leaps as a spark, closing the circle from which it came: back to the ye, and beyond” cited from (Wrathall, 2010, p.22 citing Klee 1919, p.34)

Klee (1919) suggests that art is both a descriptive and a normative function as it can show us what we see but also attune us to see things in a different light.

Phenomenology is the name for the philosophical movement whose primary objective is the direct investigation and description of phenomena as “consciously experienced without theories about their causal explanation and as free as possible from unexamined preconceptions and presuppositions” (Tappein, 2010, p.47). Edmund Husserl developed the method to supply new foundations for both philosophy and science development. He was attracted to the philosophies of Franz Brentano whose descriptive psychology seemed to offer a solid basis for scientific philosophy.

There are several variants or ‘flavours’ of phenomenology, and associated with each are different methods for their study. The distinguishing characteristics of these are summarized below (Smith, 2013, unpagged):

1. Descriptive phenomenology:
Direct exploration, analysis, and description of phenomena
2. Eidetic phenomena:
Probing of direct phenomena for typical structures of essences and for the relations within and amongst them.
3. Phenomenology of appearances:
Giving attention to the ways in which such phenomena appear, i.e. in different perspectives or modes of clarity
4. Constitutive phenomenology:
Studying the process in which such phenomena become established in our consciousness
5. Reductive phenomenology:
Suspending belief in the reality or validity of the phenomena, a process which may be considered implicit in the preceding phases
6. Hermeneutic phenomenology:
Specific kind of phenomenological interpretation designed to unveil otherwise concealed meanings in the phenomena

Further discussion will be done on descriptive phenomenology, as it allows for the direct exploration and analysis of a specific phenomenon. This ‘flavour’ of phenomenology is chosen above the others because it corresponds closely with the methods established in this study and possesses the characteristics which can also be used in this study.

2.1.1 Descriptive phenomenology

An adoption of the phenomenological attitude can emphasize perceptiveness for the richness of our experience. By challenging the restrictive rules of our experience to the data of our senses, phenomenology readmits us to a world in which everything has a claim to recognition as long as it presents itself in concrete experience (Spiegelberg, 1975). In essence whatever presents itself to anyone’s careful and discriminating observation has *prima facie* equal rights, i.e. they have a right to exist and be recognized as belonging to our world of lived experience (Spiegelberg, 1975). Even science has to start on this basis, although perhaps it is limited to those parts of experience which are public and measurable. An even more significant area of reclamation by descriptive phenomenology is the world of meanings and values (Spiegelberg, 1975). The phenomena which give rise to these experiences are vast but are the concrete basis of our experiences of value and disvalue, with no need to claim more than personal significance. It is the descriptive approach of phenomenology which can reveal a richness of qualities. We live in a world of concrete meanings (Spiegelberg, 1975). Their readmission to our consciousness is bound to make differences in our outlook, resulting in an enlarged sense of the world, and a deepened sense of self (Spiegelberg, 1975). In this sense the phenomenological approach, in making us more aware of the task of understanding others and their worlds, is a new incentive for increased efforts and increased humility in social relations (Spiegelberg, 1975).

“... since I knew that many school children have to suffer lessons in physics that scarcely let them recognize this as the science of nature. Instead, the phenomena of nature are hardly touched upon as the teacher hurries on and goes further into the instrumental, the abstract, the laboratorial, the technical and the mathematical, so that the children no longer can participate with their eyes, ears and hands. Paralyzed in a condition as mere spectators they cannot be physically present with their

senses, and for this reason they are also unable to perform the task of abstraction” (Koopman, 2016, p. 150)

These statements made by Martin Wagenshein in Koopman (2016) can be regarded as the core of the phenomenological critique of current science education. Wagenshein points out that many students in science lessons are faced with abstract and cognitive work altogether separated from everyday life experiences (Edvin Østergaard et al., 2008). Questioning how to bridge the gap between the abstract and the real in science education, he illustrates how rich conceptual understanding can grow out of experience, and also illustrates the role phenomenology might play in a meaningful science education (Edvin Østergaard et al., 2008).

Bridging this “gap” was Johann W. Goethe who studied phenomena such as colours (Goethe & Eastlake, 1840) and forms and developments of plants (Goethe & Miller, 1790) and studies on animal skulls (Steiner, 1883). Goethe’s theory of colour consists of a sequence of experimental observations of light and colour arranged in specific order. This order of observed phenomena reflected the inherent structure and essence of colour. For Goethe, there was no gap between phenomena and the theories that explain them as the phenomena themselves become the theory.

The phenomenological study of nature is used for teachings science in Steiner Waldorf schools (Edvin Østergaard et al., 2008). Using Goethe’s ideas, Steiner developed an epistemology of Goethe’s way of knowing, focusing on how perception and thinking are intertwined in Goethe’s research methods. This phenomenological thought had a role and impact on anthropology, formulated by Merleau-Ponty, and has an emphasis on action before cognition as well as the focus on culture analysis and seeing the meaning of action and the experience of meaning. Interpreting phenomenology in such a manner provides a shift in focus from mere understanding of the world, to perceiving and acting *in* the world. Our existence in the world is the domain of anthropological phenomenology and forms the foundation for a phenomenological approach in science education (Jackson, 1996). Anthropological phenomenology is relevant for science education because it broadens the perspective from science content and natural phenomena to cultures and social relations.

To relate this to science education it can be said that a teacher has two areas of focus in every learning situation – the attention directed towards the subject itself and towards the students being taught (E Østergaard, 2006). Seeing phenomenology as a primary philosophy with basic questions of epistemology and ontology, it can be applied in many different ways and thus have relevance to a complex field such as science education. The phenomenology of science education can be roughly broken into three sections/approaches (Edvin Østergaard et al., 2008, p. 99).

1. Phenomenology OF science education

This is where the process and activities of teaching and learning science are understood and analysed from a phenomenological point of view. These studies are descriptive and analytical in character as they try to unravel what goes on in the teaching and learning sciences. Human studies are often informed by anthropological phenomenology.

2. Phenomenology IN science education

This consists of phenomenological studies of natural phenomena that are taken up in the classrooms. The natural phenomenon or subject is the focus. Apart from analysing and describing the phenomena, these studies have also strong prescriptive characters, suggesting how science should be taught. These studies are often informed by Goethe's phenomenological approach to nature

[illegible]

This approach was made famous by Martin Wagnerschein, an educator in physics and mathematics, and Michael Faraday, an English scientist and public lecturer on science. Both had a common trait to grasp the whole of science education and to study and elaborate on the interrelations between teacher and teaching, and learners and learning, as well as the subject taught.

2.1.2 Phenomenology IN science education

This study focuses on phenomenology IN science education because it is a study that can essentially be taught or brought into the classroom setting. It is also a focus on the physical phenomena of casein paints, analysing and describing this as well as understanding the perspectives of the participants.

This section deals with using phenomenology as a pedagogical approach to research in the phenomena of nature, phenomena that is not man-made. Arons (1982) points out that there are pedagogical possibilities inherent in a phenomenological approach to some physical phenomena related to electricity and magnetism (Arons, 1982). Without careful observation, description, and reflection the discussion of various interpretations of perceived phenomena could contribute to misunderstanding and non-effective learning of the students, who often cannot keep up with the fast pace at which these subjects are usually covered.

For chemistry, Soentgen developed a phenomenological understanding of the concept of substance and material changes which he defined as a set of descriptors that indicate that substances appear to be more related to nature than was originally thought, contributing towards a more elaborate reconstruction of the basic concepts of chemistry, such as material change (Soentgen, 1997). For example, when dissolving salt in a classroom situation the students are shown that salt dissolves, however the highly complex process of dissolution is overlooked, and phenomenologically speaking, this can be seen as a negative process as the transformation should be made explicit to the students as an essential part of chemical phenomena. According to Kranich (2005) there is a difference between the mere

observation of appearances in chemistry, and the inner sense-making of seeing the transformations, interplay, and dynamics of forces at work *in* chemical phenomena (Kranich, 2005). There is a difference between observing appearances in chemistry and making sense of the transformations and dynamic forces at work in chemistry phenomena. This sense making style needs to be practiced in context with seeing, sensing, and reflecting on the phenomena of focus.

The common core of phenomenological mainstream science education is the concept of how to bridge the gap between “life world” and “science world” (Edvin Østergaard et al., 2008, pp. 96, 112). The underlying assumption is that these two worlds are just that, worlds apart, and that this is the major cause for student difficulties in studying, learning, and enjoying the sciences (Edvin Østergaard et al., 2008). This assumption is justified as scientists are aware of the counterintuitive nature of scientific knowledge. Many students experience science as ‘not for them’ which indicates the level of alienation they feel between themselves and the science world.

We need to question the development of connections to science across contexts which can be integrated into the various aspects of student “lifeworlds” (Edvin Østergaard et al., 2008). Questions such as “how does knowing happen?” and “how does the process of knowledge constitution take place?” are often neglected by many teachers due to the responsibility of educating students in scientific facts (Edvin Østergaard et al., 2008, p. 113). Phenomenology can help bring many of these questions into focus.

An overriding theme of phenomenology IN science education, is to teach science in such a way that it makes sense of the “meaningful wholeness” (Edvin Østergaard et al., 2008, p.113) of nature, which is the sciences, and allow it to grow in such a way that it is not separated or alienated from the students. The learning environment and situation are also important. When designing the learning situation both the natural phenomena and the students as individuals with their own lived experiences and history must be considered. One of the most powerful ways of changing students learning strategies is to change the forms of the assessments (Biggs, 1999).

In the phenomenological sense of teaching, research should be approached from three perspectives – that of the teacher, the student, and the subject being taught (Edvin Østergaard et al., 2008). There has to be an understanding of: the nature and subject being taught; understanding the students and their individual learning activities, and, lastly, connecting these two aspects with teaching and reflections of students and teachers (Edvin Østergaard et al., 2008). This has implications for shaping teacher training and discovering the key competencies that such a teacher training programs could cultivate. Studies and evaluation of the Steiner Waldorf schools in the USA indicate that more systematic investigations could be worthwhile, with their positive experiences with science teaching based on phenomenology (Edvin Østergaard et al., 2008).

The way science is being taught, with too much emphasis on the mere learning of facts, systems, and numbers begs several questions. Do teachers' attitudes towards science subjects change when using a phenomenological approach? How does a teacher's understanding of the student change as they turn to phenomenological methods for studying natural phenomena? How do 'lifeworld' experiences relate to true scientific knowledge? (Edvin Østergaard et al., 2008). The answering and clarification of these questions demand differentiation of the stances of phenomenology which could open new fields of ontological and epistemological communications and debates.

Phenomenology can be a valuable method for investigating learning as a whole, by connecting the theory and practice of science education (Edvin Østergaard et al., 2008). When phenomenology is done and turned into efforts for understanding and promoting learning, there can be a benefit to the phenomenology and science education fields, and, according to Lukenchuk (2006), phenomenology can connect the theory and the practice of science education, and further states that this process of transformative thinking and learning is phenomenological in that it connects the flow of experience with the flow of thought. This statement follows along the lines of Sarah Gravett (2004) who demonstrated how her participants transformed their "meaning structures" such as perspectives and frames of reference within a transformative learning educational setting.

Traditional scientific knowledge is one way of understanding the natural world, not the only way, and with current critiques, there is an insistence that studying sciences through phenomenological glasses transcends the learning of pure scientific knowledge. However this does not mean that making use of alternative paradigms of teaching and research means abandoning traditional ones (Moore, 2004). Phenomenology always begins in the lifeworld, and is discovery orientated (van Manen, 1990), and this results in it being an effective tool for illuminating scientific pathways that are already established through traditional paradigms.

2.1.3 Phenomenology and logical reasoning in introductory physics courses

A suggestion by Arons (1982) is that teachers in science education should not present science knowledge didactically or as inclined to teach in text and lecture. Leading the students to recognize the nontrivial questions asked and to visualize and identify the experimental variations that require us to recognize new interactions in the subject taught would be a better alternative. He further suggests that this should be driven through homework and class discussion rather than the formal presentation and explanation without exploration (Arons, 1982). In this way the students are taught a more phenomenological way of thinking and reasoning, as opposed to the mathematical, clinical, and analytical thought processes as is the norm with studies in the sciences (Arons, 1982).

Although many textbooks attempt phenomenological based questions, the effort fails in several ways. Firstly, these questions often are too complicated at too early a stage in the course. This is due to the fact that they rely on the proper use and application of fully formed concepts, rendering the guidance most students need at this stage as void (Biggs, 1999). Secondly, the questions rarely guide students into critical and significant inquiry on the subject at hand, “How do we know...?”, “why do we believe...?”, and “What is the evidence for...?” leading to the synthesis and command of the knowledge gained (Arons, 1982, p. 13). Thirdly, the phenomenological questions rarely form part of testing and examination, often interjected peripherally, and seldom made part of the full impact of a

particular development (Arons, 1982). Thus, students never regard phenomenological reasoning as important and a benefit to science education.

Teaching this way in order to assist the students to induce phenomenological reasoning, the teachers themselves must not only have mastered these insights (Freudenthal, 1993), but also be able to make them available and applicable to their students. An effective means is class discussion to collect ideas and deliberate over them, sifting through each one and discarding incorrect ideas (Arons, 1982). In this way, the class can be lead to explicate awareness of the subject at hand. Not only do questions and perspectives brought to phenomenological attention give students sense of the real nature of science (diSessa, 1993), it also has the ability to provide, through repeated encounter, solutions to increasingly sophisticated context (Arons, 1982).

This idea of explicit awareness of subjects to assist students in their understanding of a given subject can be compared to constructivism and its roll in education in the classroom.

2.1.4 Constructivism

“Constructivism is a learning theory found in psychology which explains how people might acquire knowledge and learn. It therefore has direct application to education. The theory suggests that humans construct knowledge and meaning from their experiences. Constructivism is not a specific pedagogy. Piaget's theory of Constructivist learning has had wide ranging impact on learning theories and teaching methods in education and is an underlying theme of many education reform movements. Research support for constructivist teaching techniques has been mixed, with some research supporting these techniques and other research contradicting those results” (Waugh, 2016)
The University of Sydney, Faculty of Education and Social Work,
http://sydney.edu.au/education_social_work/learning_teaching/ict/theory/constructivism.shtml

Constructivism describes how students build on knowledge based primarily on past experiences. This stems from the concept that knowledge is not discovered but rather constructed in the learner's mind (Ozer, 2004). The constructivist learning mode is not passive, but active and socially enhances the process of knowledge construction. Although

reality is objective, it has a subjective meaning with every learner constructing their own subjective interpretation on the topic of focus (Wilkinson & Hanna, 2016). According to Matthews (2015) citing Von Glaserfeld (1990):

“knowledge is the result of an individual subject’s constructive activity, not a commodity that somehow resides outside the knower” (Matthews, 2015 citing Glasersfeld 1990, p.37).

The theory of constructivism suggests that learning is a social development that involves real world situations, with interactions and collaborations amongst learners as key importance.

Ozer (2004) states:

“Learning is affected by our prejudices, experiences, the time in which we live, and both physical and mental maturity. When motivated, the learner will exercise his will, determination, and action to gather selective information, convert it, formulate hypotheses, test these suppositions via applications, interactions or experiences, and to draw verifiable conclusions” (Ozer, 2004, p.1).

In the constructivist classroom, the student is accountable for his/her own learning, with the teacher being merely a facilitator who guides, plans, organizes, and provides direction to the student. Student support is provided by the teacher by means of suggestions arising from ordinary activities and challenges that inspire creativity. Projects assigned should allow for independent thinking and new ways of learning, as well as provide students with group work in which to approach these problems in real world situations (Ozer, 2004). This leads to creation of practical solutions.

At the base of the constructivist theory of knowing is first the idea that knowledge is not an iconic representation of an external environment, but rather a mapping of ways of acting and thinking that are viable to the individual in attaining experiential goals. Secondly is the idea that this kind of knowledge is the result of the individual subjects’ constructive activity, not a commodity that resides outside the knower and can be conveyed or instilled by diligent perception or linguistic communication. Third is the idea that language is not a means of transporting conceptual structures from teacher to student, but a means of interacting that allows teachers to constrain and thus guide the cognitive contraction, or a

streamlining of thought, of the student. The solution of a problem will provide satisfaction and increased motivation to the subject by the learner only if it leads to the attainment of a goal chosen by the acting subject (Steffe & Wood, 2013). It follows that an individual's incentive to get involved in the abstract operations of any science subject can only develop in a student who has discovered the satisfaction of solving a problem chosen by oneself according to rules and criteria appropriated as one's own (Steffe & Wood, 2013).

On the other hand, I would argue that scientific laws are not static, and ultimately my construction of scientific knowledge must be consistent with the construction of scientific knowledge of those around me. This issue of tentativeness is part of the self-correcting aspect of science as science knowledge is both symbolic in nature and socially negotiated. Science itself is self-correcting (from a non-constructivist view of the knowledge) but only when new evidence is discovered. It can be said that "the objects of science are not the phenomena of nature but the constructs that are advanced by the scientific community to interpret nature" (Scanlon, 2004, p.59). When teaching science there needs to be a promotion of the critical perspective of science culture amongst students by pointing out that scientific knowledge has limitations, which is subject to relative understanding. There needs to be a shift in the current science education pedagogy, one which promotes active construction of knowledge by solving real world problems in collaboration with others and using active techniques to build more knowledge.

It can therefore be said that through a constructivist learning mode, we acknowledge the social dimension of learning whereby students make meaning of the world through personal and social processes (Kearney, 2004). Constructivism is therefore a learning theory, a learning process, and an instructional strategy.

Constructivism and phenomenology are each concerned with subjective experience. As opposed to other philosophies and science education modes which take pre-established objective knowledge as the starting point of analysis, constructivism and phenomenology seek to pre-empt knowledge by examining the structure of experience upon which understanding itself is established (Wilkinson & Hanna, 2016). So essentially, science subjects such as physics and chemistry presuppose an existing body of objective and

scientifically derived knowledge upon which subsequent ideas are developed (Wilkinson & Hanna, 2016). In these cases, the objectivist perspective is regarded as the only reliable method by which knowledge is gained. By focusing on the primacy of experience, constructivism and phenomenology agree that meaning is created through experiences in the world, and not a matter of empirically matching knowledge to absolute truths. Instead, the student actively imbues the world with meaning,

“Humans are, in a sense, meaning makers rather than object identifiers” (Wilkinson & Hanna, 2016, p.5).

Although both constructivism and phenomenology aspire to challenge the notion of objectivity shaped knowledge, they differ significantly in terms of descriptive and first person experiences (Wilkinson & Hanna, 2016). Constructivism generally bypasses the structural understanding in favour of examining subjective meaning making, while phenomenology asserts that investigating the structures of consciousness is necessary and ultimately a beneficial contribution to the learning process, seeking to identify the essence of a phenomenon and penetrate beyond misunderstandings and false beliefs that might obscure the essential features of experience (Wilkinson & Hanna, 2016). Although I have cast them in opposition, constructivism and phenomenological learning approaches alike are guided by a humanistic vision to the extent that their roots are deeply interwoven in the same educational premises of student centred learning and self-reflection practices.

These practices should revolve around students identifying their perceptions and attitudes about chemistry and science education, and the driving forces that result in the student liking or disliking science education.

2.1.5 Perceptions and Attitudes

A paper by Hilbing & Barke (2000) reported the study of attitudes towards chemistry and chemical education of pupils with and without experience in chemical lessons. Participants were asked to draw paintings to reflect their point of view on chemistry.

From the time of a paper by Zahn (1979) who evaluated chemistry as “a girl who is able to do nearly everything”, the image of chemistry has deteriorated (Hilbing & Barke, 2000, p. 365). Depending on the idea of chemistry in a society, one can assume that the attitude of the persons towards chemistry will shift accordingly. This was investigated by Heilbronner and Wyss (1983) who examined the idea of science (Heilbronner and Wyss (1983) cited in Hilbing & Barke, 2000). Heilbronner and Wyss (1983) asked young pupils to paint images of chemistry. They collected 151 paintings, of which 66% showed critical and disapproving attitudes towards chemistry. These paintings dealt with environmental pollution, threats to the individual by industries, and animal experimentation. Only 33% showed positive attitudes by depicting science-fiction scenes of fantastic laboratories. Based on this negative result, if students have poor attitudes towards chemistry, the assumption can be made chemistry lessons have a decreased or limited effect. Hilbing & Barke (2000) state that there needs to be more “initiatives to influence in a positive way the attitude towards chemistry and chemical education”, although their target was for kindergarten and primary schools.

Hilbing and Barke (2000) proceeded with their investigation in a very different manner than is depicted in this study. They based their approach on Heilbronner and Wyss (1983, p. 368), assigning each painting to only 3 large categories (1, 2, and 3), and 2 smaller categories (4 and 5):

1. Environmental Pollution and Threat to the Individual by Industry
2. Animal Experiments
3. Laboratory Situations
4. Specialized Knowledge
5. Everyday Life

Simply assigning each painting to only one category reduces the information and message of the painting “in an unacceptable way” (Hilbing & Barke, 2000, p. 367). They decided to consider not only the main message of the painting but assigned paintings to two or more categories according to the motifs that appeared in the paintings. They concluded that there was a significant positive change in pupil attitude towards chemistry than in 1980s, with

particular emphasis on the balance of knowledge about chemistry being more extensive with pupils often considering the risks as well as the advantages of chemistry (Hilbing & Barke, 2000).

Hilbing and Barke's (2000) study had a second hypothesis which stipulated that even without actual experience of chemical education – pupils develop an attitude towards chemistry and chemical education. Their findings indicated clearly that pupils without experience in chemistry lessons also possess a basic knowledge of chemistry. The results showed the importance of giving young children some background in chemistry, allowing the pupils to develop informed attitudes towards both the subject and its teachings (Hilbing & Barke, 2000).

“Preconceptions about chemistry are naturally brought by pupils into their introductory chemistry lessons. Emotionally burdened prejudice against chemistry can cause pupils to show a degree of apathy towards chemical education in its early stages. Additionally, a lot of pupils without experience in chemistry lessons hold concrete – predominantly negative – ideas of chemistry lessons possibly imparted by parents, friends and media”. (Hilbing & Barke, 2000, p. 370)

The conclusive remarks to their study are that pupils' emotional attitudes towards chemical education need to be addressed while taking part in chemistry lessons, more importantly before the pupils develop concrete and prejudice laden views of the subject. Initiatives designed to introduce children to chemical phenomena and to scientific thinking at early stages in schooling may contribute to this end (Hilbing & Barke, 2000).

E. B. Spear (1915) (cited in (Sandi-Urena, Cooper, Gatlin, & Bhattacharyya, 2011)) proposed the use of experimental investigation to gather evidence that might contribute in enhancing the effectiveness of chemistry teaching. The hands on experiences in the laboratory are an ideal setting to develop meaningful conceptual understanding of chemistry, to access understanding about the nature of science and to engage in doing science (Hofstein & Lunetta, 2004; Hofstein & M. Naaman, 2007; Sandi-Urena et al., 2011).

It has been noted that a cooperative learning approach allows students to become engaged cognitively, physically, and emotionally in constructing knowledge as a fundamental step

in assisting pupils in becoming active agents in a learning experience (Sandi-Urena et al., 2011). Springer, Stanne, & Donovan (1999) provided evidence showing that varied forms of small group learning are effective in promoting student science learning including academic achievement, attitudes, and persistence.

However, to reach a thorough understanding, researchers need to realize that “the effect or value of the laboratory experience might not be measurable in a quantitative sense” (Nakhleh, Polles, & Malina, 2002).

A study done by Sandi-Urena et al., (2011) investigated the laboratory experience as lived by students, through their “participant-observer lens”. The fundamental strengths of this approach are the length of time the students played their role as observers and the intensity of their engagement as participants. Through the years, multiple traditions of qualitative inquiry have been developed, often building on each other and producing methodological overlaps that impose conscientious choosing of analytical procedures. The paper goes on to state: that

“we make the methodological case here for a phenomenological approach based on its distinct ability to provide access to understanding of the meaning of a chosen human experience by describing the lived experience or phenomenon as perceived by the participants” (Casey, 2007, p.118).

This phenomenological method seeks to uncover the internal and invariant structure of the experience not in its empirical individuality but in its essence. However the potential of phenomenology as a research tool to study academic laboratory experience has seldom been utilized (Sandi-Urena et al., 2011), and there are miscommunications between the educator, the student, and the education institution.

2.2 Educator, Student, and the Education Institution

Educative teaching means to accompany/lead, to show, and to direct/instruct (Van Schalkwyk, 1992) a person who has not yet developed to the full so that they might realize

their potential. They must be shown how to use this potential and instructed in ways and means of applying this to their life tasks (Van Schalkwyk, 1992). This activity of accompaniment, helping, supporting, nurturing and literally drawing out the individuals' full potential to obtain a higher level of existence only really takes place when both parties are actively involved. The educator should instruct with passion and the learner must learn with intentional, purposeful, and willing involvement (Van Schalkwyk, 1992).

The activity of knowing is subjective and since everyone who absorbs facts interprets and understands them in a different manner

“Everybody is a genius, but if you judge a fish by its ability to climb a tree, it will live its whole life believing that it is stupid” – Albert Einstein.

Knowledge is always influenced by the principles and values that are believed in, the more genuine these principles and values are, the more reliable is the knowledge, with the truest of knowledge being obtained in time and authentic principles of reality (Van Schalkwyk, 1992). Educative teaching will only be educationally accountable if it exposes learners to educational content which is based on the authentic principles of the educator (Van Schalkwyk, 1992).

During lesson planning and goals, consideration should be given to the students or learners and especially to the attitudes, interests, and preconceptions that the students might have (Barke, Harsch, Schmid, & Gerdau, 2011). These will have an impact on the success of the planning and conducting of the lessons (Barke et al., 2011). Today's learning theories have a constructivist point of view as every learner needs to build their own cognitive structure; knowledge changes are constantly built and maintained by that individual (Barke et al., 2011).

Students come to the chemistry classroom with cognitive structures which have been developed on the basis of their lifelong experiences (Barke et al., 2011). These preconceptions can be deep-rooted or spontaneous conceptions and each has their own difficulty in correcting these preconceptions (Barke et al., 2011). These concepts may be

discussed in class before the new scientific are taught through experiments and models (Barke et al., 2011).

Attitude and interest should be taken into account while planning lessons, if the learner has a negative attitude towards chemistry as a whole or a specific topic of chemistry, it is more difficult to teach and reach the educational goal in the subject (Barke et al., 2011). If there is a more positive attitude towards the subject, students will be more motivated to follow the lessons (Barke et al., 2011).

Barke et al. (2011) did experiments with an exercise “draw your picture of chemistry” in 1983 and again in 1998. The first showed that the majority of the class felt that chemistry was threatening themselves and their environments (Barke et al., 2011). The study concluded that 65% of students drew negative images of chemistry, with the percentage decreasing to 40% on the second study 15 years later. Müller-Harbach, Gisela, Wenck, & Bader (1990) analysed the attitudes of secondary school students and found that they were influenced by their place of residence (Barke et al., 2011). Students who lived close to industrial areas showed more negative attitudes towards chemistry than those who lived further away from industries (Barke et al., 2011). It was concluded that when students have a positive attitude towards a subject, they are more likely to develop an interest in the contents of the subject.

Educational content must be relevant to the learners situation as obsolete and outdated learning matter, teaching methods, or structures cannot equip the learner for modern situations (Van Schalkwyk, 1992).

Universities only accept learners with matriculation exemptions with their approach to the task being theoretical/philosophical (Van Schalkwyk, 1992). These institutions are concerned with professional preparation and they produce scientists, thinkers, professional men and women from doctors to school teachers and architects, and provide the theoretical knowledge required for journalism, accountants, lawyers, psychologists and others. Traditionally science faculties at universities are concerned with scientific education of the

student so that they can in turn extend, systemize, and apply this knowledge (Van Schalkwyk, 1992).

A challenge faced by educators is regarding constructivism as the only viable theoretical framework for teaching and learning. By being exposed to varying perspectives and given opportunities to develop the discretion needed to choose appropriately a correct teaching method per student could change the way both teacher and student understand and enjoy a given subject. This would result in attitudes of students changing in a positive manner and reinforce a positive teaching environment.

2.3 Everyday chemistry

As a subject, everyday chemistry includes all the chemical processes and related substances that play a role in our daily lives. It results in themes and contents that should be differentiated according to individual interests. It is clear that a life-related chemistry lesson that goes unelected is no alternative to a clearly structured lesson; major efforts are needed to bridge the gap between chemistry teaching and the everyday world so that we may combine chemistry and meaningful learning (Barke et al., 2011). Lutz and Pfeifer expressed these statements, offering their reflections in many of their publications (Barke et al., 2011). The mediation role of chemical education between everyday life and scientific teachings can be achieved in various ways and thereby contribute to the diversity of methods.

Learning through hands-on experiments, presentations and discussions with special experts, audio-visual media or multimedia, subject related role plays, or project-based teachings are a few ways that individuals might incorporate their interests outside of chemistry into an educational reflection into chemistry knowledge itself (Barke et al., 2011).

In this study, hands-on experiments using everyday chemistry (making paint from milk) was used to gauge students' attitudes to Chemistry. It can be seen in the results (Chapter 6) that the non-chemist participants reacted positively to this teaching style.

The basis of scientific research is to ask new questions or ask old questions in new ways and devise ways so that they may be investigated. The most important part of the process is constructing good questions without using inappropriate or vague language so that significant results may be obtained. Chemical education research must be carried out with the same standards and attention to detail as other research areas (Bunce & Cole, 2008). Chemical education research chips away at questions by providing well documented attempts to isolate and investigate the effects of many pieces that form part of the bigger questions (Bunce & Cole, 2008).

Chapter 3 Theoretical frameworks

3.1 Colour Theory

Sydney Harry, a British artist, put colour theory into practice in a series of paintings. For instance, *Hannelore* (Figure 3.1), all the graduations of hue in the painting come from mixture of just two colours: yellow and purple. The painting does not exhaust the possibilities of the two colours used. By adding increasing quantities of black to darken the mixtures, new colours would emerge, and the boundaries of the composition would be extended well beyond the confines of the artwork.

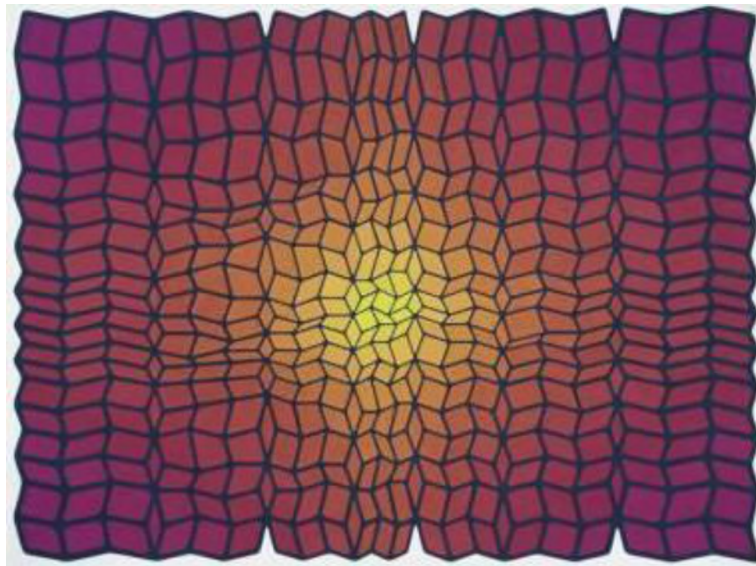


Figure 3.1 *Hannelore* by Sydney Harry

Sydney Harry did not set out to demonstrate colour theory in a self-conscious, calculated way. Having studied and assimilated the science of colour, he painted spontaneously. The insights gained from theory give his paintings an unexpected dimension, for the results of the combination of science and art often even surprise the artist. In this way, these artworks have a quality or charm that transcends the academic (Varley, 1983).

3.1.1 Colour

Questions of colour seem so technical, so scientific that we do not feel that we can evolve a perfectly satisfactory theory or explanation of them out of our inner consciousness (Witt, 1906). We may like or dislike the colouring of any picture; we may condemn it as impossible or praise it for its brilliance. And yet colour is of the very essence of painting (Witt, 1906).

Within the realms of symbolism, black and white are free to be absolute, they are literally the alpha and omega, the good and the malevolent (Varley, 1983). Apart from their individual implications, they are frequently paired: day and night, good and evil, lucky and unlucky, birth and death (Varley, 1983). The use of colour and its emotional and social implications are established in Table 2.1.1 (Appendix K).

3.1.2 Shape and Line

Psychological studies done by Lu, Suryanarayan, Adams, Li, Newman, & Wang, (2012) on characteristics of shape and their effect on human emotions suggest that roundedness and complexity of shapes are fundamental to understanding emotions. The geometric properties of visual displays convey emotions like anger and happiness (Aronoff, 2006; Schwarz & Winkielman, 2004), while curved contours lead to positive feelings and sharp transitions in contours lead to a negative bias (Bar & Neta, 2006). Although the small scale of the studies makes the results less convincing, the findings provide the start of understanding how low-level image features motivate the affective response.

Shapes in images are difficult to envision due to perceptual and emerging boundaries of objects (Lu et al., 2012). Despite many theories promoting ideas on the relationship between emotions and visual characteristics of simplicity, complexity, roundedness, and angularity, researchers have yet to capture those visual characteristics. However, by identifying the link between shape features and emotions, Lu et al. (2012) were able to

determine the relationship between these visual characteristics and emotions. Their study dissects pictures into their image contours, line segments, and continuous lines and built classifiers for each shape feature (Table 2.1.2 (Appendix K))

They did this by extracting contours from complex images and representing these contours using lines and curves extracted from the images (Lu et al., 2012). Statistical analysis was conducted on locally meaningful lines and curves to represent the concept of roundness, angularity, and simplicity postulated as having a key role in evoking emotions (Aronoff, 2006; Bar & Neta, 2006; Schwarz & Winkielman, 2004). They then leveraged the computational representation of these physical stimulus properties and evaluated the proposed shape features through distinguishing emotional images from neutral ones, classifying images according to categorized emotions, and finally fitting the dimensionality of emotions based on proposed shape features. The contours were extracted using an algorithm which used colour, texture, and brightness of each image for extraction (Lu et al., 2012).

They therefore empirically verified that the proposed shape features captured the emotions in the images, and this assisted in understanding emotions in images.

Pavlova, Sokolov, & Sokolov (2005) questioned whether the perceived dynamics of abstract figures are related to emotional attributes. Their work demonstrated that dynamics conveyed from static images enable specific emotional attributes, agreeing with the assumption that neural networks for production of movements and understanding dispositions of other are intimately linked. The findings indicate the importance of exploring the ability to reveal social properties through dynamics in normal and abnormal development, taking examples from patients with early brain injury or autistic spectrum disorders (Pavlova et al., 2005). Although no substantial link was found between deviation of geometric shapes from the vertical orientation and perceived instability, they found that irrespective of the shape of the stimulus, the most stable positions were vertical and horizontal. Furthermore irrespective of the stimulus shape, perceived instability of the geometric figure positively correlated with the intensity of negative emotions such as fear and suffering (Pavlova et al., 2005). By contrast the strength of positive emotions such as

joy and surprise does not correlate with perceived instability. Instead, for the geometric shapes used (triangle, oval, and line), the positive emotions are negatively related to the physical deviation of the figures from their respective vertical orientation, their vertical, unshifted orientation being perceived as the most joyful and surprising. The main outcome of their study indicates that dynamics conveyed through static images enables specific emotional attributes.

3.1.3 Personality and Emotions, Social and Educational, and Environmental

The personality of the painter and of the sitter will be in perpetual balance (Witt, 1906). It is just because no two painters ever see or present their model in exactly the same manner, any more than they will describe the same event in the same words (Witt, 1906).

Even within these broader distinctions there is a dependency on the social, political, and religious characteristics of the country, upon its types, customs and dress, and its physical features of both landscape and architecture (Witt, 1906).

Before the characteristics of nationality, characteristics peculiar to a country or people are considered, there are even broader distinctions that have a real influence on the art of painting (Witt, 1906). These are due to the infinite variety, differences in race, climate, history, and physical features, which cannot fail the art in which they are mirrored (Witt, 1906). Every painter identifies himself more or less with some particular kind of scenery, and however closely the painter may keep to his subject, he has his own individual manner of seeing things in landscape as well as portraiture, and no two painters see alike (Witt, 1906).

3.2 The Psychology of Visual Arts

Art is multi-dimensional and cannot be defined in terms of a single property or explained by any one theory alone. More recently, postmodern conceptual art does not concern itself with visual aesthetics but focuses instead on intellectual properties and the intentionality of the artist in constructing meaning (Mather, 2013).

Art evolved with the human species, so one might expect that it is closely dependent on cortical function. One might argue that artistic creation and appreciation are so intellectual, so complex and so remote from any specific brain function that a consideration of neural processes is irrelevant to understanding human artistic experiences. On the contrary, there is an intimate relationship between brain function and visual art (Mather, 2013).

When artists decide which colours to use and where to place them in the artwork their choices inevitably are governed by the properties of the neural systems that mediate colour vision. Red, green, blue, yellow, white, and black produce the purest, most vivid colour experiences in art because they represent the extremes of the perceptual colour axes, although they have no special status in any purely physical sense (Mather, 2013). The opposing colours in each axis interact perceptually to create phenomena such as colour contrasts, complements and coloured shadows. In the interest of compositional balance and harmony, artists often use arrangements of complementary colour pairs. When balance is not desired, complementary pairs are avoided (Mather, 2013).

3.3 Visual Social Semiotics

The analysis of visual art illustrates typical groups of elements and interrelations which form semiotic systems of these works (Somov, 2005). Somov (2005) states that a general advanced picture of semiotic systems of visual arts should be created for the integration of concepts of human verbal and semiotic systems. The substantiation of stable semiotic structures, units, and elements of visual texts will enhance the movement towards a

semiotic description and understanding of human psychic world and cultures as a whole (Somov, 2005). Semantic saturation of visual text makes it possible to give different interpretations of the main idea of the painting. The combination of connotative sign formations and specification of their meanings allows us to interpret a general metonymy (Somov, 2005).

Sonesson's paper (2007) argues the concept of sign or representation, indispensable for understanding of the human consciousness. Suggesting that meaning, which is not specifically embodied in signs, is a requisite for both a systematic and an evolutionary sense, for the attainment of sign function (Sonesson, 2007).

To illustrate this Somov uses the example of the '1981 in Petrograd' by K Petrov-Vodkin shown in Figure 3.3:



Figure 3.3 1981 in Petrograd' by K Petrov-Vodkin (Somov (2005))

"It is logical to notice that the main ratios of the picture continue traditional symbolics of icon painting. In this case, blue denotes mystic fundamentals, green refers to all that is young, new, and evolving, and the red cover, as has already been mentioned, symbolizes life and revolution. This opposition of colours clearly points to a general symbolic opposition of mystic past to a new reality developing under the cover of revolution. There is little scarlet at the picture. It only bursts through a gloomy dark blue, grey, and ochre background. This corresponds to a general idea discovered via

the sign system: new cheerful life only smoulders and germinates in contemporary reality.” (Somov, 2005, p. 27)

The quote above highlights the psychological effect that colour in visual arts has on the viewer. The arrangements of “representamens” (signs) (Somov, 2005) and visually active signals of the painting reinforce major symbols.

Sonesson (2007) suggests that phenomenology could be interpreted as a branch of psychology and thus can serve as an ingredient of cognitive science as well as a basis for semiotic theory (Sonesson, 2007).

Representational practices play a central role in the sciences (Hoffmann, 2011), with educational researchers focusing their attention on the use of visual representations in school sciences (Han & Roth, 2006). Within these science text books are the visual representations, various signs to be interpreted by the students.

In chemistry two kinds of inscriptions are used denote to macroscopic phenomena and microscopic descriptions or models, respectively. It was further noted by Han and Roth (2006) that students needed the analogy that exists between the two images provided, using a familiar inscription (the photographs) to understand an unfamiliar inscription (the model). In Korean text books the bright inscriptions (Figure 3.3.1) are intended to motivate students to learn, since “every colourful inscription has the potential to call readers’ attention” (Han & Roth, 2006, p. 175).

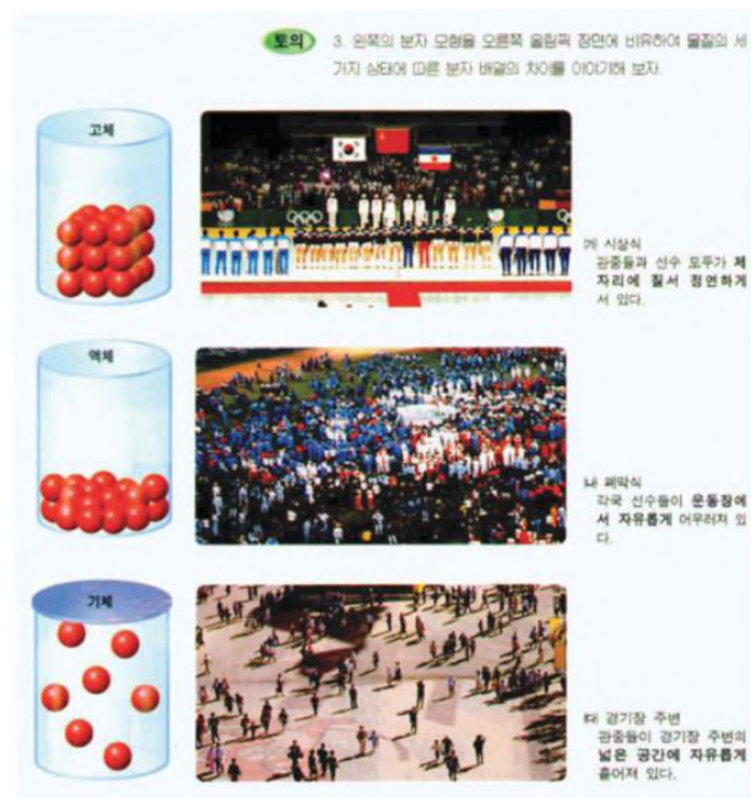


Figure 3.3.1 Example of an image from a Korean Textbook, showcasing visual representations of phases of material (Han & Roth, 2006, p.174).

