students only accepted the relevance of fact rather than theory. Dealing with student's identified misconceptions was a challenge as teachers were unable to address them. The belief that teachers had about their students that scientists are objective observers anticipated that these students are less likely to pursue science as a career of choice.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter contains conclusions, recommendations and limitations to the study. It was established from the literature that the explicit teaching of NoS has not been a priority by either practitioners or the education authorities in many countries. It has been evident that even in South Africa, there is no particular focus on this aspect.

The study originated from the evidence and recognition that student performance in physical science at matriculation level, particularly in historically disadvantaged public secondary schools of South Africa, is deteriorating yearly and has resulted in massive shortages in the scientific workforce in all sectors. Sitting with such a shortage of scientifically advanced workforce and practitioners, teachers are gradually exiting the education system. The DoE has not been turning a blind eye to this as there are programmes in place trying to mitigate the situation. These programmes range from organized winter schools, spring school to camps. From these endeavours by the DoE in the district where the research was done physical science results do not seem to be recognizably improving. This research therefore taps into various causalities in this crisis. These range from expecting students to learn without presenting lessons that activate their internal mental processes, teachers' intention to transfer knowledge to students, inadequate PCK conceptions, less focus on assessing the students' current level of cognitive strengths and weaknesses in order to apply appropriate teaching approaches to inadequate teacher developmental support for teachers.

Literature established that the use of various instructional methods could improve the current status. It is against this background that the study was undertaken to develop teachers in the use of cooperative learning to enhance teaching of NoS for scientific literacy advancement in secondary school physical science students.

This section presents the conclusions obtained from the study. It summarizes major research findings as they appear in data analysis and presentation of both questionnaires and the evaluation sheet. The purpose of the use of these instruments was to uncover whether or not the developed use of cooperative learning could enhance teaching of Nature of Science to secondary students in order to improve scientific literacy and produce improved results. Furthermore, the study relates the research findings to previous studies obtained from the literature review and justifications of this study.

It is important to highlight that some of the research findings in this study replicate results of previous studies done elsewhere in other countries. However it is also crucial to realize that this study extends those findings to the Bizana District in the Eastern Cape.

The results of this study suggest that developing science novice teachers' PCK at pre-service level would be beneficial for them, especially for those who lacked content knowledge. Nevertheless, given adequate teaching experience and continuous guidance from teacher development forums and team teaching, teachers will position their lesson presentations to teach NoS explicitly. They will not only position the lesson presentation for this particular purpose only, but also to understand the students' views about the learning aspect dealt with in class. In such forums teachers might as well develop one another on how to identify student misconceptions and derive conceptual change and scientific literacy.

After the intervention, teachers realized the benefit of explicit teaching of NoS. The lesson presentations show an effort to introduce the teaching of NoS. Such development, however, may not occur automatically, hence social interdependence is paramount for both students and teachers.

The instruments used in this research, they assisted the researcher to the students' enthusiasm at becoming sources of scientific knowledge and how they would benefit from this instructional method.

6.2 Recommendations

South African curriculum reform design promotes teaching of NoS, but there is no evidence of putting this important aspect of science education into action, especially in the previously disadvantaged communities. The departmental officials, teachers and all education stakeholders should endeavour in the explicit teaching of NoS in schools. This will encourage South African students to think scientifically and be able to derive scientific conclusions. The Department of Education should work closely with newly employed teachers and identify areas of development and NOS orientation in order to facilitate scientific literacy.

Teachers' PCK should be developed in order for them to diagnose and eliminate students' misconceptions. This will then positively affect the students' scientific literacy. Cooperative learning related theories, particularly social interdependence, should be encouraged as it will provide an opportunity for students to eliminate their misconceptions. The shared goals would be accomplished through the contribution and influence of the actions of others; hence the teachers' contributions need to be aligned with NoS in order for students to advance in scientific literacy.

6.3 Implications

The fact that teachers have limited understanding of NOS means that students are not in a position to reason scientifically. The teachers' PCK needs to be developed so that teachers can relinquish the use of the telling method. The application of cooperative learning when teaching physical science, further needs to be reinforced in order to maximise its benefits. There is also little effort by the teachers to develop scientific literacy. The students' group engagements were the only centres of scientific debate and science interrogation.