Science educators are by and large in agreement about the importance of social contexts of knowing and learning science in general, however research designs tend to focus on the individual or psychological dimensions and leave out the social dimensions. Thus the concept of inscriptions, denoting inherently social aspects, brings cultural dimensions into theorizing knowing and learning; semiotics is a science that studies the structure of social objects, and as such the authors developed a semiotic model of inscriptions in chemistry (Han & Roth, 2006).

Chemistry is about substances and their interactions, often perceived with bare eyes, but the chemistry explanations are in terms of entities and theoretical models of atoms and molecules. Subsequently chemical inscriptions can be classified as follows (Taber, 2013):

1. Macroscopic
 - Experiments and experience
2. (Sub-) Microscopic

Molecules and atoms

3. Symbolic inscriptions

Chemical formulae and equations

Johnstone (2000) cited in Taber (2013) stated:

“The psychology for the formation of most of chemical concepts is quite different from that of the ‘normal’ world. We have the added complication of operating on and interrelating three levels of thought: the macro and tangible, the sub micro atomic and molecular, and the representational use of symbols and mathematics. It is psychological folly to introduce learners to ideas at all three levels simultaneously. Herein lies the origins of many misconceptions. The trained chemist can keep these three in balance, but not the learner” (Taber, 2013, p.157 citing Johnstone, 2000, p.9)

This brings attention to the three aspects of chemical knowledge, and places emphasis on the need to coordinate thinking within these aspects, which is challenging to the novice chemist.

An example of the chemistry inscription is H_2O which may refer to a molecule, or the substance; a liquid, gas, or solid. The three levels of inscriptions of matter and the relationship between them are crucial in learning chemical concepts (Han & Roth, 2006). However the debate is whether or not the existence of the three levels of inscriptions actually helpful in learning chemistry with many researchers arguing that students find it difficult to transfer from one type of inscription to another, and rather focus on the surface features of inscriptions rather than on the underlying concepts (Han & Roth, 2006).

Students’ difficulties in learning the particle/natural view of chemistry have been attributed to the fact that the submicroscopic nature of matter contradicts the intuitive and everyday views of matter as something continuous – i.e. we do not think on a microscopic level in everyday life. Because the particulate nature of matter contains concepts of things that cannot be perceived, the use of models is inevitable in teaching and learning said concepts (Han & Roth, 2006; Hoffmann, 2011). It should be noted that when dealing with abstract concepts, be explicit about the abstract nature of the scientific models; the models are not concrete replicas of the particles (Han & Roth, 2006).

Chemistry is a visual science utilizing a variety of inscriptions (Han & Roth, 2006; Hoffmann, 2011). Special attention should be taken to consider the underlying assumptions and social conventions that are required in reading inscriptions, with teachers understanding that students might not see the same thing that teachers see (Han & Roth, 2006). As such the instructors of chemistry could make the code of chemical inscriptions available for the newcomer to the community of chemists (Han & Roth, 2006).

Semiotics is described as the ‘study of signs’. For a sign to exist, there must be meaning or content manifested through some form of expression or representation (Harrison, 2003). Signs exist within semiotic systems; for example, the green traffic light means ‘go’; words are signs in the semiotic system of language; gestures are signs within semiotic systems of non-verbal communication; etc. (Harrison, 2003).

There is a statement that says, ‘a little bit of knowledge is a dangerous thing’ with the implication being that people making judgments without in-depth knowledge of a particular subject will make mistakes. Harrison’s (2003) experience is with visual semiotics is the reverse, and he has found that even a small understanding is useful. Professional communicators find value in the framework whether focusing on one aspect or delving deeply into the theory (Harrison, 2003).

Sandi-Urena (2011) proposed that maximal learning takes place when the students are challenged with new experiences in a supportive environment. Learning is challenging, often uncomfortable, particularly for students who have not made the transition to self-directed learning. Student satisfaction should not be the only metric used to evaluate teachers and learning environments, as it is possible to provide fruitful learning environments especially for those few resistant students (Sandi-Urena et al., 2011).

Integrating these lenses or frameworks, and manipulating them in ways shown in analysis and discussion of the results, allowed for analysis of tasks as complicated as interpreting artworks and their meanings. By using semiotics to interpret signs and symbols, using colour theory to provide meaning to the participant’s choice of colour, line, and shape, this allowed for more accurate and ‘colourful’ interpretations of the data.

Chapter 4 – Chemistry of Milk Paint

4.1 Introduction

In this study participants made paint from milk. This chapter is based on the history of the use of casein from milk (Section 4.1.1), the many uses of casein within industry (4.1.3), the chemistry and composition of milk (4.2), and the many techniques of extracting casein from milk. Finally, the most appropriate technique for the extractions of casein from milk to be applied in this work is addressed in section 4.3.

4.1.1 History

The use of casein as a binder for paint is seen in history as an ancient art, with Hebrew texts mentioning a decorator or painter, more specifically the autumn decorator, where the house is painted for the Succoth (Reyerson, 1940). Craftsmen in ancient Egypt, Greece, Rome, and China have used casein glues in many of their woodworks (Reyerson, 1940). Manufacture of casein glue as a separate industry appears to have started in Switzerland and Germany in the early 19th century, the increased demand at this time was perhaps due to its usage in coating paper (Reyerson, 1940).

4.1.2 Biology

Milk is a pale liquid produced by mammals' mammary glands. Milk is the source of nutrition for infant mammals before they can digest whole foods. The females of all mammal species can produce milk. Cow's milk dominates the commercial product, with 85% of all milk being produced from cows in 2011, with dairy production contributing to household livelihood, food security, and nutrition (Gerosa & Skoet, 2012). The composition of milk differs greatly among species, and factors such as protein type and proportion of fats and sugar, levels of minerals and vitamins, size and strength of the

butterfat globules, all vary. Cow's milk contains 2.82% protein (caseins), 3.42% fat, and 4.47% lactose, 0.7% minerals (John, 2008) while goats milk contains 3.48% protein, 5.23% fats, and 4.11% lactose (Ceballos, Morales, de la Torre Adarve, Castro, Martínez, & Sampelayo, 2009).

Milk often contains colostrums, which contains the mother's antibodies, such that once ingested by the young, the risk of many diseases will be reduced. In an agricultural sense, milk is extracted from mammals during or soon after pregnancy. Milk consumption continues beyond infancy in humans, using milk from other animals such as cows, goats, and sheep, as a food product. Initially the ability to digest milk was limited to children as historically, adults did not produce the lactase enzyme necessary for digestion of lactose (Curry, 2013). The development of cheese/yoghurt processes produced milk products, for adults, can be traced to the earliest farmers.

The function of the enzyme lactase is the digestion of milk and the activity of this enzyme is dramatically reduced after weaning (Ingram, Mulcare, Itan, Thomas, & Swallow, 2009). Although individual differences in humans' ability to digest milk has been observed since Roman times, genetically determined traits were not established until the second half of the 20th century (Ingram et al., 2009), and some humans still have lactose intolerance.

Structurally, milk consists of a microscopic dispersion of fat within an aqueous plasma, containing dispersed lactose, mineral salts, and colloidally suspended proteins such as calcium caseinate, calcium phosphate, and lactalbumin which can be readily filtered out (Palmer, 1924). This filtrate possesses many different industrial applications, which will be discussed within the following section.

4.1.3 Industrial Application of Casein

4.1.3.1 Glue and Varnishes

“Glue” is classified conventionally according to the manner in which gelation is brought about, a scheme based on the physical properties of the glue instead of the raw materials from which it was made. The casein used in this thesis can be considered as a glue, one in which gelation sets in without a temperature change, but taking place in solution (Reyerson, 1940). The sodium caseinate extracted from milk is dissolved in a solution of calcium hydroxide (lime), with the calcium caseinate forming by reaction between the sodium compound and the lime, and as the reaction progresses the glue slowly forms a jelly (Reyerson, 1940).

Unpigmented casein coatings, or varnishes, can be created either alone or in conjunction with natural resins, phenolic resins, alkyd resins, some coatings being simply a mild alkaline solution of casein (Reyerson, 1940).

4.1.3.2 Miscellaneous Industrial Coatings

Casein paints made with a high content of lime have been used for road markings (Reyerson, 1940). Solutions emulsified in oleoresinous enamels or nitrocellulose lacquers are used as means of making mottled decorative paints (Reyerson, 1940). Casein was one of the raw materials for the bio-plastic caked galalith, which was used for making buttons, personal decorative items, and as insulation material in electronic installations (Thielen, 2014).

Steel molders sometimes use casein paints to spray on surfaces of molds for the purpose of obtaining castings with clean surfaces (Reyerson, 1940). Due to the high ratio of pigment to nonvolatile vehicle in casein paints, they are suitable for plastic paints (Reyerson, 1940).

The paint itself is very porous and this good for acoustical paints and paints designed for high reflection of UV light (Reyerson, 1940).

4.1.3.3 Casein derivatives as paint for artistic work

Milk paint is a nontoxic, water based mixture made from lime and milk with pigments added for colour. Borax may be added to the recipe to assist the lime in interacting with the casein and as a preservative. Extremely durable, this paint can last for hundreds of years if protected from the elements. Being made from all natural ingredients, milk paints are safer than any other paints and non-toxic once applied, however due to acrylic and oil paints being made in vast quantities, milk paints do not have an economy of scale and are more expensive, sold in smaller quantities, and do not come premixed. Milk paint will keep as a powder for half a year or more if sealed against moisture, losing its functionality as paint once it has expired. Once mixed, unless refrigerated, the paints need to be used within a few days or the paint will spoil (Rogers, 2016).

Casein can be used in making water colours. These have the advantage of making paintings more water resistant than paintings with water colours made with animal glue as a vehicle (Reyerson, 1940). Once the milk paint has set on the painting, the water-resistant properties are evident. The colours used need not be protected by a glaze coat or fixative and therefore retain their flat surfaces and clarity of colours; they have been widely used for architectural sketches (Reyerson, 1940). These watercolours are often sold in a soft paste form or dry cakes with diethylene glycol added to prevent the dry cake paints from not dissolving properly when rehydrated (Reyerson, 1940).

Casein paints can be made glossy with the addition of sodium/potassium silicate as the vehicle (Reyerson, 1940). These silicate paints carry special fire retardant properties, with additions of ammonium salts and phosphates which increase this property and allows these paints to be used in theatrical scenery (Reyerson, 1940).

4.2 Composition and Properties of Milk and Casein

Milk is an emulsion of butterfat globules, colloiddally suspended within a water-based fluid matrix that also contains dissolved carbohydrates and protein aggregates with minerals. Its purpose is as a food source for infant mammals, and, due to this it contains appropriate nutrition to be used as the sole food source during early stages of infant growth. This nutrition includes lipids, lactose, and proteins, the lactose providing the energy source. Non-essential amino acids are also present within milk proteins as well as essential fatty acids, vitamins, minerals such as calcium and magnesium, and of course water.

Caseins themselves are a type of phosphoprotein that are present in the milk; phosphoproteins are proteins modified by phosphate groups (Reyerson, 1940). There are several methods of isolating the casein from milk. Casein has a commonality with other proteins in that it is considered amphoteric, capable of combining either with acids or with bases to form salts.

Casein was first recognized as a constituent of milk along with butter fat, lactose, and salts by Scheele in 1780 and for many years was regarded as chemically individual amongst other natural proteins due to its ease of isolation in a reasonably pure state (Reyerson, 1940). The term “casein” sometimes refers to a product isolated from milk, rather than a biochemical substance that occurs in the milk.

Milk fat is secreted in the form of fat globules surrounded by membranes. Each globule is composed predominantly of triglycerols and is surrounded by membranes consisting of complex phospholipids along with proteins. These act as emulsifiers which keep the individual globules from coalescing, as well as protecting the proteins from various enzymes within the fluid matrix. Normal bovine milk contains 30-35 grams of protein per litre, with 80% being arranged as casein micelles.

These casein micelles are the largest structures in the fluid portion of the milk. With aggregates of several thousand protein molecules with superficial resemblance to a

surfactant micelle, each is bonded with the help of calcium phosphate particles, and is roughly a tenth of a micrometre in diameter.

There are four different types of caseins, namely the α_1 , α_2 , β , and κ -caseins. Collectively they make up between 76% and 86% of the protein in milk by weight. As already mentioned, most of these are bound into micelles. These micelles have an important feature – the outermost layer consisting of κ -casein strands that reach out from the body of the micelle into the surrounding matrix. These κ -caseins all have negative electrical charges and repel each other which force the micelles apart and keep them separated in the fluid matrix, keeping the fat globule suspended in a stable colloidal precipitate.

Cow or bovine milk contains a variety of cations and anions, namely minerals and salts of calcium, phosphate, magnesium, sodium, and potassium. The milk salts strongly interact with the casein, most notably being that of calcium phosphate which is present in excess.

The exact microscopic structure of the casein micelle is the subject of much debate, especially the internal structure (Dalglish & Corredig, 2012). The first proposed model was a relatively simple model of casein, however structural models have developed two major contenders for this structure – the sub-micellar and the nano-cluster models respectively (Dalglish & Corredig, 2012).

The sub-micellar model was derived from the observation that the proteins in sodium caseinate (the protein being extracted from micelles when calcium phosphate has been removed by acidification) formed small aggregates when dispersed in fluid matrix via noncovalent interactions. The micelles then form these aggregates, linked by calcium phosphate. With κ -casein bound mainly to the surfaces of the micelles, it implies that at least two sub-micelles must exist – those with κ -casein rich content and those of κ -casein poor content. Although not clearly demonstrated that these different particles exist, κ -casein tends to self-aggregate through formation of intermolecular disulphide bonds (Groves, Dower, & Farrell, 1992) that are widely present in caseinate salts (Rose, Davies, Yaguchi, Ashworth, Mackinley, Wake, Marier, Tessier, Rose, Purkayastha, Yaguchi,

Marier, Rose, Rose, Tessier, Rose, Marier, Schmidt, Both, Koning, Sullivan, Fitzpatrick, Stanton, Waugh, Ludwig, Gillespie, Melton, Foley, Kleiner, Woychik, & Kalan, 1969).

As an alternative, the nano-cluster model was derived from observation of the phosphopeptides from the β -casein component which are capable of stabilizing the calcium phosphate in solutions that provoked precipitation (Holt & Little, 2004). Later study showed that the phosphopeptides bind and stabilize small domains of calcium phosphate, and that these are the nanoclusters. Cross linking of the calcium phosphate nanoclusters by α s1 and α s2 caseins which are more phosphorylated, would allow growth into micelle particles (Kruif & Holt, 2003). Bridging is unlikely between the nano-particles due the 18nm distance between adjacent nanoclusters. Lacking phosphate centers the κ -casein cannot participate in the formation of nanoclusters; it will however be available to associate with aggregating proteins via noncovalent interactions thus forming the surface layer and acting as a monofunctional chain terminating agent (Horne, 1998, 2008), and stabilizing the nanocluster aggregations. The micelles would then have a substructure rather than a distribution of calcium phosphate within the uniform protein matrix, being different than that of the original sub-micellar hypothesis by Dalgleish (2011). Instead of casein particles linked by calcium phosphate, there are calcium phosphate and calcium casein particles linked by noncovalent bonds.

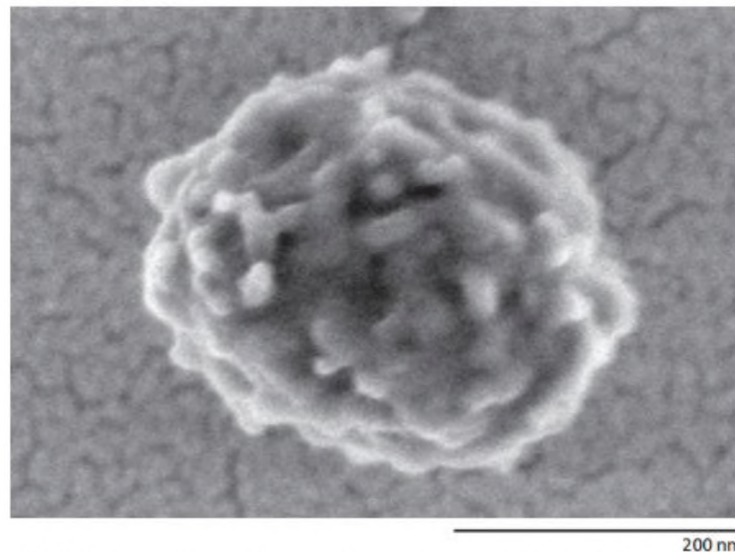


Figure 4.2.1 FE-SEM of a casein micelle, chemisorbed to a carbon film (Dalgleish, 2011)

The controversy around the models results from the fact that it should be easy to dissociate the micelles and measure the composition and size of the resulting particles and thereby reinforce the idea of one of the models, however there is no way for this to happen with certainty of maintaining the integrity of the assumed subunits. The acidification treatment of the micelles dissolves the calcium phosphate, destroying the nanoclusters, and using urea would keep the nanoclusters together however dissociate the sub-micelles. It has thus been urged that the observed patterns of dissociation are inconsistent with a sub-micellar model from electron microscopy, X-rays, SEM and TEM. The most detailed micrographs of uncoated specimens using FE-SEM show irregular structures with apparently tubular features and deep clefts leading to interiors of the micelles (Figure 4.2.1).

Most of the κ -casein is present on the surface of the particles. This causes the micelle to be stable against aggregation because the macro peptide appears to be extended from the micellar surface to create a layer around the particles (Figure 4.2.2).

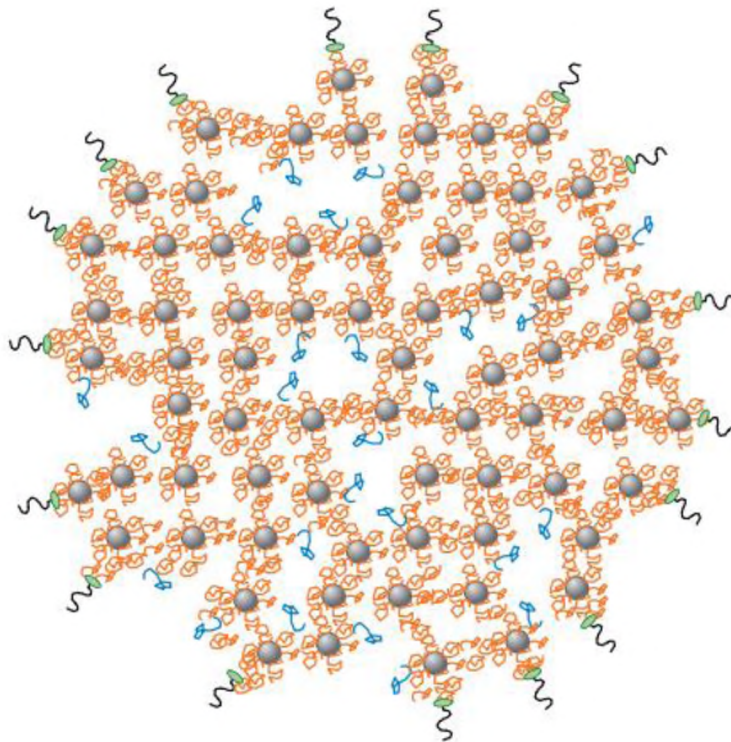


Figure 4.2.2 Milk Casein Schematic. Orange - Alpha and Beta Caseins; Grey Spheres - Calcium Phosphate Nanoclusters; Green - Para-K Casein; Blue - Hydrophobically Bound Beta-casein; Black – Caseinomacropolymers (Dalgleish & Corredig, 2012, p. 455).

In Figure 4.2.2 (Dalgleish & Corredig, 2012), a representative structure of the milk casein nanocluster model is present, showing the links between the different classes of casein and the calcium phosphate nanoclusters.

The extended κ -casein on the surface of the particle provides steric stabilization so that the micelles cannot approach one another (Figure 4.2.3 (Dalgleish & Corredig, 2012)), yet this arrangement will still allow individual protein molecules to pass through and penetrate the layer to form disulphide bonds with the inner κ -casein. This model is useful in rationalizing the chemistry of the extraction of casein from milk.

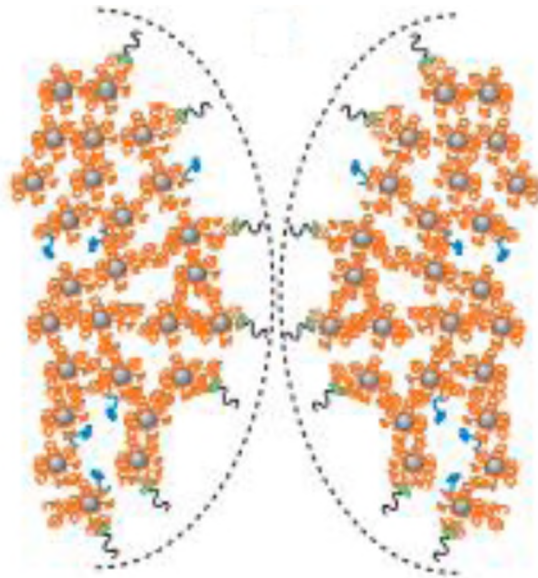


Figure 4.2.3 - Sterically stabilized micelles through the action of the caseinomacropeptides (Dalgleish & Corredig, 2012, p. 456)

4.3 Extraction of casein from Milk

There are many ways in which to collect the casein from milk. As such the behaviour of the micelles during the extraction process may be explained in terms of the structure and properties of the micellar surface, and how the stability is affected in different ways.

4.3.1 Methods of Precipitation

4.3.1.1 Acids and Bases

Fresh skimmed milk is nearly pH neutral, (pH 6.6, compared to pH 7.0 for neutrality) (Reyerson, 1940). It is a very good buffer solution due to the combination of calcium caseinate and calcium phosphate (Reyerson, 1940). If acid is added (Figure 4.3.1.1 (Dalglish & Corredig, 2012)), for example, this combination undergoes chemical changes to consume the acid, with the calcium phosphate dissolving and producing more soluble salts that pass into the solution (Reyerson, 1940). Calcium caseinate at the same time releases free casein and the electric charge and hydration of micelles decreases (Reyerson, 1940). At the low pH of 4.6 the micelles become isoelectric and thus coagulate. The coagulate is the free casein isolate used in laboratory and commercial preparation (Reyerson, 1940).

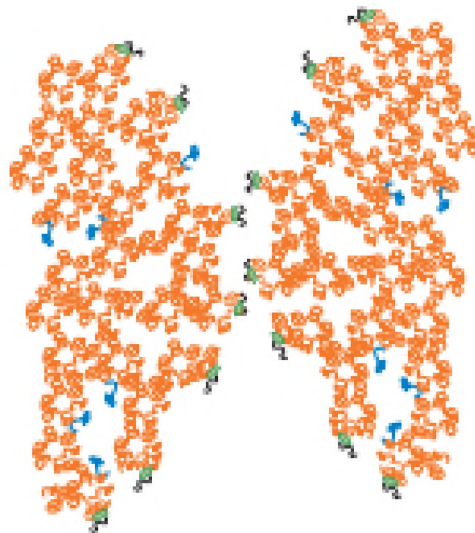


Figure 4.3.1.1 Acidified micelles. Casienomacropptide chains are collapsed due to the dissolving of the calcium phosphate (Dalglish & Corredig, 2012, p. 456)

It is important to note that where the acidification of gelation is high, there is residual colloidal calcium phosphate at the time of gelation. Rearrangement of the micellar structure and gel may occur as the pH decreases further. The gradual solubilization of this residual

material will result in an electrostatic imbalance within the micelles, with many of the sights in the core of the casein particle not yet being neutralized (Dalglish & Corredig, 2012). This enhances protein-protein repulsion within the gel network causing weakening of the gel until full charge neutralization occurs, and the gel again strengthens (Dalglish & Corredig, 2012). This phenomenon can be seen when making casein gels at temperatures of 40°C, or with rapid acidification.

For the purposes of this thesis, a rapid acidification of the casein has been adopted, using a household acid in the form of spirit vinegar. With a pH value of 2.6 (2.2 at 10% concentration), the acetic acid (CH_3COOH) is a strong acid for use in isolation of casein even when diluted.

4.3.1.2 Heat

Commercial methods of precipitating out the casein do so in slightly heated milk because more loss of casein can be seen at lower temperatures of the milk (Reyerson, 1940).

The heat stability of milk is affected by pH. The instability of milk to heat is not only caused by the micelles, but also by the denaturation of the whey proteins (a mixture of alpha and beta lactalbumin and serum albumin which are not affected by changes pH) and their interaction with the micelles, as well as changes in the calcium equilibrium (Dalglish & Corredig, 2012). At temperatures above 100°C the calcium phosphate precipitates as a function of pH greater than 6.5 (O'Connell & Fox, 2001). These changes do not appear to cause disruption of the overall basic structure of the micelles or colloidal destabilization (Dalglish & Corredig, 2012).

At 70°C the whey proteins denature and aggregate and the surface of the micelles is modified due to the association of whey proteins with the κ -casein (Figure 4.3.1.2) (Dalglish & Corredig, 2012). It has been suggested that the heat induced aggregates coating the micelles become less homogenous as the pH decreases, with larger portions of whey proteins binding to a singular κ -casein site. These changes to the surface of the

micelle (Figure 4.3.1.2) have important consequences in the behavior of the processed milk.

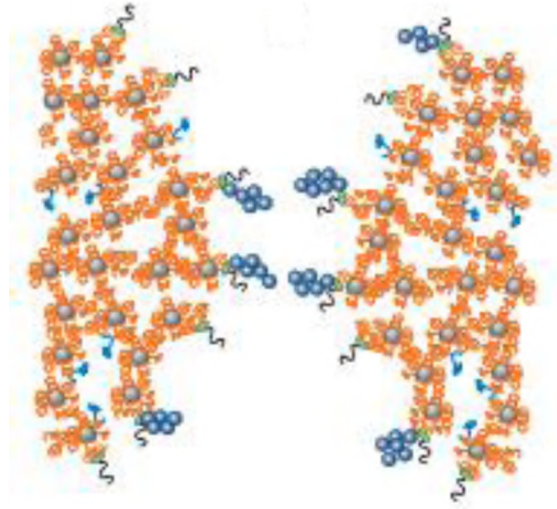


Figure 4.3.1.2 Heated milk with attached whey protein or K-Casein complexes (Dalglish & Corredig, 2012, p. 456).

The micelles are stabilized by steric repulsion generated by the polyelectrolyte layer of κ -casein, any process that removes the c-terminal region (a hydrophilic protrusion from the surface layer) which causes a decrease in colloidal stability of the micelles and causes a sol-gel transition – producing solid materials from the small molecules. The process involves conversion of monomers into colloidal solution (sol) that acts as the precursor for an integrated network (gel) of either discrete particles or a network of polymers (Dalglish & Corredig, 2012).

Heating is generally unsuitable for casein preparation due to coagulation of the proteins lactalbumin and lactoglobulin and the salts. The presence of all of these in the casein precipitate will produce a brown discolouration of the usually white casein. Heating also chemically alters the casein, reducing the solubility of the caseins due to modifications of the salt equilibria (Broyard & Gaucheron, 2015).

4.3.1.3 Alcohol

In sufficient concentrations alcohol can be used to coagulate milk (and the process has some similarities to that of heating milk to cause coagulation), however the main difference to that of heating milk is that there is no sudden release of phosphates. The casein appears as a coagulum as calcium caseinate but is often contaminated with other proteins, is also altered chemically, and its solubility thus also impaired.

4.3.1.4 Action of Rennet

Calcium caseinate and calcium phosphate can be coagulated with the enzyme chymase or chymosin. Similar enzymes are widely distributed in plants and animals, but the only true chymase (rennase or rennin) is obtained from the fourth stomach inner lining of young calves and lambs, its action extending the period in which the milk is retained in the stomach of these animals. This extract contains rennin, and its dried preparations, are termed rennet (Reyerson, 1940). Rennin, a protein digesting enzyme, curdles milk by transforming caseinogens into insoluble casein.

In milk that has been heated, the κ -casein is broken down by the chymosin as with unheated milk, but the micelles do not aggregate well. This is due in part to the presence of denatured whey proteins on the micellar surface, preventing the approach of the potentially interacting sites on the micelles (Dalglish & Corredig, 2012).

4.3.1.5 Electrodialysis

Milk can also be electrolyzed as the electrodialysis of the dissolved salts decreases the pH to the isoelectric point, dissolves and removes calcium phosphate, removing the calcium from the calcium caseinate, thus allowing for the coagulation of casein (Reyerson, 1940).

Skimmed milk is placed in the middle of three compartments separated by membranes that are permeable to dissolved substances but impermeable to micelles yielding caseins (Andrés, Riera, & Alvarez, 1995). Electrolysis of the dissolved salts decreases the pH to the isoelectric point, dissolves and removes calcium phosphate, removes calcium from calcium caseinate, and allows casein to coagulate.

4.3.1.6 Salt

Soluble salts and other divalent or polyvalent cations are effective at coagulation of calcium caseinate and calcium phosphate at lower concentrations than e.g. sodium chloride, but lactalbumin and lactoglobulin are left behind (Samel & Muers, 1962). The salt coagulation is used to remove casein and phosphates on preparation of both lactalbumin and lactoglobulin but rarely used for the production or preparation of casein.

4.3 Pigments

When the casein is extracted in its solid form, its colouration is white to off-white and pigments need to be added to give the colours to be used for painting. The coloured pigments for casein paints should be lime proof and non-reactive with alkalines otherwise for example in powder paints the vehicle could be alkaline enough to change the colour of the pigment (Reyerson, 1940). Most of the coloured pigments used are inorganic, either minerals or manufactured products however a few of the lime proof lake pigments made with organic dyes may be used for the brighter colours in casein paints (Reyerson, 1940).

The relative proportions of pigment, nonvolatile and volatile vehicles in casein paints compared with 3 oil paints (flat wall, interior enamel, and exterior house (Reyerson, 1940)) are presented in Figure 4.3. From this it may be observed that casein paints have a much

greater volatile component than the other paints. For casein paints this volatile component is water.

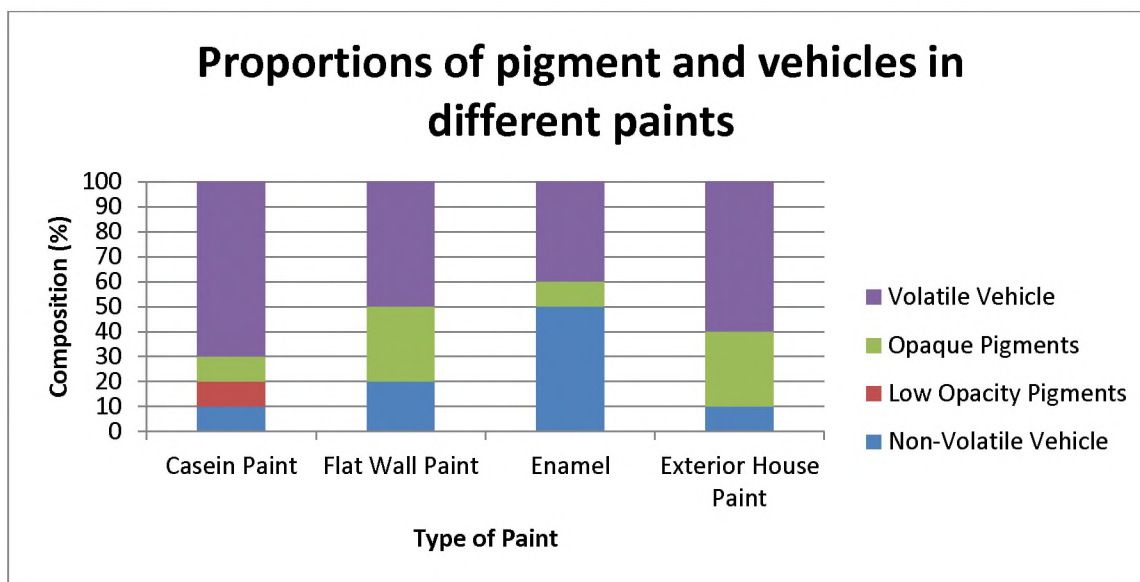


Figure 4.3 Graph depicting the composition and proportions of various paints. Non-Volatile Vehicle differs in each. Casein for the Casein Paint, Drying Oils and Resins for both the Flat Wall Paint and Enamel, and Linseed Oil for the Exterior House Paint (Reyerson, 1940, p. 315).

Opacity is the measure of impenetrability to various kinds of radiation, especially visible light. The opacity and colour saturation depend on the pigmentation. Pigments are fine, insoluble, organic or inorganic particles of colourant that are suspended in the vehicle (which carries the pigment and assist the pigment in adhering to the substrate) (Reyerson, 1940). The pigments not only provide colour, but more specific properties such as transparency (low opacity), opacity, and resistance to heat, chemicals, water, or oils. The pigments thus help determine the suitability of the paint to a particular process or use.

The principle pigments of low opacity used in caseins paints are calcium carbonate and white china clay or kaolin (Reyerson, 1940). There are other suitable low opacity pigments used for casein paints – magnesium silicate (fibrous talc), barium sulfate, silica, diatomaceous earth, and calcium sulfate (Reyerson, 1940). Paints for special purposes sometimes require special pigments to produce specific modifications of the coatings such

as asbestos, granular pumice, sawdust, cork, magnesium oxide, magnesium carbonate, and alumina (Reyerson, 1940).

In powder paints the vehicle is alkaline enough to change the colour of the pigments sensitive to alkalis. Most of the coloured pigments traditionally used are inorganic substances, either minerals or manufactured products, however a few lime-proof lake pigments made with organic dyes could be used for brighter colours in casein paints.

In terms of a vehicle, which describes the liquid or paste in which a pigment is suspended, there are various types ranging from organic to inorganic. The range of vehicles includes water, oils, and synthetic vehicles developed from polymers such as polyurethane and styrene-butadene (Agarwal, 2006). Paints with water soluble vehicles include the calcimines (a whitewash with zinc oxide and pigments formerly used as coatings for plaster walls and ceilings), with a suitable vehicle being glue, and casein paints in which the vehicle is casein protein and water. The vehicle can also be termed as volatile vehicle (which uses evaporation to dry and adhere to the surface) or solvents, with a wide range of organic solvents such as petroleum distillate, alcohols, ketones, esters, and glycol ethers (Agarwal, 2006).

The non-volatile vehicles are often known as resins, or binders, and strictly speaking should include pigmentations (any portion of the paint left after drying). Typical binders include synthetic and natural resins such as acrylics, polyurethanes, polyesters, melamine resins, epoxy, or oils (Agarwal, 2006).

4.4 Conclusion

For this work, the best extraction technique for casein had to follow specific criteria. It had to use readily available materials (in terms of household materials) to keep with the idea of Kitchen Chemistry. The materials had to be non-toxic so as to avoid hazards within the laboratory environment, especially since non-chemists, unfamiliar with safe practice, would be doing the experiments. Another criterion was that it could not rely on machinery

or complicated apparatus, because the technique needed to be as applicable and user friendly as possible. Severe heat usage was also not condoned with this experiment as this adds an unnecessary risk factor for the participants.

The acidification method chosen here, however, is not the best technique in its totality for the extraction of casein from milk. If resources allowed and the participants had had chemistry training, the technique used would be a dual method of acidification and the action of rennet termed Acid-Rennet Aggregation. This method is used in many cheese making processes, with the stability of the micelles depending on the relative rates of pH changes and release of caseinomacropptides. With this method, there is freedom to stop the rennet action at a low level of κ -casein breakdown before acidification starts, so obtaining a final gel with greater elastic modulus than from other methods. Although, with this mixed method approach, there are still substantial amounts of colloidal calcium phosphate remaining that subsequently dissolve and weaken the gel (Dalglish & Corredig, 2012).

The decision was thus made to apply the acidification technique, using acetic acid in the form of spirit vinegar. Following the set criteria, spirit vinegar with no heat source was the best choice when working with participants not skilled in the ways of the chemistry laboratory.

With regards to the volatile component, it was chosen to consist of water which also acts as a diluting agent to control viscosity, while the non-volatile components were to be that of casein protein and pigmentation, although another suitable option would have been wood glue/Craft glue (polyvinyl acetate) which would have had the added benefit of creating a stronger adhesive property to the casein paints.

For this study, the pigments used were in the form of food colouring. This is due its availability in stores, as well as it being non-toxic to work with while still imparting a vibrant colour. The food colouring also falls in line with the kitchen chemistry aspect of study, as it was an aim to use reagents found within the household.

Chapter 5 – Research Methodology

The aim of this study is to explore the perspectives – and possible perspective changes – of non-chemists. The intention is to identify the possible circumstances that have led to these perspectives, either positive or negative, in the hope to establish valid reasons as to why non-chemists chose their university careers, and not a career in chemistry.

To explore perspective, its changes, and its relevance to chemistry education of non-chemists, three research questions were prepared/ formulated:

- Question 1: What are the perceptions of chemistry held by Rhodes University students who do not study chemistry?
- Question 2:** What is the experience of the participants during the chemistry practical in a laboratory?
- Question 3:** How do participants' perspectives about chemistry change during the experience?

To answer the research questions, two art works, a chemistry laboratory experiment, and several interviews were used. One artwork was before the laboratory experiment and the second done post-laboratory experiment. The focus of the second artwork was on the participant's unique and individual experiences in the laboratory with the creation of paint from milk. The interviews provided key triangulation of the data gathered from the laboratory experiment and the artworks, in addition to providing data on the participants lived experience or phenomenology of the practical.

The elements of background, foreground, and subject are form parts to a successful painting. The background provides the artist with a relevant surface on which to represent their subject matter, while the foreground provides the scene nearest the viewer and this is more prominent and an important position. Both the foreground and the background set the stage for the subject matter, which is essentially what the artwork is all about. It is the subject of discussion and essence of the piece. All three elements need to be coherent in themselves to provide the viewer with a cohesive artwork. As such I use these terms to

paint the picture which is my thesis. Each element influences the other, and is specific in gathering data about the artist and the subject. Similarly, in my thesis, the background – Phenomenology and laboratory experiment; the foreground – Visual Semiotics and Art Works; and the Focus/Subject – Interviews – all work together in the research data collection and analysis. The integration of these systems, characteristic of the spatial behaviors of human beings and organisms, enables the composition of artworks to facilitate their task of reflecting the nature of human experience (Arnheim, 1983).

It was of utmost importance that the analysis of the artworks be free from bias, and thus the analysis was done using reference material, and not the researchers own views. In the same vein the researcher tried his best not to influence the participants in their creation of their respective artworks, nor in the interviews or laboratory data.

5.1 Background

The Background is the actual phenomenological experiences of the participants. This involved the participants taking part in the creation of paint from milk in a laboratory setting. It was assumed that by allowing participants to assume the role of a chemist and removing them from their comfort zone, an increased emotional response would be promoted, facilitating a clearer recall of chemistry from their past.

The initial intent of this study was to invite the Bachelor of Fine Arts students to participate as they held a greater grasp of the artistic principles of art and could use their knowledge to create artworks of psychological importance. However due to lack of volunteers within that field other students were also invited to participate. Nine students volunteered. Of these, only one participant was involved in visual arts at university, and one other had done visual art in high school.

5.1.1 Laboratory Experiment

The participants conducted the experiment in a laboratory in the Rhodes University Chemistry Department in small groups (1 group of 4, 1 group of 2, and 3 individuals). Before they entered the laboratory for the milk paint synthesis, the participants were shown a presentation on the various safety measures in a laboratory, the various reagents, and the apparatus that they were going to use. At that time, the participants received a consent form, if they had not received one in advance through email or personally, which had to be signed and handed back before any participant could enter the laboratory or hand in their prerequisite art work.

Participants were asked to create these prior and subsequent pieces of art under specific instructions of points of focus, namely their preconceptions and lived experience of the laboratory experiment. In the practical session participants created milk paint from ingredients purchased at a grocery store. They did this in the chemistry laboratory to assume the role of a chemist, thus removing them from their comfortable environments promoting an increased emotional response and memory recall of chemistry. During the process, participants were questioned about their earliest chemistry memories, their high school subject choices and reasoning behind them, as well as about the chemistries behind the procedure they were following in the laboratory. Answers to verbal questions and laboratory notes made by the participants in a laboratory book were analysed using the coding software ATLAS.ti 7 (“ATLAS.ti: The Qualitative Data Analysis & Research Software,” 2016, unpagged). The iterative analysis of the resulting themes led to the emergence of dimensions that constitute the core of the laboratory experience.

In the laboratory, the participants were given a methods page (Appendix B) and a laboratory book (Appendix C). At all times the participants were assisted in the proper protocol for the experiment and led through each section.

Participants formulated paint from milk using an adapted recipe from Marks & Farrell, (2014) and the website “Earth Pigments” (“Milk Paint with Lime - Earth Pigments,” 2016,

unpaged). They did this using techniques that had been demonstrated in the pre-laboratory slide show.

Participants measured out the volumes of milk using a measuring beaker and the vinegar using a measuring cylinder, writing in their laboratory books the quantities used (Appendix C).

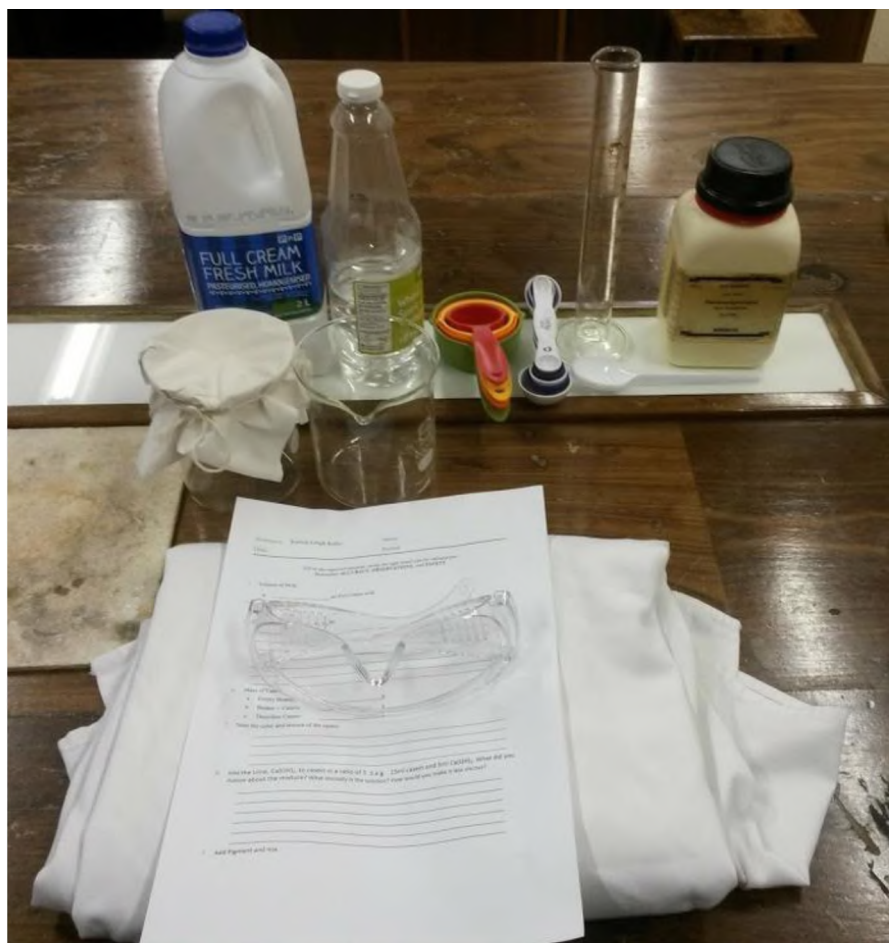


Figure 5.1.2 Equipment set up for participants (Photograph: Kelvin Kelly 2016).

The participants then mixed the milk and vinegar, waiting 15 minutes for the casein to coagulate and solidify (see Chapter 4). Once coagulated, the casein was filtered by gravitational filtration using a disposable cloth and a beaker. Excess liquid was squeezed out of the solid casein and the casein was weighed on a balance. The participants added the

lime to the casein, making it hydrophilic, and lastly the pigments in the form of powder and liquid food colouring were added.

While the milk stood to allow time for the casein extraction to happen, participants were asked a series of questions:

- What did you notice about the mixture?
- What do you think happens to the milk when you add the acid?
- What is your first memory of chemistry?
- What happens when you mix the casein with the lime?
- How would you make the paint mixture less viscous?
- How does Pigment work?
- Why did/didn't you Choose chemistry at High School?

The participants noted their answers to these questions in their laboratory books. After the laboratory experiment was concluded, participants had to clean up the glassware, return the borrowed laboratory safety equipment (laboratory coat and safety glasses), and hand all their information (laboratory book, questions, and methods pages) for analysis.

5.2 Foreground – Art Works

Artworks have been used in the study of psychology to diagnose, to evaluate, and to relieve tensions of patients (Collie, Bottorff, & Long, 2006). As such, artworks were identified as being able to combine artistic expression focused around a phenomenon, and chemistry experimentation. The artworks were used as a tool to evaluate participants' pre- and post-perceptions of chemistry in conjunction with the laboratory experiments. Four participants were interviewed to triangulate the data, making use of the notes from the laboratory books for all the participants as a triangulation method. The artworks had an added benefit as they provided a visually stimulating memory recall of their emotions and perspectives.

An external observer making meaning of symbols created by unknown and unfamiliar participants is complicated. Kress and Van Leeuwen (1996) state that:

“Social semiotics is an attempt to describe and understand how people produce and communicate meaning in specific social settings, be they “micro” settings such as the family or settings in which sign-making is well institutionalized and hemmed in by habits, conventions and rules. But social semiotics, sign-making in society, is so varied an activity that any attempt to capture it in a general theory must look crude by comparison with the richness of the actual semiotic world” (Kress & Leeuwen, 1996, p.264).

Visual social semiotics is an effective tool for understanding the conventions in Western imagery evoking generally uniform reactions, however using this framework for a multitude of images is complex and introduces a vast collection of new terminology (Harrison, 2003). The complexity of the individuals responsible and their perspectives and intentions behind the image need to be taken into account.

5.2.1 Artwork 1

One to two weeks prior to the laboratory experiment, the participants were requested to produce an artwork with the intention of illustrating their preconceptions, or perspectives of chemistry. The artworks could be in any medium of choice and done in any style or form (impressionism, surrealism, digital, abstract...etc.). This allowed the use of typical art analysis techniques, looking at line, colour, and shape (Chapter 3) to determine what each participant thought about chemistry, and if these artworks depicted a negative, positive, or neutral depiction of the subject. Participants were expected to hand in their artworks before the pre-laboratory slide show and laboratory session.

5.2.2 Artwork 2

After completion of the practical, participants were asked to produce a second artwork. Similarly, the participants could use any medium of choice, however with a different focus. Participants needed to focus not on how they felt after the practical laboratory session, but rather on how and what they felt during the laboratory session (i.e. their focus was of the phenomena and their emotional response to the event rather than how they felt post-practical).

Analysis was done on the artworks using a variety of methods, as the artworks themselves were done in a variety of ways, from abstract art to collage, and even poetry. The evaluation of the art was by using the methods of DiBartolomeo, Clark, & Davis, (2015), which provided a framework used to compare, analyse, and review the visual data received. Use was also made of more specific analysis techniques like those of Villarreal, Minton, & Martinez, (2015) which illustrate how the crafting of visual text influences children's picture books; Collie et al., (2006) who looked at art therapy and art making as an avenue for psychosocial support for women with breast cancer; and Lu et al., (2012) who investigated how shape features in natural images influence human emotions.

The participants' artworks could then be dissected, meaning found, and symbolism identified through how each participant used colour, shape, line, and subject matter, which were then triangulated through interviews with several selected participants.

Participants were advised to write down their emotions, memories, or thoughts on the phenomena as they happened on spare paper provided, so as to better assist their recall for the completion of the second artwork.

Several participants took the artwork a step further in that they accompanied the second (and sometimes the first) artwork with their own analysis of their artworks. These were considered only after an initial analysis by the researcher, and they thus had no influence on the initial analysis of each participant's art.

5.3 Focus/Subject – Semi-Structured Interviews

Semi-structured interviews were held with four participants (1, 2, 7, and 9) whose artworks showed specific aspects of interest, namely those artworks that held interesting notes of colour and line application, those that created something insightful and unorthodox in their depictions of their preconceptions and lived experience. The selection of artworks was based on several criteria:

- Bizarre Shapes/Objects/ Central images.
Geometric and natural versus abstract and non-objective shapes
- Colours that provoke emotion
e.g. Red is emotionally intense, enhancing metabolism and increasing respiration and blood pressure (Gage, 1999). It is used as warning indicators (stop signs). It is also associated with courage, vigour, rage, and anger. Conversely, blue is considered beneficial for the body and mind and slows metabolism and produces a calming effect. It is used to promote ideas of cleanliness, tranquility, and understanding (Gage, 1999).
- Line
Horizontal lines evoke calm, quiet, and rest, while a vertical line creates a feeling of strength, activity, and energy (Bradley, 2010a).

The interviews yielded valuable data and offered a triangulation technique that connected well with the notes from the laboratory session and the artworks created by the participants.

The interviews of the selected participants were of a conversational nature and lasted anywhere between 45 to 80 minutes. The interviews were conducted in an informal setting to create a more natural environment free of anxiety, in a semi-structured manner. Several relevant questions were asked (Appendix D), and these could be followed up with conversational twists and turns and accommodate unanticipated discussion about the laboratory session, their artworks, and history pertaining to chemistry (Vincent, Decker, & Mumford, 2002).

5.3.1 Analysis of the Interviews

This qualitative research methodology involved asking questions that focused on the how and why of participant interactions (Agee, 2009). Although interviews were audio recorded and then transcribed using an external transcriber (Appendices G, H, I, and J), the interviewer noted important points to follow up without disrupting the flow of conversation (Agee, 2009). Thus, the interviewer (researcher) could articulate information about the intentions and perspectives of the individuals involved about their interactions with the experiment. Qualitative questioning thus is an integral part of understanding the “unfolding lives and perspectives” of the participants (Agee, 2009, p.431).

Once transcribed, theme identification took place using the coding software ATLAS.ti.7 (Figure 5.3.1). Themes are abstract constructs, linking not only expressions found in text but also within images, sounds, and objects (Ryan, Health, & Bernard, 2003). Analysing the data involves tasks such as discovering the themes and linking them with theoretical models (Ryan et al., 2003). The themes were found in the transcribed interviews by predominantly sifting through the data and coding the text (Ryan et al., 2003). Coding of the transcribed interviews was done using ATLAS ti.7 software. The text was coded in several ways such as by searching for words of repetition, topic, and basic sifting through the raw data.

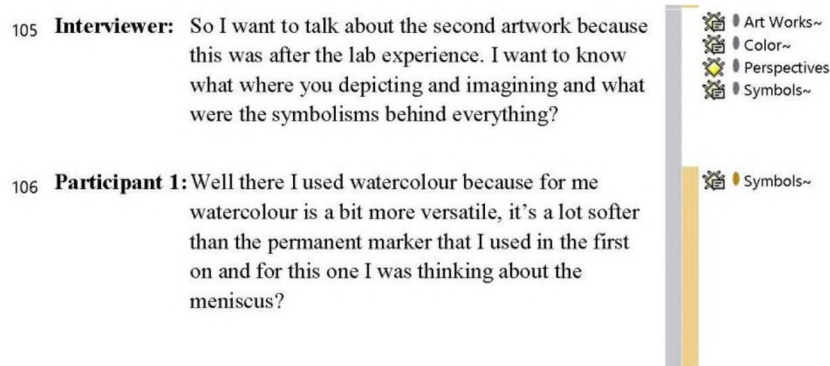


Figure 5.3.1 Coded text using ATLAS.ti.7 software

Thematic analysis is a widely used method for qualitative studies beyond that of psychology (Braun & Clarke, 2006). Through its theoretical freedom, thematic analysis provides a flexible and useful research tool which can provide rich and detailed accounts of the data. Themes of the interview data were analysed making reference to Braun & Clarke (2006); Ryan, Health, & Bernard, (2003) who supplied information on discovering themes, building theme code books, and linking themes to theoretical models; Creswell, (2007) who provided information on qualitative approaches to data analysis; as well as (Creswell, Sobczak, & Lee, 2003) which gave an indication of frameworks for design, strategies and plans that link methods to outcomes, and appropriate techniques and procedures to use.

It should be noted that analysing qualitative data is complicated and subject to analyst bias. This was minimized by providing the transcripts to the interviewed individuals to validate the data, giving the individuals freedom to provide supplementary information and to ensure reliability of the transcription.

5. 4 Validation of methods

5. 4.1 Artworks

The choice of using art works as a means of visual communication versus the traditional concepts of questionnaires and surveys was not taken lightly. Although it would have been easier to select a set of relevant questions and have the participants write out their answers systematically, it was resolved that the negative aspects of surveys outweighed their positive aspects (Fricker & Schonlau, 2002; Wright, 2006). Surveys provide a high level of representing a large population with the data gathered possessing a better description of the relative characteristics of the general population. Thus, due to small population sizes, a survey technique would not yield significant results. On the other hand, there could be an argument of observer subjectivity, as surveys condone a high reliability due to a standardized stimulus, eliminate a researchers own biases (Fricker & Schonlau, 2002).

Artworks, given weeks in advance, could be done in any medium. Each artwork in itself was unique and relevant to each participant. Their images and symbols used in such a creative manner meant that they were drawing inspiration from a personal source.

Semiotics, the study of works of art, signs, and symbols within sign systems can give us more insight and meaning from the work source/art (Labbo, 2014). There is a resemblance between art creation and the use of written language. Unlike surveys, semiotic theories are not definitive but constantly being reviewed, extended, and developed to become more precise and improve the significance of the information gathered when these theories are applied to works of art. As visual consumers, people are becoming increasingly sophisticated readers of these signs and signals as everything surrounding us today, including our own identities, are molded and manipulated by signs, images, and are our visual language. Language is normally thought of as straight forward and clear, whereas the visual language is an expression of emotional, deeper thoughts and ambiguous ideas. Thus visual expression needs the linguistic explanation to clear up superfluous meanings (Somov, 2005). This can be seen in advertisements where a message is always attached to

the image in order to help establish and anchor the meanings behind the picture shown. Naturally we interpret objects in images as signs by relating them to familiar systems and conventions.

Sonesson (2007) makes his own suggestion in that phenomenology could be interpreted as a branch of psychology and thus can serve as an ingredient of cognitive science as well as a basis for semiotic theory (Sonesson, 2007). Sonesson's paper argues that the concept of sign or representation, indispensable for understanding of the human consciousness, and suggests that meaning, which is not specifically embodied in signs, is a requisite for both a systematic and an evolutionary sense, for the attainment of sign function (Sonesson, 2007).

Creating art works provided another advantage. Not only was it possible to use visual semiotics as a flexible method for analysing the perceptions of the participants, it also afforded the opportunity for its use as a system of visual recall during interviews. During the interview the participants described their works of art in as much detail as could be provided and this was also used to establish their emotional motivation behind the colours, shapes, and symbols that were chosen. Combining this information with the prior independent analysis created a richer, more personal interview with each participant, and allowed for the collection of the relevant data in a fun, albeit unorthodox, manner.

Kress and Van Leeuwen (1996) state that:

“Social semiotics is an attempt to describe and understand how people produce and communicate meaning in specific social settings, be they “micro” settings such as the family or settings in which sign-making is well institutionalized and hemmed in by habits, conventions and rules. But social semiotics, sign-making in society, is so varied an activity that any attempt to capture it in a general theory must look crude by comparison with the richness of the actual semiotic world” (Kress & Leeuwen, 1996, p.264)

That being said, visual social semiotics is an effective tool for understanding the conventions in Western imagery evoking generally uniform reactions, however using this framework for a multitude of images is formidable because it is complex and introduces a

vast collection of new terminology (Harrison, 2003) not to mention the complexity of the individuals responsible, their perspectives and intentions behind the image, which also need to be taken into account.

5.4.2 Interviews

The aims of this study involved proximity with participants in order to understand their perspectives, if this perspective changed during the course of the study, and to investigate the lived experiences of participants 1, 2, 7, and 9, within a chemistry environment.

This was specifically important for the research as it involves phenomenology, the lived experience of individuals brought on by phenomena. Using a semi-structured interview technique proved to be the best choice as it allowed for a deeper understanding through rich narratives, thus ascertaining of the meanings of participant actions and experiences and enabling an investigation into their underlying expressed opinions in a rather personal setting and manner (Bates, Droste, Cuba, & Swingle, 2008). The phenomena (milk paint), from the viewpoint of the participant, and interviews were used to unravel these events (the lived events of the participants during the laboratory experiment), and to determine how the event evolved over the time frame.

As a research tool, the qualitative interview imposes different social roles, the idea that a greater intensity of listening leads to active listening.

5.4.3 Ethical considerations

Ethical concerns stem from discussions about codes of professional conduct for researchers (Creswell, 2009). In other words, each stage in the research process raises ethical issues. Most qualitative research requires obtaining consent and cooperation of people or

institution to be involved in the study or providing facilities for the study (Cohen, Manion, & Morrison, 2013).

Permission to conduct this research was given by the department of education ethics committee, Rhodes University. Volunteers were Rhodes University students and thus consent was given individually through signed letters explaining the research and the anticipated learners' involvement. A sample of consent letter given is included in Appendix A.

Learners were assigned identification numbers from 1-9. These numbers were used when referring to students in the reporting of the research to ensure anonymity. Learners were assured of confidentiality; that data was being used for research purposes only, data would be stored in a secure place and their responses would not be revealed to their teachers or parents. Participants were assured of voluntary participation in the study and they could withdraw anytime without prejudice.

5.5 Conclusion

The above-mentioned methods for analysis of the art, laboratory notes, and interviews were chosen as crucial methods to the success of the research. These methods provide a direct and concise data collection technique, allowing for the collection of all the relevant data in their respective formats.

Chapter 6 – Results, Analysis, and Discussion

As mentioned in the previous chapters, the main goal of this research was to determine the perspectives non-chemists had about chemistry, and discover if making chemistry more interesting and applicable could change these perspectives. Utilizing several data gathering techniques, elaborated in Chapter 5 – Methodology, was possible to gather considerable data using the laboratory exercise and notes, semi-structured interviews, and art analysis. The aim of this chapter is to report and discuss this data.

In this study, the nine participants were all students of Rhodes University, who have had little or no instruction in chemistry.

During this study, no compensation was offered and confidentiality and anonymity was strongly emphasized, which follows the criteria found within the Ethical Clearance for Rhodes University. Nine Rhodes University students (two males and seven females) participated, with semi-structured interviews being held with four of these students (Participants 1, 2, 7, and 9). Data analysed were from notes made during the laboratory exercise, artworks, and interviews. ATLAS.ti 7 was used to code the qualitative data (Appendices G, H, I, and J), establishing themes within the interviews, and providing networking capabilities to link all this data.

6.1 Laboratory Experiment

The laboratory experiment was run in the Rhodes University Chemistry Department first year laboratory, using rudimentary glassware such as beakers, stirrer rods, as well as reagents and equipment bought at the supermarket.

6.1.1 Preparation

All participants were given a safety talk discussing the various equipment and reagents to be used, as well as the basic procedure (Appendix B) in the synthesis of paint from milk. During the talk participant queries could be answered and the various notes handed over and signed (Appendix A and C).

Questions were asked of the participants during waiting times. This, along with the laboratory workbook, formed the laboratory data.

6.1.2 Results

The focus of the laboratory data was not on how much casein each participant managed to synthesize, or how great their techniques were while using the chemistry laboratory equipment, but rather working through this medium I could observe how non-chemists worked in this setting, and gain insight into their perceptions, motivations and emotions, and what has set into motion these perceptions, motivations and emotions.

Several questions were asked during the experimental process. Some questions were part of the laboratory workbook, while some other questions were provided verbally, guided by the research aims.

The participants had to write the question down first and then provide their answers on spare paper provided, which assisted the researcher when transcribing the data.

These questions are listed below, combined with participant answers transcribed from their laboratory books tabulated in Appendix L. Some participants did not answer all the questions. All participant answers are recorded as seen in context (SIC).

- What is your first memory of chemistry?
- What happens to the milk when you add the acid?
- What do you think happens when you mix the casein with the lime?

- What do you notice about the mixture?
- What were your high school subjects? Why/Why not chemistry?

It was observed that there was a range of memories related to chemistry, both in terms of timeframe and in terms of having both a positive and negative effect on the participants. Thus, exploring the background of the participants was enlightening with respect to their choice of not pursuing chemistry further. For example, Participant 3 made this statement when recollecting feelings about the laboratory.

“feeling really unsure and confused! Not something I enjoyed, that feeling!” – Participant 3

Statements following this indicate that this was the reason the subject was not followed into high school during subject choice. This statement illustrates how easily a student can falter from a subject based in part to the emotions felt during the class”- “I always felt this way about physics/science and therefore I didn’t take the subject from grade 10 onwards” – Participant 3.

Participant 4 and Participant 9’s first memory of chemistry was their 1st year at Rhodes University.

“Finding out that chem 101 was a prerequisite for my zoology degree (Never took chem in high school). Made me feel anxious” – Participant 9

“My first day of first year - or o-week, when I went to my intro lecture for chem - that was my first chem experience because I never did it at school”

“I actually wanted to do journ, but then it was a prerequisite for my zoology major so then I just had to go and do it anyway. Even if I didn't want to”.

This is a possible indication of why there is such a high failure rate in Chemistry 1. Students have no interest and very little to no background in chemistry, but are forced to take it, since it is a prerequisite for subjects which they would like to study. Participant 9 sums up the year by stating:

“I think during it (Chemistry 101) was negative because it was really hard, but then afterwards if I look back on it then it's positive if that makes sense. I struggled with chemistry so much that during

the year it was such a stress and burden, but if I look back on it I am proud by how hard I worked and what I achieved”

On the other hand, there is some commonality in terms of positive experience with participants 5, 6, and 7. Participant 6 commented:

“ignition of Mg in Grade 10 chemistry class. Sodium and water in grade 10 chemistry class” --
Participant 6

Her first chemistry memory was not an activity done in early school, but in grade 10. This shows how little chemistry features while growing up. Looking further at her comments, Participant 6 states the feeling of excitement and “amazingness of reactions”, showing the participant’s enjoyment in the subject.

Sharing earliest memories within her interview, participant 7 commented,

“Earliest chemistry memory would be doing that thing you do at school with the volcano, that volcano thing with vinegar and bicarb” – Participant 7

The volcano experiment, with its use of colouring, the explosion it caused, and the excitement and unorthodox display made the memory a positive one highlighted by a statement made by Participant 5 – “we added food colouring vinegar & bicarb - volcano erupted rainbow colours of red, orange + yellow” and Participant 7 – “Yah it worked so that was exciting”, describing the volcano experiment.

Further probing into Participant 5’s memories prompted by the laboratory experiment were also fond memories. Her statement:

“Yes, I remember in school that I would always be like “Oh what did you guys do in chemistry?” and they would be like “Well we did this.” And then I’m like “Oh that sounds so cool.” And I’m thinking well maybe I should have done it. But then I’m also kind of happy I didn’t because I get to still experience it and see something new that would’ve been boring if I had done chemistry at school” – Participant 5

gives an indication of how her social interactions with her peers were important to her and that she felt something akin to regret at not choosing chemistry.

There are indications that as participants proceeded through the chemistry curriculum in school, with information deemed critical to be in the curriculum, the subject has with time lost the appeal and fascination possibly due to the portrayal of the information becoming increasingly more static.

The importance of practical experience can be seen from Participant 1's comments. Her statement about memories of sciences was also a positive one:

“Yes, the first thing that pops into my head is in biology, we had to dissect a kidney or something. I can't remember what animal it was and I just remember thinking “Finally we get to dissect something” because it was the first thing we got to dissect and I always just wanted to dissect a frog or something” – Participant 1

The participant's enjoyment came from “Learning how everything functioned and worked”. Participant 1's reaction to being asked if there was an interest in chemistry during high school was a timid “No, it was all confusing to me and I never understood it”, with her reasoning being “I think it was just my own brain going no. This isn't for me, I'm meant to be doing art right now”.

During the laboratory session participant 1's interactions were anything but timid from the start “we went into the lab and put on the lab coats and that was quite exciting”. Being an art student her enjoyment escalated when the experiment was fully underway –

“Yes, I really enjoyed that and then we started with the experiment. And that was very interesting, it wasn't what I expected at all. A little bit of confusion, but excitement, all positive feelings I think. It was very interesting” – Participant 1

A few participants used descriptive vocabulary like Participant 1, “instantly go off or creamy”, Participant 2's comment of “curdles?Bubbles?Thicker(sic)”, and Participant 5's comment “It curdles :Σ, Bubbly, changes, aero-like(sic)”.

This shows the focus on the phenomena and what their expectation was. These answers were written before the addition of the acid and thus relied on the participant's scientific intuition.

Participants 3, 4, 7, and 9 used specific vocabulary to describe what they thought was going to happen before they added the acid to the milk.

“Acid changes the consistency and structure of the milk; Acid changed pH (-ve)”

shows Participant 4 using scientific vocabulary to establish the changes seen through the phenomenon in the practical, and understanding that the acid is the cause of the change in phase from milk being liquid, to solid casein.

Participant 7 used past experiences in working around the kitchen, and drawing on previous observations, commented that:

“The protein in the milk or fat is separating from the water of the milk. Like when milk defrosts”

This shows the focus on phenomena and the participant’s ability to draw and apply knowledge gained from experiences in the past.

Participant 9 stated “May have something to do with the difference in alkalinity” which draws on specific science knowledge based on acidity of the reagents that were discussed during the laboratory safety discussion.

It should be noted here that the researcher did not use the word ‘alkalinity’ to describe the process of paint creation from milk, and thus the term used was a product of Participant 7’s prior knowledge.

During the laboratory experiment, there was no expectation for participants to use scientific vocabulary in their descriptions. Participants’ use of vocabulary to describe these events made the most sense to them and in their way of thinking.

Aside from the comments about bubbles, the comments here show how different people use different vocabulary to describe the same event (Sonesson, 2007). Thus, using different vocabulary and methods to teach chemistry would increase the response of students who do not necessarily understand the vocabulary of the traditional scientific pedagogy.

Both the casein and the calcium hydroxide are both in solid phase. The expectation is that the mixture would form a more solid structure. However due to the difference in pH, with

the calcium hydroxide being basic and the casein being approximately neutral, the casein is forced from a hydrophobic state into hydrophilic state, thus making it water soluble and the solution fluid.



Figure 6.1.2.1 Photograph of cloth and beaker showing a kitchen chemistry method of gravity filtration

The responses were made by participants before the addition of the lime but after the casein had been extracted using a gravity filtration method using a cloth and a beaker to keep with a kitchen chemistry theme.

Participant 4's expectation was, "forms a large lump, dough-like" indicating the general expectation of the addition of a powder to a solid, while Participant 9 commented the opposite "The casein will become less solid and more liquid but not runny".

Participant 4 indicates the surprise that follows when adding the calcium hydroxide "becomes liquid? → counter intuitive → haha".

Participant 1 is another example of a participant that correctly estimated the reaction of the calcium hydroxide commenting that "the lime melts the casein?".

The comment is of interest because Participant 1 was the only participant with a purely artistic background. Thus, the comment must have been provided through a past experience. It shows chemistry intuition being applied by a true non-chemist and correctly

depicting and evaluating the phenomenon under focus. Even though scientifically it is not correct to say that the casein “melts”, the casein and lime transition from a solid phase into a liquid phase and technically speaking, looking at ice that melts into water, is known and termed as “melting” (Brandriet, Xu, Bretz, Lewis, Eilks, Byers, Gabel, Ram, Xu, Lewis, Smith, Furió, Azcona, Guisasola, & Giunta, 2013).

Participant 8 suggested that the lime “Maybe also make it so that it can be influenced by the pigment”. This in-depth thought of Participant 8 as to the possible reasons how this reagent could affect the binding property of the colouring on the casein. Although scientifically this is incorrect, the statement shows a more scientific thought process. The participant had the intuition to suggest a viable reason behind using the reagent aside from mere precipitation.

The statements in Table 6.1.2.4 (Appendix L) indicate that participants were surprised that upon addition of lime the mixture became more fluid, instead of more solid which was the expectation. These comments can be seen by Participant 7:

“Adding a solid to a solid. Once stirring it looks like cookie dough. It not doing what I thought it would do. Its now becoming more liquid”

Table 6.1.2.5 (Appendix L) shows additional comments made by participants on paper provided for verbal questions and extra notes. These notes could be made during the practical session at any point. What is important to note in this category is the use of words and their connotations and meanings.

Participant 2’s extra comments showed her fond memories of “pudding with granny” and childhood memories of “milk = coco pops” ending with the colloquialism “LOL” (Laugh out loud).

“vinegar reminds me of making malva pudding with granny :) ; reminds me of making milk kefir; milk = coco pops LOL; My milk is broken :(; doing the experiment took me back to school when I did biology - I actually really enjoyed doing those labs :)” Participant 2

These comments strengthened her final statement of “doing the experiment took me back to school when I did biology - I actually really enjoyed doing those labs :)”. It was interesting to see the participant enjoy a subject she was not inclined to participate in.

Participant 4, who has some background in chemistry and science, stated that “every question in science can be answered by/in nature” which indicates the participant’s inclination towards applicable sciences in everyday life. The participant had initial conflicts with the practical as her experience in the past was one of anxiety “ANXIETY→clinical”. What was interesting was seeing this participant being particularly clinical and analytical in her artworks and in the laboratory session.

Participant 6’s comments were optimistic, “Excellent experience”, and further stating that the experience was “pleasurable and enjoyable”. Although having experienced sciences in high school, the participant had spent a few years after matriculation not working in any science field. The experiment was her first experience of a chemistry laboratory, and shows the applicability of the methodology on a typical non-chemist.

A participant who had a more negative experience was Participant 7. This can be seen from the comment that “Vinegar is seen as a cleaning agent in my family so I don’t like the smell” showing her distaste to the acidic smell of the reagent. This comment however was eclipsed by “3 completely different colours but fun! YAY!” and “Everything is linked! whaat” which shows that even though the smell and memory was unpleasant, the participant enjoyed the experience.

Further discussion in the interview about the comment above, Participant 7 highlighted the fact that during the experiment she remembered her high school home economics class, where they discussed the proteins of different foods, including milk, and the participant was pleased that this knowledge translated into the laboratory experiment. Thus Participant 7 saw the relevance in chemistry and how it is an integral part of life.

Participants were asked about their high school subjects and reasons as to why chemistry was or was not chosen as a subject in grade 10 (Appendix L, Table 5.1.2.6).

Four of the participants had taken science (Physics and Chemistry or Physical Science) as a subject in grade 10-12. Participant 5 commented that she “was convinced that physics would open more doors”, and coupled with Participant 4’s statement about “Also doing science opened more doors for you in future studies” sums up their reasons as to why the subject was chosen in high school. From this we can glean that science is chosen in high school not because of an enjoyment with the subject itself but rather the choice was made because they felt compelled to take it to further their careers. For instance, Participant 6 chose sciences in high school for “university exemption”.

A positive aspect came from Participant 8 when he stated:

“Chemistry was part of physics, as in it had to be done alongside physics. This and the way chemistry is portrayed by guests (who are chemists) on talk shows with all the interesting and really awesome things they show that can be done with chemistry” – Participant 8

This shows genuine interest within the subject itself, but also the influence of the media on how chemistry is portrayed.

Participants who did not choose chemistry or physical sciences at school did so through lack of interest or understanding of the subject.

Participant 2 stated:

“.... I didn't take chemistry because it didn't interest me and I don't feel like my brain is programmed that way”

A similar statement which came from Participant 3:

“I've always been more inclined towards subjects in the Humanities which involved a lot of speaking, writing and explaining, and had to work harder to understand more scientific subjects”

This need to only choose subjects in which we excel is a feature seen again by Participant 1 “I took them cause I was interested and did well in them” and Participant 6 “Comp Sci - cause im (sic) naturally gifted”.

From the notes made by the participants during the experimental procedure the chemistry perception of non-chemists is more negative than positive. There is anxiety, stress, and lack

of interest in the subject often due to reasons such as “went over my head and I didn't enjoy being forced to take a subject” by Participant 4, and “didn't interest me and I don't feel like my brain is programmed that way” by Participant 2.

However, the experimental procedure with milk paint was met with genuine enthusiasm and enjoyment with the overall comments being

“fun, a little messy (but that’s part of the fun)” – Participant 8

“Very pleasurable and enjoyable experience” – Participant 6

“3 completely different colours but fun! YAY!” – Participant 7.

As to the participant perspectives changing during the experiment, with the above comments and noting how the participants behaved during the laboratory process, a positive shift towards truly enjoying the chemistry aspects of the procedure was observed. The participants with little to no experience with chemistry could be seen getting involved in the phenomena under observation.

6.2 Art Analysis

Participants’ artworks were analysed using typical groups of elements and interrelations which illustrate and form semiotic systems. The analysis of these works looked at the form of line, shape, colour, and symbolism of icons used, as explained in the Research Methodology (Chapter 5). A summary of colours and what they represent is found in Appendix K, Table 2.1.1.

Analysis of both artworks of each participant was done before the interview with the participant in order to produce meanings independently from input by the participants. Interviews with selected participants provided their perspective of the artwork and what symbolism it held for them and is reported as such.

The following section discusses the art analysis accompanied by relevant interview triangulation details, showing that even through the complexity of semiotics of art, the information provided from this proved useful to the study.

6.2.1 Analysis of Participants' Artworks

6.2.1.1 Participant 1

6.2.1.1.1 Artwork 1:

Description—A4 Textured Sketch/paint paper; Multimedia (Pen and Permanent marker).
Landscape.

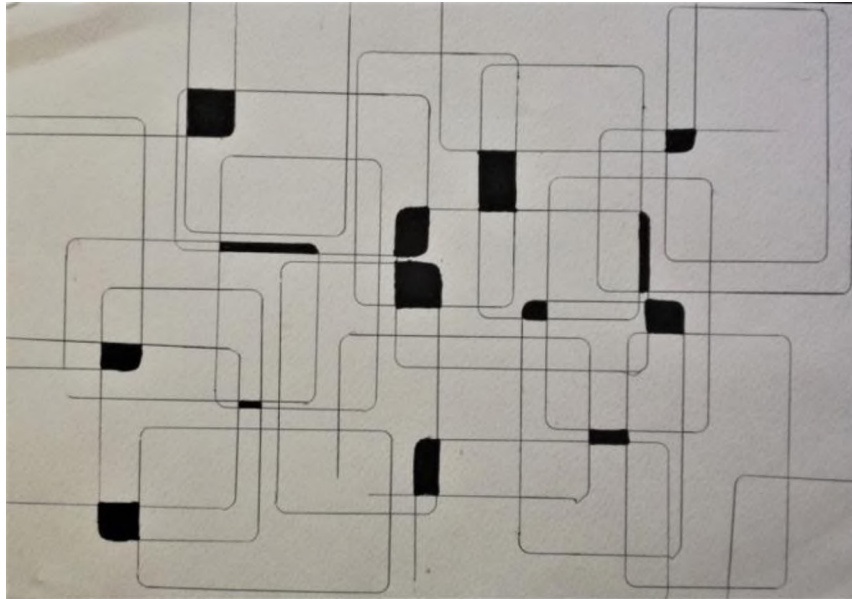


Figure 6.2.1.1.1 Participant 1, Artwork 1 Multimedia Landscape

The image is geometric with smooth cornered black pen ink rectangles overlaid with each other. 14 interlocking squares have been coloured in with black permanent marker. The artwork consists of only two dimensional shapes that lock together to promote the geometric illusion.

The artwork has a predominant feeling of confusion and sadness, seen through the participant's use of shape and colour. Although there might have been understanding in chemistry (geometric value of the painting suggests foundation) it does not show appreciation or interest. It has a very cold feeling that is accentuated by the vast spaces of white.

The only colour differentiation is that between the stark pitch black of the permanent marker and the lighter black of the pen ink (ballpoint pen).

Using black indicates the artist may think of chemistry as sophisticated and complex (black being made up of all colours) as black creates a sense of weight and seriousness and might reflect that chemistry has no room for creativity (Varley, 1983).

White adds to the coldness of the artwork and instills unfriendliness and elitism (Wright, 2016). The contrast between the black and white is not as stark as it could be, due to the texture of the paper, thus making the white not as strenuous to look at.

Squares and rectangles are stable forms and are familiar and trusted shapes suggesting honesty (Bradley, 2010b). They also represent order, rationality, and formality which was triangulated with her interview, stating that she “used permanent marker because I thought of chemistry as quite rigid and quite structured, permanent, you know it’s this way or the highway kind of thing. Quite complicated”. This is emphasized by the fact that she “used a credit card at that stage just because it’s got hard lines and it’s structured”.

The smudges outside the lines of the squares (the dark patches) were unintentional as permanent markers tend to leak in that way and drain into the paper. This too can be said for the fact that some of the squares are not complete with 4 squares not having a full pen ink boarder, although this adds to the frailty of the image.

6.2.1.1.2 Artwork 2:

Description— 24.5 x 18.4cm Thick Artist Sketch Paper (Textured); Multimedia (Permanent Marker, Watercolour Paint). Landscape

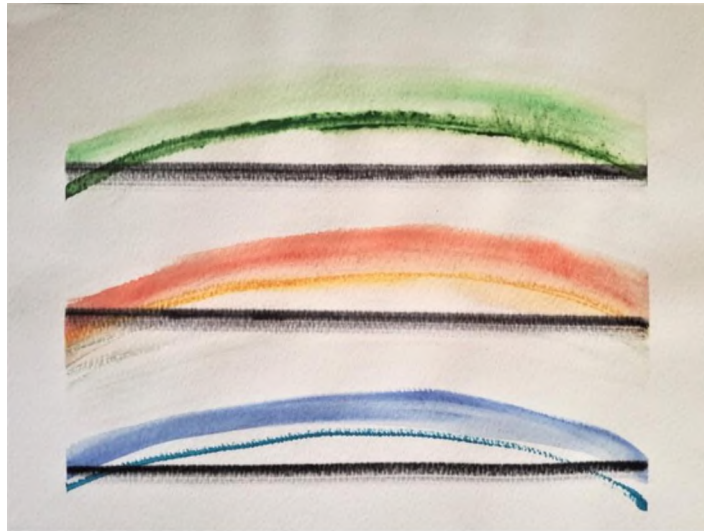


Figure 6.1.1.1.2 Participant 1, Artwork 2 Multimedia Landscape

The artwork consists only of lines. There are three horizontal black lines made with permanent marker (Artificial Line) and three rainbow lines of colour (Bottom to top: Purple & Blue; Orange & Red; Dark green & Light Green) of watercolour (Natural/FreeHand Line).

The black lines are all thick and frayed while some of the coloured lines are both thick and thin. Thick lines appear difficult to break and suggest strength (Bradley, 2010a); giving emphasis to the nearby curved rainbow lines (elements). The horizontal black lines suggest a calm and relaxed atmosphere (Bradley, 2010a). They accentuate width, again conveying absence of conflict or restful peace. By their connection to the horizon they are associated with earth bound ideas.

The black lines are parallel and stacked with a uniform width and spacing. This creates a feeling of static and the orderly. Even the curved lines, due to their repetition, create order even though they are more dynamic and show more movement.

Thin lines on the other hand appear to break and suggest frailty and convey an elegant quality (Bradley, 2010a). They produce a delicate and ephemeral quality to the painting.

The curved coloured lines express fluidity of movements and due to the less dynamic curve, produces a calmer feeling of the art.

Blue and purple in this artwork promote the positive ideas of serenity and coolness, a reflection of calm and trust (Varley, 1983).

Red, coupled with orange, suggests a warm, friendly energy. Its positioning between the purple and green curved lines promotes the idea of strength and energy as both purple and green are soothing colours that promote serenity and healing (Wright, 2016). Orange is the complementary colour to blue, while green is complementary to red. The arrangement of the lines allows for mutual complementation and thus the eye is first drawn to the red, before scanning the rest of the artwork (Varley, 1983).

These coloured lines situated on top of the black lines promotes the ideals that the colours represent. The colours are vibrant and playful and could mean a joy in the laboratory session, and found the chemistry behind the milk paint enjoyable and, being of paint, quite comforting.

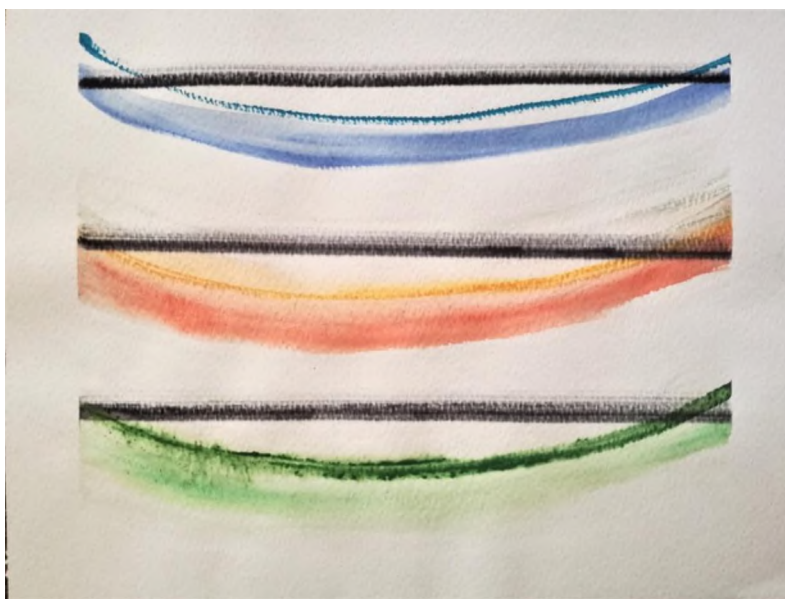


Figure 6.2.1.1.3 Artwork 2 corrected orientation

During the interview, Participant 1 revealed that the “rainbows”, when rotated 180°, in fact resembled the meniscus seen when looking at the fluid reagents through the glassware specifically when measuring the volume of vinegar. This shows the subjectivity of art; however, it does not detract from the positive picture of chemistry.

When asked about her artworks during the interview, Participant 1 commented:

“Art to me is a way of expressing myself and a lot of my artworks, everything is quite personal and has to do with me, my own life so it’s a way of expressing myself without having to say anything”

Her first artwork was geometrical with no colours. Although still abstract and ordered, the introduction of freehand lines and colour in the second artwork are all symbols of pleasure, delight, and maybe satisfaction. This shows a positive change in perspective and emotion towards chemistry.

Participant 1 was interviewed because her artworks were in such stark contrast with one another. Her use of line and shape are very expressive. This coupled with the fact that Participant 1 is currently studying a Bachelor of Fine Arts degree, are the reasons why the choice was made to interview her.

6.2.1.2 Participant 2

6.2.1.2.1 Artwork 1:

Description: A4 plain paper. Pencil and Coloured Pencils. Landscape

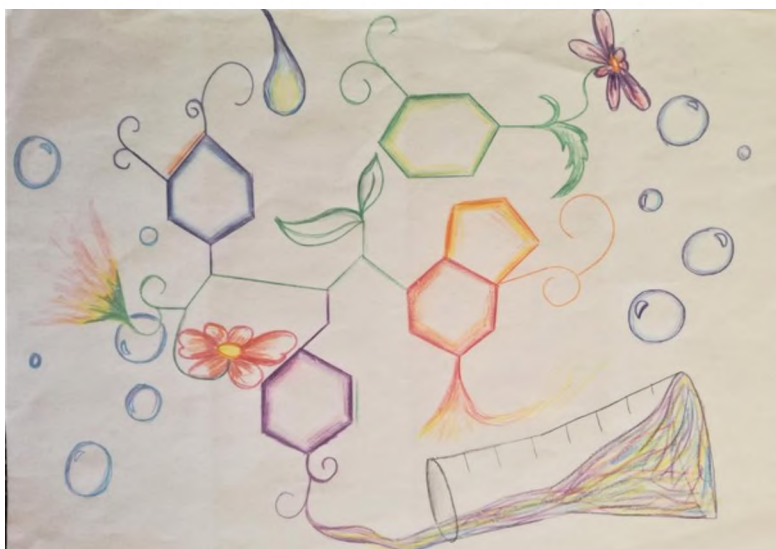


Figure 6.2.1.2.1 Participant 2, Artwork 1 Pencil and Coloured pencil Landscape

The art work contains various geometric (circles of the bubbles, hexagons and pentagons), and organic shapes (leaves, flowers, bubbles). These shapes vary in colour from orange, green, blue, purple, red, and yellow. The Erlenmeyer flask is on its side with the shapes and liquid flowing from it. The liquid is multi-coloured and flows into the geometric and organic shapes. All the flowers and leaves sprout from the lines between the geometric shapes with a small droplet in the right-hand margin dripping sideways, the participant stating that “the water droplet is just like another element adding to chemistry I suppose”. The bubbles float at the top and bottom of the geometric/organic chemical structure.