The feedback that was given by students in the second questionnaire showed that students benefited a great deal from the cooperative orientated lesson in which they were taught NoS. That was shown by the students' eagerness to cooperate in the cooperative groups. Their personal development could be witnessed during the discussions and elaborations they made when presenting their work. Therefore, educational administrators and practitioners should start rethinking the teaching of NoS using cooperative learning.

The implication of this to teacher training is that novice teachers are presently unable to connect their content knowledge to the students' views about science. This research has indicated clearly that teachers must be engaged in serious reflection on how to use that knowledge which guides the transformation of content, in planning for instruction. That reflection needs to be initiated by the Department of Education through subject advisors setting up continuous teacher advancement programmes, science expos, and vigilant guidance of teachers in this most important field of education for the future of South Africa and its peoples.

Further, it is highly desirable that private business, which relies on well- educated, scientifically literate future employees, should continue to be involved in these advancement programmes which would lead to mutual gains.

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APPENDIX A: QUESTIONNAIRE

Pedagogical Learning for Scientific Literacy Questionnaire (PLSLQ)

The questionnaire was designed for the purposes of research aiming at uncovering the extent to which physical science teachers engage their students during lesson presentation and also to determine whether or not teachers need to be developed in the use of the cooperative learning approach when teaching nature of science to the secondary school students. The information obtained from this instrument will be used to inform the researcher on preparation of mentoring programme material and generalize on the future needs for professional development of teachers. The names of the respondents will be kept anonymous from this day until the end of the research and also during the reporting stage.

The questionnaire has three categories i.e. teaching of nature of science, cooperative learning use and demographic category. **Please complete all items.**

SECTION A: BIOGRAPHICAL VARIABLES

Answer each question by **circling** the appropriate number in the box.

1) Age

23 – 30	1
31 – 36	2
37 – 42	3
43 – 50	4

2) Overall teaching experience.

0 – 2	1
3 – 5	2
6 – 8	3
>9	4

3) Physical science teaching experience.

0 – 2	1
3 – 5	2
6 – 8	3
>9	4

4) Number of years trained to teach Physical science

0 – 2	1
3 – 5	2
6 – 8	3
>9	4

5) What is your highest qualification in teaching?

Teacher’s certificate (Certificate in Education)	1
Teaching Diploma (Diploma in Education)	2
Bachelor of Education Degree	3
Advanced Certificate in Education	4
Post Graduate Certificate in Education	5
Honours Bachelor of Education Degree	6
Master’s in Education	7

6) What was your major (main) subject(s) during your teacher training course?

Science only	1
Mathematics only	2
Both Science and Mathematics	3
Other (Specify)	4

7) Indicate your post level in your position as a science educator

Post level 1 science educator 1	1
Post level 2 science educator	2
Post level 3/ 4 science educator 1	3
Other (Specify)	4

8) Which grades (classes) are you currently teaching?

Grade 8	1
Grade 9	2
Grade 10	3
Grade 11	4
Grade 12	5
Other (Specify)	6

9) Are you pleased by the general performance of your students in physical science?

Not at all	1
Sometimes	2
Often	3
Generally	4
Almost always	5

10) How frequently do you think there should be professional development particularly in teaching strategies?

Not at all	1
Sometimes	2
Often	3
Generally	4
Almost always	5

11) Do your students accommodate change in teaching strategies?

Not at all	1
Sometimes	2
Often	3
Generally	4
Almost always	5

SECTION B: Custody of Student Ideology

The following statements ask for your opinion about the curriculum and its day to day elementary activities. Next to each statement please indicate your perception based on the items for the themes given below. The questionnaire included a small number of scales (5), each containing a relatively small number of items. The scale's mean ranged from 1 to 5, with 1 for the most negative perception that represents almost never, 2 represents seldom, 3 represents sometimes, 4 represents often, and 5 for the most positive perception, which represents very often.