All the shapes and forms are shaded which gives them a glowing quality, drawing the eyes into the centre of the shapes. Similarly, the flowers and leaves are shaded to promote a three-dimensional quality.

The purple used here, a vibrant hue, presents qualities that are uplifting and calming both mind and nerves (G. Kress & Van Leeuwen, 2002). It offers encouragement to be creative and embodies the balance of stimulation by red and calming effect of blue (Varley, 1983). This colour is often linked with creative and eccentric personality types.

There are several spirals which indicate and express creativity. Spirals are found in the natural growth pattern of many organisms, and this suggests an evolution within the artwork. The spirals convey ideas of fertility, birth/death, expansion and transformation (Bradley, 2010b). Spirals move in either direction and represent returning to the same point in life's journey with new levels of understanding while maintaining flexibility through the transformation. The directions of the spirals have their own suggestions. Clockwise spirals indicate projection of an intention while counterclockwise spirals show the fulfillment of an intention (Bradley, 2010b).

Two of the flowers have typical daisy shapes while the other two are more symbolic of protea. However, a different interpretation could be one of explosions of colour. The suggestion here is that they are representations of flowers, with the protea flower attached to the "stem" of the drawing. The protea stands for change and transformation, signifying daring and resourcefulness and is symbolic of diversity and courage ("Flower Meaning," 2016). In her interview, the participant referred to the flowers stating that "The flowers represent like the nature and how chemistry occurs in nature".

The bubbles suggest a fleeting and fragile metaphor for life, while also bringing with it a uniquely beautiful quality. Once the bubble bursts it becomes part of the earth and air, and the greater whole. Bubbles represent hopes and dreams, providing a rare moment of magic, serving as reminders to appreciate charm and grace of the present moment (Streep, 2013). The soap bubble features in our language as both a symbol of that which should be approached (the joy of the bubble floating in air and reflecting unseen rainbows) and the dangers of hanging your happiness on something so ephemeral that it needs to be avoided (Streep, 2013). This representation suggests an evanescence in which the interest is seen – i.e. it is not a roaring passionate flame but is not in its own right an uninteresting subject matter.

The artwork has strong scientific depictions with the hexagonal shapes, referenced by the participant as "just thought that's what chemicals look like", the suggestion of biology in the symbols of life (flowers, water, and bubbles), and a strong chemistry representation via the upturned Erlenmeyer flask and colours used – "I don't know, I've always thought of

chemistry as creating random explosions of colour. Yes, that's why". The orientation of which suggests negative emotions such as anxiety, loss, and sadness. This sadness, however, is paled when considering the colours that were used, which suggest a happier emotional state.

The flowers in conjunction with the hexagons and Erlenmeyer flask suggest that chemistry is all around us. A centre of yellow, seen in one of the pentagons, is viewed as a happy emotion rather than one of sadness, which is strengthened by the lack of black colouration and thus no oppressive emotion.

She confirmed that the symbols used was representative of the chemistry processes, with the upturned Erlenmeyer flask being representative of "Creating a mess".

She then confirmed the statement as being from her own perspective, commenting:

"No I think that's just my own perspective. That's what I would like to do if I was doing chemistry; just make a bunch of weird things for fun"

In total the artwork, and the interview data, represents a positive outlook on chemistry with fleeting interest (the bubbles) and a colourful disposition. Although the lines and geometric shapes provide rigidity and order, referencing the sciences, the application of the natural and organic symbols suggests creativity within those bounds.

6.2.1.2.2 Artwork 2:

Description: A4 plain paper. Acrylic Paint. Landscape



Figure 6.2.1.2.2 Participant 2 Artwork 2 Acrylic paint Landscape

The second picture is very different from the participant's initial picture. Artwork 1 was pencil and coloured pencil with spaces of white and very geometric with a lot of abstract, organic, and geometric shapes. Artwork 2 has no real shapes, just the word "Science" written in red surrounded by colours in sequence – orange, yellow, light green, dark green, dark blue.

The word "science" was written in red, a powerful colour (Varley, 1983), which draws attention to the word. The letters are shaped, smooth and almost organic in script, the colour here is more representative of the positive emotions – strength, excitement. The colour is stimulating, lively, and friendly in its positioning and form. It is interesting to note that the colours go in the same sequence as the colours of the rainbow, and although missing the indigo and violet colours, the colours are vivid and bright. Rainbows are often seen in Judeo-Christian symbolism as positive symbols more of love and strength in your faith and vision, bringing fresh beginnings and new prosperity (Lee & Fraser, 2001), however to Participant 2 it means "That science is quite colourful and exciting and different and can be artistic as well as sciency".

The colours are aligned and drawn in the shape of a cloud similar to a cumulus cloud. Clouds have a variety of meanings, sharing much of its symbolism with water and air (its

components). Water usually symbolizes clarity and purity while air represents the mind, emotion, and intelligence. Together they can represent the idea of clear thinking and emotional purity (Weininger, 1998). It is also often seen as a symbol of mystery, potential, and dreams. Together with the word “science” this could be symbolic of Participant 2 enjoying the laboratory session and discovering some new way of looking at the world. Maybe she discovered that in this way she really could have a potential passion for chemistry if kept fun and exciting such as with the milk plastic paints.

“Science” as she has drawn it, could itself be a symbol representing an abstract idea – that of the broad knowledge base of “science”. One of the definitions of science is “archaic knowledge, especially that gained through experience” (“Science - definition of science by The Free Dictionary,” 2016), which is the focus of this study.

Phenomenology is “inquiry based on premise that reality consists of objects and events as they are perceived or understood in human consciousness and not of anything independent of human consciousness” (Gay & Kirkland, 2003) and “the science of phenomena as opposed to the science of being” (Sandi-Urena et al., 2011). The connection between science and phenomenology is simply knowledge gained through experience of events and objects as they are perceived by the individual.

This image is one of very positive outlook in the events of the lab session, with the participant’s use of colour and shape. Comparing the two artworks there has been an increase in interest and loss of the doubt that chemistry was undoable and oppressive, since the artworks shift from that of geometric shapes, and rigid structure, to one of flowing lines and vivid colours, and thus depicts this as a positive shift in perception.

Participant 2 was selected for the interview process due to her interesting representation of her perspectives about chemistry (Artwork 1), and change in perspective in Artwork 2 with her use of bold and vivid paints.

6.2.1.3 Participant 3

6.2.1.3.1 Artwork 1:

Description: A4 cardboard with no texture. Felt-tip or Koki Pen. Portrait



Figure 6.2.1.3.1 Participant 3 Artwork 1 Felt-tip Portrait

In this picture, there is only one image on the entire page – that of a girl with blonde hair with no legs shown, holding up a test tube in which a reaction is happening. She has a half-drawn speech bubble in which she says “**WHAT.IS.HAPPENING?!**” She has blue eyes and blonde hair, wearing a green shirt, with the reaction vessel being orange and red. She is Caucasian.

The figure occupies the positive space while the white space surrounding her is the negative space. The disproportionate amount of negative space to positive space accentuates the figure’s vulnerability and isolation (Getty, 2016).

The green of the shirt is vibrant and suggests stability and balance (Varley, 1983), while the text is dark blue (WHAT IS), its soothing qualities (Wright, 2016) diminished by the red (HAPPENING), which is commanding and draws attention. These qualities strengthen the idea that the reaction in the vial (also red in colour) is unfamiliar and powerful.

The image is in cartoon form as it is a stylized version of a recognizable person. The artist herself has blonde hair and blue eyes which could mean that this picture represents her own ideas of chemistry which, in conjunction with the speech bubble, are those of confusion and possible frustration as the letters are all capitals. What could also be an explanation is she likes to write in capitals as the letters are more pleasing to write and look more professional.

Cartoons are good at communicating ideals and theories (for instance Calvin and Hobbes and Garfield), and gain amplification through simplification (Krishnakumar, 2003). In this image a lot is conveyed, for instance the vial is held away from the body indicating that the figure does not know what is happening and it could be bad due to the vial being held far from the body, which is highlighted by the question mark and exclamation mark after the text. It is a safety precaution that is inherent to humanity. Holding something at arm's length is the first instinct when it is disgusting or dangerous. Her eyes are wide but not fearful and her lips are pursed in an expression that represents curiosity rather than disgust or fear (Carr & Lutjemeier, 2005). The eyes, although larger than possible (characteristic of a cartoon), are also curious and invoke a feeling of surprise. Cartoons have great appeal and their symbolism often targets taboo subjects with strong social commentary (Stevens, 2001).

The cartoon and its relation to chemistry can be seen in its totality. The figure is expressing concern and anxiety within the speech bubble while also portraying curiosity. With its bright colours of the test tube and shirt, sharp lines, and cartoon representation, the image is seen as generally positive through the vulnerability and isolation of the subject matter.

6.2.1.3.2 Artwork 2:

Description: 25.0 x 18.3 cm Diary Paper; Mixed media (Highlighter & Milk Paint).
Landscape

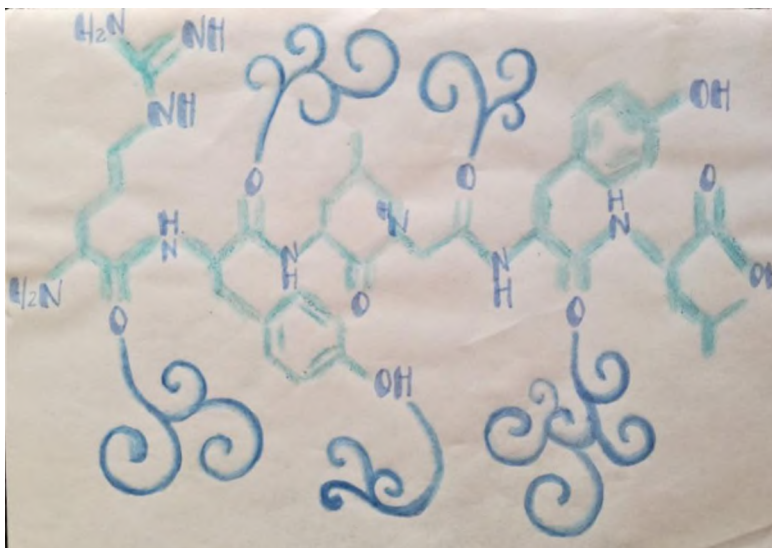


Figure 6.2.1.3.2 Participant 3 Artwork 2 Milk paint and Highlighter Landscape

The entire page is taken up by the chemical formula of Alpha-Casein (90-95) drawn with milk paint made in the laboratory session. The computer-generated image of the participant's chemical structure is shown below:

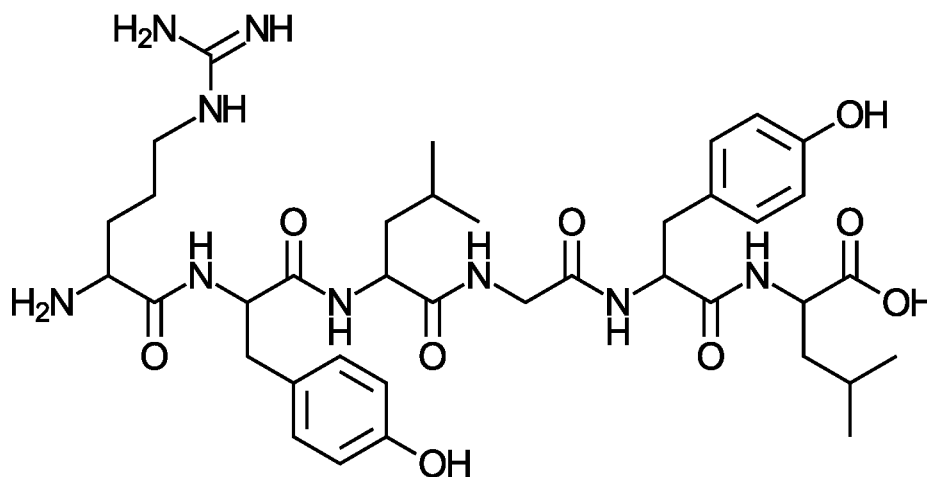


Figure 6.2.1.3.3: 2-[2-(2-{2-[2-(Arginylamino)-3-(p-hydroxyphenyl)propionylamino]-4-methylvalerylamino}acetylamino)-3-(p-hydroxyphenyl)propionylamino]-4-methylvaleric acid

During the experiment and procedure, no mention was made of the chemical structure of casein and it is thus inferred that the participant did her own research into the chemical structure of casein. This indicates that the participant enjoyed the experiment and went “the extra mile” and put effort into the artwork, with the inference being that if the participant had not enjoyed the experiment, she would not have done the research.

The oxygen, nitrogens, and hydrogen atoms are written in blue highlighter. Five oxygen atoms have spirals of blue milk paint extending into the free space of the paper.

Blue reduces stress and induces relaxation, with the paler the blue increasing our sense of freedom (Varley, 1983). This indicates that the participant was more relaxed creating her second artwork, and promotes the idea that this is a positive shift in perspective.

Most of the drawing of the chemical structure (the bonds) is of a paler blue than the spirals and the atoms. This pale or pastel blue is reduced in intensity creating an increased mood of sedation but also seriousness. The thick bond lines and spirals appear difficult to break and suggest strength and give emphasis to each other (Bradley, 2010a).

Spirals are expressions of creativity and the amount of various spirals promotes the feeling of activity and motion and can be seen as a representation of happiness in conjunction with the blue in which it was drawn (Bradley, 2010b).

From the participant’s first artwork, we see a shift in perspective, from not knowing “WHAT.IS.HAPPENING?!” with a multitude of colours, to a more symbolic representation of understanding. The second image promotes this by addition of the creative spirals, and the fact that the participant did research into the chemical structure of milk which had not been provided. One could possibly ascertain that, although of interest, the participant is happy not doing chemistry stating in her notes of the laboratory session:

“I’ve always been more inclined towards subjects in the Humanities which involved a lot of speaking, writing and explaining, and had to work harder to understand more scientific subjects”

The way the participant has used the space of the page in the second artwork also indicates a positive change in perspective when comparing it to the first artwork which has a

disproportionate amount of negative space to positive space symbolizing and accentuating vulnerability and isolation, while the second artwork fills the page provoking emotions of activity and accessibility.

6.2.1.4 Participant 4

6.2.1.4.1 Artwork 1:

Description: A4 Plain paper; Mixed Media (Colouring pencil and black pen). Portrait

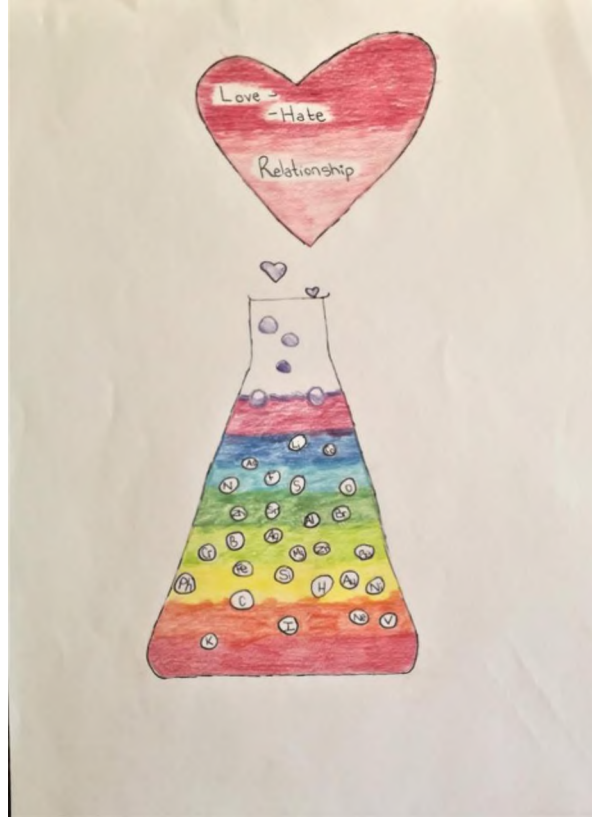


Figure 6.2.1.4.1 Participant 4 Artwork 1 Pencil and Pen Portrait

This artwork contains two large images. The first image is an Erlenmeyer flask filled with layers of rainbow colour and symbols of the elements of the periodic table in bubbles. The second image is a large heart floating above the opening of the flask in a gradient of pink to red with the words “Love-Hate Relationship” in black pen.

Although the images take up most of the paper, the free space or positive space is not taken up with any other colours or images and this promotes the idea of vulnerability and isolation, also reflected in the fragility of line used (Getty, 2016).

The heart symbol has many meanings, and not just that of love or affection. It can also mean cohesion, a mirroring or reflection, unity, and sensuality (Kemp, 2012). As a first

perception, this heart could be symbolic of great interest in chemistry (the pink-red colouring adds to this), and an attraction to the subject. The “love-hate relationship” could be that, although interesting and passionate, the hard work never paid off in good grades.

In the Erlenmeyer flask, iconic of chemistry, the colours are arranged in order from bottom to top: red, orange, yellow, light green, dark green, light blue, dark blue, pink, and purple. The representation of these colours possibly following along the same lines as a rainbow symbol (Lee & Fraser, 2001) with the participant showing creative license, can be viewed in a positive light.

The lines with which the heart and flask are drawn are both thin and sketchy indicating a fragile quality and could possibly reflect the participant’s hurt emotions in that she sees herself as a bad chemist or bad at chemistry.

The bubbles with symbols of the elements could be the participant’s representation of chemistry, and the fact that these bubbles are found within the fluid might show that this participant understands that everything is made up of chemical elements. The periodic table is a familiar image to most people and can be referenced as iconic in that all chemists seeing this will reference the periodic table. These bubbles are not arranged in any specific sequence and add a haphazard quality.

The fact that these elements appear as bubbles, something seen as whimsical and fun, could mean that the participant possibly enjoyed the inorganic part of chemistry, or the analytical side rather than the organic side. (The participant has done chemistry before as a first-year prerequisite for current course).

6.2.1.4.2 Artwork 2:

Description: A5 Plain Paper; Printed. Portrait

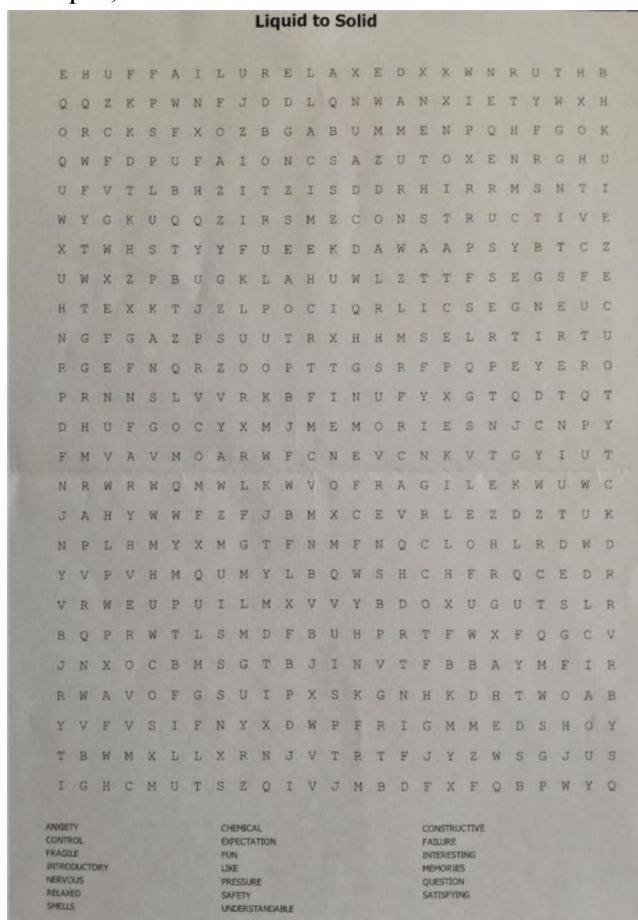


Figure 6.2.1.4.2 Participant 4 Artwork 2 Print Portrait

This participant's second artwork is a word search puzzle. It is entitled "Liquid to Solid" which in chemistry terms is freezing or solidification. This title, with respect to the assignment given, could mean that some anxiety was dispelled (when water freezes it becomes more ordered), however it was necessary to look at the words used in this game to establish if this is the case, or if this freezing is in fact the solidification of the disinterest in chemistry.

The puzzle was made online using PuzzleMaker by DiscoveryEducation.com (<http://puzzlemaker.discoveryeducation.com/WordSearchSetupForm.asp>) where a title and selected words are entered and the online program creates a word search puzzle.

By using this mechanism, the participant has referred to strict organization and control. As an artwork, it is analytical and structured. Words in black on white give a feeling of high formality and seriousness. There is a quantity of analytical or linguistic creativity, not in the way of traditional visual arts. Thus, we need to focus on the words used in context with the assignment “Depict your Emotions and Perceptions of the Chemistry Laboratory Session with Milk Paints”. As the focus is only the period of the laboratory session, the participants lived experience can be analysed by looking at the words and their positive or negative connotations (suggestive) and social meanings (positive; negative; neutral Table 6.2.1.4.2) as well as their denotations (Literal).

Table 6.2.1.4.2: List of words based on positive or negative connotations

Positive	Neutral	Negative
Constructive	Chemical	Anxiety
Fun	Control	Failure
Interesting	Expectation	Fragile
Like	Introductory	Nervous
Relaxed	Memories	Pressure
Safety	Question	
Satisfying	Smells	
Understandable		

By comparing quantity of the words used, the words with positive associations outweigh those of negative associations. These negative words such as anxiety, failure, and pressure are the driving force behind discontinuing an attempt at the sciences as seen with the participant’s comments during the laboratory experiment “ANXIETY→clinical” and “As part of my BSC chem was compulsory as an undergrad... didn't really enjoy it though, it went over my head and I didn't enjoy being forced to take a subject, it kind of killed the interest that I had in high school”.

Although there is some deliberation between the emotional qualities behind the words used, the artwork in total is positive, albeit analytical and static in form.

Comparing the two artworks, although there was no use of colour in the second artwork, this is a positive characteristic, as the participant felt more comfortable in creating the artwork. This comfort is established in the positive association with most of the words used and the strength of the organized word search. Thus, there is a positive shift in the emotional intention of the artwork, with the “love-hate relationship” depicted in the participant’s first artwork to the second artwork which is more familiar.

6.2.1.5 Participant 5

6.2.1.5.1 Artwork 1:

Description: 19.5 x 12.9cm Mixed Media (Paper, Pencil, Paint). Portrait



Figure 6.2.1.5.1 Participant 5 Artwork 1 Pencil and Paint Portrait

This artwork has been done on a page on which is a poem entitled “The Tiger” by William Blake, page 105 from “A Book of Poetry”.

The symbolism of the poem is evident: the tiger being evil or Satan, the lamb of goodness or God, the distant deeps representing Hell and the Skies reference Heaven. Of the two themes in the poem, The Mystery of Creation and Creator is more appropriate to the analysis and not the Existence of Evil (Cummings, 2003).

The relevance of the poem probably came from the fact that the participant felt like the creator, making a usable material from consumable products of milk and vinegar. Possibly feeling powerful and creative in such a respect made her think of the poem.

Drawn on the paper are symbols related to chemistry and physics: three connected benzene rings; the corner of a periodic table with symbols of elements, $E=mc^2$, H_2O , $C-C-O=$, as well as the symbol of the atom with electron paths. These can also be seen as icons of chemistry and physics as they are familiar to the general populous.

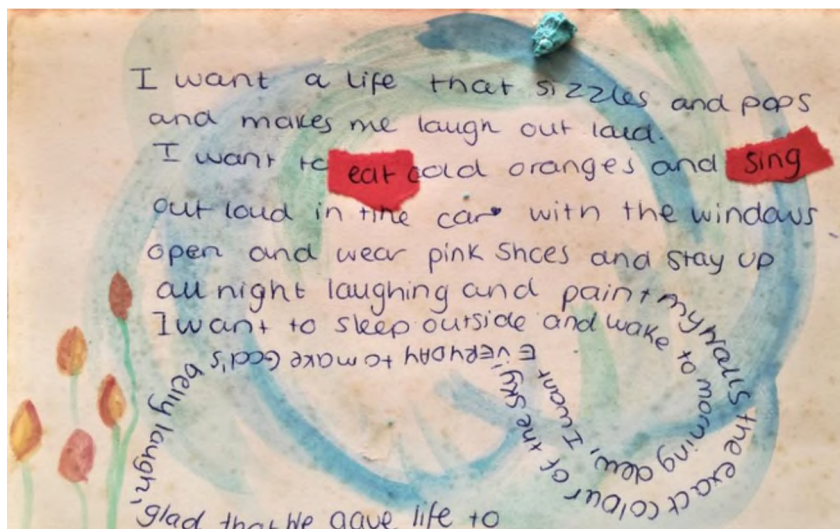
In this we can see the participant's perception of chemistry as that of analysis and structure and although Participant 5 did take sciences in high school - "English, Afrikaans, Mathematics, Biology, Drama (Physics & Chem till grade 11). I had to work hard in physics in High school" – the artwork indicates that the participant views chemistry as the creation of bad and good products, the tiger and the lamb. This ambiguous nature that the participant sees in the subject can be seen when looking at the extra notes she provided (Appendix M) which states:

"there is nothing quite like the feeling of balancing a chemical equations correctly or learning the family names in organic chemistry, however all the fun moments *Argon* when the stress of getting it wrong starts to kick in, trial and error trial and error...trial and error"

The participant's art form is one of words and linguistics, rather than pictures and colours, which reflect a personality of logic, reasoning, numbers, critical thinking, and language. The symbols and equations along the side are possibly the participant's attempts at being creative in a typical artistic manner.

A statement can be made about the participant's use of symbols, which could be seen as the way chemistry and physics are portrayed in social media. Kozma and Russell (1997) discuss the role that representations play in the understanding of chemistry, with emphasis on developing representational competence in chemistry students. They further state that "chemistry as a field of study is inherently representational or symbolic" and as chemists we make use of these representations to communicate (Kozma & Russell, 1997). An argument can be made that it is not the medium which influences learning but instead

certain attributes of media that can be modeled by learners and can shape the development of unique cognitive processes (Clark, 1994). It can be suggested here that the participant, being a non-chemist, would not know the symbol meanings of the atoms and equations ($E=mc^2$) and thus drew on media representations of chemistry. This could hint at the great influence that media has in its role in chemistry education.



Description: 19.5cm x 13.0cm Plain Paper Mixed Media (Milk Paint, Blue Ballpoint Pen, Paper, Water Paint). Landscape

and paint my walls the exact colour of the sky. I want to sleep outside and wake to morning dew, I want every day to make Gods belly laugh, glad that he gave life to someone who loves the gift.”

Neiquist’s words:

“I want a life that sizzles and pops and makes me laugh out loud.
And I don't want to get to the end, or to tomorrow, even, and realize that my life is a collection of meetings
and pop cans and errands and receipts and dirty dishes.
I want to eat cold tangerines and sing out loud in the car with the windows open and wear pink shoes and
stay up all night laughing and paint my walls the exact colour of the sky right now.
I want to sleep hard on clean white sheets and throw parties and eat ripe tomatoes and read books so good
they make me jump up and down, and I want my everyday to make God’s belly laugh, glad that he gave
life to someone who loves the gift.” – (Niequist, 2010, p.213)

The quote is written in traditional form from left to right except for the last 2 sentences. The words “and paint my walls the exact colour of the sky. I want to sleep outside and wake to morning dew, I want every day to make God’s belly laugh, glad that he gave life to someone who loves the gift”, twist and turn with the blue water paint beneath. It forces the reader to either read upside down or turn the page around a number of times. This style, often done in poetry, is termed “concrete”, “pattern”, or “shape poetry”. This type of poetry is an arrangement of linguistic elements in which the typographical effect is more important in conveying meaning than the verbal (Holcombe, 2015, unpagged) and relates more to the visual arts than to the linguistic arts as it considerably overlaps in the product it refers to (Lorimer, 2008). These poems break down language through materialist practices where the formal features of letters, words, the page, and even the book are important components of the poetic meaning (Borkent, 2012).

The way participant 5 has written the shape of her poem reflects her whimsy and joy. The shapes flow smoothly and look like the eye of a needle (my own subjective view). Suggesting that she enjoyed the flow of the words and how it appeared on paper.

In the script, there are 2 words that appear over torn red paper. They are “eat” and “sing”. They are important as the red paper draws our eyes to these two words. The indication is that these two words, in conjunction with the red, are positive and show courage, warmth

and excitement. The imagery of the poem is also one of positivity and excitement. She has shifted the focus to specific words which remove the possible contribution of semantic content. The meaningfulness of these visual cues; like the lines, figure ground effects, and texture; construct a visceral, perceptual, and affective meaning to the reader as well as to the poet/writer.

The use of the solid milk paint in the artwork also displays a certain whimsy in that it is in stark contrast with the rest of the artwork. This could show a need to make use of the paint she created in the laboratory. Possibly because that is what she thought was expected of her – to specifically use the paint created in the lab.

This could mean that she involved herself in the practical exercise she made the most of the session that was afforded to her.

The tan/brown of the paper is made by staining it with tea. Being a solid and reliable colour, most people find browns to be pleasant and supportive, unlike black which is often seen as suppressive (Caivano, 1998). Using tea to stain the paper creates a less glaring page to look upon, making reading more comfortable and less strenuous on the eyes.

The flowers have not yet bloomed and are red and orange in colour. They create an unobtrusive visual symbol of development and life's continual journey ("Chinese Symbolism of Plants - Chinese Customs," n.d.), and are strengthened by the blue spirals, which also indicates a journey or personal growth.

Between the two artworks there is a shift in perspective from strict logic and splattered attempts at creativity, to the swirling movement of the second poem and dynamic quality of the blue water colour swirls and orange flowers. This shift I believe to be positive, as it is also a shift from an expectation of the formality of chemistry and physics in the first artwork, to the phenomenon of chemistry as it can be used in art, seen in artwork 2. This can be substantiated when looking at Participant 5's notes on her experience, stating that "my expectations of science for the day were surely ignited with a new perspective on science".

6.2.1.6 Participant 6

6.2.1.6.1 Artwork 1:

Description: A4 plain paper Mixed Media – Black Ballpoint Pen, Highlighter. Landscape

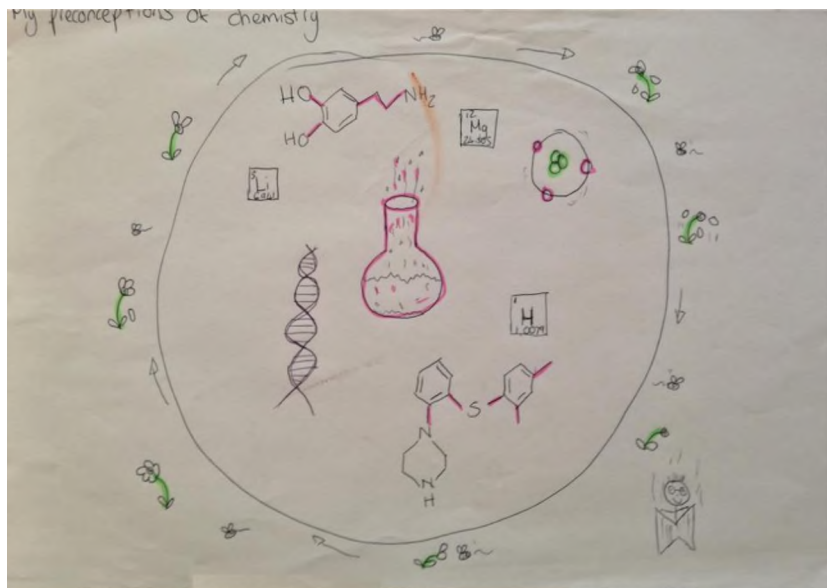


Figure 6.2.1.6.1 Participant 6 Artwork 1 Black pen and highlighter Landscape

The main component in the picture is a circle with flowers that grow and wilt, each accompanied by a bee. Inside the circle are several icons depicting science – a DNA strand; chemical symbols for magnesium, lithium, and hydrogen; an atom, and two molecules (Figure 6.2.1.6.1.1):

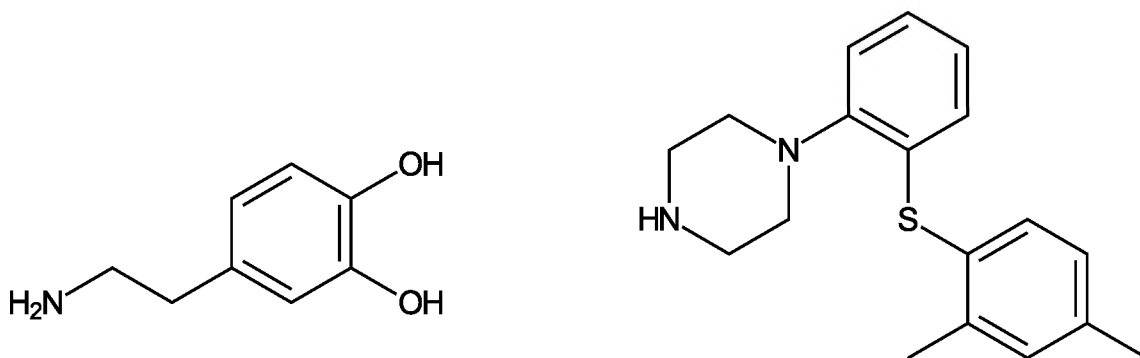


Figure 6.2.1.6.1.1: Left: 4-(2-aminoethyl)pyrocatechol or Dopamine, and Right: 1-[o-(2,4-xylylthio)phenyl]piperazine or Vortioxetine

The central figure inside the circle is a round bottomed flask that is bubbling with pink bubbles and spraying out the top. Other pink items are bonds, electrons, and the flask. The neutrons and stems of the flowers are green, and the DNA strand has blue (dark purple) pen on the main backbone of the DNA. There is a little figure in the bottom right corner of a man with glasses and a large book, the size of which could mean that the participant places a high value on education.

The shapes are predominantly organic and free flowing with the rigid shapes being that of the benzene ring, the square borders of the symbols of the elements, and the circles of the atoms (electrons, electron path, and neutrons).

There are several different shapes including geometric (circles and squares) as well as natural (flowers and bees) and abstract (the figure and book).

Geometric shapes are easily recognizable and this regularity suggests organization and efficiency. They suggest structure as well as the symmetry promoting order. In the image, we see the entire page taken up by a circle. Circles have no end and no beginning and suggest well roundedness and completeness, with the tighter the circle referencing anger (Table 2.1.2, Appendix K). Circles also promote the idea of confining what is inside and keeping things outside offering safety and restriction. They are also a symbol of harmony and femininity (Bradley, 2010b).

The natural shapes although irregular is more comforting and reinforce themes and add interest. The free form in which they are drawn suggest spontaneity (Munger, 2006). The following symbols are depicted:

- Bees protect their hive and queen for mutual benefit. Egyptians saw the bees as a symbol of wisdom and regeneration, industriousness and cooperation (Worrel, 2000). Used in this artwork, the bee is gathering honey from the flower. Regarding

the chemical symbols used, the honey could be the medication that the participant uses every day.

- The flower themselves look symbolic of a daisy which symbolizes innocence, patience and simplicity (“Symbolic Meaning in the Language of Flowers,” n.d.). However, in this depiction I believe it also is symbolic in conjunction with the bees of the cycle of growth and death, a depletion and renewal showing a cycle that is infinite, which is highlighted by the circle that dominates the page.
- The DNA strand means evolved life or human (Sonesson, 2007). However, the double helix (congruent geometric helices with the same axis) also means evolution and growth or journeying. DNA undergoes continual repair to the strands and this could enhance the idea of renewal and depletion, growth and infinity (Sebeok, Merrell, Stokoe, Jackendoff, Kress, Verschueren, Aitchison, Salkie, Harris, Coupland, & Jaworski, 2011) which again stresses the cyclic symbols found in the circle and flowers, .
- Atoms make up everything and could be a symbol of life. The “atomic whirl” has also been used as a symbol of atheism with the ideal “only through the use of scientific analysis and free, open inquiry can humankind reach out for a better life” (Whissel, 2016). It is also suggested that the atomic whirls are symbols for singleness, and a metaphor for individuality, power, and knowledge (Kling, 1996).

The abstract shapes have recognizable form but are not real (Bradley, 2010b). They symbolize and signify versions of organic shapes. The stick figure is considered an abstract shape symbolizing a person and the round bottom flask symbolizing chemistry or chemicals reacting together (the pink bubbles indicating a reaction). The flask itself could possibly be the focus of the image as all the other items behind it make sense if they are in the same vessel.

Dopamine is an organic compound that plays important roles in the brain and body. It functions as a neurotransmitter – a chemical released by neurons to send signals to other nerve cells. The brain includes several distinct dopamine pathways, one of which plays a major role in reward-motivated behavior (Creese, Burt, & Snyder, 2016).

Vortioxetine is an atypical antidepressant in the treatment of depression and anxiety working in conjunction with lithium and magnesium (Kanazawa, 1972). Keeping these inside the circle promotes the idea that the chemicals work together to continue the cycle of depletion and renewal as the medicines need to be taken daily.

Pink represents physical tranquility (possibly from the medicines) and ironically survival of the species. Negatively it represents inhibition and emotional claustrophobia, emasculation and physical weakness (Wright, 2016).

Green here is representational of refreshment and restoration (symbolism increases when introducing the images together that this happens with the medications). Negatively it represents boredom and stagnation (the circle continues and it is not as pleasant). It is at the centre of the spectrum and thus increases the idea of it being the colour of balance (Varley, 1983), a balance which the participant relies on.

All in all, the image is complex with all the separate pieces making up the whole in the continuous cycle of renewal and depletion. The fact that he uses bright colours indicates that he is optimistic about chemistry possibly realizing its importance in his life (psychiatric medications which need to be taken daily to have a sustainable life), an idea which is strengthened using flowers, bees, and chemistry symbols.

In this artwork chemistry is abstract molecules and atoms, but using medication, is useful and necessary. This artwork shows that chemistry is often perceived at a molecular level, and not one of phenomenological value.

This specific participant has not handed in a second artwork and thus we cannot assume a positive or negative shift in the experience. However, artwork 1 has been analysed. It is important to consider the prospect of how vastly different this participant has experienced chemistry from a medicinal/clinical point of view.

6.2.1.7 Participant 7

6.2.1.7.1 Artwork 1:

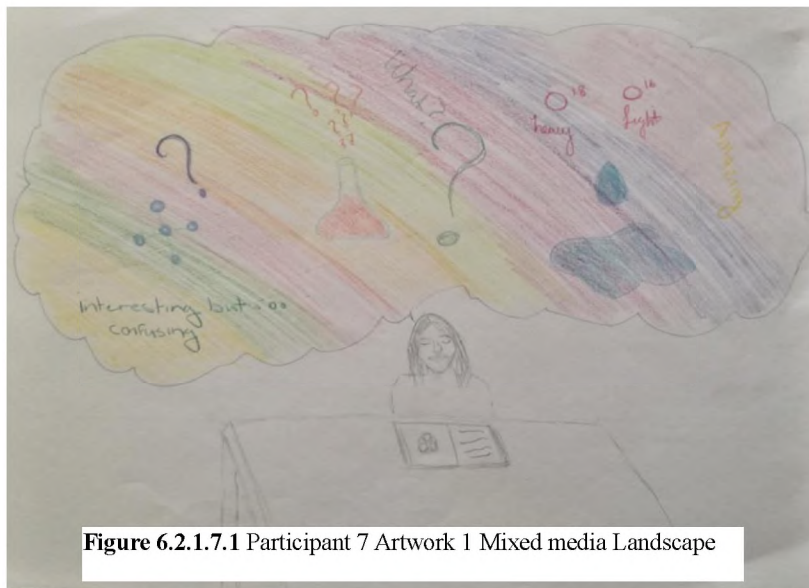


Figure 6.2.1.7.1 Participant 7 Artwork 1 Mixed media Landscape

Description: A4 Plain Paper; Mixed Media (Pencil and Colouring Pencil). Landscape

The art work depicts a girl sitting at a desk reading a book, and according to the participant in her interview is “a very bad attempt of me drawing me and sort of reading something on chemistry”. On the book, you can clearly see an atom depicted on the right-hand side page.

Above the girl’s head is a speech bubble or thought bubble (typical of cartoons) which the participant has filled with colours of the rainbow. These colours are lightly drawn in a pattern of yellow, green, red, green, yellow, red, dark blue, light blue (left to right). Within the speech rainbow are several icons of chemistry such as the round bottomed flask, the symbol for oxygen (18 and 16) with the words “heavy” and “light” written beneath respectively.

There are two free floating question marks with seven other question marks escaping from the round bottom flask. Beneath the oxygen is a drop of water/fluid that is collecting in a pool. The word “Amazing” is written vertically in yellow. In the middle of the bubble is the word “What?” written in grey pencil, while in the bottom left corner of the speech

bubble is written also in grey “Interesting but...confusing” above which are five atoms arranged in a square, and the other question mark already accounted for.

The speech bubble, full of colour and images, is the focus of the work and fills most of the page giving the impression that these thoughts are quite heavy and oppressive (even with all the colours that are symbolic of interest). The figure’s face suggests deep contemplation (her eyes are closed) with no emotion portrayed by her lips (i.e. her lips are not smiling yet are not turned down to suggest sadness). This could be symbolic of the fact that the participant has not yet decided if chemistry is good or bad and is ambivalent of chemistry – although her thoughts suggest otherwise.

The table is empty except for the book. This could mean the participant feels chemistry is pure theory with very little practical, real world applications. During the interview, Participant 7 commented,

“The table is really out of proportion because you know you’re in this learning environment and it can seem quite daunting and big and it might seem boring at the time, like at school I didn’t enjoy it I think because of the teacher so I also thought it was a bit boring. And then I didn’t colour myself in because I’m like thinking so I’m not focusing on myself. I’m in my head”

The lines that are drawn for the figure and table are very thin and sketchy (i.e. not drawn with one stroke but with many smaller strokes of the pencil). This gives an increased impression of fragility and uncertainty (Bradley, 2010a), in conjunction with the question marks and that statement “Interesting but... confusing”.

The entire artwork is drawn in this sketchy style which could be personal preference of the artist but could refer to her lack of confidence in the subject, which also increases her confusion. The colour of the speech bubble inside obscures several of the images that weren’t redrawn with darker pencils (e.g. the one question mark has been drawn several times over to make it darker and give it a presence within the speech bubble confusion) while the word “amazing”, “what?”, and the round bottomed flask are barely noticeable at a glance.

There are several areas where the colouring was not kept inside the lines indicating a rushed artwork which possibly matches the participant's unenthusiastic approach to chemistry. Although there might be interest deep down, the confusion is too great and this promotes the idea of lack of enthusiasm.

The rainbow colours used within the speech bubble are representative of the participant's overactive mind "the cloud here is like basically my brain and my mind running. That's why it's so colourful". The participant also stated that the colours were:

"My brain working and trying to figure out things and just sort of... You know I'm not one of these people that are, I'm very like all over the place, deurmekaar or I suppose more creative so that's why I did the colours as not very straightforward and analytical or step to step and so my mind bounces up and down and if you look at my workbook, my thesis workbook, I don't always just do readings and then write up. I do readings and then I do a poster and then I do this for all these different things"

During her interview, the participant stated, "This is so interesting, but like it all seems a bit confusing" in response to being asked about artwork 1. The idea that chemistry is of interest to the participant is strengthened when looking at "amazing" written in yellow. Yellow itself is a colour associated with positive emotions of confidence, friendliness, and creativity (Wright, 2016), and the word is further highlighted by it being written within the blue/purple background of the speech bubble.

Chemistry, for this participant, is confusing, but is also viewed on a molecular level of symbols and atoms, with the reaction flask being an iconic emblem of chemistry. This viewpoint is one that depicts chemistry as being far removed from the study of phenomena, but rather book or rote learning, strengthened by the confusion of the question marks.

6.2.1.7.2 Artwork 2:

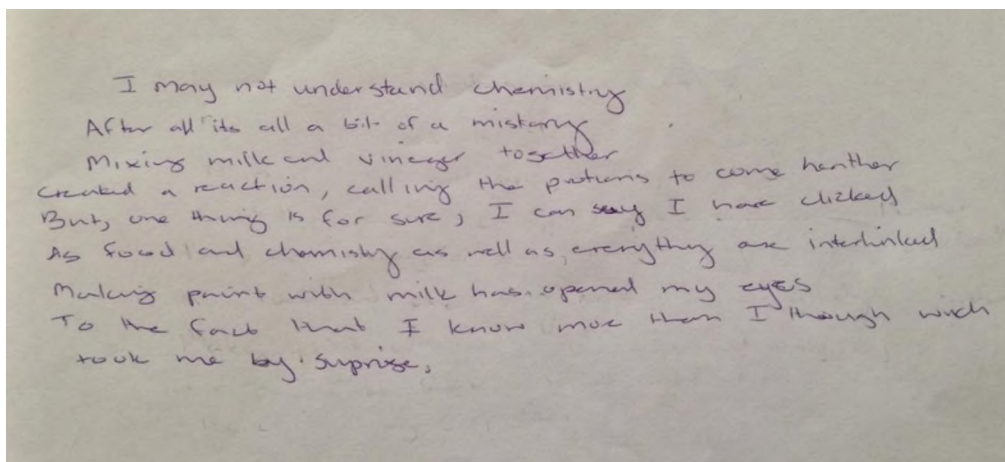


Figure 6.2.1.7.2 Participant 7 Artwork 2 Poem in blue ball point pen

Description: A4 Plain Paper and Blue Ball Point Pen. Landscape

The artwork is a poem created by the participant, entitled “A Chemical Experience” (The title is not written here, however I asked the participant for one separately, as the title often gives an indication of the topic and impact/impressions of the poem to come).

It reads:

I may not understand chemistry
After all it's all a bit of a mystery
Mixing milk and vinegar together
Created a reaction, calling the proteins to come heather(sic)
But, one thing is for sure, I can say I have clicked
As food and chemistry as well as everything are interlinked
Making paint with milk has opened my eyes
To the fact that I know more than I thought which
Took me by surprise

The title of the poem “A Chemical Experience” tells us the subject of the poem. It is describing an event, the experience of the participant in a chemistry situation, namely the laboratory session in which the participant participated.

The poem describes the participant's emotions as she experienced them, which are listed below:

1. The emotions behind chemistry "not understand chemistry" and "It's all a bit of a mystery" indicating her hesitation with the subject.
2. The actions of the participant "calling the proteins to come heather".
3. The participant's emotions during the session where the chemistry being studied was understood – "I can say I have clicked as food and chemistry as well as everything are interlinked".
4. The effect after the experiment – "Making paint with milk has opened my eyes" and the wonder therein.
5. The participant's delight in knowing "more than I thought" indicates the participant's amazement which "Took me by surprise".

Thus, the poem expresses the journey taken during the laboratory session. We move from not understanding or appreciating chemistry, through the lab experiment where the confusion changed to understanding, and finally enjoyment with the realization that the participant knew "more than I thought". The participant chose poetry because:

"I thought "No I don't want to draw something because that's not going to show what I experienced" so I was going to draw something, you know like an experience of my own like that one in first year. And then I sat there and I was like I don't know how to get what I was trying to say across through my artworks and then I was like "Well, I know I can get it through with poetry and that is seen as a form of art I suppose. So I decided to do that and I love poetry so I thought it would be nice to do something a little different"

The voice is a direct voice of the poet expressing thoughts and feelings, without the necessity for an answer. The words used in the poem, do not suggest negativity behind these thoughts and emotions (although it starts with negativity but then changes to positive), but rather a happy contemplation of the event – "I can say I have clicked" and "took me by surprise".

The poem is not organized with separate stanzas but rather the lines being connected via themes of physical and psychological, the pattern being psychological, psychological, physical, psychological, physical, physical, psychological, and psychological. It also

moves through two emotions – that of confusion which is replaced midway with understanding and surprise. The structure, although hand written (suggesting a more organic shape) is still structured as a traditional poem (in comparison to “I want a life that sizzles and pops” by participant 5 in which the last sentences flow in organic twists and turns).

The sound and rhythm of the poem is quite complex as it doesn't follow a set meter. This possibly indicated that the participant, although pleasantly surprised, still views chemistry as complicated. There is no definite rhyme scheme, however if stressed correctly words like “Chemistry” and “mystery” as well as “eyes” and “surprise” form a rudimentary rhyme.

The sound of the poem reinforces the idea of chemistry being complicated and not well understood by the participant (although the lab session there were moments of understanding) which adds to the confusion of the poet and the poets subject (i.e. the event).

The symbolism behind “Created a reaction, calling the proteins to come heather” is one of control. It appears the participant felt as if she understood the situation even through the mystery of what they were doing, which ultimately led to understanding and surprise at that understanding.

With the statement “As food and chemistry as well as everything are interlinked” we can see the essence of what the laboratory session was driving at, that chemistry and art are interlinked (here of course it is food and chemistry, however the symbolism is there).

Thus, the main idea of the poem is that the participant, although feeling overwhelmed by the chemistry and laboratory, enjoyed the experiment and felt it enlightening, increasing her own understanding of chemistry.

Participant 7 was interviewed based on the contrast in artworks from drawing to poetry, from unfamiliar to familiar.

We can see then the shift in perspective. In artwork 1, the confusion and overwhelmed sensation came from the use of colours and question marks, seeing chemistry on a purely

molecular level with the use of chemistry symbols and reaction flask. In artwork 2 we see the focus being one of the phenomenon about the experiment. The poem establishes her comfort as it is a medium she enjoys and can express herself in “I like poetry so I always...weirdly enough I’m not very good at English but I got poetry”.

6.2.1.8 Participant 8

6.2.1.8.1 Artwork 1:

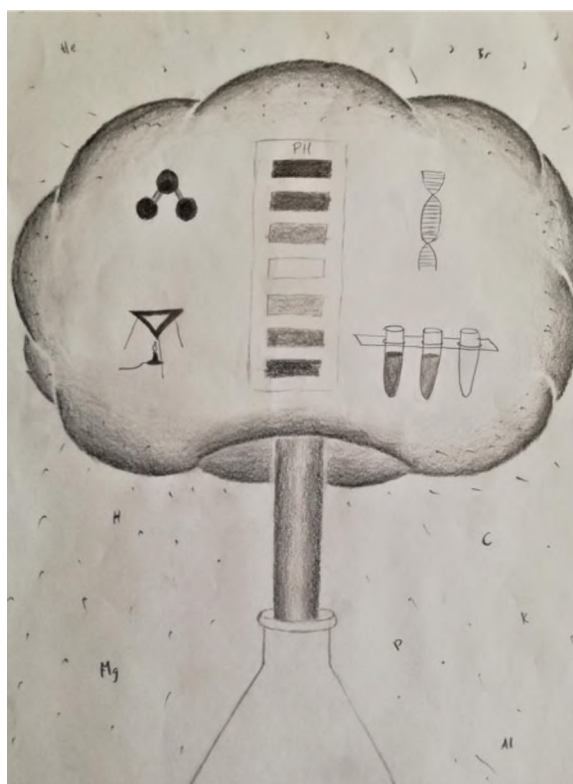


Figure 6.2.1.8.1 Participant 8 Artwork 1 Pencil Portrait

Description: A4 Plain Paper, Pencil. Portrait

In the image, we see an Erlenmeyer flask erupting into a mushroom cloud. The cloud is textured around the edges. Inside the cloud are five images, four of which are placed in the four quadrants of the cloud and the fifth being a central column. This shows a great deal of control and almost analytical precision – nothing is haphazard. This gives the image a hard, strict quality. The images are a Bunsen burner, pipette vials in a holder, a DNA strand, an

atom molecule in ball-and-chain/stick representation, and the central column is representational of a pH test strip.

Around the beaker and cloud are specks (of debris?), with chemical symbols scattered around the cloud (O, Mg, Al, P, K, C, H, He, Br).

The cloud is drawn spanning the width of the page, and with its darker more textured edges, it gives the impression of consuming the entire page. The negative space does not overwhelm this feature and thus the impression is not one of loneliness and isolation, but of a darker more brooding energy, the idea being that the symbol the image represents is vastly bigger than the scope of the participant.

The grey of the pencil (although well shaded and textured in the cloud) is symbolic of psychological neutrality, as it has no direct psychological properties. It is, however, suppressive, a virtual absence of colour which constitutes as depressing (Wright, 2016). When the world turns grey we are instinctively conditioned to draw in for hibernation to wait the more colourful times of the year. The other negative property of grey is that it is often linked with dampness and lack of confidence.

The lack of colour and high level of analytical formality in the image tells us that the participant is not thinking creatively about chemistry.

The most noticeable item in the artwork is the mushroom cloud jettisoning from the Erlenmeyer flask as the cloud is more detailed and defined showing more effort being placed on the cloud than on the background and flask. The mushroom cloud has passed through several iconic meanings in its time since the bombing of Hiroshima and Nagasaki. First it was linked to military triumph as it was released to the public in conjunction with Japan's surrender. Historian Paul Boyer stated that the cloud was "the quintessential visual symbol of the new era" (Melorose, Perroy, & Careas, 2015, p2 citing Paul Boyer). Through the years the mushroom cloud motif continued to surface in more diverse ways from a catalyst of fear, to the realms of nostalgia, to one of the leading symbols of anti-war protests (Melorose et al., 2015). The mushroom has been a symbol for transmutation – a symbol for the atomic age which stems from the "collective unconscious" (Melorose et al., 2015,

p.4). The symbolism in the participant's exploding mushroom cloud could be any of these, as the participant's own transmutation through high school and university, or taking a more nostalgic air to reminisce a subject the participant no longer pursues. In her laboratory analysis, she commented that she would "wonder what will cause the change and why it [reaction] did what it [reaction] did" (Participant 8, laboratory notes), this mentions the fascination that change has with the participant. It could be deemed that the transmutation through the participant's life is the correct portrayal.

The depiction of the mushroom cloud with the chemistry orientated icons within could mean a collection of ideas about chemistry, as all the icons used are symbolic of, or related to, chemistry "an explosion with various chemical instruments" (Participant 8, laboratory notes). This could also be the chemistry reactions leading to the explosions.

No direct cause of the mushroom cloud is shown; neither a chemical reaction nor a nuclear reaction.

The image thus gives the viewer both sides of chemistry – the good and the bad, which is highlighted with the participant's use of grey-scale tones. The neutrality of the image comes through as the negative quality of the mushroom cloud and its historic devastation, but inside are positive images of DNA and other chemical endeavours that were advantageous scientific endeavors.

The participant has written their own interpretation of the artwork which is transcribed below:

"My first artwork depicted an explosion with various chemical instruments. This drawing depicts my memories of chemists being on TV shows/talk shows. These chemists will come on and show something miraculous, leaving an impression of chemistry being fun and exciting" (Participant 8, own notes accompanying Artwork 1)

6.2.1.8.2 Artwork 2:



Figure 6.2.1.8.2 Participant 8 Artwork 2 Pencil and Milk Paint

Description: A4 plain paper. Pencil and Milk Paint. Portrait.

The artwork consists of two items of glassware, a measuring cylinder and a beaker, out of which coloured liquid is pouring. The liquid flows, in an interrupted stream, through the centre of a bi-layer lipid membrane, which could be representative of the filtration cloth used in the experiment, although. As it flows through the membrane the liquid changes colour. The cylinder liquid goes from dark grey to purple. The colour of the liquid flowing from the beaker changes from light purple to green. Under each pool of coloured liquid is a number – 100 for the purple and 22 for the green.

The vessels are textured and quite accurately drawn showing an acute eye for detail, and the participant's analytical side. The membrane is drawn freehand, and based on the

accuracy of the drawings of the vessels; the direction of the membranes is specifically chosen to be more organic in shape, moving freely.

It is unclear if there is any numeric meaning given to the numbers.

Purple is representative of awareness, even into the realms of spiritual values (Varley, 1983). It is highly introversive.

Green, on the other hand, is the colour of balance and harmony (Wright, 2016). The pool of green liquid is textured rather darkly, and this promotes a negative quality to the colour indicating stagnation or blandness. This is not a vibrant toxic green but more of a corrosive dark sludge green that seems to say, “corrosive on contact” although there is no indication that either of the pools is toxic in any way. The overall impression is that through chemistry there can be a change in the matter.

Comparing the participant’s previous art work, there is a shift in outlook, I am not sure if the change is positive or negative, as the green represents toxicity rather than life. Based on the fact that the participant used colour in the second art work, and not in the first, is representative of a positive shift in psychology.

The participant wrote their own interpretation of the artwork:

“Going through the experiments it is clear to see that chemistry is very precise, hence the scales. The mixing of the colour substance with the membrane causes it to change colour (the membrane is used because I heard “Membrane” in the experiment. This change begs the question “Why?”

From this it is clear to see that with this added memory, chemistry is not only exiting (sic) but also intriguing, satisfying (the changing of colour) and very deep. Looking at things on a minute scale really is interesting and filled with mystery, as well as rewarding” (Participant 8, own notes accompanying Artwork 2)

Comparing the participant’s two artworks and subsequent analysis provided, the artworks suggest genuine intrigue and enjoyment within the subject. There is a possible positive shift in perception with the use of colour within the second artwork. Based on all the information given, both artworks are positive within their own right, promoting a passionate view on sciences, specifically chemistry.

6.2.1.9 Participant 9

6.2.1.9.1 Artwork 1:

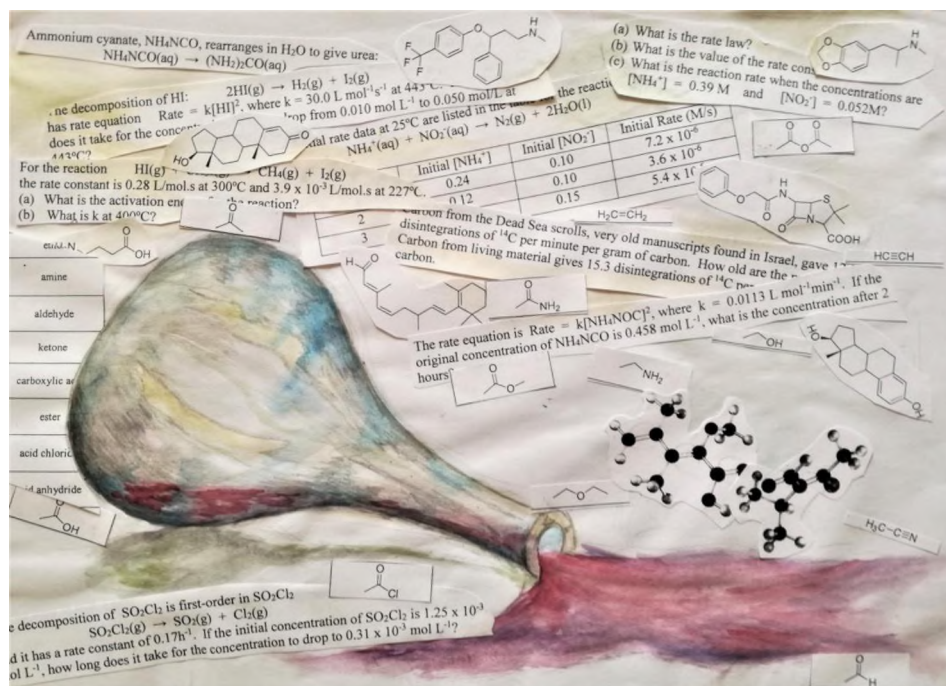


Figure 6.2.1.9.1 Participant 9 Artwork 1 Mixed Media Landscape

Description: A4 Plain paper. Collage and Water colour. Landscape

The artwork consists of a collage made from an old chemistry exam papers haphazardly organized on the A4 paper with a watercolour round bottom flask overlaid, painted in pastel colours. The flask has tipped and is spilling purple contents over the page.

The origins of the collage technique can be traced back hundreds of years; however its comeback in the early 20th century made its appearance as an art form of novelty (Vincent et al., 2002). It emphasizes the “concept and process over end product, collage has brought the incongruous into meaningful congress with the ordinary” (Jaffe, 2009, http://www.benjaminjaffe.net/home/collage_photo_montage accessed 2016-07-06). There are both negative and positive aspects in the medium of choice (collage) as the exam paper from which the pieces were cut had to be destroyed to make way for this participant’s

creative art piece. There is a sinister quality in the cutting and gluing of paper onto a sheet although it makes an interesting sight to see the chemistry questions and schematic molecules overlaid in an artwork. In talking to the participant during the laboratory session it was noted that first year university chemistry was the first time she had had any experience in the subject, as she had not taken it in high school. Participant 9 commented in her interview “so the feeling of working really hard and then still failing and like defeat I guess” in reference to this.

The harsh overlaying of the exam questions does not allow for easy reading, and the viewer cannot make out the questions or even some of the symbols. This can be seen as representative of the participant’s feeling of being overwhelmed with the subject. There is no path through the questions and no answers to any. One can almost feel the participant’s anxiety through this piece.

The overturned flask highlights this feeling of anxiety and adds another element of negativity. Participant 9 commented on her chemistry 1 laboratory experiences in her interview:

“well this built - what would you call it - solution I guess was representative of my lab days and how I don't know how I would get the answer at the end of my lab practical, but I did. But I always felt very chaotic and never felt like I knew exactly what I was doing. The painting had a beaker that had fallen over spilling a solution everywhere which happened a lot during my pracs. This also represents my anxiety over chemistry. The collage is made out of different exam papers and tests that I didn't do well in or failed. It represents how I would work hard but not achieve my goals, therefore I felt like tearing the paper apart”

It is a mistake to knock over something whether from being unaware of surroundings or on purpose. We can infer that for the participant it was a mistake to select chemistry. The spill oozing over the desk and being a mess that needs to be cleaned up. Comparing this flask to that of the other participants, there is high emphasis placed on its detail and depiction, suggesting and stressing the symbolism it represents further than the other participants’ artworks.

The juxtaposition of the very detailed flask in water colour with the highly analytical collaged chemistry questions shows how vastly contrasting the participant saw chemistry in relation to her own identity – the participant being the flask, an out of place ornament, in an uncreative laboratory, overwhelmed in a sea of unfamiliar chemistry.

The colour palette is consists of purples, blues, and beiges that all mesh together very well showing the participant's skill and creativity in art. The participant's emotions show through, and are confirmed by her statement about feeling:

“frantic and then it's kind of why the blues are in there as well because it's like sad or confusion. And then all of these are from my exams that I failed because I had so many exams that I failed and tests that I failed for chemistry. So this painting is quite negative but it's still my true representation of how I feel about chemistry”

If purple can be seen here as “deep contemplation”, and blue as seen as “coming from the mind”, then it can be deduced that the participant, although feeling anxious and overwhelmed with the science, possesses the mental capacity to understand and draw knowledge from the subject. However, the subject still eluded the participant. A possible cause is the way chemistry is taught in the traditional pedagogy which is probably not correct for this student who needs a creative outlet.

6.2.1.9.2 Artwork 2:

Description: A4 Plain Paper, Milk Paint and Pencil.



Figure 6.2.1.9.2 Participant 9 Milk-paint and Pencil Landscape

In this artwork, we see three pink and yellow flowers on a field of green grass. There is a purple butterfly to the right-hand side of the flowers, flying away from the flowers towards a yellow sun in the top right hand corner of the page. The background is awash with vibrant colours of blue, pink, and yellow.

The symbolism that this picture carries is beautiful. It should be noted that on handing in the artwork the participant made it clear that the focus of the artwork was not of the lived experience in the laboratory session, but rather the ideas and effect the session had post experiment, not during. Artwork 2 of this participant thus reflects the way the session influenced her afterwards, and does not truly reflect the events or the emotional response during the experiment.

At first glance this art work is quite child-like in appearance. This could be due to the possible difficulty in painting with the medium (as the milk paint had dried) (regarding the participant's previous art work, which was incredibly detailed). I say "child-like" because the flowers, butterfly, and sun are all painted in a highly-stylized way. The sun is just a wedge of yellow in a corner, the butterfly has only two wings, a body, and two legs, and

the flowers with the typical five leaf design and non-descript green leaves and green stems, are all typical of how a child would draw in preschool.

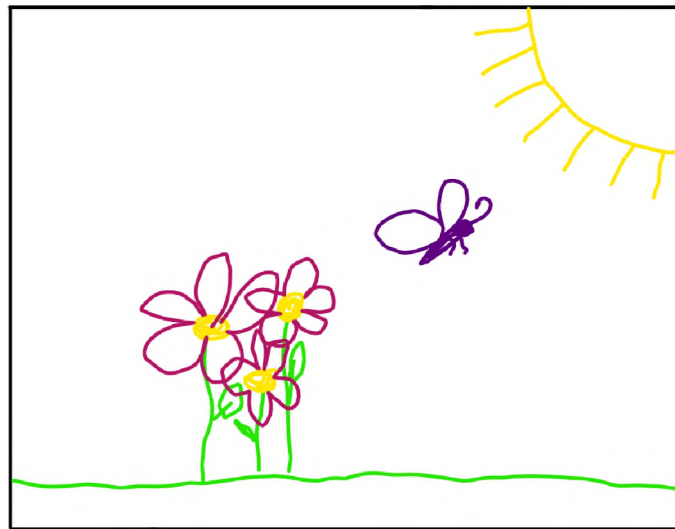


Figure 6.2.1.9.2.1 Researchers depiction of the child-like qualities depicted by Participant 9 Artwork 1

Another aspect relevant to the child-like appearance of this artwork is the use of vibrant, primary colours with little application of art principles like shading, texture, and dimension. As such the artwork carries with it a two-dimensional quality.

On closer inspection of the artwork we can see that on the stems there are 2 yellow lines. These could represent caterpillars that grow and change into the beautiful purple butterfly. This growth, due to the vibrancy of the colours chosen, is a positive self-depiction of the participant. The yellow lines could also be young flowers in bud as a metaphor for continual growth.

Flowers which are drawn in a daisy-like design, symbolizes innocence. Using pink for the petals is representative of compassion, nurturing, and love (Bradley, 2010a). A combination of red and white, pink contains the action of red for the potential of success and white, for insight. It is the passion and power of red softened by the purity and openness of white, and thus the deeper the pink the more passion and energy the colour exhibits. It also depicts unrealistic expectations, naivety, lack of will power, and self-worth (Wright, 2016). However, to the participant, the symbolism was simplistic:

“Yes - it's just the biology. And when I saw the paint colours that I had, the first thought that came to my head was actually just flowers because I liked the pinks and the purples and so that's why I just thought flowers”

This shows the subjectivity of art, and how complex systems of signs are to analyse and evaluate.

In cultural myth and law, the butterfly is a symbol of transformation (clearly seen with the caterpillars) because of its metamorphosis (Deonna, 2016). However, the variety of interpretations and meanings differ between countries, cultures, artistic periods, and civilizations. We can suggest that in this artwork, due to the colouration and general design, that the butterfly here represents the end goal in the participant's transformation from a caterpillar to butterfly. The inference is that the participant has had a challenging past (with chemistry, whether it was recent or a long time ago) but emerged in the splendour of a butterfly, which can be strengthened by her interview where she states:

“So it's like a work. Or a caterpillar turning into a butterfly and going onto the next stage of life. And I am... Yes, transformation. So it's about that - and also not being too clear and everything feels a little bit weird at the moment”

The second artwork could be seen as a change in the participant's idea about themselves or about chemistry (for which the art work was drawn). In this context, the butterfly cannot be seen as a negative omen, but rather the more creative, uniqueness that a butterfly represents.

Typically seen as a symbol of power, growth, health, passion, knowledge, the yellow sun is more importantly seen as a symbol of the cycle of life (Republic & Plato, 1944). It can also be seen as a representation of a higher self (Caivano, 1998). In this artwork, it could be that the participant used the sun as a “filler” image, however it does tie in with the representation and idea of the metamorphosis of the butterfly, in that it represents a cycle. In this instance, it can also be a positive symbol of growth and prosperity as it provides energy to sustain plant and agricultural life.

The colour yellow is the best colour to create enthusiasm for life, awakening greater confidence and optimism. It is seen as the optimist of colours, and is cheerful and confident, and adds to the positive emotional quality of the artwork (Wright, 2016).

The artwork has many positive symbols and characteristics. The colours and symbols can be seen as a positive attribute to the art work. The participant commented that “the painting was very ethereal and dream like... This is because I’m finishing my degree, becoming an adult and deciding what direction I want to go in life”

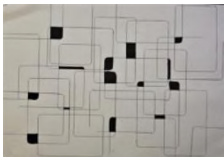
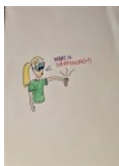
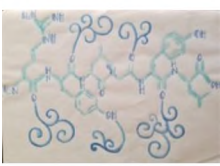
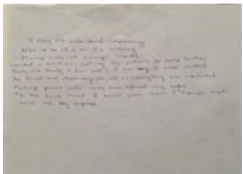
In the total sum of the artwork, from the first artwork with the confusion of the collage and tipped over vessel, to the brightly coloured and symbolic representation of the second artwork, it can be said that there was a positive shift in perception of chemistry of the participant, and a move away from the molecular representation of chemistry, to one that is focused on the phenomenon of personal growth and development within the subject’s context.

Participant 9 was chosen to be interviewed because her artworks were highly creative, artistic, and made use of symbols and visual metaphors that were intriguing. Another reason to interview her was because she had done chemistry in university and had had a negative experience, which fit in line with what the study is trying to accomplish.

6.2.2 Summary of Art Analysis

Table 6.2.2.1 shows all the participants’ initial artwork, depicting their preconceptions of chemistry, and their final artworks, depicting their lived experience through the laboratory experience. Artworks were examined using methods of Visual Semiotics and classical art analysis techniques, looking at the psychological implications of line, shape, and colour choice. The artworks showed varying changes of a positive shift in perspective and expressed favourable and enthusiastic experiences of the laboratory session.

Table 6.2.2.1 Summary of artworks depicting perceptions (Artwork 1) and lived experience (Artwork 2) of participants

Participant #	Artwork 1	Artwork 2
1 – From negative black and strict geometric lines to colourful and organic lines (Positive Shift)		
2 – Strict geometry, spilled Erlenmeyer flask and surrealist style to rainbow colours and a passionate “SCIENCE” framed by it (Positive Shift)		
3 – Negative space and isolated anxiety and confusion to calming blues, researched material, and organic spirals (Positive shift)		
4 – Love – Hate relationship, fragile lines compared with structure, positive associated words outweighing the negative. (Positive shift)		
5 – Poem depicting Good vs. Evil, rushed attempts at chemistry symbols, compared with organic flowing poem depicting enjoyment in life, more colourful and creative. (Positive shift)		
6 – No comparison. Cycle of renewal and depletion, with the dependence on the medication, references a positive perspective about chemistry		
7 – From confusion and anxiety in the artwork, to relaxed (Poem as preferred medium of expression) and clear indications of understanding and appreciation (Positive Shift)		

8 – Devastation of mushroom with scientific achievements to transformation and enjoyment (slight Positive shift)		
9 – Anxiety, loss, sadness, and failure to colourful imagery of transformation and growth (Positive shift)		

Reevaluating the artworks produced some interesting aspects common throughout the participants. Several artworks contained upturned flasks, symbols of elements, molecules, and atoms. These symbols can be seen as representative of the focus of chemistry being at a molecular level. The initial artwork of the participants seems to focus around the idea that chemistry is of disinterest and of high anxiety and stress, which can.

The second artworks of the majority of the participants focused on the phenomenon of the experiment, and show the shift in perspective when compared to their initial artwork. This phenomenological focus can be seen with participants selecting to represent their art in the style that is preferred, such as Participant 4 with her word search, Participant 7 who expresses herself more eloquently with poetry, and Participant 5 who showed creativity and application of shape poetry which moved away from the mere copying of a poem to enforcing her own twists and turns of the poem. All the artworks, thus, show that the participants experienced, in some measure, a positive shift in their perspectives of chemistry, through the phenomenology of paint created from milk.

6.3 Interviews

In this section, the interviews of participants 1, 2, 7, and 9 are discussed using a semi-structured interview method which allows for reflective discussion about the phenomena for both the interviewee and interviewer. Interviews of the selected participants were of a

conversational nature and lasted anywhere between 45 to 80 minutes. The interviews were conducted in an informal setting to create a more natural environment free of anxiety. This allowed for the construction of several relevant questions (Appendix D), and provided the freedom to follow the conversational twists and turns and accommodate unanticipated discussion about the laboratory session, their artworks, and history pertaining to chemistry (Vincent et al., 2002).

6.3.1 Theme creation and processing

The interview is considered as an important method for data collection as it provides a situation where participant's descriptions can be explored and the data gathered (Wimpenny & Gass, 2000). Interviews were transcribed with an external transcriber, but before analysis, the transcribed interviews were checked and validated by each participant, to ensure reliability of the transcription.

Processing this data was done using a network feature in ATLAS ti.7 which allowed for the researcher to link codes together and form a cohesive mapping of the codes and quotes with that of its neighbours to create the themes.

Four themes were established:

1. Perspectives

This theme is in correlation with the research questions and thus was coded as a topic theme. The participants' perspectives are either negative or positive in relation to chemistry. This theme also contains a sub-theme of perspective change, which incorporates data from the participant artworks.

2. Influence

This topic looked at the pressure participants experience around subject choices in high school and university, and what essentially forced the participants into their respected fields of focus. These influences could be internal such as the participant being disinterested in the subject or external with pressure coming from parents, peers, or prerequisites for a degree.

3. Emotions

The theme was generated by looking at the emotions that were because of the practical, often also seen in participant artworks.

4. Applicability

The question “Did you find the experiment applicable to yourself and others?” generated information around this theme.

6.3.1.1 Perspective

This theme deals with participant perspective on the subject of chemistry and/or chemistry education. “Perspective” defines the “state of one’s ideas” or “a mental view or prospect” (“Dictionary.com ‘perspective,’” 2016, unpagged). The participants’ perspectives and their individual ways of regarding situations, judging for them the relative importance of the subject can assist in highlighting the various ways chemistry is viewed by non-chemists. These views can either be positive or negative, with the theme analysis investigating what these perspectives are.

The implication of the theme is that the positive perspectives of the participants should be built upon and used in chemistry education to facilitate better understanding and enjoyment of the subject, while the negative perspectives and their reasoning’s should be minimized as they counter the positive learning environment. The need to simulate chemistry education that is relevant to the new knowledge society is recognized (King, 2012). The concern is that present pedagogical approaches are not motivating students to enter or continue with studies in chemistry (King, 2012).

The theme “perspective” tries to suggest answers to my research questions:

1. What are the perceptions of chemistry held by Rhodes University students who do not study chemistry?
2. What is the experience during the practical?
3. Do participant perspectives change during the experience?

6.3.1.1.1 Perspectives of non-chemists

To initiate the study of the perspectives of non-chemists, it was crucial to gain the participants initial perspective to evaluate if Kitchen Chemistry, used in the synthesis of milk paint, through the participants' experience (6.3.1.1.2) within a laboratory setting could elicit a perspective change (6.3.1.1.3).

Participant's initial perspectives are generally negative, which can be seen in a comment made by Participant 2 "That it was very rigid and calculating I suppose. And not very fun".

Participant 2's mental image of what a chemist should be is one of "crazy hair. Glasses, lab coat". A comment during the interview of Participant 9 states that "When I think about chemistry I think of fancy machines that measure atoms and energy etc..."

These views are negative and result in disinterested students who then select subjects which they find more interesting or easier (Table 5.1.2.6), which add value to the participants' life.

A comment by Participant 9 shows the stigma that chemistry is only for a select few:

"I always thought that people who did chemistry were really clever and I still think that. I feel like I did it but I still don't understand so much. Like I did it to pass. I don't know what else I feel about it"

And when prompted for further details:

"I think it's because I find it so hard so when people understand I'm like wow - you're so clever. The stigma attached to science and chemistry in particular that all the smart kids do science... In first year if you met someone who was continuing to chem 201 you would immediately think they were super clever"

This reinstates the idea that chemistry is viewed as being clinical and analytical, subject to those few deemed clever enough to understand the complexity of the subject, which often dissuades students from pursuing studies in the field. This idea is confirmed by Participant 7 who states:

“I think it was just like the elements and stuff was very overwhelming like doing the molecule thing and it was just very overwhelming and confusing and no one really explained it properly that’s probably why [lost enjoyment of chemistry]”

The comment also shows the idea that chemistry as a subject is chosen by individuals who don’t get overwhelmed with abstract concepts of molecules at the “molecular explanatory level” (Taber, 2013, p.156). The sub-microscopic explanations of chemistry are a concern when teaching the subject as they make demands of the learners to accept the existence of minute theoretical entities, and then learn to use them as tools in building explanations, which is advanced cognitive work (Taber, 2013).

For this reason, amongst others, chemistry possesses a negative initial perspective. These negative perspectives can be seen in Artwork 1 of the participants which encapsulate Participant 2’s comment of “rigid and calculating”.

6.3.1.1.2 Experience during the practical

Participants were asked to give a description of the practical to evaluate their experience.

Participant 2 commented:

“Well we obviously made paint using the different steps that you told us to and I found that really cool. It was really interesting to see how one element can turn into another by just adding things together and how you can create something from a bunch of different ingredients. I found it really fun - it was interesting. I like creating things”

She commented about her emotions that were “definitely more positive and I found it a lot more free flowing then I thought it would be” and “excited and...I don't know. I didn't really know what to expect so I guess I was interested to see what was going to happen - what we were doing”

This is in response to the unorthodox way of teaching the participants not only to create paint from milk but also establishing and teaching the chemistry behind the process.

This process was important to participant 7. I asked the question “what was the most striking part [of the laboratory session] for you?” and she commented:

“I think realising that I actually knew what was going on without having to have a chemistry background, like a classic chemistry background per se and that was cool”

This also provides comment on the applicability of the teaching method (briefly discussed in 6.3.1.4 Applicability to Chemistry Education) and reaffirms the idea that accomplishment within a given field facilitates learning and enjoyment of the subject.

The phenomenological process of the synthesis of milk paint is seen as a positive experience by the participants, which can be seen through participant notes during the laboratory experiment as well as within participant artworks which reflects similar ideas to that of Participant 9:

“Well in a way I wouldn't think that making paint out of milk was like a form of chemistry, but now thinking about it - it is. So maybe this changes what I think chemistry is”

6.3.1.1.3 Perspective change

Participant perspective change is the essential aim of the research. The idea being that the deep rooted often negative perspectives of non-chemists could be changed using a more applicable chemistry education method. This change in perspective can be seen with all the participant interviews, seen in the comments listed below:

“I think they're [Art and Chemistry subjects] very different, but I think after this experiment I saw that they could connect and places where they could overlap. Yes, I think you could be very creative with chemistry and do a lot of artistic things with it” – Participant 1

“That science is quite colourful and exciting and different and can be artistic as well as sciency”
“No it definitely has. It made me realise that you can apply it to a much broader range of subjects than just the hectic scientific stuff. So it's quite cool” – Participant 2

“Yes, I think it’s made me not fear in the idea of chemistry and maybe being open to one day learning more about chemistry. Maybe at my own pace though”

“Basically I’m feeling less fearful about it and more open to the idea of learning and actually it probably sparked a little bit of excitement for me, and now I’m interested”

“it’s not so daunting, it’s not this big grey cloud like coming” – Participant 7

“Well in a way I wouldn’t think that making paint out of milk was like a form of chemistry, but now thinking about it - it is. So maybe this changes what I think chemistry is” – Participant 9

The idea that chemistry is only for the clever students, only for the analytical, and is uncreative and inapplicable to everyday life is an idea that during this research has been shown can be changed if taught in a way that promotes creativity and understanding.

This change in perspective did not come about by merely making chemistry more fun, but also through introducing the participants into the environment of a chemist. Wearing the laboratory coats and goggles, understanding the safety elements, and appreciating the experiment for what it was, and not purely for the ideas and educational aspects of the experiment. It was also facilitated by the phenomenological aspect of focusing on the casein paint (phenomena) that was in itself familiar to the participants and could thus be related to their past and current endeavours.

“Especially with people who are intimidated by it. Because I think I found chemistry quite intimidating. And now not so much”. – Participant 2

The participant’s perspective change is evident within their artworks (Section 6.2) which can be seen in the change in subject matter and their use of colour and line.

6.3.1.2 Influence

In this theme, influences in the subject choice of the participants will be investigated. These influences range from that of external pressure of parents and friends, to self-imposed internal pressure. 6.3.1.2, although not facilitated within the research questions, is added here as it was an interesting observation that came out as a result of the data.

The initial perspectives of participants are often formed at school and have a large impact in subject choices and ultimately career development. All participants interviewed were asked about their subject choices in high school and to provide comments on the decision to take or not to take chemistry as a subject.

Participant 1, when asked if there was any interest in chemistry in high school stated that “No, it was all confusing to me and I never understood it” and further stated that “I think it was just my own brain going no... This isn’t for me, I’m meant to be doing art right now”.

While it is true that Participant 1’s focus or interest lies within the visual art realm, the factor of decision was based around the fact that the science subject was difficult to understand, and looking at Participant 7’s comment, we can see a clear avoidance of the subject entirely:

“I did a BA to avoid chemistry on purpose. Because I just thought no, I’ve heard you know I’ve heard stories like Chemistry 101 is the most failed subject blah blah blah so I didn’t want to risk it because my dad has this rule that if you fail, you pay for the next year”

These statements provide the suggestion that science education is only applicable to a select few who enjoy the traditional methods of teaching the subject, making it difficult to study for those who do not think in the ways a typical scientist would.

Participant 1 had several comments pertaining to the pressure she felt during high school regarding subject choice: “what do your parents think about art and science?”

“Actually all through high school my parents didn’t really agree with art. Well they didn’t mind me taking it but they wouldn’t... I don’t know they didn’t agree with me taking it after university...I don’t know, they just thought that there was no career in it I think”

This illustrates parental pressure in the career choice of the participant. There is a stigma attached to the sciences and art alike, for students being perpetual academics, and the fear associated being that that career choice is unsupportive for the working individual (Fu, Fitzpatrick, Connors, Clay, Toombs, Busby, & O’Driscoll, 2015). A statement made by Participant 1, who says that “they [parents] just thought that there was no career in it [art]

I think”. This follows along the traditional lines of achieving a career that can support the individual in their endeavour to start their own family.

Participant 1 answered the questions “What do they [parents] think of sciences?” and “which subject choices did they [parents] push you to go into?” by stating:

“It was more biology and...my parents, they’ve never been to varsity and they’ve never really done...I think they both went to tech and they both did practical” ... “Yes, I think that’s definitely influenced me. My parents are both very practical”

A similar statement is made by Participant 7:

“My dad really wanted me to [study science] but it’s my life so he was like you choose. He was really upset when I wasn’t doing science”

Interviewer: “Why was your dad so upset?”

“I think because he just did science and physics and found it very interesting and he loves that kind of stuff. And I think he just wanted us to experience the joy that he had with it”

These comments show that parents try to influence their children as to what direction to follow, often with the intention to be caring and, in their eyes, supportive. However, they did allow their children to follow their interests.

Another influencing factor is the idea that the measure of expectation is concerned with hopes for favourable outcomes rather than with their sense of personal mastery (Bandura, 1977). This can be seen with several of the participants (Table 5.1.2.6), particularly Participant 1 who states, “I never chose chemistry because I always felt I’d never be able to understand it or excel in it”.