Items	Rating				
1. I permit students to asks questions whenever the need arises in class	1	2	3	4	5
2. Before I respond to lesson questions in class, I first give the chance to students to attempt answering the questions.	1	2	3	4	5

3. A variety of assessment tools are used for the purpose of validating learning.	1	2	3	4	5
4. My students are self-motivated and have high self-efficacy	1	2	3	4	5
5. I give students a variety of theory-laden questions in order to challenge their conceptual sentiments	1	2	3	4	5
6. My lessons promote diagnostic patterns of students' views of NOS.	1	2	3	4	5
7. The science knowledge gained from my science class is linked to the needs of the individual social life of a student.	1	2	3	4	5

SECTION C: Student Perspective of NOS

Items	Rating				
1. My students view science as a practical subject capable of empirical testing.	1	2	3	4	5
2. My students have an understanding that scientific knowledge is developed through understanding nature which contributes to a network of laws, theories and concepts.	1	2	3	4	5
3. Students' enthusiasm towards science investigations is aggravated when they are given an opportunity to exercise their creativity in order for them to arrive at the plausible hypotheses.	1	2	3	4	5
4. Whenever the students are expected to work in an individual project, they perform better than when working in groups.	1	2	3	4	5
5. The socio-cultural context of the majority of my students emphasizes and encourages the learning of certain scientific related skills while minimizing others.	1	2	3	4	5
6. Students hold a perception that science is procedural more than creative.	1	2	3	4	5
7. Students believe that existing scientific knowledge remain relevant only when there is non- refute on such.	1	2	3	4	5
8. Students adhere to the notion that scientists are particularly objective	1	2	3	4	5
9. Students seldom explain scientific phenomena by their indigenous knowledge during in class discussions.	1	2	3	4	5
10. Students are able to design their own problem solving plan which leads to uncovering the scientific truths or supporting existing findings.	1	2	3	4	5

SECTION D: Nature of Science as a Choice (NOSAC)

Items	Rating				
1. I believe that science is developed through observation and empirical evidence is required for justification.	1	2	3	4	5
2. Observations are theory-laden	1	2	3	4	5
3. I am able to raise awareness to my students about the tentativeness of science without them doubting its authenticity and encourage them to identify own field of concern for future scientific research.	1	2	3	4	5
4. Laws and theories serve different roles in science and hence theories do not become laws even with additional evidence.	1	2	3	4	5
5. My lessons engage creativity and expand student imagination and enable them to use their social and historical culture to influence their thoughts.	1	2	3	4	5
6. Scientists use their creativity for the generation of plausibility of their hypotheses in order to formulate theories.	1	2	3	4	5

SECTION E: Curriculum Principles and Teacher Support on Teaching Strategies

Items	Rating				
1. I find it easy to unpack the aims of the current curriculum.	1	2	3	4	5
2. The aims of the current curriculum encourages the teaching of NoS.	1	2	3	4	5
3. The education department is doing something to assist you in understanding and delivering on the aims of the curriculum	1	2	3	4	5
4. There are tools used by the education department to develop and assess the understanding of the teaching strategies promoting scientific literacy.	1	2	3	4	5
5. There are interactions in forums or clubs with other physical science teachers in the cluster from which we discuss teaching strategies for improving student performance.	1	2	3	4	5

SECTION F: Humanistic Orientation

Please answer these questions to the best of your understanding.

1. Describe the extent to which you can allow your students to use their local knowledge in a science class.

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2. Which endeavours do you employ when a student shows less interest in physical science lessons?

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3. How do you develop a sense of team work amongst students during your physical science lesson presentation?

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4. How do you ensure that safety precautions practiced during your lesson presentations in class do not in any way hinder students' willingness to explore and learn scientific concepts?

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5. What are your contributions towards ensuring that students learn in cooperative interactions and experience?

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6. Science is a social enterprise. What are your views about this statement? Elaborate giving classroom related situations.

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7. Would you encourage students to work as individuals or in groups when giving them class activities? What are the reasons for your choice?

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8. How would you encourage your students to learn NoS?

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APPENDIX B: TRAINING MANUAL

Welcome to the training session

Section A: Curriculum

Students are taught within a certain framework; hence the lessons are designed in such a manner that they achieve the outcomes within that framework. The national curriculum is the culmination of the efforts of the government over a period of time to transform the curriculum bequeathed to the black South Africans by apartheid. From the start of democracy, the government has built the curriculum on the values that inspired the Constitution (Act 108 of 1996). The *National Curriculum Statement Grades R-12 (January 2012)* represents a policy statement (CAPS) for learning and teaching in South African schools from which the general aims are stipulated.