Bandura (1997) says that:

“People will explore, and try to manage situations within their perceived capabilities, but unless they are externally coerced, they avoid transactions with those aspects of their environment that they perceive exceeds their coping abilities” (Bandura, 2010)

We can thus assume that to make sciences more attractive to students, there needs to be an environment where students do not perceive the anxiety and stress of the subject.

There needs to be an attempt made to change the perception of science studies from one that exceeds students' abilities to one of capability.

Teachers of science have a large role to play in these perceptions. When asked the question "What did you not enjoy about chemistry?" Participant 7 stated:

"I think it was just like the elements and stuff was very overwhelming like doing the molecule thing and it was just very overwhelming and confusing and no one really explained it properly that's probably why"

Interviewer: "So your teacher, was she really good or...?"

"The one we had, no. But you know there were quite a few of them so if I had maybe a different teacher..."

This statement applies across all the subjects. It shows the large influence teachers have within the academic environment. The inference being that teachers should work hard to make their subject understandable for each individual, which in itself is complicated and difficult. A note can be made on the constructivist view of learning, which suggests that learners construct knowledge out of their experiences (Armezzani & Chiari, 2014). The suggestion is to teach the same subject in a multitude of ways, and thus make it applicable to a broader audience. This is even more apparent when considering participant 9's comment:

"The lecturers would teach organic chem expecting the students to have a background in it, which most did, but it made it harder to understand the course"

This participant had not taken physical science at high school, but due to prerequisites had to complete the chemistry 101 and 102 university courses to be able to study her field of interest.

This sections shows the extent of the influence of teachers, parents, and self-imposed internal pressures have on the perceptions of the participants, which often lead to a negative portrayal of chemistry and the sciences.

6.3.1.3 Emotions

Some scientists recognise the importance of grounding science in experience and emotions. Orr (1992) states:

“[Descartes’] philosophy separated humans from the natural world, stripped nature of its intrinsic value, and segregated mind from body. Descartes was at heart an engineer, and his legacy to the environment of our time is the cold passion to remake the world as if we were merely remodelling a machine.... A growing number of scientists now believe, with Stephen Jay Gould, that “we cannot win this battle to save [objectively measurable] species and environments without forging an [entirely subjective] emotional bond between ourselves and nature as well—for we will not fight to save what we do not love” (Buxton, 2007, p. 1251, citing Orr 1992 citing "Enchanting Evening", Natural History, Sept. 1991)

The emotions of participants are initially negative, which can be seen by Participant 7 who comments:

I think that was also one of the fears is that they do it in such a way that I just have so many questions. And you know at school, it was a very competitive school so like if you had a question that sounds stupid you don't dare ask it because they going to criticise you” – participant 7

However, these negative emotions were subject to change using Kitchen Chemistry in the synthesis of milk paint. This change is a positive one, where participants who were initially anxious and fearful, felt emotions of excitement and enjoyment.

Participant 7, in her description, provided a much more detailed description, however a key comment is made within:

“And we had to write down all the measurements and what we're feeling and how excited we were about that”

Another participant who expressed excitement was participant 9, who stated:

“Okay, well it was really fun, it was informative. It was nice that I had something to take home afterwards. You know like - I felt accomplished and it was really interesting to hear about your project and stuff”

Donning the laboratory coats and goggles proved to be an exciting endeavour in itself with participants commenting:

“and then we went into the lab and put on the lab coats and that was quite exciting... Yes, I really enjoyed that and then we started with the experiment. And that was very interesting; it wasn’t what I expected at all” – Participant 1

“No I felt cool, I felt like a scientist” – Participant 2

Participant 7: “I was excited and nervous at the same time – I didn’t want to break anything.

Interviewer: And when you donned the lab coat and goggles did that kind of increase or decrease or...

Participant 7: It kind of increased for me, I was like this is cool, I don’t wear lab coats so this is fun. Yes, I enjoyed it, I thought it was... I just remember being like I don’t get to put on this kind of things or gear when I’m in the lab so...”

“No that [wearing laboratory coats and safety glasses] made me excited” – Participant 9

A study done by Fu et al., 2015 showed that their volunteers responded positively to material related to the chemistry of love and emotions, as well as to the ideas around the chemical composition of the body and atmosphere.

This section shows not only the influence of positive and negative emotions involved in chemistry education, but that the environment in which chemistry is taught and the applicability (6.3.1.4) of the content to the individual is also of importance.

6.4 Conclusion

The initial perspectives of the participants about chemistry were negative, as can be seen through their artworks, laboratory notes, and interview analysis. Using Kitchen Chemistry in the synthesis of milk paint these perspectives changed to a more positive outlook on chemistry, noted through the comparison between Artwork 1 and Artwork 2 and in the interviews with the selected participants.

The participants responded positively to the idea that chemistry was not the sole territory of chemists and experts, but could be applicable to the non-chemist as well. The study suggests that chemistry is not something they, the participants, could do, but rather something that they were already doing (Fu et al., 2015). Kitchen chemistry proved to be a useful method in changing the perspectives of non-chemists, and instilling an interest in the subject based on its applicability to the real world. This experiment proved that focus on the phenomenon yielded positive results, as opposed to viewing chemistry on the molecular level.

Chapter 7 – Conclusion, Limitations, and Future work

7.1 Conclusion

The phenomenological study presented here posed a path to reach a deeper understanding of the experiences of the non-chemist through the processes taking place in the laboratory. The use of Kitchen Chemistry to make sciences, specifically chemistry, more applicable is a technique that may promote a deeper understanding of chemistry in general and change the perspective of non-chemists towards the subject.

It is not the intention of this study to diminish or degrade the importance and significance of pure quantitative analytical modes of teaching – which is beneficial to those capable of learning that way. It is, however, the intention to establish that there is an imbalance between the phenomenological and the analytical modes of teaching. With a rebalance and paradigm shift in the focus of the modes of teaching, there could be an improvement in the learning, comprehension, and enjoyment of chemistry

Current teaching methods promote vast quantities of rote learning, with little emphasis placed on the phenomena under study or any attention being paid to those students with genuine interest in the sciences but lack the capability to study within the bounds of the traditional pedagogy. This research focused on the individuals and on their lived experience in a chemistry laboratory, and established answers, through visual arts and Kitchen Chemistry, to the research questions:

1. How is chemistry perceived by non-chemistry students at Rhodes University?
2. What is the experience during the practical?
3. How do participant perspectives change during the experience?

Creativity and expression should not be frowned upon if those methods prove useful to assimilate knowledge. Through this collaboration of artistic expression and chemistry education, I believe that students will not only find chemistry more enjoyable to learn, but also promote chemistries applicable in everyday life outside Academia. Applicable

knowledge is useful knowledge, and it is hoped that the results of this research will impact chemists and non-chemists alike.

7.2 Limitations

There were several limitations to this study which need to be noted. The first is the subjectivity of the art analysis. Although bias was mitigated through use of art analysis techniques and visual semiotics, basing conclusions through journal, book, and web sources, the analysis would have had increased validity if done through a non-objective external source. Secondly, not all the participants were interviewed due to time constraints. This left a hole in the analysis and conclusion of the research as the analysis of Participants 3, 4, 5, and 8 could not be triangulated, limiting the sample size further. Sample size is the third limitation as only four participants were interviewed out of a sample size of nine. Increasing the sample size would add further validity to the research and its aims. The fourth and final limitation was that of participant demographic. Initially the research was aimed at Bachelor of Fine Arts (BFA) students who understood the nuances of art and its application. This would add value to the art analysis data with the understanding that there would be more meaning placed into the elements of an artwork, namely the line, form, shape, subject matter, and colour. In practice, these limitations were not damaging to the quality of the research.

For this thesis, the artistic skill was not a limitation. Everyone chooses colours, shapes, and lines depending on how these items influence their emotions and perceptions. Thus each “artist” or participant would reflect in their artwork what they were feeling and experiencing and express this not only in their art but in their interview as triangulation data.

A further limitation to the study was the software. As the researcher, I took it upon myself to find a software that provided adequate qualitative data analysis and ease of gathering this data. Atlas ti.7 proved to be the most efficient software the researcher could buy. The

limitation arrives due to no instruction on the software and only using online sources to discover the software for myself, as well as constant emails to the developers who assisted me with my queries. The software is beautifully complex however the realization is that data analysis could have been better and as beautiful if I had had training in the software and could utilize the software's full potential as a qualitative data analysis tool.

Through further research the limitations stated above could be overcome, reflecting and building on what this research paper has initiated.

7.3 Future work

7.3.1 Indigenous Knowledge

IK is knowledge that is unique to a given culture/society and contrasts with the knowledge systems generated by universities and research institutions and is based on experience and tested over centuries of use and adapted to local culture and environment (Reddy, 2009). “Amasi”, or fermented milk, is traditionally used in food recipes. The casein, or “Ingqaka”, is the solid mass formed by the fermented milk while the whey or “Intloya” is the water substance left over. Both are used traditionally in food recipes for instance the “Ingqaka” is separated and mixed in with mielie meal (maize flour) to create a rich creaminess to the porridge and sometimes eaten straight as “Ingqaka”. This thesis has potential to be used as a tool to make chemistry more applicable to rural schools as this process of “amasi” is totally ingrained in Zulu and Xhosa culture.

7.3.2 Schools

Buxton (2007) states that “if mainstream school science is viewed as immersion in the culture of western science, perhaps immersing mainstream teachers in indigenous or sustainability-orientated cultures and communities holds the potential to help them teach more complex, systems-orientated science that supports environmental literacy and recognizes the role of culture in learning”. The suggestion here is that learning sciences in the context of personal places and indigenous values and practices provides benefits for both the teacher and the student, with an emphasis on the rationale and agency to restructure curricula towards field-based science learning (Buxton, 2007). However it is important to mention the urgency to conserve the diversity of local cultures and the indigenous knowledge held within (Gadgil, Berkes, & Folke, 1993).

In the context of prospects for the current research, teaching sciences in this unorthodox way could deal with the unfamiliarity that Western Sciences pedagogy brings with it. The

current findings of the thesis suggest that sciences taught through familiar reagents in an unorthodox way promoted the learning and enjoyment of science for the non-chemist participants.

7.3.3 Future Research

A study by Warra (2013) suggests that soap production can be regarded as a business that is both lucrative and money conservative considering the available resources, with the intention being to utilize the full benefits of raw materials via available indigenous knowledge. Warra (2013) explored the ways of improving indigenous technology for soap production by using locally available raw materials (Warra, 2013). A similar process but using the creation of soap as the activity would provide for a lived experience of chemistry within a culture that would also have reaching implications economically, which is congruent with a phenomenological method of teaching chemistry.

According to Chowdhury (2013) chemistry curricula should emphasize manifestations and implications of science, technology, environment, societal, and economical issues. In this way, using scaffolding strategies and linking learning experiences to industrial applications, the suggestion was that it improves students' interest, motivation, and engagement. This thereby increases the relevance of chemistry through authentic applications of chemistry concepts that include social, economic, technological, and industrial applications.

In the context of this thesis, casein has a variety of applications if one knows how to use and work with it. Tessa Silva-Dawson explores a project for methods of processing casein extracted from bovine milk as a natural alternative to oil based polymers (Silva-Dawson, 2016). She herself uses surplus milk from the UK dairy industry to produce these functional tableware objects. Her project is a hands-on approach to designing whilst promoting the consumption of more sustainable products and supporting a local economy.

The suggestion here is not to reinvent Tessa Silva-Dawson's wheel, but to improve on the method by creating a durable casein product that is biodegradable, non-toxic and with the addition of indigenous seeds could be planted after use in the consumer's garden. The idea being that during creation the casein plastics are infused with colouration that matches the seed codes. With regards to how the methodology will change, use of formaldehyde would be substituted with a less toxic reagent, use of an Ultra-Violet drying agent so the wares can be dried in the sun omitting ovens which consume electricity.

In this way, the project aims to

- Provide local employment through a self-sustaining business opportunity
- Utilize raw waste material from local dairies (no mass increase in dairy production)
- Assist in applied industrial chemistry education

In writing this, there are two suggestions that come to mind:

1. Provide employment around the Grahamstown area by creating a process of utilizing waste from local Dairies to create functional objects from casein. These wares are creative, artistic, and rustic in appearance, making it ideal for instances like the Grahamstown Arts Festival.
2. Chemistry students at Rhodes Universities can use their third year or honors year (those interested in industrial applications of chemistry) to facilitate the creation of these casein based ornaments, utensils, and art using this method. This could be done by students running the business or by teaching new recruits the method in which to make the products and the chemistry behind it.

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Appendix A: Consent form

Consent Form

I hereby consent to participate in research regarding the synthesis and evaluation of the biodegradable, organic polymer, casein. I understand that I am participating freely, without being forced in any way to do so. I also understand that I can withdraw from the research process at any stage should I not wish to continue. This decision will in no way affect me negatively.

I understand that the purpose of this research project is not necessarily to benefit me personally, but that my input and participation will aid in the thesis, to the benefit of all chemistry and art students, and the Chemistry Department itself.

I have received the contact details of Kelvin Kelly (g11k6712@campus.ru.ac.za), and the supervisors, Mrs Joyce Sewry (j.sewry@ru.ac.za) and Dr Kevin Lobb (k.lobb@ru.ac.za), and will contact any of them should I need to speak about any issues that may arise from my participation in the research process.

I understand that this consent form will not be linked to my reflections. My answers, assessments, and reflections will remain confidential. Information given will only be subject to analysis by the supervisors and the researcher of the thesis. Names and identifying features will be omitted from the analysis and pictures taken (if any) on the day of the experiment.

I understand that feedback will be given to the Chemistry Department and to Rhodes University and that the research work may be published on the results of the completed research.

Signed:

Date

Student Number/Name of Participant

KELVIN LEIGH KELLY
Rhodes University Chemistry Masters

0765263190 | g11k6712@campus.ru.ac.za

Appendix B: Instructions

Making Paint from Milk

1. Measure out the milk (200ml) using the measuring cylinders provided, and decant the milk into the heat resistant flasks.
2. Measure out the acid (vinegar – 30ml), using the measuring cylinder, and pour it into the milk.
3. Allow mixture to react for 15 minutes. While this happens, individuals must come to the front desk to light a Bunsen burner as this forms part of the workshop in lab skills.
4. After the time is up filter the casein from the milk plasma, using filter paper provided. Squeeze out excess fluids using disposable cloth.
5. Weigh out the casein using the beaker provided to get a final weight of the synthesized polymer.
6. Place Solids, Ca(OH)_2 , and Water in a ratio of 3:1:... e.g. 15ml solids, 5ml Ca(OH)_2 . Mix till incorporated into a smooth mixture. Pigment needs to be added till adequate brightness and colour is achieved.
7. Paint with the newly created Casein Paint

Appendix C: Laboratory workbook

Instructor: Kelvin Leigh Kelly

Name: _____

Date: _____

Period: _____

*Fill in the required amounts, using the right-hand side for calculations. Remember **ACCURACY**, **OBSERVATIONS**, and **SAFETY**.*

1. Volume of Milk:

a. _____ ml _____

2. Volume of Vinegar/Lemon Juice (indicate which one):

a. Initial: _____ ml _____

b. Final: _____ ml _____

c. Total Volume: _____ ml (b-a)

3. Observations: During the Process:

4. Mass of Casein

d. Empty Beaker: _____ g

e. Beaker+Casein: _____ g

f. Therefore Casein: _____ g (b-a)

5. Question: How do you read a Measuring Cylinder Properly? Why do we read it to 2 decimal places?

6. Add solids, $\text{Ca}(\text{OH})_2$, and water in a ratio of 3: 1: 0.4 e.g.. 15ml solids, 5ml $\text{Ca}(\text{OH})_2$, and 2ml water. What did you notice about the solution created:

7. Add Pigment and mix. What viscosity is the solution? How would you make it less viscous?

Appendix D: Interview Questions

Interview question List

- What is your earliest memory? Can you describe it?
- What was your subject choices in high school?
- Why or why not chemistry?
- What are your university subjects now?
- Where there any pressure involved in your subject choice?
- Did you find high school helpful?
- Before the laboratory session, what was your perspective on chemistry?
- What were your feelings upon entering the laboratory and when you put on the laboratory coat and goggles?
- Describe the laboratory session in your own words
- How did you feel during the experience?
- Were there any memories or emotions that occurred in the laboratory session?
- Can you summarize your experience?
- Post-laboratory, how do you feel now about chemistry?
- Has the experience changed your perspective on chemistry?
- Please describe your first artwork?
- What were you trying to represent?
- Can you describe the symbolism of the objects used in your artwork?
- Can you describe your second artwork in detail?
- Would you recommend this process for other non-chemists?
- What do you think should change to make chemistry education more appealing?

Appendix E: Validity Agreement of Interview Transcription

The research is being undertaken by Kelvin Kelly, Masters Student in Department of Chemistry, Rhodes University. The purpose of this research is three-fold, to determine:

- (a) How Chemistry is perceived by non-chemists
- (b) What is the experience of the participants during the workshop
- (c) Do the Perspectives about Chemistry of the Participants change during the workshop

Thank you for agreeing to be interviewed as part of the above research project. Ethical Procedure for academic research requires a Validity Agreement for the Transcribed Interview stating the truth and soundness of the transcribed interview which can be used for the research project. Signing this form means that you approve the following:

1. You have been sent the transcript of the interview and have been given the opportunity to correct any factual errors therein.
2. The transcript of the interview will be analysed by Kelvin Kelly and/or his supervisors (Dr Kevin Lobb and Mrs Joyce Sewry) and access will be limited to Kelvin Kelly and academic colleagues and researchers with whom he might collaborate as part of the research process
3. Any summary Interview content, or direct quotations from the interview, that are made available through academic publication or other academic outlet will be “anonymized” so that you cannot be identified, and care will be taken to ensure that other information in the interview that could identify yourself is not revealed.
4. The recording will be kept till the research is complete. Upon completion, the recording will be destroyed.
5. Any variation of the conditions above will only occur with your further explicate approval.

I, _____, agree that:

1. I have reviewed the transcription collected during the research pertaining to my participation.
2. I can be quoted directly if my name is not published and a pseudonym is used
3. The researcher (Kelvin Kelly) may publish documents that contain quotations by me.
4. All or Part of the content of the interview may be used
5. I can/have request/requested a copy of the transcript of my interview and may make edits I feel necessary to ensure the effectiveness of any agreement made about confidentiality.
6. I have been able to ask any questions I might have, and I understand that I am free to contact the researcher with any questions I may have in the future.

Interviewee:

(Print)	(Signature)	(Date)
Researcher: Kelvin Leigh Kelly		27/06/2016
(Print)	(Signature)	(Date)

Appendix F: Confidentiality Agreement

The research is being undertaken by Kelvin Kelly, Masters Student in Department of Chemistry, Rhodes University. The purpose of this research is three-fold, to determine:

- a. How Chemistry is perceived by non-chemists
- b. What is the experience of the participants during the workshop
- c. Do the Perspectives about Chemistry of the Participants change during the workshop

As a transcriber of this research, I understand that I will be hearing recordings of confidential interviews. The information on these recordings has been revealed by interviewees who agreed to participate in this research on condition that their interviews would remain strictly confidential. I understand that I have a responsibility to honor this confidentiality agreement.

I agree not to share any information on these recordings, about any party, with anyone except the Researcher and Researcher Supervisors of this project. Any violation of the terms would constitute a breach in ethical standards and I confirm that I will adhere to the agreement in full.

I,

_____, agree to:

7. Keep all research information shared with me confidential by not discussing or sharing the content of the interviews in any form or format with anyone other than the Researcher and Supervisors.
8. Keep all research information in any form or format secure while it is in my possession.
9. Return all research information in any form or format to the Researcher on completion of the transcription tasks.
10. After consulting with the Researcher, erase or destroy all research information in any form or format regarding this research project that is not returnable to the Researcher.

Transcriber:

(Print name)	(Signature)	(Date)
Researcher: Kelvin Leigh Kelly		17/06/2016
(Print name)	(Signature)	(Date)

Appendix G: Interview Transcription of Participant 1

001 **Interviewer:** Alright, interview with [REDACTED] about
phenomenology and stuff like that. So I just want
to ask, is it okay if I start recording? Record your
voice and everything on it?

002 **Participant 1:** Yes.

003 **Interviewer:** Okay cool. So I want to start with like a little bit of
like general questions on art and how like you
perceive art and all that kind of artistic things. So
the first thing is; what does art mean to you?

004 **Participant 1:** Art to me a way of expressing myself and a lot of
my artworks, everything is quite personal and has
to do with me, my own life so it's a way of
expressing myself without having to say anything.

005 **Interviewer:** Okay, and your medium of choice?

006 **Participant 1:** For these artworks?

007 **Interviewer:** Yes for the artworks that you've done now.

008 **Participant 1:** The first one was permanent marker and the
second one was watercolour and permanent
marker.

009 **Interviewer:** Is there a reason you chose those?

010 **Participant 1:** Yes, the first one, before the whole experiment I
used permanent marker because I thought of
chemistry as quite rigid and quite...

011 **Interviewer:** I've got them here so that's why I'm digging...

012 **Participant 1:** Quite structured, permanent, you know it's this
way or the highway kind of thing. Quite
complicated.

Background~
Perspectives
Subject Choices~
University~

Art Works~

Art Works~

Line~
Medium~

Line~
Medium~

013 **Interviewer:** Yes, so it was very geometric.

014 **Participant 1:** Yes, very abstract, something that's not...yes that's it.

015 **Interviewer:** Alright so that's the permanent marker and then the fact that you used super awesome, really strict shapes.

016 **Participant 1:** I used a credit card at that stage just because it's got hard lines and it's structured.

017 **Interviewer:** Okay, more structured, awesome. And then the emotions you wanted to depict with this?

018 **Participant 1:** Just confusion.

019 **Interviewer:** Just confusion. Okay, I'm so glad my maths is almost spot on with this. Okay cool, yes and then your artistic choice in everyday life, like what you're doing now in your exam pieces, is that influenced by like...was that influenced by anything?

020 **Participant 1:** No, what do you mean, the medium?

021 **Interviewer:** The medium, yes.

022 **Participant 1:** I use oil paint, I paint quite quickly and oil paint doesn't dry fast so I get to change things so it's more like a process kind of thing when I paint. So I will paint a painting and the next day it will be a completely different painting and I will just keep changing it.

023 **Interviewer:** Until it's right?

024 **Participant 1:** Yeah.

Shape~

Emotional Response~
Line~
Shape~

Personality~

025 **Interviewer:** That black paint is horrible. So you obviously did art in high school, what were your other choices and why were they made?

High School~

026 **Participant 1:** Biology and accounting.

Subject Choices~

027 **Interviewer:** That's crazy, why those choices?

028 **Participant 1:** Biology because I would just not manage with science.

029 **Interviewer:** With the hard sciences.

030 **Participant 1:** And accounting, when we did accounting in grade 9 I really enjoyed like drawing up the books...

031 **Interviewer:** Okay so very systematic?

032 **Participant 1:** Hated the theory part but I liked the practical part of actually calculating the...

033 **Interviewer:** Oh that's so weird because accounting is like completely different to art. That's so cool. And in your opinion what role do artists have in society in general? Like I know it's a very big question but, what does that mean to you?

Background~
Personality~
University~

034 **Participant 1:** I think quite a big role, art is everywhere, creativity is everywhere.

035 **Interviewer:** Okay, and so you've just done this whole lab session and have you ever done research into the chemistries of art?

036 **Participant 1:** No.

037 **Interviewer:** No not at all? And let's go into something a little more personal, do you have an earliest chemistry

Memories~

memory?

038 **Participant 1:** Yes, the first thing that pops into my head is in biology, we had to dissect a kidney or something. I can't remember what animal it was and I just remember thinking "Finally we get to dissect something" because it was the first thing we got to dissect and I always just wanted to dissect a frog or something. That was the first thing.

039 **Interviewer:** Oh that's so cool see all the organs and everything, in [REDACTED]

040 **Participant 1:** No, Christian school.

041 **Interviewer:** Oh in the [REDACTED] That's awesome. So you did biology in high school and you felt really excited with that whole dissecting of the frog. What were the other emotions throughout those years of doing the course. Throughout those years of high school? Were they negative, positive?

042 **Participant 1:** No they were all positive, I really enjoyed it. Learning how everything functioned and worked.

043 **Interviewer:** And then no interest in chemistry at all in high school?

044 **Participant 1:** No, it was all confusing to me and I never understood it.

045 **Interviewer:** And what do you feel was the reason for that? Was it teaching or was it just your own brain just going no.

046 **Participant 1:** I think it was just my own brain going no.

047 **Interviewer:** Will not get this in no matter what I do.

 Background~
 CON chemistry~
 High School~
 Perspectives
 Preconceptions

048 **Participant 1:** This isn't for me, I'm meant to be doing art right now.

049 **Interviewer:** I know, I felt exactly the same way. So I'd like to know, you did the lab session, could you describe the lab session in as much detail as possible. From when you entered the door to where you walked out the door again.

050 **Participant 1:** Say what we did?

051 **Interviewer:** Yeah, everything.

052 **Participant 1:** Okay, well we waited for people to come and they didn't come so we went and did a presentation on how things were going to happen, what we were going to do, all the rules and regulations and what not and then we went into the lab and put on the lab coats and that was quite exciting.

053 **Interviewer:** Oh really?

054 **Participant 1:** Yes, I really enjoyed that and then we started with the experiment. And that was very interesting, it wasn't what I expected at all.

055 **Interviewer:** That's exciting. What were your emotions at that stage? Elation or kind of confusion again?

056 **Participant 1:** A little bit of confusion, but excitement, all positive feelings I think. It was very interesting.

057 **Interviewer:** Any memories during that lab session that sparked?

058 **Participant 1:** When I had to dissect the kidney.

 Laboratory~

 Memories~

 Emotional Response~

059 **Interviewer:** Oh, that was sparked in the lab session?

060 **Participant 1:** Yes, and then also another biology project where we had to do where we had to test...we had to cut up potatoes like chips and we had to test which...like if you soaked them in water first...

061 **Interviewer:** Okay, the osmo-regulation? Oh that was your like step into theory and thesis. And then you found that exciting or boring or not as exciting as dissecting the frog?

062 **Participant 1:** Yah, not as...

063 **Interviewer:** Do you think those memories and those emotions kind of impact your choices in now what you're doing as an artist?

064 **Participant 1:** No, I wouldn't say they did.

065 **Interviewer:** What would spark those emotions? What gets you inspired?

 Personality~

066 **Participant 1:** Actually I really don't know, sometimes I just have an urge to paint and then other times I just don't...

067 **Interviewer:** Nothing specifically sparks it?

068 **Participant 1:** I don't think anything sparks it, it's just...It's weird, I've been trying to figure it out but I really don't know.

069 **Interviewer:** So I also want to know, you've done this art and chemistry, do you think that they are the same or different or do you think they could connect at any

 Perspective Change~

conjunction?

070 **Participant 1:** I think they're very different, but I think after this experiment I saw that they could connect and places where they could overlap. Yes, I think you could be very creative with chemistry and do a lot of artistic things with it.

071 **Interviewer:** Awesome. So I want to know on a broad scheme, you were completely outside your environment of preference which is art and splashes of paint everywhere and you went into something that was far more clinical and systematical. How was that for you?

072 **Participant 1:** I actually found it very difficult. To be clean and to have everything, you know...

073 **Interviewer:** Precise.

074 **Participant 1:** No water splashes there.

075 **Interviewer:** But not awkward, it was just...?

076 **Participant 1:** Yes, not awkward, it was just very different from what I was used to.

077 **Interviewer:** Very different. That's awesome. So I want to know before the art, before the lab session and the chemistry session that I gave, what were your perceptions of chemistry? I know we went into it with the artwork but generally speaking were they quite negative towards chemistry or were they more positive?

078 **Participant 1:** I think positive. It was just something that I would not picture myself ever doing or ever

 CON chemistry~
 Emotional Response~

 Perspective Change~
 Perspectives

understanding. I've always thought of it as very complicated.

079 **Interviewer:** And given the opportunity, would you like to do
more of those chemistry art sessions and
080 understand a bit more about the chemistries behind
art?

 Applicability to Others~
 Emotional Response~
 PRO chemistry~

080 **Participant 1:** Yes, I would love to learn more.

081 **Interviewer:** What would excite you like a lot? What would you
like to know chemically more about?

082 **Participant 1:** Like the paints we use. I would like to learn more
about the oil paints, how they're used and what
gives them the colour kind of thing.

083 **Interviewer:** Cool! Like pigments and how to correctly
manipulate them and strain and everything?

084 **Participant 1:** Yeah.

085 **Interviewer:** Okay cool. And has going through the laboratory
process and everything, has learning chemistry
through this milk paint changed your perspectives
of chemistry?

 Perspective Change~

086 **Participant 1:** Yes, definitely.

087 **Interviewer:** From?

088 **Participant 1:** From being complicated to being a bit more
versatile. I always thought of it as being; this is
chemistry and that's what you do and now I
don't...

089 **Interviewer:** There's a grey area?

090 **Participant 1:** Yeah, something in between.

091 **Interviewer:** So this is one of my own questions that I thought was beside the point. So knowing what you know now with the chemistries, if you could go back and change your decision from bio to chemistry would you do that? Or would you still be...

092 **Participant 1:** It would be still be bio.

093 **Interviewer:** I'm always interested because I always have a history with my parents. What do your parents think about art and chemistry or art and sciences? Do they have a specific viewpoint, has that influenced you?

094 **Participant 1:** Actually all through high school my parents didn't really agree with art. Well they didn't mind me taking it but they wouldn't... I don't know they didn't agree with me taking it after university.

095 **Interviewer:** Okay, why was that?

096 **Participant 1:** I don't know, they just thought that there was no career in it I think.

097 **Interviewer:** And obviously you think differently?

098 **Participant 1:** Yes, well I don't know what I'm going to do but...

099 **Interviewer:** But it's going to be something with art?

100 **Participant 1:** Yes.

101 **Interviewer:** Okay, and then that follow up was on sciences, what do they think of sciences, your parents? Or let's rephrase it, which subject choices did they push you to go into?

102 **Participant 1:** It was more biology and...my parents, they've

 Background~
 High School~

 Subject Pressures~

never been to varsity and they've never really done...I think they both went to tech and they both did practical...

103 **Interviewer:** Oh so they're very hands on people? And that hasn't influenced you at all? Like arts and craft or the arts is hands on and you work with your hands all the time.

 Background~

104 **Participant 1:** Yes, I think that's definitely influenced me. My parents are both very practical.

105 **Interviewer:** So I want to talk about the second artwork because this was after the lab experience. I want to know what where you depicting and imagining and what were the symbolisms behind everything?

 Art Works~
 Color~
 Perspectives
 Symbols~

106 **Participant 1:** Well there I used watercolour because for me watercolour is a bit more versatile, it's a lot softer than the permanent marker that I used in the first on and for this one I was thinking about the meniscus?

 Symbols~

107 **Interviewer:** Okay.

108 **Participant 1:** Is that what it's called?

109 **Interviewer:** Yes, so it was this way? So I got the orientation wrong? Okay so it's flipped? Okay cool!

110 **Participant 1:** Also abstract, also a bit more of an understanding with chemistry but not fully there yet.

 Symbols~

111 **Interviewer:** And then the colour choices?

 Color~

112 **Participant 1:** I was thinking about the colours that we used for

the paint and just the bright...the variety you can use chemistry in.

113 **Interviewer:** Oh nice. And you've got variances of lines and stuff, was that also just...

114 **Participant 1:** Yes, a bit more free a bit more...

115 **Interviewer:** A bit more free and fluid and organic. Okay, that's awesome. I was actually thinking rainbows because it was flipped and I was like "Oh wow, the rainbows symbolises everything." Okay cool, meniscus I must definitely write that in. Okay I wonder if there is...Yes I think we are done. Any questions from your side?

116 **Participant 1:** No, I hope you got what you wanted.

117 **Interviewer:** Yes, thank you so much.

Appendix H: Interview Transcription of Participant 2

001 Interviewer: Interviewer Kelly

002 Interviewee: Participant 2

003

004 **Interviewer:** Alright - interview with Participant 2 on the 5th of August. Is it okay if I interview you and record?

005 **Participant 2:** It is perfectly.

006 **Interviewer:** Okay cool. I'm just going to put this closer to you. Alright so the first thing I want to know is what was your earliest chemistry memory and can you describe that for me?

007 **Participant 2:** Probably building a volcano when I was little. I don't know how old I was though. Probably I would say maybe six or seven.

008 **Interviewer:** The bicarb and food colouring.

009 **Participant 2:** Yes, exactly that. So we had to sculpture the volcano and do that stuff.

010 **Interviewer:** Okay and was this generally a positive emotion?

011 **Participant 2:** Yes! I loved doing that stuff. It's exciting.

012 **Interviewer:** And then your subject choices later on at school, what were they?

013 **Participant 2:** I chose biology, geography and consumer studies and then maths literacy.

014 **Interviewer:** Okay, what is consumer studies?

015 **Participant 2:** It's basically like cooking and home ed kind of stuff.

016 **Interviewer:** And then you enjoyed that?

017 **Participant 2:** I loved that yes.

018 **Interviewer:** And why were the choices made? The bio, geo and

📁 Emotional Response~
📁 Memories~
📁 PRO chemistry~

📁 Background~
📁 Emotional Response~
📁 High School~

📁 Emotional Response~
📁 High School~
📁 Subject Choices~

consumer studies?

019 **Participant 2:** I just had a general interest in them. I enjoyed doing them before we had to choose subjects. And I just loved that field of studying I guess.

020 **Interviewer:** Did marks have anything to do with your subject choice?

021 **Participant 2:** Not really no - I don't think so. It was so long ago.

022 **Interviewer:** And then why not chemistry?

023 **Participant 2:** I don't know. My brain is not subject to chemistry. I just couldn't get it.

024 **Interviewer:** What part? Was it the molecules? Was it the way the teacher taught it?

025 **Participant 2:** I think the whole course outline - it wasn't really of interest to me. I wasn't interested in doing all the equations and molecules and all that stuff. I mean it was the same as math core - I wasn't interested in doing any of that stuff.

026 **Interviewer:** Did you know then where you wanted to be later on in life? Like did you have a goal?

027 **Participant 2:** No. I thought I knew, I didn't know. So no. I think I just chose the easiest subjects actually.

028 **Interviewer:** Alright and so there weren't any parental pressure in your subject choice at high school?

029 **Participant 2:** No, none at all.

030 **Interviewer:** And to follow through into university, did you take any of those courses again?

031 **Participant 2:** I did geography and I did cell biology and I did HKE so it was very similar to what I did at school.

032 **Interviewer:** In cell bio, there's quite a lot of chemistry involved.

 Subject Pressures~

 CON chemistry~

 High School~

 Preconceptions

 Personality~

 Emotional Response~

 Subject Choices~

 University~

- Did you find the applicability of the chemistry more enjoyable?
- 033 **Participant 2:** Yes, I found it more basic. It was more like general.
- 034 **Interviewer:** And applicable?
- 035 **Participant 2:** Yes.
- 036 **Interviewer:** What are your university subjects now?  University~
- 037 **Participant 2:** Right now I'm doing HKE 3, organisational psychology 3 and zoology 1. Random.
- 038 **Interviewer:** Right, and are you enjoying zoology at the moment? I know there's not a big chemistry component but...
- 039 **Participant 2:** No not at all, it's more biology and stuff. But yes it's interesting and very different. We're learning about tape worms. Not my thing.
- 040 **Interviewer:** Did you find your high school information and studies help you in university?  University~
- 041 **Participant 2:** To a degree. It was basically like three years after doing high school that I came to university so a lot of that stuff was forgotten and I think that the course outline changed a lot. So in cell bio they would say oh so you did this in high school and I was like no! No I didn't.
- 042 **Interviewer:** Quite a lot has changed and it hasn't processed through the systems yet. And then going onto what I actually want to talk about - I'd like to know before you entered the lab session - what were your preconceptions or your perspectives on chemistry?  CON chemistry~
 Perspectives
 Preconceptions
- 043 **Participant 2:** That it was very rigid and calculating I suppose. And not very fun.
- 044 **Interviewer:** Do you have a mental image of what a chemist

- should be?
- 045 **Participant 2:** Yes - crazy hair. Glasses, lab coat.
- 046 **Interviewer:** Okay - the general. And focusing now on the feelings as you entered the lab.
- 047 **Participant 2:** I was excited.
- 048 **Interviewer:** Just excited?
- 049 **Participant 2:** Excited and...I don't know. I didn't really know what to expect so I guess I was interested to see what was going to happen - what we were doing.
- 050 **Interviewer:** And what did you expect?
- 051 **Participant 2:** I don't actually know. I try not to have too many expectations of things. I just kind of expected it to be making paint and learning about new things.
- 052 **Interviewer:** Because you obviously knew what my topic was before entering?
- 053 **Participant 2:** Yes.
- 054 **Interviewer:** And then actually putting on the lab coat and the goggles - did that make you feel anxious or did you get a little excited?
- 055 **Participant 2:** No I felt cool, I felt like a scientist.
- 056 **Interviewer:** You don't often put lab coats on?
- 057 **Participant 2:** No - not in HKE or any of that. Just in cell bio and zoo.
- 058 **Interviewer:** And I wanted to know, can you describe to be the lab session - what you did, what you found interesting?
- 059 **Participant 2:** Well we obviously made paint using the different steps that you told us to and I found that really cool. It was really

Emotional Response~
Laboratory~

Emotional Response~
Laboratory~

Emotional Response~
Laboratory~
PRO chemistry~

interesting to see how one element can turn into another by just adding things together and how you can create something from a bunch of different ingredients. I found it really fun - it was interesting. I like creating things.

060 **Interviewer:** So your emotions during that time was more positive?

061 **Participant 2:** Yes, definitely more positive and I found it a lot more free flowing then I thought it would be.

062 **Interviewer:** Okay, free flowing being kind of creative? More zen?

063 **Participant 2:** Yes, more zen than numbers and calculation.

064 **Interviewer:** And during the process did any emotions or memories spark that you were like that's really interesting - I hadn't remembered this in a while?

065 **Participant 2:** I suppose memories of when I was young and used to do a lot of artistic things. Like I went to this 6:21 when I was at school and I was much younger and we did all sorts of weird little things. So I thought of memories like that which was nice.

066 **Interviewer:** And then you had a memory written down your paper.

067 **Participant 2:** Oh kaifer?

068 **Interviewer:** Kaifer? Yes, tell me about that - why did that spark?

069 **Participant 2:** So kaifer - I forgot about that. So keeper is like a probiotic kind of thing and you culture it and you make water or like a yogurt with it. So I think because I used to do that, it was kind of like a chemistry kind of thing because you've got to feed them, you've got to water them and then it creates you know - another product. So I suppose that's why because it's similar to

Emotional Response~
Laboratory~
Memories~

creating something from - you know paint from different ingredients as well.

070 **Interviewer:** That's very cool - I had no idea.

071 **Participant 2:** It's so cool. I should keep doing that.

072 **Interviewer:** So during this process, has the learning of chemistry through milk paint changed your perspective of chemistry?

🔍 Perspective Change~

073 **Participant 2:** No it definitely has. It made me realise that you can apply it to a much broader range of subjects than just the hectic scientific stuff. So it's quite cool.

074 **Interviewer:** That's awesome. Alright, so what we're going to do now is just take a look at your artworks. Because I just want to go through them. So you're going to go through artwork one first and thereafter...Nothing too serious.

075 **Participant 2:** I tried to do artwork with my milk paint but it dried up.

076 **Interviewer:** Yes, it tends to do that. Alright so taking a look at your artwork, what were you trying to represent?

🔍 Art Works~

077 **Participant 2:** The little molecules and the equipment used and I don't know - I'm not quite sure actually. Bubbles?

🔍 Symbols~

078 **Interviewer:** So I'm going to go through the symbolisms so what do the flowers represent? The flowers and leaves?

🔍 PRO chemistry~
🔍 Symbols~

079 **Participant 2:** The flowers represent like the nature and how chemistry occurs in nature.

080 **Interviewer:** And the water droplets? There's only one of them?

081 **Participant 2:** I don't know. The water droplet is just like another element adding to chemistry I suppose. There's Joe.

🔍 CON chemistry~

082 **Interviewer:** And these nice geometric shapes over here - what gave you that idea?

Shape~

083 **Participant 2:** I just thought that's what chemicals look like.

084 **Interviewer:** That's awesome. And any significance of the colour? You kind of kept it a very colourful scheme.

Color~
PRO chemistry~

085 **Participant 2:** I don't know, I've always thought of chemistry as creating random explosions of colour. Yes, I that's why.

086 **Interviewer:** So it's actually representative of the chemistry process?

087 **Participant 2:** Yes, like the different elements and all of that.

088 **Interviewer:** And then the overturned beaker because it's spilling?

Perspectives
PRO chemistry~
Symbols~

089 **Participant 2:** Yes.

090 **Interviewer:** Is that representative of anything?

091 **Participant 2:** Creating a mess.

092 **Interviewer:** Is that generally what you think about chemistry or is that just your own perspective?

093 **Participant 2:** No I think that's just my own perspective. That's what I would like to do if I was doing chemistry; just make a bunch of weird things for fun.

094 **Interviewer:** Just see what happens. Okay, going onto the artwork two - this is post lab. This is quite a bit different.

095 **Participant 2:** A little bit more abstract.

Perspective Change~
PRO chemistry~
Symbols~

096 **Interviewer:** A little but more abstract - over here, what were you trying to portray?

097 **Participant 2:** That science is quite colourful and exciting and

different and can be artistic as well as sciency.

098 **Interviewer:** 10:08

099 **Participant 2:** Yes, which was more laid out.

100 **Interviewer:** And the colours you used. It was arranged in a rainbow sequence - did you plan that?

101 **Participant 2:** Yes, I love rainbows, I love rainbow colours.

102 **Interviewer:** Oh awesome - what does the rainbow symbolise to you?

103 **Participant 2:** Well I suppose it also has to do with chemistry because I mean it's a whole think taking place in the sky.

104 **Interviewer:** It's more physics.

105 **Participant 2:** Well I don't know.

106 **Interviewer:** And then you wrote the word in the middle with red being science.

107 **Participant 2:** Just science.

108 **Interviewer:** Why science?

109 **Participant 2:** Well I suppose chemistry would fall under the category of science so it's a much broader range rather than just focusing on one specific thing.

110 **Interviewer:** And was that indicative of your change in perspective that chemistry could be applied?

111 **Participant 2:** Yes, to different kinds of...

112 **Interviewer:** That's awesome. And I wanted to know - did you enjoy the sessions from beginning to end? Did you find anything weird?

113 **Participant 2:** Yes, I really really enjoyed it. Especially when you

Color~
Symbols~

PRO chemistry~
Symbols~

Applicability to Others~

were telling us all about the chemistry of it.

114 **Interviewer:** And you learnt something?

115 **Participant 2:** Yes I did, I learnt a lot.

116 **Interviewer:** Would you recommend this process to other people
- other non chemists?

117 **Participant 2:** Definitely - it's really fun. I mean if people want to
find out more about what you can do with chemistry - it's really
cool. Especially with people who are intimidated by it. Because I
think I found chemistry quite intimidating. And now not so much.

118 **Interviewer:** Awesome - that's exactly what I want to hear. Are
there any questions from your side?

119 **Participant 2:** Nope. Are you going to put my art on your wall?
Are you going to frame it?

120 **Interviewer:** I will - eventually. Thank you so much and I will
get back to you later.

Appendix I: Interview Transcription of Participant 7

001 **Interviewer:** Alright so this is just an interview with [REDACTED]
on the tenth of June and I just want to know,
before we start, is it okay if I record you? I can put
it off if I need to.

002 **Participant 7:** Yes you can record me.

003 **Interviewer:** Yes, okay that's perfect. Alright so I'm just going
to go through a few questions going from your
history to now, a little bit on your past, a little bit
on what's happening at the moment and then
hopefully it will be a really good interview.

004 **Participant 7:** Yeah.

005 **Interviewer:** So the first thing I want to know is, we're just
going to start off like the earliest thing, what is
your earliest chemistry memory? Can you describe
it for me?

006 **Participant 7:** Earliest chemistry memory would be doing that
thing you do at school with the volcano, that
volcano thing with vinegar and bicarb, yeah that
would be the first one.

007 **Interviewer:** And was it a good memory? Did you enjoy it?

008 **Participant 7:** Yah it worked so that was exciting.

009 **Interviewer:** You used colour, lots of colour? Right?

010 **Participant 7:** Yes red, lots of red food colouring.

011 **Interviewer:** Awesome. Okay so it was a very positive memory
for you?

012 **Participant 7:** Yes.

013 **Interviewer:** And then later on in life – what was your subject

📁 Emotional Response~
📁 Memories~

📁 High School~

choice in high school.

014 **Participant 7:** Consumer studies which was cooking, history and geography and then obviously maths, English.

015 **Interviewer:** Okay cool, do you know why those choices were made? Why did you choose them?

016 **Participant 7:** Well I wasn't really enjoying biology so I didn't want to take that. Chemistry just seemed very foreign to me and I didn't really get it although I was interested in it, which was weird. But I loved geography; geography was my favourite so I knew I was taking that and I really enjoyed history and learning about the past so that's why I took that one. So consumer studies was the one that I wasn't sure and then I spoke to our headmistress and she's like – well it's silly, you get like nineties, you might as well do consumer studies, it makes sense. And I was like okay.

017 **Interviewer:** Oh okay, well what didn't you enjoy about chemistry? So you said you really enjoyed the kind of other side, but what were the factors that stopped...

018 **Participant 7:** I think it was just like the elements and stuff was very overwhelming like doing the molecule thing and it was just very overwhelming and confusing and no one really explained it properly that's probably why.

019 **Interviewer:** So your teacher, was she really good or...?

020 **Participant 7:** The one we had, no. But you know there were quite a few of them so if I had maybe a different

High School~
Perspectives

CON chemistry~
Subject Choices~

CON chemistry~
High School~
Perspectives

CON chemistry~

teacher...

- 021 **Interviewer:** It would be a different story. Okay. So was there any parental or external pressures for your subject choice or to do sciences.

 Subject Pressures~

- 022 **Participant 7:** My dad really wanted me to but it's my life so he was like you choose. He was really upset when I wasn't doing science (– he's a scientist so...) But I wanted to do well so I chose the subjects that I enjoyed and I knew I would do well in them.

 CON chemistry~

- 023 **Interviewer:** Why was your dad so upset?

- 024 **Participant 7:** I think because he just did science and physics and found it very interesting and he loves that kind of stuff. And I think he just wanted us to experience the joy that he had with it.

- 025 **Interviewer:** That's understandable.

- 026 **Participant 7:** My mom was just like "Do whatever."

- 027 **Interviewer:** And now, how did those from your high school subject choices. What are they now in university? Have they followed through or are you doing something completely different?

 University~

- 028 **Participant 7:** I'm doing geography still so that's completely a follow through from high school. Obviously a lot more focussed and honed in on things we never touched on in school. And we learnt stuff that were actually wrong in our text book and now when I tutor I'm like "Oh my God, this stuff is wrong that we're teaching." So that's kind of cool to see that. And then I took some interesting subjects in varsity like philosophy which we could never have done in school and anthropology which was my other major so that was nice. I did do

history for a term so I did follow that but not throughout the year.

029 **Interviewer:** Okay and then – just got to get my thoughts straight – so you didn’t do chemistry in university to do your geography course.

030 **Participant 7:** No. I did the sneaky way. So I did a BA to avoid chemistry on purpose. Because I just thought no, I’ve heard you know I’ve heard stories like Chemistry 101 is the most failed subject blah blah blah so I didn’t want to risk it because my dad has this rule that if you fail, you pay for the next year. So I asked why...

031 **Interviewer:** There is no way.

032 **Participant 7:** No way. I’m allowed to fail a subject but if I fail like all of them, more than two then I pay. And I didn’t actually want to, I wasn’t really interested in chemistry so I was – well I’m interested in it but I didn’t really want to do it if that makes sense. So I opted out of that and I’m now doing an MSc without ever having done chemistry. Sometimes I wish I did it because we did a lot of courses in Enviros and Geography where we looked at like heavy water and light water so oxygen eighteen and sixteen and deuterium so proxy measures for climate change using chemistry and stuff. So in that respect sometimes I wish I had done it because maybe I would understand more. But every year, like in Enviros we did it in second year and in Geography in third year and in third year I understood it more because I did research about it and stuff. So I think if I had that background that it would probably be a bit easier and maybe as well when I’m doing some of my own research for Masters, some of them talk about chemistry stuff.

Background~
CON chemistry~
Subject Pressures~

CON chemistry~

PRO chemistry~

I'm a little wobbly but I just do it myself, learn I suppose.

033 **Interviewer:** I suppose every subject is overwhelming if you don't know anything about it. So I want to know as well, before our lab session that we had a few weeks ago, can you describe your perceptions of chemistry in a few words. Perceptions and thoughts.

 Preconceptions

034 **Participant 7:** Like so what I thought about it, about being there?

035 **Interviewer:** Yes, about being there.

036 **Participant 7:** I thought it would be like you know, it's a little Bunsen burner and beaker sort of situation and it was not what I thought it would be which was really cool. It was actually in a field that I do understand, chemistry in terms of the cooking side in terms of milk and vinegar.

037 **Interviewer:** Because of your cooking background?

038 **Participant 7:** Yah, so in high school, in consumer studies we did actually learn why and egg is a binding agent and all those things so from that aspect I knew where I was going but I didn't click that it was actually chemistry, like you don't click until you're actually doing it, that they all link and everything is so cool when they're linked. So I thought it was going to be a typical beaker with some dangerous chemical and then do magic – well not magic – but you know, burn it or something.

 Background~
 High School~
 Laboratory~
 Preconceptions

039 **Interviewer:** So how would you describe your emotions before you went into the lab?

 Emotional Response~

040 **Participant 7:** I was excited and nervous at the same time – I

didn't want to break anything.

041 **Interviewer:** And when you donned the lab coat and goggles did that kind of increase or decrease or...

🔍 Laboratory~
🔍 Perspective Change~

042 **Participant 7:** It kind of increased for me, I was like this is cool, I don't wear lab coats so this is fun. Yes, I enjoyed it, I thought it was... I just remember being like I don't get to put on this kind of things or gear when I'm in the lab so...

043 **Interviewer:** Awesome, so you were a slight more positive or more negative?

044 **Participant 7:** More positive.

045 **Interviewer:** I would also like to for you to describe the lab session, our laboratory session in as much detail as possible. Can you do that for me?

🔍 Laboratory~

046 **Participant 7:** Okay, so obviously we met you at the chemistry building and then you took us back to the lab and you did a presentation on what we were going to do and the reason behind your thesis and everything. And then we had to put on lab coats and had to find smaller sized goggles. And then you explained that we're going to make paint with milk and vinegar and the reaction will cause the proteins to come away and together like on the water and that we were going to use that to make the paint. So first we had to take the milk and measure it precisely – oh wait before that you showed us how to do the diary, like the chemistry notes.

047 **Interviewer:** The workbook?

048 **Participant 7:** Yes, that's it. The workbook. And we had to write down all the measurements and what we're feeling

and how excited we were about that. And then we started doing it and we had to measure everything. Measure the milk and then you had to pour it into the beaker and then the vinegar and you added it in and then we had to stir it and see what was happening and write down our reactions and our thoughts of what was going to happen. And then mine was working but Jenna's wasn't working so well so we put it in the water bath that you set up and we let it do its thing for a bit and we carried on writing what we think and you asked us questions and we had to write down answers. And then we took it out the water bath and we had to now strain it so we first strained it through a sieve and then realised actually a tea towel would probably be better. So we did it through the tea towel and we got a lot of the protein which was nice and quite clear water, you said it was the clearest you'd seen.

049 **Interviewer:** It was definitely.

050 **Participant 7:** And then we had to... I don't know what that stuff's called. That powder?

051 **Interviewer:** The calcium hydroxide, the lime.

052 **Participant 7:** Okay, the lime, calcium hydroxide. So we had to add that in to make it more of like a runny thickness temperature... I mean thickness like subsistence I suppose. And then that basically was the paint and then we could add colours to it. So I did the crazy yellow and the blue and I think it was a green.

053 **Interviewer:** That's cool. I really liked your colour choice. Looking at the workbook and the lab book, would you use this in your Masters at all?

054 **Participant 7:** I kind of do already. So I have a book that every

day I write the date and then I write down like what I'm doing or if I've completed something. So maybe I could write in I've been sick so I didn't do anything, and then also when I have an idea I can quickly jot it down.

055 **Interviewer:** Is it yours? You use a notebook?

056 **Participant 7:** Yes, and then I also have like a rough notepad so at the moment I'm trying to figure out all the graphs to make so I will just try and draw a quick scatter plot and I will see I think it should look like and you know what you're going to put on the x and the y axes and then I'm like "no I don't like this" and I scrunch it up and I do another one you know. But that's more I don't want that in my book because it doesn't need to be there.

057 **Interviewer:** Yes, so on the side, it's just for you, not for...

058 **Participant 7:** The book is also for evidence for our supervisors to see that we're actually doing work. Well I prefer it because he's not like very hands on so if I need him to do something when he's like well you're not doing anything and I can be like well look I have. Here's our meetings, here's all of my notes.

059 **Interviewer:** Yeah, that's awesome, that's one of the reasons why I love a workbook as well.

060 **Participant 7:** And I draw in it sometimes.

061 **Interviewer:** Doodles and all that, they all help. During the lab session, what was the most striking part for you?

062 **Participant 7:** I think realising that I actually knew what was going on without having to have a chemistry background, like a classic chemistry background

🌀 Emotional Response~
🌀 Laboratory~
🌀 Perspective Change~

per se and that was cool.

063 **Interviewer:** Yes, you wrote in your lab book “everything is connected, what?” I really enjoyed that.

064 **Participant 7:** And I think [REDACTED] was quite shocked that I actually knew what was happening because I didn’t learn chemistry and I think it kind of frustrated her a little bit because she did chemistry and she’s kind of orientated that side.

065 **Interviewer:** Yes, very analytical. So during the process did any emotions spark, did any memories happen, anything like that?

 Memories~
 Perspectives

066 **Participant 7:** Yes, I remember in school that I would always be like “Oh what did you guys do in chemistry?” and they would be like “Well we did this.” And then I’m like “Oh that sounds so cool.” And I’m thinking well maybe I should have done it. But then I’m also kind of happy I didn’t because I get to still experience it and see something new that would’ve been boring if I had done chemistry at school. So I don’t think you can go ‘what if?’ you know I think you must just live with it. And it also brought back all the nice memories of cooking at school and hearing all the different ways of food and stuff.

067 **Interviewer:** Because food and chemistry link really well together. So has learning chemistry through my milk paint synthesis in that laboratory session change your perspectives on chemistry at all?

 Perspective Change~

068 **Participant 7:** Yes, I think it’s made me not fear in the idea of chemistry and maybe being open to one day learning more about chemistry. Maybe at my own pace though. I think that was also one of the fears

 High School~
 Memories~

is that they do it in such a way that I just have so many questions. And you know at school, it was a very competitive school so like if you had a question that sounds stupid you don't dare ask it because they going to criticise you.

069 **Interviewer:** A very high peer pressure involved with that.

070 **Participant 7:** Yes, and I have a lot of questions and some of them can seem stupid and so I think if do want to learn chemistry I should find someone or find a way that I can ask these silly questions and all the things I want.

071 **Interviewer:** Something a little bit more social rather than so analytical and book fact-y.

072 **Participant 7:** Yah, and I mean this is not very related but like why is the sky blue? You know, those stupid questions that I want to be able to ask. Because it doesn't make sense for me if I don't have answers to questions that I'm pondering about.

073 **Interviewer:** Yah, completely understand what you mean I also had those questions.

074 **Participant 7:** Yes.

075 **Interviewer:** Still, it would've been nice at the time to have someone to actually just sit down, describe it for you, take the time.

076 **Participant 7:** Like why does this chemical bond or why does this do that?

077 **Interviewer:** So your feelings now towards chemistry after the laboratory session in a few words.

 Perspective Change~

078 **Participant 7:** Feelings? Basically I'm feeling less fearful about it and
more open to the idea of learning and actually it
probably sparked a little bit of excitement for me, and
now I'm interested.

079 **Interviewer:** So there's not so much anxiety?

080 **Participant 7:** Yah, it's not so daunting, it's not this big grey cloud
like coming.

081 **Interviewer:** Okay, that's really cool, I really liked that. Alright so
we're going to just take a look at your artworks so I
have to do some analysis on your artworks and I really
enjoyed what you did and this is one of the reasons
why I'm interviewing you. The way you did your
artworks was so different from other people, so I'm
just going to bring them out quick and when you go
through your first work, we're going to go through the
first artwork and then the second because that's in line
with what we did. Pre-laboratory and then post
laboratory. So I've got it here in front of you and
there's just a few things I want to know. First of all,
can you describe your first artwork for me?

082 **Participant 7:** Okay, so basically that is a very bad attempt of me
drawing me and sort of reading something on
chemistry and the cloud here is like basically my brain
and my mind running. That's why it's so colourful and
I'm basically going "This is so interesting, but like it
all seems a bit confusing." And that's why there are
lots of question marks, I have lots of questions about it.
I'm not really sure this is what I do know about
chemistry or I've learnt on my own and it makes sense.

083 **Interviewer:** Which is?

084 **Participant 7:** Heavy water and light water and the whole deuterium
stuff as well.

085 **Interviewer:** That you learnt with your geography course?

 Art Works~

 Symbols~

 Color~

 Symbols~

086 **Participant 7:** Yah, I think that's also because it's linked to
geography so it kind of made more sense because it
was taught in a relative way that I could understand.
But you know I still had lots of questions about
molecules and all these different things that I don't
know about and a lot of people do.

087 **Interviewer:** Which is interesting but confusing?

088 **Participant 7:** So I don't know if you know the series Through the
Wormhole?

089 **Interviewer:** Yes I do.

090 **Participant 7:** So sometimes they talk about it and I'm like "This is
so cool." But then I'm like "But wait, why, what?"

091 **Interviewer:** How can this be?

092 **Participant 7:** I really enjoy like absorbing new information but it
doesn't mean I always understand it. So that's my first
one.

093 **Interviewer:** Okay so the rainbow colours are just indicative of
your...

 Color~

094 **Participant 7:** My brain working and trying to figure out things and
just sort of... You know I'm not one of these people
that are, I'm very like all over the place, deurmekaar or
I suppose more creative so that's why I did the colours
as not very straightforward and analytical or step to
step and so my mind bounces up and down and if you
look at my workbook, my thesis workbook, I don't
always just do readings and then write up. I do
readings and then I do a poster and then I do this for all
these different things. So I work in a very weird way
that people don't understand so I suppose that's why
the colours are...

095 **Interviewer:** So then why didn't you colour her or the table?

 Color~

096 **Participant 7:** Good question. The table is really out of proportion
because you know you're in this learning environment
and it can seem quite daunting and big and it might
seem boring at the time, like at school I didn't enjoy it
I think because of the teacher so I also thought it was a
bit boring. And then I didn't colour myself in because
I'm like thinking so I'm not focusing on myself. I'm in
my head.

097 **Interviewer:** So the speech bubble is the predominant image of your
artwork?

098 **Participant 7:** That's all.

099 **Interviewer:** Okay so what I want to do is I'm just going to say a
few colours and I want you to give them meanings,
your meanings behind them so like I say a word you
say a word.

100 **Participant 7:** Okay so like if you say [REDACTED] [19:08] whatever pops in
my head.

101 **Interviewer:** Yes, the first thing that pops in your head. So try direct
them towards feelings that you're not limited to that. I
want to more get the feeling behind these colours.
Green?

102 **Participant 7:** The environment.

103 **Interviewer:** Red?

104 **Participant 7:** Anger.

105 **Interviewer:** Yellow.

106 **Participant 7:** Happy.

107 **Interviewer:** Blue?

108 **Participant 7:** Thoughtful.

 Symbols~

 Symbols~

 Color~

 Emotional Response~

- 109 **Interviewer:** Pink?
- 110 **Participant 7:** I don't like that colour so I don't know, bad then.
- 111 **Interviewer:** Purple?
- 112 **Participant 7:** Love.
- 113 **Interviewer:** Violet?
- 114 **Participant 7:** But that's purple? Okay I suppose it isn't. I don't know, love again.
- 115 **Interviewer:** Okay, and then black and white, you can do black first.
- 116 **Participant 7:** I find both of them connected in my opinion, they're structured, there's no blurred line. It's either this or no, and you know life's not like that because there is a blurred line.
- 117 **Interviewer:** So someone said something to me along those lines. It's like life isn't black and white, there's so many areas of grey that you need to consider. You can't see something as completely wrong or completely right, because you can see it from both sides.
- 118 **Participant 7:** And that you can see, I don't know about you but when we do readings they always argue each other and it's like well you've got to find the in between.
- 119 **Interviewer:** Cool, so your second artwork is now post laboratory session, and you did something very beautiful, you did a poem for me that you created yourself and what I would like you to do, the first thing, is can you read your poem for me because I want to get the emphasis right.
- 120 **Participant 7:** Okay, I like poetry so I always...weirdly enough I'm not very good at English but I got poetry and like now I'm Shakespeare so it's quite nice, I like doing it. Okay, so my poem, I gave it a title but I can't

 Poetry~

remember what it was...experiment or something.

121 **Interviewer:** Chemistry experiment or something?

122 **Participant 7:** Yes. I may not understand chemistry, after all it's all a bit of a mystery. Mixing milk and vinegar together, creating a reaction. Calling the proteins to come hither. But one thing is for sure, I can say I have clicked, as food and chemistry as well as everything is interlinked. Making paint with milk has opened my eyes to the fact that I am no more than I thought, which took me by surprise.

123 **Interviewer:** Thank you that's awesome, yay! I found that really cool. So for you definitely it's more words-y creation rather than say colour creation? So you already told me but just can you give me more reasons of why you chose poetry as your artwork. Because all I did was I said, here's an artwork, please do it for me, you chose words and poetry.

124 **Participant 7:** I think because I couldn't... I mean I sat down originally and I was like "Okay I will draw something" and I'm one of these people that I can either draw a picture like and I can almost read through it on a piece of paper or I can draw my own and I thought "No I don't want to draw something because that's not going to show what I experienced" so I was going to draw something, you know like an experience of my own like that one in first year. And then I sat there and I was like I don't know how to get what I was trying to say across through my artworks and then I was like "Well, I know I can get it through with poetry and that is seen as a form of art I suppose. So I decided to do that and I love poetry so I thought it would be nice to do something a little different.

125 **Interviewer:** The last thing I want to know is, like it's always just fascinating to me, is how would you describe yourself?

126 **Participant 7:** How would I describe myself?

- 127 **Interviewer:** You can do it in like five points.
- 128 **Participant 7:** So you want me to just describe my personality or...
- 129 **Interviewer:** Yes, your personality type.
- 130 **Participant 7:** I think I'm very loving and caring but fair. So like if you, I suppose piss me off you will find out about that. But like if we got a good relationship, I will always be there for you and be able to help you out. I also think I'm very strong minded and determined to do things that I want to do and persevere. Everyone has their own struggles and demons from their past and so I think that builds your character and I do think having dyslexia has made me push myself further than I thought I'd be able to go, so that's exciting. Yah and I think my mind gets me in trouble sometimes.
- 131 **Interviewer:** Always.
- 132 **Participant 7:** Yah, I think that's all. Probably down to earth is probably another word.
- 133 **Interviewer:** Yes, that's a really good one.
- 134 **Participant 7:** And I'm not two faced and trying to portray someone that I'm not trying to be. I'm me like for example everyone's like "Oh you're from Joburg, I wouldn't picture you from Joburg" and I'm like "Well, I'm not the usual" I've never been the usual, I never follow the crowds.
- 135 **Interviewer:** Like the fish follows the stream.
- 136 **Participant 7:** I do my own thing and I'm very original in my own way, always have been.
- 137 **Interviewer:** For people who are scared of chemistry, would you suggest doing something like I've been doing with the milk lab chemistry?
- 138 **Participant 7:** I think so, definitely. I think if they approached it in a

 Applicability to Others~

way that appeals to people who find it daunting or don't fully understand, I think it would be a good way because you would be able to learn as well as have fun that it's not an environment where you're going to get shouted at for being wrong or making a mistake or something.

- 139 **Interviewer:** Yeah, and that's imperative, I mean you said so at the beginning. We've gone full circle now. So you wish chemistry was a little bit more fun in highschool? It would've changed a lot of things. Awesome, I think we're done here, thank you so much!

Appendix J: Interview Transcription of Participant 9

001 Interviewer: **Interviewer**
002 Interviewee: **Participant 9**
003
004 **Interviewer:** Alright, so this is an interview with Participant 9
Upfold on the 11th August. So I just want to know before we get
started, is it okay if I record?

005 **Participant 9:** Yes.
006 **Interviewer:** Awesome, that's perfect. Alright so first questions
first - what is your earliest memory and can you describe it as
much as possible?

007 **Participant 9:** Okay, my earliest memory is going to the dining
hall at Salisbury House because I used to live on campus, my dad
was the warden and we would go there every evening and we
would walk with my family. And that's all.

008 **Interviewer:** Okay, was that a chemistry memory?
009 **Participant 9:** Oh, is the first chemistry memory?
010 **Interviewer:** Yes. So was that a chemistry memory?
011 **Participant 9:** No, that was legit my first memory ever.
012 **Interviewer:** Like when you were very young. What age was
this?

013 **Participant 9:** I must have been two.
014 **Interviewer:** Oh wow, that's quite a memory span there.
015 **Participant 9:** Or three, I'm not sure.
016 **Interviewer:** And your earliest chemistry related memory?
017 **Participant 9:** My first day of first year - or o-week, when I went
to my intro lecture for chem - that was my first chem experience
because I never did it at school.

 Memories~
 University~

018 **Interviewer:** Oh really? Okay - and what interested you in the chemistry lecture?

CON chemistry~
University~

019 **Participant 9:** I actually wanted to do journ, but then it was a prerequisite for my zoology major so then I just had to go and do it anyway. Even if I didn't want to.

020 **Interviewer:** Okay, so you never did chemistry before in high school and you had to do chemistry in university for your zoo major? How did you find that first year in chemistry?

CON chemistry~
Emotional Response~
Subject Choices~
University~

021 **Participant 9:** It was hectic. It was really hard. I learnt a lot about myself because I didn't think I'd pass - and I didn't pass but I didn't fail by a lot. I got forty eight.

022 **Interviewer:** And was this chemistry 101?

023 **Participant 9:** 101.

024 **Interviewer:** 101 wow.

025 **Participant 9:** I did the whole year of one and then just repeated one semester.

026 **Interviewer:** Oh that's really good - well done.

027 **Participant 9:** Thanks.

028 **Interviewer:** Right. So all in all, if you had to sum up the whole year - was it positive for you or was it negative?

Perspective Change~
PRO chemistry~
University~

029 **Participant 9:** I think during it was negative because it was really hard, but then afterwards if I look back on it then it's positive if that makes sense. I struggled with chemistry so much that during the year it was such a stress and burden, but if I look back on it I am proud by how hard I worked and what I achieved.

030 **Interviewer:** Okay, and in the course structure, what did you find most enjoyable about it and what did you find not enjoyable about it?

031 **Participant 9:** I really liked thermal dynamics - I know a lot of people hated but I really liked all the equations because it's easy to learn. You just follow the equations and you practice - it's like maths. But then I hated the organic chem because I just could not understand those bonds and all of that. I don't know why, I just found that the hardest.

032 **Interviewer:** Okay - would you say your lecturers had an influence on that? Do you find your lecturers very understanding or lecture-worthy? Or was it just your own brain that just said no to organics?

📍 CON chemistry~
📍 University~

033 **Participant 9:** Yes, I feel like it was more that. Because the rest of my class really enjoyed it. It was actually the other way around so I think it was just how my brain worked. The lecturers would teach organic chem expecting the students to have a background in it, which most did, but it made it harder to understand the course.

034 **Interviewer:** Okay cool - and would you say you would define yourself as quite analytical?

📍 Personality~

035 **Participant 9:** I actually don't - I don't think I'm analytical at all. I think I'm way more creative but for some reason. I actually feel like I'm both...

036 **Interviewer:** Oh that's really really interesting. Okay so going back to high school - what were your subject choices?

📍 Background~
📍 High School~
📍 Subject Choices~

037 **Participant 9:** Okay so my three ones that I chose were geography, life science and art. I did visual art.

038 **Interviewer:** Right, and the visual art was just a creative outlet?

039 **Participant 9:** Yes - so I did two sciences and then one art, cultural thing.

040 **Interviewer:** Oh that's awesome - that's a really good choice I

- think. And then why did you not choose chemistry?
- 041 **Participant 9:** I would've done physics but I hated chem so at school it's both, it's combined.
- 042 **Interviewer:** Yes, and was that because you just didn't like chemistry or because teachers...
- 043 **Participant 9:** Yes, I think my grade nine teacher wasn't very good at explaining chemistry but she was very good at explaining physics. So then our year was split where from January to July we did physics which I did so well in and then from July to November it was chemistry and I did so badly so I think that's just why I hated it.
- 044 **Interviewer:** And you stopped from there?
- 045 **Participant 9:** Yes.
- 046 **Interviewer:** Okay, that's totally understandable. And were there any pressures into your subject choices? Say parental pressures or external pressures?
- 047 **Participant 9:** There was pressures to do like pure math.
- 048 **Interviewer:** Maths? Maths core?
- 049 **Participant 9:** Yes, so not maths lit.
- 050 **Interviewer:** From your...
- 051 **Participant 9:** From my own family. And I don't think they would have wanted me to do two art subjects like drama and art. They would've preferred accounting or...if that makes sense. So two sciences or like a science and accounting or something.
- 052 **Interviewer:** Two things that can progress you with that one thing that you just enjoy? Okay - I completely understand. And did you follow any of those subject choices through now to university?
- 053 **Participant 9:** I did Geography until second year and then

 CON chemistry~
 High School~
 Subject Pressures~

 Background~
 High School~
 Subject Pressures~

 High School~
 University~

zoology I'm majoring in.

054 **Interviewer:** Okay - and that ties in with biology.

055 **Participant 9:** Yes, and entomology.

056 **Interviewer:** And I just wanted to know, did you find your high school information in following through to your university knowledge?

057 **Participant 9:** Yes, in a way. But there was a lot I was unprepared for when I came to university. I feel like at school, you don't really have to think for yourself. You don't have an opinion. But then at university they really want your opinion about things and stuff, so it's different.

058 **Interviewer:** Yes, and they kind of teach that wrote learning over true expression of learning. That's pretty cool. Alright now to completely change the subject - before our lab session - what were your perspectives on chemistry.

 CON chemistry~
 Laboratory~
 Preconceptions
 University~

059 **Participant 9:** Okay - let me think about this. I always thought that people who did chemistry were really really clever and I still think that. I feel like I did it but I still don't understand so much. Like I did it to pass. I don't know what else I feel about it.

060 **Interviewer:** What promotes this clever...

061 **Participant 9:** I think it's because I find it so hard so when people understand I'm like wow - you're so clever. The stigma attached to science and chemistry in particular that all the smart kids do science... In first year if you met someone who was continuing to chem 201 you would immediately think they were super clever.

062 **Interviewer:** Okay, so it's like the unknown territory that other people dabble in.

063 **Participant 9:** And it's also like...I don't know it's cool - chemistry - it just sounds cool.

- 064 **Interviewer:** Oh awesome. And then when you entered that lab for the lab session - what were your feelings?
- 065 **Participant 9:** I was a bit nervous because I didn't know what exactly we were going to do. Then I was also a bit excited because Joyce had kind of explained.
- 066 **Interviewer:** Any anxiety? Stress?
- 067 **Participant 9:** I was a bit anxious but I wasn't like dying.
- 068 **Interviewer:** But generally positive or negative?
- 069 **Participant 9:** Positive.
- 070 **Interviewer:** And then actually donning - I know this is like this for because when I don my lab coat I always get excited - so actually putting on the lab coat and goggles - did that also worry you?
- 071 **Participant 9:** No that made me excited.
- 072 **Interviewer:** Okay. And then what I would like to know is please describe the lab session that we did.
- 073 **Participant 9:** Okay, well it was really fun, it was informative. It was nice that I had something to take home afterwards. You know like - I felt accomplished and it was really interesting to hear about your project and stuff.
- 074 **Interviewer:** Awesome. And during the lab session - did any other emotions spark other than the ones that you just mentioned?
- 075 **Participant 9:** Like a bit of nostalgia for my lab days in first year. It was mainly when we were weighing the stuff out it was like this reminds me of first year.
- 076 **Interviewer:** And those first year nostalgic feelings - were they positive?

🧪 Laboratory~ 🧪 Emotional

🧪 Emotional Response~
🧪 PRO chemistry~

🧪 Emotional Response~
🧪 Perspective Change~
🧪 PRO chemistry~

🧪 Emotional Response~
🧪 Memories~
🧪 PRO chemistry~
🧪 University~

077 **Participant 9:** Positive. Although I used to hate pracs and now I think back and they were fine.

078 **Interviewer:** Okay so some really good memories. Any other memories that were sparked?

079 **Participant 9:** Mainly nostalgia. Because that's really my only memory of chemistry was first year.

080 **Interviewer:** Because you hadn't experienced it before then. Okay, and then with regards to my milk paint - has learning chemistry through this changed your perspective on chemistry itself?

081 **Participant 9:** Well in a way I wouldn't think that making paint out of milk was like a form of chemistry, but now thinking about it - it is. So maybe this changes what I think chemistry is. I think it's all like atomic and not necessarily... When I think about chemistry I think of fancy machines that measure atoms and energy etc...

082 **Interviewer:** Because you never really had a very positive perception? Okay - I'm glad we changed that. Right, and then your post lab - not the feelings about chemistry, but would you recommend this laboratory experiment to other people to learn about chemistry?

083 **Participant 9:** Yes, I think it was really really fun, it was happy, it was cool.

084 **Interviewer:** Alright and now we're going to go onto something a little different - is the artworks. I need to get some information so let me just scribble through here to find your file. Just to talk briefly about your artworks and what they mean and what they symbolise. Need some recall. So we can go through your first artwork and what I would like to know first is what were you trying to represent here?

085 **Participant 9:** Okay, well this built - what would you call it -

CON chemistry~
Laboratory~
Perspective Change~

Perspectives
Preconceptions

Applicability to Others~
Emotional Response~
Perspective Change~
PRO chemistry~

Art Works~

solution I guess was representative of my lab days and how I don't know how I would get the answer at the end of my lab practical, but I did. But I always felt very chaotic and never felt like I knew exactly what I was doing.

Medium~
Symbols~

086 The painting had a beaker that had fallen over spilling a solution everywhere which happened a lot during my pracs. This also represents my anxiety over chemistry. The collage is made out of different exam papers and tests that I didn't do well in or failed. It represents how I would work hard but not achieve my goals, therefore I felt like tearing the paper apart..

Emotional Response~
Symbols~
Emotional Response~
Medium~

087 **Interviewer:** And frantic?

088 **Participant 9:** Yes, and frantic and then it's kind of why the blues are in there as well because it's like sad or confusion. And then all of these are from my exams that I failed because I had so many exams that I failed and tests that I failed for chemistry. So this painting is quite negative but it's still my true representation of how I feel about chemistry.

Color~
Emotional Response~

CON chemistry~
Emotional Response~

089 **Interviewer:** This was your perspective of chemistry and the first year lab.

090 **Participant 9:** Yes, and it's quite negative.

091 **Interviewer:** And I just want to know the collage - what is that a reference to?

CON chemistry~
Emotional Response~
Medium~
Symbols~

092 **Participant 9:** So these are all my tests that I failed and my exams.

093 **Interviewer:** And the emotion behind it.

094 **Participant 9:** So the feeling of working really hard and then still failing and like defeat I guess.

095 **Interviewer:** Cool, I really like this.

096 **Participant 9:** Like I still couldn't tell you what that is - or that.

097 **Interviewer:** Alright, and so we've gone through the colours and everything else. Oh so the medium of choice is water colour.

🌀 Medium~

098 **Participant 9:** Yes, I just always usually paint in water colour - it's what I have at home.

099 **Interviewer:** Oh awesome. It is just like a personal preference?

100 **Participant 9:** Yes. I can't really use the oil or acrylic.

101 **Interviewer:** They're a little more forgiving. That's just about everything that I need to know about this artwork which is beautiful. Okay, going onto the second one, this is post lab.

102 **Participant 9:** It's so positive.

🌀 Perspective Change~
🌀 PRO chemistry~

103 **Interviewer:** It's really really colourful which is awesome. So can you tell me about the picture - what you're trying to represent?

104 **Participant 9:** Okay - well you said it was after my lab experience right - but it's not based on my lab experience. So since then I've had to choose what I'm going to do next year. If I'm going to do honours or stay and I turn 21 so then I kind of wanted to do like a dream theme so that's why the sky is very watery and not like proper sky. And when like this imagery is so...

🌀 Medium~
🌀 Symbols~
🌀 University~

105 The painting was very ethereal and dream like... This is because I'm finishing my degree, becoming an adult and deciding what direction I want to go in life.

106 **Interviewer:** Abstract - or what are you trying to...

107 **Participant 9:** Like if you try to represent time and you put a clock there.

108 **Interviewer:** Oh. It's symbolic.

🌀 Symbols~

109 **Participant 9:** Yes, but it's not very like deep but anyway. It's

meant to be like a butterfly because I do ento and I love animals.

110 **Interviewer:** Oh lovely.

111 **Participant 9:** So it's like a work. Or a caterpillar turning into a butterfly and going onto the next stage of life. And I am.

112 **Interviewer:** Oh the transformation.

113 **Participant 9:** Yes, transformation. So it's about that - and also not being too clear and everything feels a little bit weird at the moment.

114 **Interviewer:** A little bit surreal? Okay, that's very very cool. And flowers? Do they represent much to you? Is it just the biology?

115 **Participant 9:** Yes - it's just the biology. And when I saw the paint colours that I had, the first thought that came to my head was actually just flowers because I liked the pinks and the purples and so that's why I just thought flowers.

116 **Interviewer:** Oh cool, and is that like an internal metaphor for your own personality?

117 **Participant 9:** Maybe - I'm not sure. I haven't given it much thought actually.

118 **Interviewer:** Okay cool. And what medium is this?

119 **Participant 9:** So this is your milk paint on paper and then some pencil just because it was hard to do the outsides.

120 **Interviewer:** So how did you find the paint? I know it gets a bit funny after a while.

121 **Participant 9:** It was really cool, it almost looks like, not like pastel but a bit like crayons.

122 **Interviewer:** It does get that look and unique texture.

Color~
Shape~
Symbols~

Emotional Response~
Medium~
PRO chemistry~

123 **Participant 9:** It looks cool though.

124 **Interviewer:** Okay awesome, that's perfect. Thank you so much.

125 **Participant 9:** 14:46

126 **Interviewer:** Yes, it's really cool. I can see the colours you've used are 14:49. A few more questions just before we go. If you had to look at chemistry in general, what would you wish could be a little bit different to make you feel a little bit more comfortable, maybe get the information better?

📌 Applicability to Others~
📌 University~

127 **Participant 9:** I feel like at Rhodes especially - you're forced to do chemistry even if you didn't do zoology and entomology like I was going to do which I found really funny. I think there should have been a chemistry course for my major because so much that I had to do for chemistry, I haven't ever used.

📌 CON chemistry~

128 There are so many parts of chemistry that I don't use in my degree, in fact I don't think I will ever use. I don't feel that chem should be a prerequisite for zoology and entomology, maybe we could have done a course in first year in cell bio or zoo 101 on the chemistry we need for biological science.

129 **Interviewer:** So it's just totally un-applicable to your...

📌 Applicability to Others~
📌 CON chemistry~
📌 PRO chemistry~
📌 University~

130 **Participant 9:** And I know it has been a debate for a long time. It's not un-applicable because I wanted to do micros in second year instead of geo which means I would have needed it.

131 **Interviewer:** Yes, you've answered all my questions perfectly. Thank you so much.

Appendix K: List of Tables

Table 2.1.1 List of colours and their symbolic connotations based on Varley (1983) and Wright (2016)

Colour	Comment by author
Black	Black is the negation of colour. Perceptually it implies weight and solidarity; darkness implies space which is infinite (Varley, 1983). Black is inherently ominous in that it is unknown – a feature it holds in common with death. However black is a tremendous source of strength as it combines mystery with power which may be used for good or ill (Varley, 1983).
White	White suffers a certain inhumanity as it can both be a positive symbol of purity and a negative symbol of cowardice or the white elephant of a burdensome possession (Varley, 1983). Hygiene, sterility, clarity, purity, cleanness, simplicity, sophistication, efficiency, Sterility, coldness, barriers, unfriendliness, elitism (Wright, 2016).
Grey	Grey suggests intelligence – the grey matter of the brain reinforced by the grey head of wisdom. In addition to clear thinking, grey also suggests confusion and the loss of distinction in a world where it is claimed that nothing is totally black or completely white (Varley, 1983)
Red	It is the fastest moving colour in terms of catching the eye, and has the greatest emotional impact. The physical effect of red, with exposure to larger quantities of the colour quickens the heart rate, prompts the release of adrenalin into the blood stream and engenders a sense of warmth. Red's multifarious meanings start with its most salient association – blood. Red is equated with the heart, flesh, and emotions in comparison to its fellow primaries of blue (a symbol of spirit) and yellow (a symbol of mind) (Varley, 1983). The emotions evoked by red are those that get the blood pumped up, from love and courage to lust, murder, rage, and joy (Varley, 1983).
Pink	Red's dynamic range alters dramatically where the colour turns pink. It becomes gentle, acquiescent, and alters the gender from masculine to feminine (Varley, 1983). Positive: Physical tranquility, nurture, warmth, femininity, love, sexuality, survival of the species. Negative: Inhibition, emotional claustrophobia, emasculation, physical weakness (Wright, 2016). Positive: Physical tranquility, nurture, warmth, femininity, love, sexuality, survival of the species. Negative: Inhibition, emotional claustrophobia, emasculation, physical weakness. Being a tint of red, pink also affects us physically, but it soothes, rather than stimulates. (Interestingly, red is the only colour that has an entirely separate name for its tints. Tints of blue, green, yellow, etc. are simply called light blue, light green etc.) Pink is a powerful colour, psychologically. It represents the feminine

	principle, and survival of the species; it is nurturing and physically soothing. Too much pink is physically draining and can be somewhat emasculating (Wright, 2016)
Orange	Orange has always suffered something of an identity crisis. It has virtually no negative associations, emotional or cultural, and its emphatically positive meanings are few (Varley, 1983). Orange is unequivocally a warm colour. Psychologically it is linked to comfort and security (Varley, 1983). Its practical and conservative nature makes it more popular with adults than with children, who use it to convey sadness in painting. In French, <i>brun</i> , means melancholy, gloomy, and dull – “a thoughtfulness of expression concealing vacuity of mind” (Varley, 1983).
Yellow	Yellow is the bond between two phenomena of importance in human history: the life giving sun, and a measure of earthly wealth, gold (Varley, 1983). It is a natural symbol of enlightenment. With its fellow primaries of blue and red standing for spirit and heart, yellow represents the intellect or mind (Varley, 1983). A sullied yellow feels treacherous, but in its pure form, yellow radiates warmth, inspiration, and sunny dispositions making it the happiest of colours (Varley, 1983).
Green	Green is the most ambivalent of hue. It is the colour of mould and decay, as well as of life itself. Despite the traditional associations of nausea, poison, envy, and jealousy, it is the colour of foliage, rebirth of spring, and of the power of nature (Varley, 1983). Green is the most restful colour to the eye. The lens of the eye focuses green light exactly on the retina. Perhaps the association of this colour with the qualities of stability and security stem from its ease of perception (Varley, 1983). Among greens crowning ironies are the facts that this colour, associated with emotional balance, also signifies the most vertiginous emotion – jealousy. Positive: Harmony, balance, refreshment, universal love, rest, restoration, reassurance, environmental awareness, equilibrium, peace. Negative: Boredom, stagnation, blandness, enervation (Wright, 2016)
Blue	Blue has historic and symbolic associations with royalty, yet it is also the people’s colour. It is the peacemaker of all colours; cool, soothing, orderly. Its negative meanings are confined mainly to sadness or depression, are merely extensions of positive traits such as cool to cold, solitude to isolation, tranquility to inertia (Varley, 1983). Blue surroundings produce a calming effect, even lowering the blood pressure, and thus are recommended in every room in the house designed to be restful (Varley, 1983). The emotional meanings of blue divide themselves naturally according to light and dark. The jubilant blues would never be used to express depression, or used to describe being turned blue with fear (Varley, 1983). Positive: Intelligence, communication, trust, efficiency, serenity, duty, logic, coolness, reflection, calm. Negative: Coldness, aloofness, lack of emotion, unfriendliness (Wright, 2016).