Activity 1: Group work

1. List the THREE general aims of the current South African Curriculum and explain how you can use physical science lessons to achieve them.
2. Design a lesson presentation which will achieve at least two aspects of the general aims of the curriculum.
3. What challenges do you face when teaching physical science that may result to learning hindrance in your teaching?

Section B

Activity 1

Work in groups of THREE and answer the questions below.

(i)	What do you understand about nature of science?
(ii)	Identify one scientific theorist whose work informs the current science curriculum and discuss what you understand about the work of the scientist you chose and how you can use it to influence the students' understanding of their curriculum context.
(iii)	Which activities to do you perform in your class that enhance your teaching and ensures the elimination of misconceptions?
(iv)	Have there been any scientific innovations on the work of the scientist of your choice?

(v)	What do you understand about the general aims of the current curriculum and how do you think the understanding of scientific methods can play a crucial role in the achievement of these aims?
(vi)	Discuss whether or not physical science subject matter learning relies on in-depth understanding of scientific theories and laws, interrelating concepts, principles, and themes.

Activity 2

Work individually when answering this question.

Read from A to I, and then choose one of the statements and in your opinion state and elaborate with examples on your position regarding the statement which says "scientists are always very open-minded, logical, unbiased and objective in their work. These personal characteristics are needed for doing the best science".

(A) The best scientists display these characteristics otherwise science will suffer.

(B) The best scientists display these characteristics because the more of these characteristics you have, the better you'll do at science.

(C) These characteristics are not enough. The best scientists also need other personal traits such as imagination, intelligence and honesty. The best scientists do NOT necessarily display these personal characteristics:

(D) Because the best scientists sometimes become so deeply involved, interested or trained in their field, that they can be closed-minded, biased, subjective and not always logical in their work.

(E) Because it depends on the individual scientist. Some are always open-minded, objective, etc. in their work; while others can become closed-minded, subjective, etc. in their work.

(F) The best scientists do NOT display these personal characteristics any more than the average scientist. These characteristics are NOT necessary for doing good science.

(G) I don't understand.

(H) I don't know enough about this subject to make a choice.

(I) None of these choices fits my basic viewpoint

4.2.3 Pre-understanding of cooperative learning

Teacher Background

Use of cooperative learning in physical science classrooms.

Collaborative learning of NoS

1. Recent research studies on science education acknowledge that scientific knowledge relies heavily, but not entirely, on observations, experimental evidence, rational arguments, and scepticism. What is your opinion with regard to this statement? Give a detailed explanation with examples based on a physical science lesson presentation in order to support your opinion.
2. In your experience as a physical science teacher would you argue that observations are theory-laden?
3. Considering the fact that science changes with new developments in research, explain how you would make your students aware of that fact without them doubting the authenticity of science as a way of explaining natural phenomena.
4. You are asked to elaborate on the statement that says Laws and theories serve different roles in science and hence theories do not become laws even with additional evidence; how would you explain that?
5. Research shows that the number of emerging scientists is not growing the way it is expected, looking at the number of challenges the world is facing. In order to remedy this situation, science teachers are urged to motivate students into considering science growth and development. Explain how you would enable students to use their social and historical culture to influence their scientific thoughts.
6. Scientists are creative and often resort to imagination and speculation; explain how you would provide insight into that kind of behaviour to your students.

In order to achieve this goal, two categories were identified.

Category 1: Nature of science exposition

With the aid of the fact that the important aspects of NoS are in one way or the other viewed controversial, the aspects, which I believe are accessible to secondary school students and relevant to their daily lives, were adopted and emphasized for the purpose of developing the views of nature of science (VNOS). NoS views considered were tentativeness of scientific knowledge; scientific knowledge being empirical; theory-laden; partly the product of human inference, imagination, and creativity; and socially and culturally embedded. The following questions were given to the participants and they were expected to respond to them individually.

Questions

1. *Recent research studies on science education acknowledge that scientific knowledge relies heavily, but not entirely, on observations, experimental evidence and rational arguments. It is also evident that science changes with new developments in research, and students have to be aware of this fact and still not doubt the authenticity of science as a way of explaining natural phenomena. Design a physical science lesson from which the above can be proved to be true. Give brief explanation with examples based on the current curriculum in order to support this notion.*
2. *Scientists do not have direct access to most natural phenomena. Explain how you think they gather information explanations they have with regard to natural phenomena.*
3. *Laws and theories serve different roles in science and hence theories do not become laws even with additional evidence. How would you explain that?*
4. *In your experience as a physical science teacher would you argue that scientific knowledge is theory-laden?*
5. *Research shows that the number of emerging scientists is not growing the way it is expected, looking at the number of challenges the world is facing. In order to remedy this situation, science teachers are urged to motivate students into taking part in science growth and development. Explain how you would encourage students to use their social and historical culture to influence their scientific thoughts while you advocate for science as a human enterprise.*
6. *Scientists are creative and often resort to imagination and speculation. Explain how you would provide insight into that kind of behaviour to your students.*

3.4.2.1 How to teach NoS explicitly using cooperative learning?

'Those who understand, translate the information and those who don't, transfer it.'

The teacher asks the students to describe what an atom is. After they have given the answer to their understanding, they are then asked to explain how they came about with the definition they gave. After the discussions on the sources of their knowledge, the teacher will have to reveal to the students that even the knowledge they have may not be like that in the years to come due to new evidence that could result from new investigations. During this session, the students are taken through the **Development of the Theory,** closely looking at how scientists know what they claim more than what they know**.** Through this process students are enlightened through scientific developments that what they know today could have been transferred to them but they should view science as a way of knowing.

An atom is the smallest particle into which an element can be divided and still be the same substance and an Element is a pure substance that cannot be separated into simpler substances by physical or chemical means. Atoms make up elements and elements combine to form compounds. Furthermore all matter is made of elements or compounds, so all matter is made of atoms, though no one had ever seen one. However ideas, or theories, about atoms have been around for over 2,000 years.

What is a Theory? This is a unifying explanation for a broad range of hypotheses and observations that have been supported by testing. This therefore means that there were investigations done on this concept and there were observations made that led to this conclusion. Then we speak of how scientists know what they know, i.e. through theory-laden. Scientific knowledge is subjective and/or theory-laden. Scientists' theoretical commitments, beliefs, previous knowledge, training, experiences, and expectations actually influence their work. All these background factors form a mind-set that affects the problems scientists investigate and how they conduct their investigations, what they observe (and do not observe), and how they make sense of, or interpret their observations. It is this (sometimes collective) individuality or mind-set that accounts for the role of subjectivity in the production of scientific knowledge and is noteworthy that, contrary to common belief, science rarely starts with neutral observations. Observations and investigations are motivated and guided by, and acquire meaning in reference to, questions or problems surrounding a particular concept. These questions or problems, in turn, are derived from within certain theoretical perspectives. Often, hypothesis or model testing serves as a guide to scientific investigations.

Development of the Atomic Theory

Democritus (440 B.C.)- proposed that if you kept cutting a substance in half forever, eventually you would end up with an indivisible particle which he called atoms, meaning “indivisible” in Greek. Democritus thought that atoms were small, hard particles of a single material and in different shapes and sizes. He thought that atoms were always moving and formed different materials by combining with each other. Contrary to this, Aristotle disagreed with Democritus’s idea that you would end up with an indivisible particle and, because he had greater public influence, this led to Democritus’s ideas being ignored for centuries.

From the fact that scientists knew that elements combined with each other in specific proportions to form compounds, John Dalton (1803) claimed that the reason for this was because elements are made of atoms. He published his own three-part atomic theory:

1) All substances are made of atoms and atoms are small particles that cannot be created, divided, or destroyed.

2) Atoms of the same element are exactly alike, and atoms of different elements are different.

3) Atoms join with other atoms to make new substances. For a long time much of Dalton’s theory was correct, though some of it was later proven incorrect and revised as scientists learned more about atoms.

J.J. Thomson (1897) used a cathode-ray tube to conduct an experiment which showed that there are small particles inside atoms. This discovery identified an error in Dalton’s atomic theory and proved that atoms can be divided into smaller parts. Because the beam moved away from the negatively charged plate and toward the positively charged plate, then Thomson knew that the particles must have a negative charge. He called these particles corpuscles which we now call electrons.

After Electrons were discovered to be the negatively charged particles found in all atoms, Thomson changed the atomic theory to include the presence of electrons. He hypothesised that there must be positive charges present to balance the negative charges of the electrons, but he didn’t know where. Thomson proposed a model of an atom called the “plum-pudding” model, in which negative electrons are scattered throughout soft blobs of positively charged material.