Purple/Violet	They evoke heavenly delicacy or incomparable richness, mishandled and they are unsettling and degenerate. Since the mind may be confused as to whether it is responding to masculine, physical red or the feminine, spiritual blue, these hues are defined as “psychologically oscillating” (Varley, 1983). Purple and violet between them encompass vast differentiations in hue. Violet is not merely a lighter purple, it is a pure spectral hue, while purple is a dual or mixed colour. Purple is the colour naturally synonymous with sensuality. It can be orgiastic and ostentatious; not exclusively the colour of power, but also the power corrupted. In psychology, violet is associated with internalization and sublimation, indicating depth of feelings. Self-esteem radiates purple, but a preference for violet in the Lüscher colour test indicates immaturity. The ambivalence inherent in lavender has sometimes caused it to be labeled effeminate and linked to homosexuality. However, no one can pin the red-and-blue bred shades down to specific single identity (Varley, 1983). Positive: Spiritual awareness, containment, vision, luxury, authenticity, truth, quality. Negative: Introversion, decadence, suppression, inferiority, It is highly introversive and encourages deep contemplation, or meditation (Wright, 2016)
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Table 2.1.2 Features of Artworks and their related emotional connotation (Lu et al., 2012)

Emotion	Features
Angry	Circularity
Disgust	Length of line segments
Fear	Orientation of line segments and angle count
Sadness	Fitness, mass of curves, circularity, and orientation of line segments
Amusement	Mass of curves and orientation of line segments
Excitement	Orientation of line segments
Contentment	Mass of lines, angle count, and orientation of line segments

Appendix L: Participants' Laboratory Notes

Table 6.1.2.1: Participant responses to the question "What is your first memory of chemistry?"

Participant	Comment
1	In biology I had to chop up a kidney of some sort - It smelled really bad. It was a good memory but I remember thinking I really wanted to do something with chemicals.
2	Making a volcano using bicarb and vinegar
3	My first memories of chemistry were from school. I have absolutely NO hands on experience with chemistry but I remember learning bout molecules and basic chemistry stuff in Bio/NS and feeling really unsure and confused! Not something I enjoyed, that feeling! I always felt this way about physics/science and this is why i didnt take the subject from grade 10 onwards
4	1st year
5	Earliest memory →Preschool we were giving dishwashing liquid in a cup with water and a straw - blow = bubbles = fun. →Primary school - volcanoes - Mt vesuvias in pompeii - we added food colouring vinegar & bicarb - volcano erupted rainbow colours of red, orange + yellow. → High School? - Stress! breaking down & beakers, tears, & testtubes; My physics + chem teacher had a saying "If it is green & wriggly its biology... if it stinks, its chemistry and if it doesnt make sense, its physics"
6	ignition of Mg in Grade 10 chemistry class. Sodium and water in grade 10 chemistry class, discovering how exciting chemistry can be, the amazingness of reactions
8	This would be when I did my first really good experiment for a school project. Mine was nominated by the teacher to come show and present it at Rhodes for an event with other from other schools. I didn't win but seeing all the other projects was intriguing and brought to light how much really is to chemistry.
9	Finding out that chem 101 was a prerequisite for my zoology degree (Never took chem in high school). Made me feel anxious.

Table 6.1.2.2: Participant responses to the question “What do you think happens to the milk when you add the acid?”

Participant	Comment
1	It seems to make it instantly go off or creamy
2	curdles? Bubbles? Thicker?
3	A CHEMICAL REACTION. I anticipate the milk will bubble and separate. →It starts thickening and clumping. The milk is breaking down and casein is becoming water insoluble
4	Acid changes the consistency and structure of the milk; Acid changed pH (-ve)
5	Before adding thoughts - It curdles :Σ, Bubbly, changes, aero-like. What did happen? Thicker, coagulates, smells sour :O
7	The protein in the milk or fat is separating from the water of the milk. Like when milk defrosts (that's what it looks like)→LINK TO MY BACKGROUND IN COOKING AND DÉCOR CONSUMER STUDIES AT SCHOOL. Food>reaction<chemistry
9	The milk separates and becomes clumpy instead of a liquid. May have something to do with the difference in alkalinity

Table 6.1.2.3: Participant responses to the question “What do you think happens when you mix the casein with the lime?”

Participant	Comment
1	the lime melts the casein?
4	Forms a large lump, dough-like; creates a paste after forming dough; becomes liquid?→counter intuitive → haha
7	I think it will make the protein that has separated more solid. It becomes more fluid like a really runny dough.
8	Again not sure but I would reckon that it will simply add to the casein allowing the casein to be more abundant, in other words more casein. Maybe also make it so that it can be influenced by the pigment.

9	The casein will become less solid and more liquid but not runny.
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Table 6.1.2.4: Participant responses to the question “What did you notice about the mixture?”

Participant	Comment
1	18.84 = 20ml of lime; goes more liquid -- less like rubber; not expected; mixture heating up
2	casein goes thick then more liquid; added 20ml Ca(OH) ₂ ; added 1.25 ml to get rid of lumps; paint is very bubbly
3	it becomes a thick liquid that is smooth; to make it thinner/less viscous, add water.
4	2 solids = liquid paste; same colours, no change; quite viscous, more like paste; add more water to make it less viscous
5	add H ₂ O to go
6	17.654ml lime. Begins to liquify the casein- creating a liquid now. Very strong smell again more sour than acidic. To make it thinner -- add more lime
7	Adding a solid to a solid. Once stirring it looks like cookie dough. It not doing what I thought it would do. Its now becoming more liquid.
8	For a 3 to 2 ratio we need 84.69 so I will take 85ml -- FALSE. We need 9.41 however I rounded to 15ml. We mixing the casein with the base, the mixture becomes very tough like glue. The viscosity of the mixture is very high. I would guess that in order to make it less viscous, add water since water has a neutral pH.
9	added 1.25ml of base (extra). Begins to feel sticky. Has a thick consistency. Added some water (twice). Added more base (1.25ml) and more water <Casein was being stubborn>

Table 6.1.2.5: Participant written responses during the experiment

Participant	Comment
2	vinegar reminds me of making malva pudding with granny :) ; reminds me of making milk kefir; milk = coco pops LOL; My milk is broken :(; doing the experiment took me back to school when I did biology - I actually really enjoyed doing those labs :)
3	The milk is thickening awhile lot! It smells really bad. The colour has not changed although on the surface it is cloudy and clumping together. I started filtering the mixture into another beaker. The process was slow and so we added more acid? vinegar - $\pm 40\text{ml}$. Then the filtrate was more clear and ran through quicker. Decided to use a new filter and beaker and add the remainder of the mixture in the original beaker. SUCCESS! about 40ml ran through quite quickly; with some help i filtered out another 50ml
4	$\text{Ca(OH)}_2 \leftarrow \text{Base}$; Milk will separate out more than currently; faster reaction rate? After casein separated out: will become more like a liquid once added the base; change the state of casein; will dissolve the casein. "every question in science can be answered by/in nature" - someone famous.; ANXIETY $\rightarrow$ clinical; Off milk $\rightarrow$ cheesey, smell $\rightarrow$ think of coffee and chunks; Danoe yogurt $\rightarrow$ cottage cheese $\rightarrow$ chalky once filtered.
5	Next: straining milk & casein = cottage cheese/feta; $+20+20+50$ - Milk was stubborn on separating <calculations> Added is me 15ml lime - smoothed out nicely! Grace icing
6	creating the paint - Excellent experience. The vibrant pigments are excellent. Very excited to paint with the paint I have made. Very pleasurable and enjoyable experience.
7	Vinegar is seen as a cleaning agent in my family so I don't like the smell; The casein (protein) is not thick. $\rightarrow$ after taking out water baths you can see the separation. Then we strained it and you are left with just the protein (that is thick and soft). the water from the milk after being strained is clear and yellow (light) in colour. 3 completely different colours but fun! YAY! Pigments bind to the molecules, different types of pigments. Everything is linked! what.
8	fun, a little messy (but that's part of the fun). Exciting before starting. Always intrigued by what will happen when adding something. After

	adding something and the mixture changes, wonder what will cause the change and why it did what it did.
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Table 6.1.2.6: Participant responses to the question “What was your high school subjects? Why or Why not Chemistry?”

Participant	Comment
1	my high school subjects were art, biology and accounting. i chose them because they were the subjects i thought i would enjoy the most and i never chose chemistry because i always felt id never be able to understand it or excel in it
2	High school subjects: biology, geography, consumer studies, maths lit, computer science (instead of Afrikaans), English.... I didn't take chemistry because it didn't interest me and I don't feel like my brain is programmed that way....
3	English, Afrikaans, Mathematics, History, Biological Science, Accounting, Life Orientation. Why did you make the choices? I wanted to keep my options open so I selected subjects that would give me the broadest field of knowledge. Why/why not Chemistry? While I know I said I wanted to keep my options open, I was sure by mid-Grade-9 (when we had to make the choices) that I didn't want to go into medicine or any other career path that would require me to have taken Physics/Chemistry. I've always been more inclined towards subjects in the Humanities which involved a lot of speaking, writing and explaining, and had to work harder to understand more scientific subjects. I also really wanted to take both History and Biological Sciences, and the way my high school had the subject lines set up, I couldn't take History, Bio and Physics.
4	My high school subjects were; English, Afrikaans, Maths Core, Geography, Science and Biology (triple science, whoo!) I chose these subjects as they interested me, and were prerequisites for a BSC at many of the major universities in the country. Chemistry at this stage was combined with physics and I actually enjoyed it more than physics itself... Also doing science opened more doors for you in future studies... As part of my BSC chem was compulsory as an undergrad... didn't really enjoy it though, it went over my head and I didn't enjoy being forced to take a subject, it kind of killed the interest that I had in high school

5	English, Afrikaans, Mathematics, Biology, Drama (Physics & Chem til grade 11). I had to work hard in physics in High school (Danville Park Girls High) and always knew that I enjoyed and love history more but was convinced that physics would open more doors.
6	High School Subjects: English, Afrikaans, Maths, Science, Biology, Drama, Comp Sci. Why - English, Afrikaans, Maths - compulsory. Science - for university exemption, Biology - cause it was interesting, Drama - cause i loved it, Comp Sci - cause im naturally gifted.
7	I did maths, maths p3, history, geography, consumer studies, English, Afrikaans, life orientation. I took them cause I was interested and did well in them
8	Chemistry was part of physics, as in it had to be done alongside physics. This and the way chemistry is portrayed by guests (who are chemists) on talk shows with all the interesting and really awesome things they show that can be done with chemistry.
9	Visual Art, Geography, Life Science. They were my favorite subjects at the time. I didn't choose chemistry in High School because I didn't enjoy physics.

Appendix M: Participant 5's Lived Experience

MY SCIENCONSCIOUSNESS

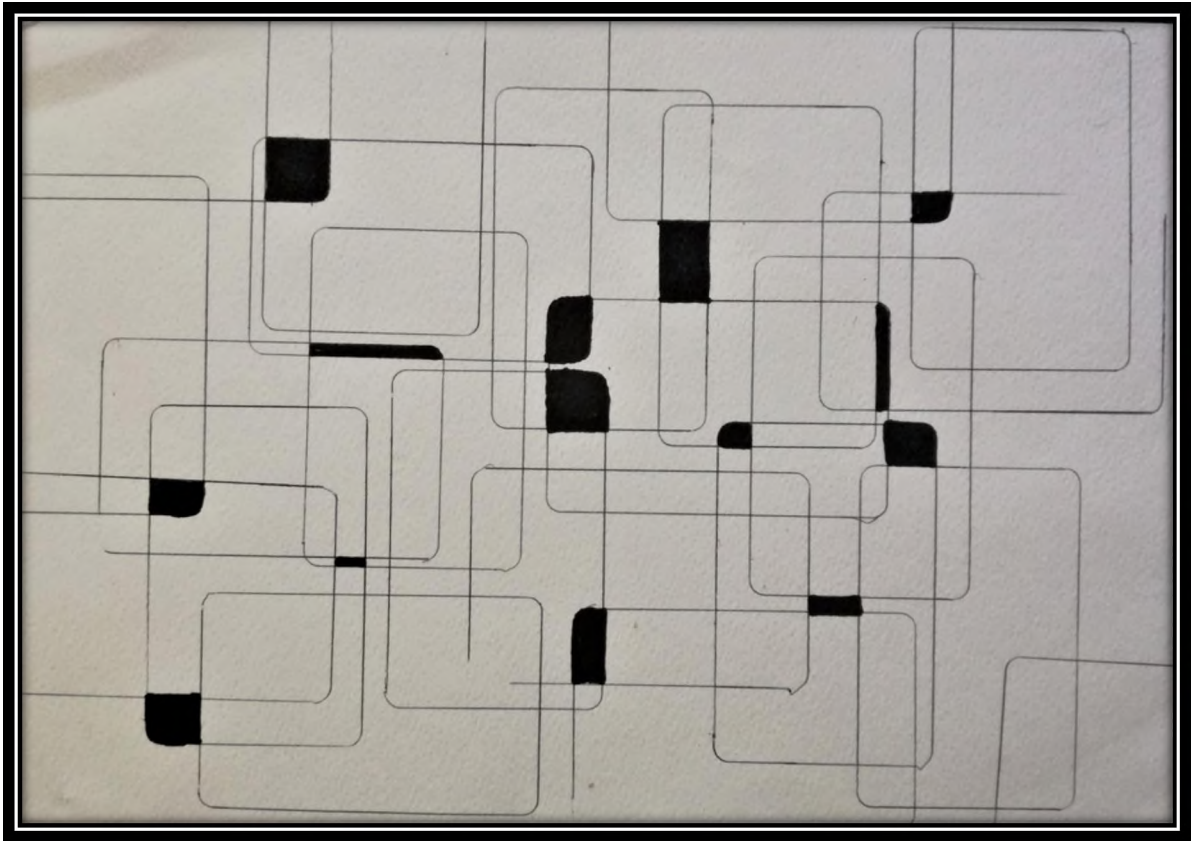
HIGH SCHOOL: PHYSICS AND CHEMISTRY were nothing short of memories involving extreme stress, there is nothing quite like the feeling of balancing a chemical equations correctly or learning the family names in organic chemistry, however all the fun moments *Argon* when the stress of getting it wrong starts to kick in, trial and error trial and error... trial and error. Science took my patience – practice and that coffee is a staple dietary requirement!

Day at the labs:

In a mcfurry-hurry of rush I sprinted with coffee in hand and mixed emotions in mind (Please Lord let there be no math involved!), when I arrived the emptiness of the department was overcome by the friendliness of the crew dressed in lab goggles(sic) and white lab coats, while the chemistry coordinating guru dressed in an energetic orange coat. The explanation before entering the lab gave me necessary expectation for the adventures beyond the lab(sic) door... the first thing I noticed when I walked in was the small tub of lumo purple powder paint (excitement within me stirred...just a little). Measurements and instructions were accompanied by interactive chatter as we analysed the contents of our cups begin to curdle. This led to a little comparison and frustration (My milk was being super stubborn) but as soon as we added the powder pain(sic) (I combined blue and green to make a aquamarine – happy mermaid)

Heading home with my cup of paint I couldn't wait to show the diggies – one diggie thought it was icing – her expectations were not sweetly satisfied but my expectations of science for the day were surely ignited with a new perspective on science

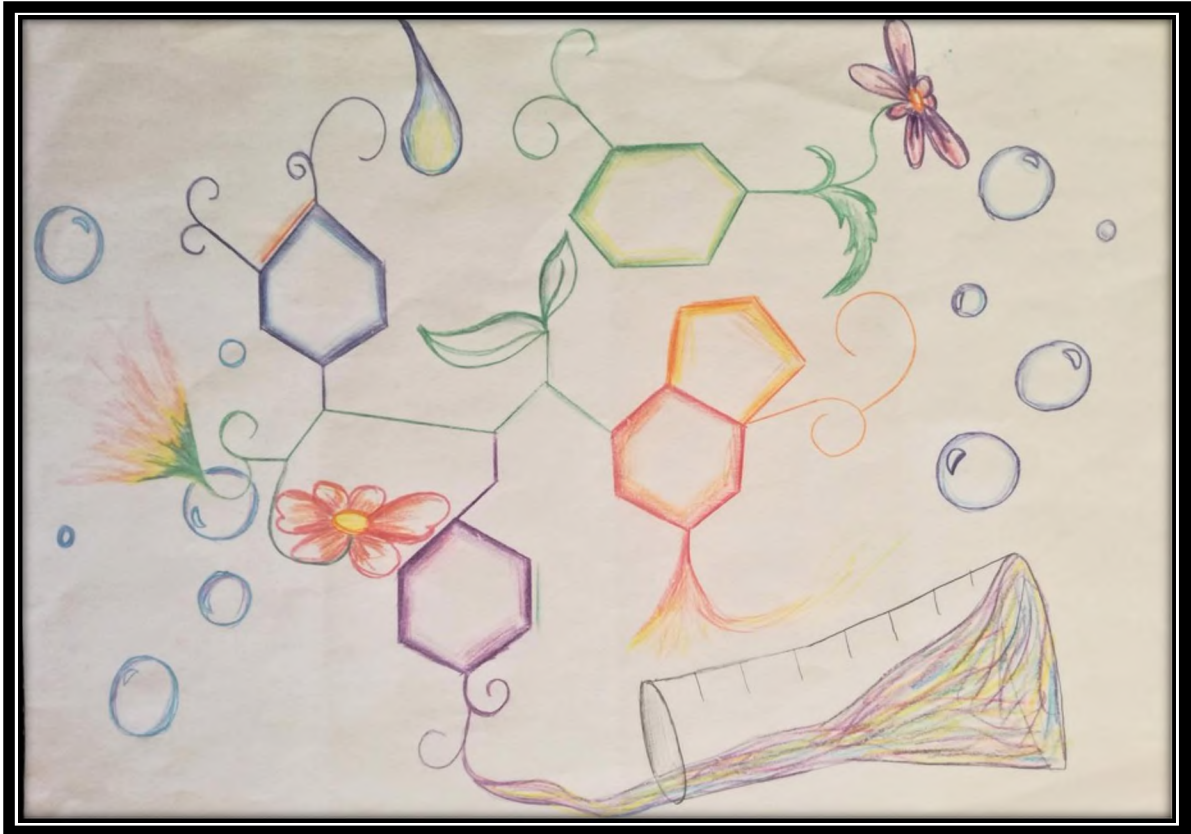
Appendix N: Participant Artworks



Participant 1 Artwork 1



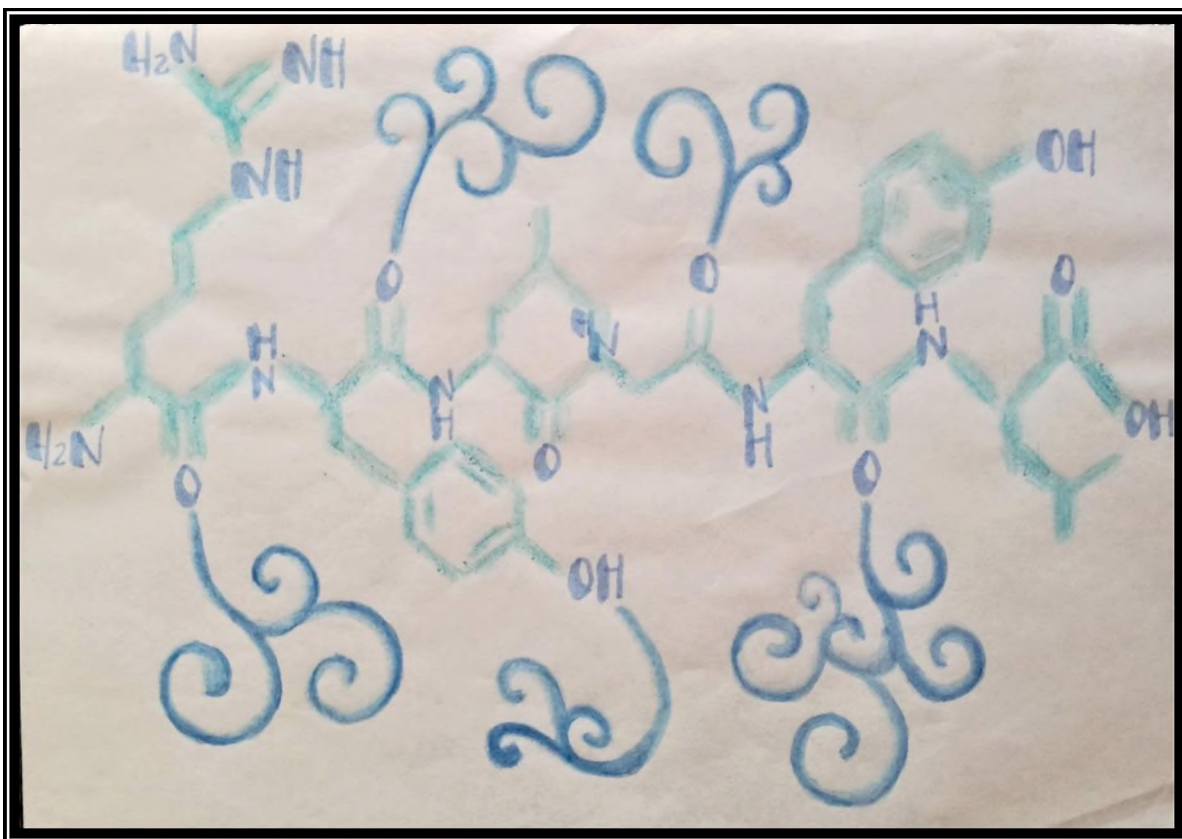
Participant 1 Artwork 2



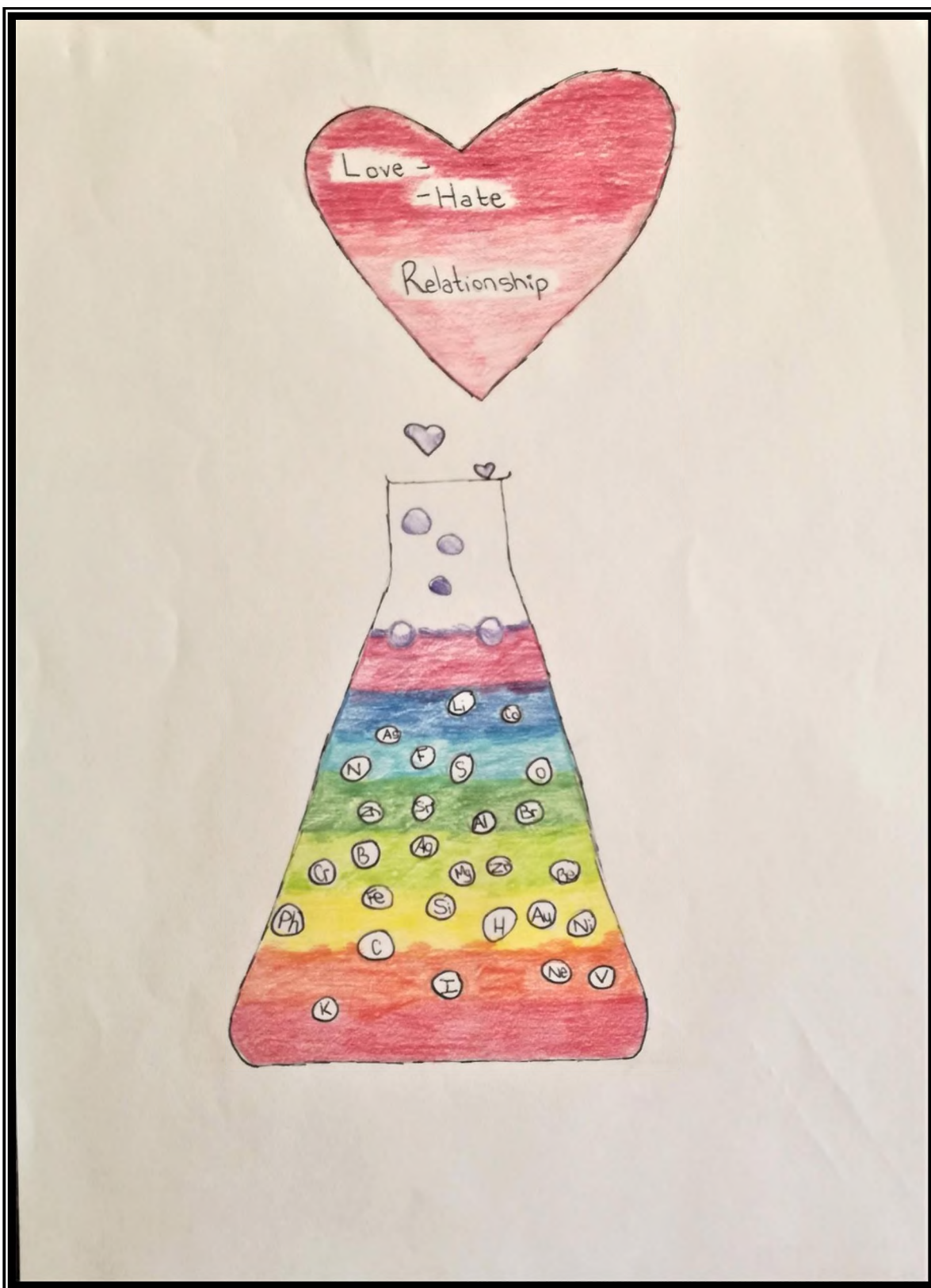
Participant 2 Artworks 1&2



Participant 3 Artwork 1



Participant 3 Artwork 2



Participant 4 Artwork 1

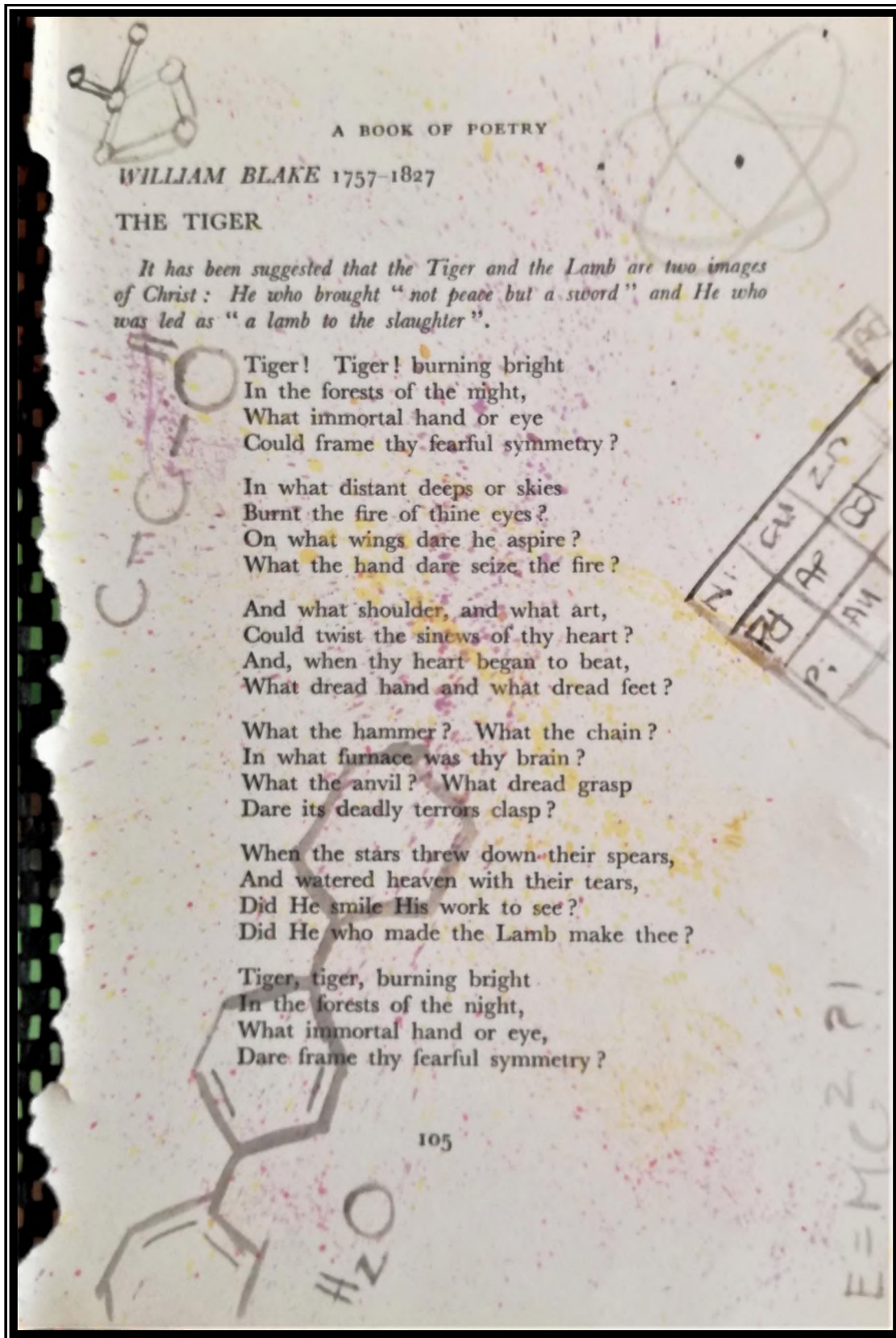
Liquid to Solid

E H U F F A I L U R E L A X E D X X W N R U T H B
 Q Q Z K P W N F J D D L Q N W A N X I E T Y W X H
 O R C K S F X O Z B G A B U M M E N P Q H F G O K
 Q W F D P U F A I O N C S A Z U T O X E N R G H U
 U F V T L B H Z I T Z I S D D R H I R R M S N T I
 W Y G K U Q Q Z I R S M Z C O N S T R U C T I V E
 X T W H S T Y Y F U E E K D A W A A P S Y B T C Z
 U W X Z P B U G K L A H U W L Z T T F S E G S F E
 H T E X K T J Z L P O C I Q R L I C S E G N E U C
 N G F G A Z P S U U T R X H H M S E L R T I R T U
 R G E F N Q R Z O O P T T G S R F P Q P E Y E R O
 P R N N S L V V R K B F I N U F Y X G T Q D T Q T
 D H U F G O C Y X M J M E M O R I E S N J C N P Y
 F M V A V M O A R W F C N E V C N K V T G Y I U T
 N R W R W Q M W L K W V O F R A G I L E K W U W C
 J A H Y W W F Z F J B M X C E V R L E Z D Z T U K
 N P L H M Y X M G T F N M F N Q C L O H L R D W D
 Y V P V H M Q U M Y L B Q W S H C H F R Q C E D R
 V R W E U P U I L M X V V Y B D O X U G U T S L R
 B Q P R W T L S M D F B U H P R T F W X F Q G C V
 J N X O C B M S G T B J I N V T F B B A Y M F I R
 R W A V O F G S U I P X S K G N H K D H T W O A B
 Y V F V S I F N Y X D W P F R I G M M E D S H O Y
 T B W M X L L X R N J V T R T F J Y Z W S G J U S
 I G H C M U T S Z Q I V J M B D F X F Q B P W Y Q

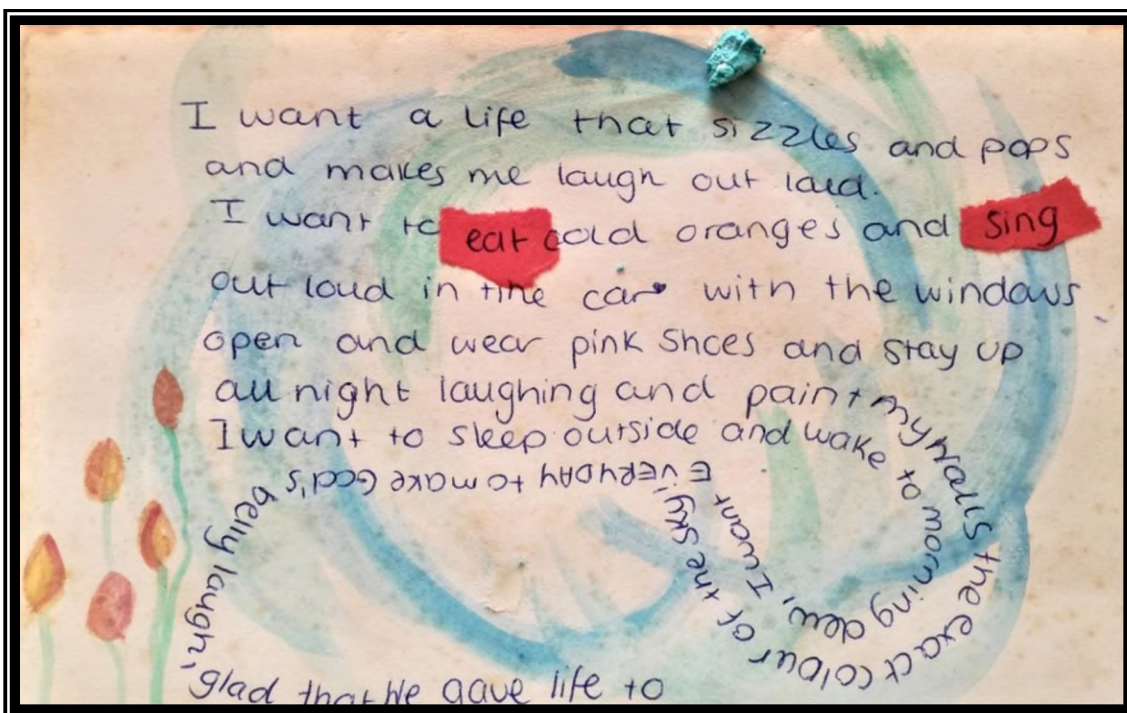
ANXIETY
 CONTROL
 FRAGILE
 INTRODUCTORY
 NERVOUS
 RELAXED
 SMELLS

CHEMICAL
 EXPECTATION
 FUN
 LIKE
 PRESSURE
 SAFETY
 UNDERSTANDABLE

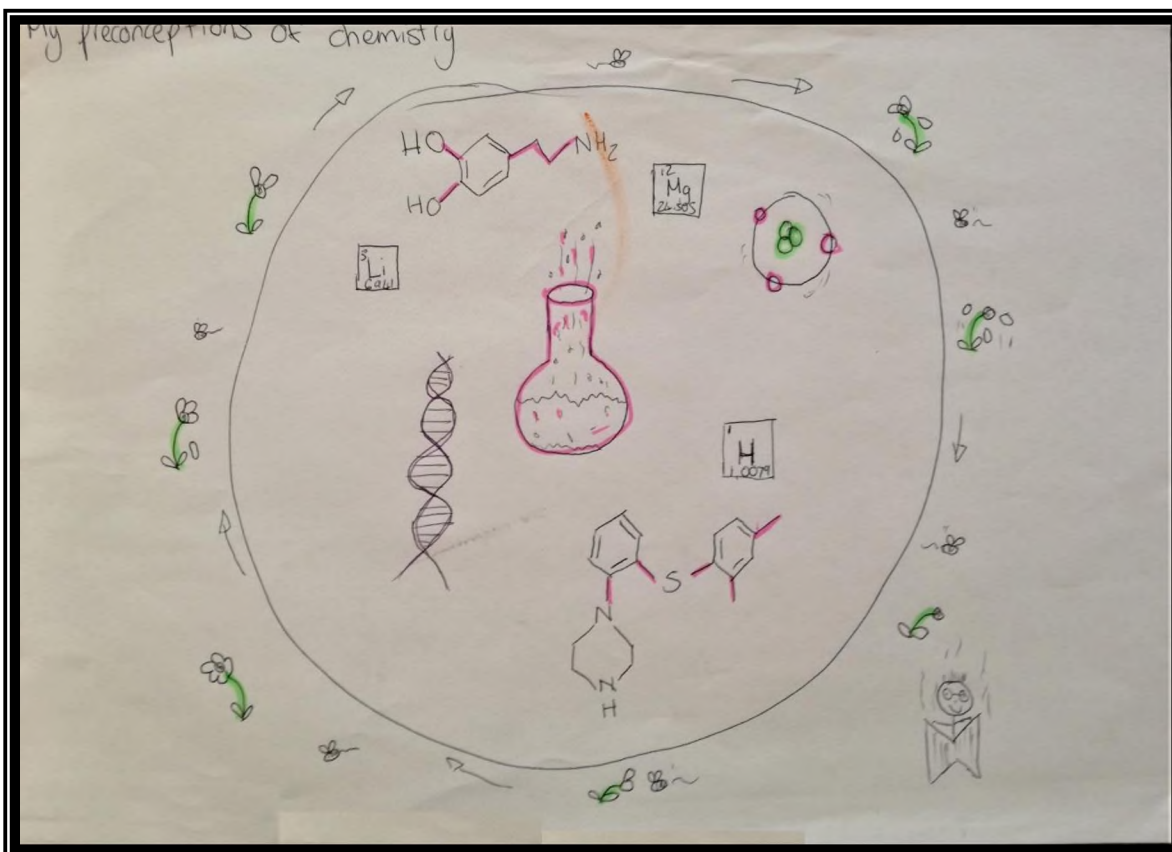
CONSTRUCTIVE
 FAILURE
 INTERESTING
 MEMORIES
 QUESTION
 SATISFYING



Participant 5 Artwork 1



Participant 5 Artwork 2

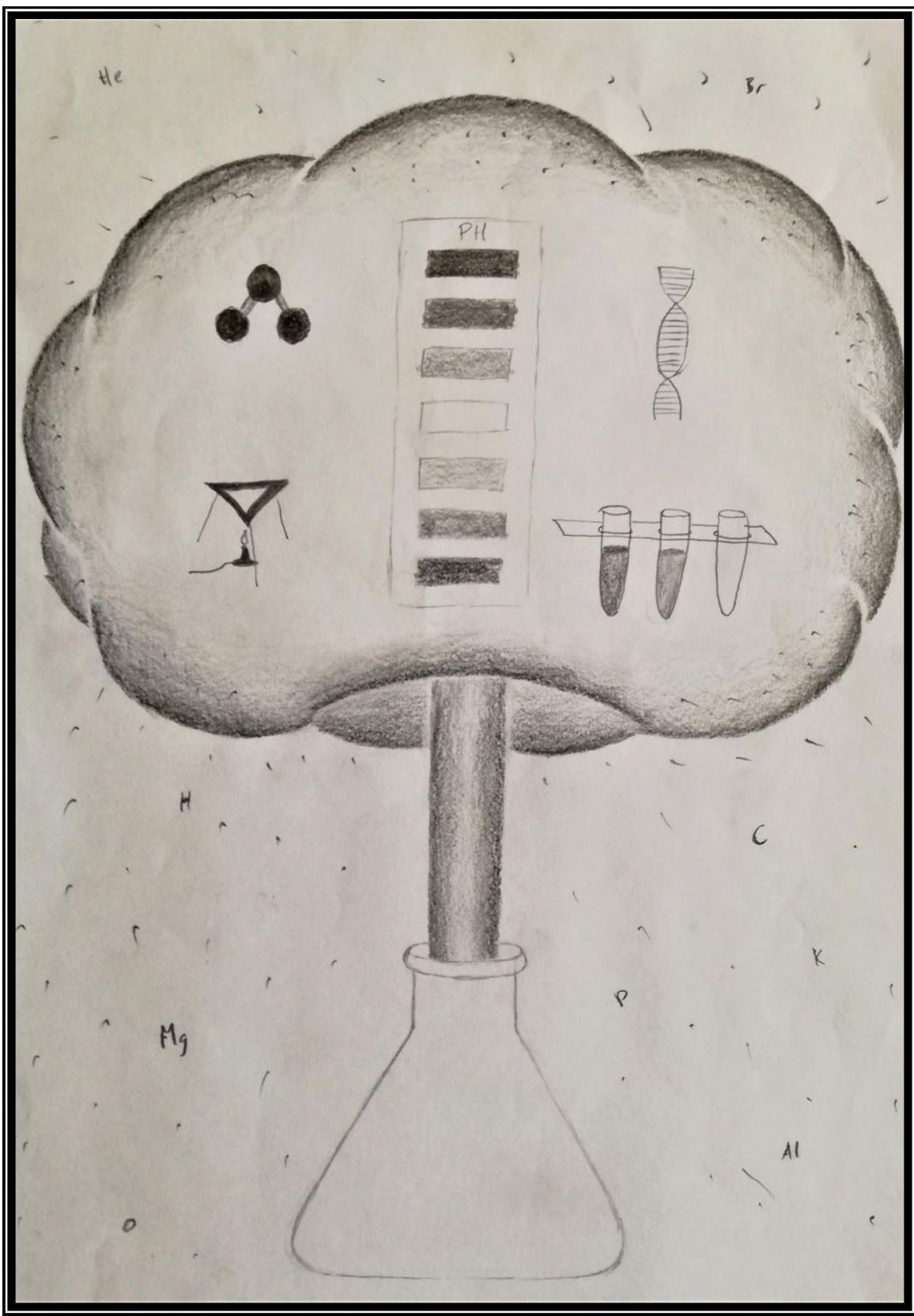


Participant 6 Artwork 1



I may not understand chemistry
 After all its all a bit of a mystery
 Mixing milk and vinegar together
 created a reaction, calling the proteins to come together
 But, one thing is for sure, I can say I have clicked
 As food and chemistry as well as everything are interlinked
 Making paint with milk has opened my eyes
 To the fact that I know more than I thought with
 took me by surprise.

Participant 7 Artworks 1&2



Participant 8 Artwork 1



Participant 8 Artwork 2



Participant 9 Artwork 2