Whilst satisfied with Thompson’s model, Ernest Rutherford (1909) conducted an experiment in which he shot a beam of positively charged particles into a sheet of gold foil and had predicted that if atoms were soft, as the plum-pudding model suggested, the particles would pass through the gold and continue in a straight line. Most of the particles did continue in a straight line. However some of the particles were deflected to the sides a bit, and a few bounced straight back. Rutherford realized that the plum pudding model did not explain his observations and decided to change the atomic theory and so developed a new model of the atom. Rutherford's model says that most of the atom's mass is found in a region in the centre called the nucleus and the nucleus being the tiny, extremely dense, positively charged region in the centre of an atom. Rutherford had calculated that the nucleus was 100,000 times smaller than the diameter of the atom. In his model the atom is mostly empty space, and the electrons travel in random paths around the nucleus.

In 1913, Niels Bohr suggested that electrons travel around the nucleus in definite paths located at certain levels from the nucleus. Electrons cannot travel between paths, but they can jump from one path to another which is the current or modern model that exists. The exact path or position of moving electron cannot be predicted or determined. Rather, there are regions inside the atom where electrons are likely to be found in electron clouds, which are regions inside an atom.

This therefore drives us to conclude that scientific knowledge is never absolute or certain. This knowledge, including "facts," theories, and laws, is tentative and subject to change. Scientific claims change as new evidence, made possible through advances in theory and technology, is brought to bear on existing theories or laws, or as old evidence is reinterpreted in the light of new theoretical advances or shifts in the directions of established research programmes. Adding to this discussion scientific knowledge is, at least partially, based on and/or derived from observations of the natural world (i.e., empirical), it nevertheless involves human imagination and creativity. Contrary to common belief, science is not a totally lifeless, rational, and orderly activity, but rather involves the invention of explanations, and this requires a great deal of creativity by scientists. This aspect of science, coupled with its inferential nature, entails that scientific concepts, such as atoms, black holes, and species, are functional theoretical models rather than faithful copies of reality.

The atomic theory model discussed in this study and its development, observation and inference, remained distinct from scientific laws and therefore students have to understand that theories and laws are different kinds of knowledge, and one does not develop or become transformed into the other. Scientific models are common examples of theory and inference in science and moreover, theories are as legitimate a product of science as laws. Scientists do not usually formulate theories in the hope that one day they will acquire the status of law (Lederman, 2007).

Category 2: Cooperative learning tools and Pedagogical Content Knowledge scheme

In this category, teachers were given notes and activities that can be given to students in class, on the main principles that were taken into consideration.

3.4.2.2. Cooperative learning as pedagogy and the structure of a CL incorporated lesson presentation.

There are three main types of cooperative learning groups: informal learning groups, formal cooperative groups and cooperative base groups. We'll define each and discuss the best situation to use each type of group.

Informal Learning Groups

These groups are short term and not very structured. They typically involve activities where classmates turn to a neighbour to discuss a problem or concept, ranging from few minutes to a class period. Informal groups are generally small, usually ranging between two to four people (Johnson, Johnson, & Holubec, 1998). It is most convenient to use informal learning groups for quick activities such as checking for understanding, brainstorming, quick problem solving, summarising, or review. These groups are a great way to vary a lecture format by giving students a few minutes to discuss a concept with a peer in order to achieve a joint learning goal.

Formal Learning Groups

Formal learning groups are assigned a task or project and stay together until it is complete. There is a clear structure to these groups, set by the teacher, which includes task and behaviour expectations. Formal learning groups can be heterogeneous or homogeneous, depending on the assignment. Most groups perform well with three to five people and any more than five could become unproductive. According to Smith, Sheppard, Johnson & Johnson (2005) formal learning groups can be effective in the classroom when students are engaged in activities are project based, solving a series of problems, reviewing for a test, or writing a report. They further emphasised that these activities are very beneficial in content intensive classes where the focus is on mastery of conceptual or procedural materials.

Cooperative Base Groups

These groups are different from the previous two in that they are long term support groups. Base groups should last for a minimum of a semester but can be anywhere up to several years. Since they are long term commitments, typically these groups become more than just academic problem solving groups. Members in base groups often become a personal support system for each other, building relationships and trust during the duration of their cooperative learning process. The goal of cooperative base groups is that the members develop peer accountability and support each other while learning together.

It is acceptable to use more than one type of group at a time! For example, you can assign a project using formal learning groups and still use informal groups during teaching time where the formal groups are not working together. If you have a class where cooperation is a challenge, you may need many opportunities for your students to practise working together. Begin simply and work your way towards more formal cooperative learning situations.

During the mentoring programme, informal and formal cooperative groups were practised more often in order for teachers to acquaint themselves with the teaching strategy.

Possible classroom activities

In order to engage students' cognitive thinking, teachers were advised to use informal cooperative groups and give students a glass rod with a silk cloth; ask them what happens when you rub against the two objects as shown in Figure 4.

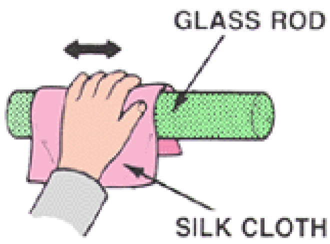

Figure 4: Silk cloth rubbing the glass rod

Identify roles for the group members so everyone has a particular task to do and specific way to contribute, depending on the task at hand, e.g. student A will facilitate thought sharing, student B take notes of the different ideas, student C presents the group's conclusive idea and student D leads in answering of questions from the classmates and additions on the idea. Students should also be given time to think individually about the question and enable them to write their thoughts down before they can share them, and time to share their thoughts with their group members. By doing so you allow yourself to get things off to a good start by structuring and enforcing collaborative learning, and build their confidence as they could be grouped with people they do not know.While groups are working during class, circulate in the room to make sure everyone is connected with a group, follow up afterwards with feedback about what went well with the groups and what could be improved next time, and reiterate the importance of everyone contributing. Students will be more committed to group work and more comfortable with it if they see your commitment to making sure groups work well for their learning.

After they have finished giving their group reports, explain to the students by first explaining the origin of atoms, and its scientific developments, e.g. J. Dalton's atomic theory which describes all matter in terms of atoms and their properties, J.J. Thomson's experiments with cathode ray tubes showing that all atoms contain tiny negatively charged subatomic particles or electrons, Thomson's plum pudding model of the atom having negatively-charged electrons embedded within a positively-charged "soup", and Rutherford's gold foil experiment showing that the atom is mostly empty space with a tiny, dense, positively-charged nucleus. Indicate to students how the atomic models differ from each other according to the scientist's claims e.g. an atomic model according to Figure 5.

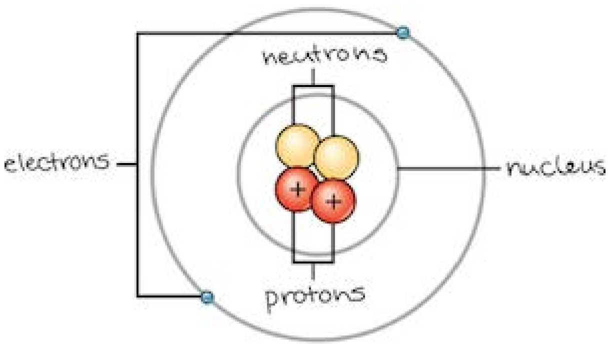

Figure 5: Atomic Model

As you highlight the development of science around the atom structure your students should take notes and later discuss them with their peers in a group. Whilst doing so, reiterate on static electricity, electric charge and its conservation.

Static electricity is referred to as electricity at rest. It is an electrical charge that builds up due to friction between two dissimilar materials. Due to electrons being loosely bound, in conducting objects, they are so loosely bound that they may be induced into moving from one portion of the object to another portion of the object. Friction removes electrons from one object and deposits them on the other and each object is said to be charged. The one acquiring electrons is said to be negatively charged, while the one that lost electrons is said to be positively charged.

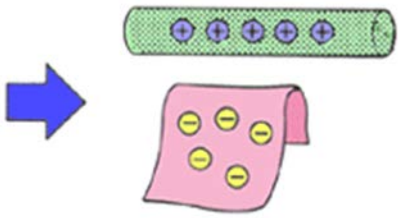

Figure 6: Charged objects from rubbing

Let students experiment that the two objects have gained different charges by allowing the objects closer to uncharged objects. Allow students to brainstorm on what could be the reason for the objects to behave in the manner in which they do. Later explain to your students the concept of polarisation, like charges cause repulsive behaviour and unlike or opposite charges attractive behaviour.

Polarisation and repulsive, attractive behaviour of charges

Part (a)

To get an electron in a conducting object to *get up and go*, all that must be done is to place a charged object near the conducting object. If the negatively charged object (e.g. balloon) is brought near any conducting object (e.g. aluminium pop can), the electrons within the pop can will experience a repulsive force. The repulsion will be greatest for those electrons that are nearest the negatively charged balloon. Many of these electrons will be induced into moving away from the repulsive balloon. Being present within a conducting material, the electrons are free to move from atom to atom within an object. As such, there is a mass migration of electrons from the balloon's side of the aluminium can towards the opposite side of the can. This electron movement leaves atoms on the balloon's side of the can with a shortage of electrons; they become positively charged, and the atoms on the side opposite of the can have an excess of electrons; they become negatively charged. The two sides of the aluminium pop can have opposite charges. Overall the can is electrically neutral; it's just that the positive and negative charge have been separated from each other. We say that the charge in the can has been polarized.

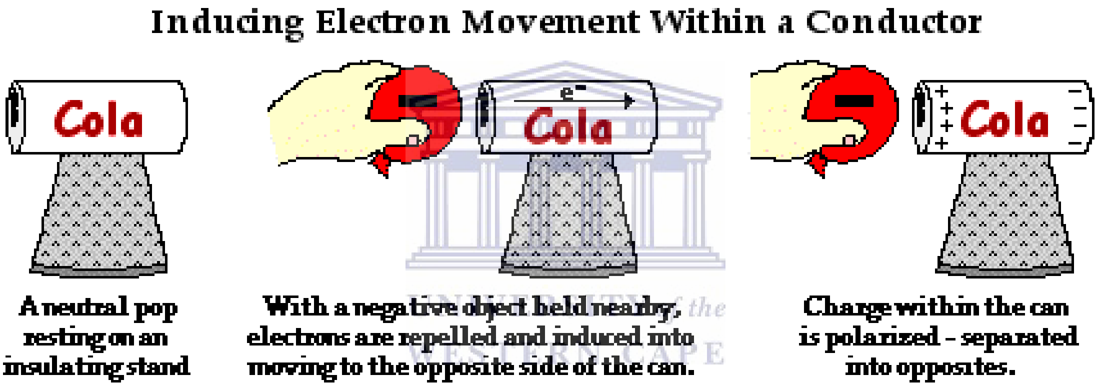

Figure 7: Polarisation in a conductor

Therefore, explain to students that, with respect to electric charges, polarization process involves the use of a charged object to induce electron movement or electron rearrangement, which can be identified with both repulsive and attractive behaviour of charges, where a negative charge by the cloth repels the negative charge of the can and positive charge of a can is attracted to the negative charge of the cloth.

Part (b)

With the insulator, the process occurs in a different manner than it does within a conductor. In an insulator, electrons merely redistribute themselves within the atom or molecules nearest the outer surface of the object. To understand the electron redistribution process, it is important to take another brief excursion into the world of atoms, molecules and chemical bonds.

The electrons surrounding the nucleus of an atom are believed to be located in regions of space with specific shapes and sizes. The actual size and shape of these regions is determined by the high-powered mathematical equations common to Quantum Mechanics. Rather than being located a specific distance from the nucleus in a fixed orbit, the electrons are simply thought of as being located in regions often referred to as electron clouds. At any given moment, the electron is likely to be found at some location within the cloud. The electron clouds have varying density; the density of the cloud is considered to be greatest in the portion of the cloud where the electron has the greatest probability of being found at any given moment. And conversely, the electron cloud density is least in the regions where the electron is least likely to be found. In addition to having varying density, these electron clouds are also highly distortable. The presence of neighbouring atoms with high electron affinity can distort the electron clouds around atoms. Rather than being located symmetrically about the positive nucleus, the cloud becomes asymmetrically shaped. As such, there is a polarization of the atom as the centres of positive and negative charge are no longer located in the same location. The atom is still a neutral atom; it has just become polarized.

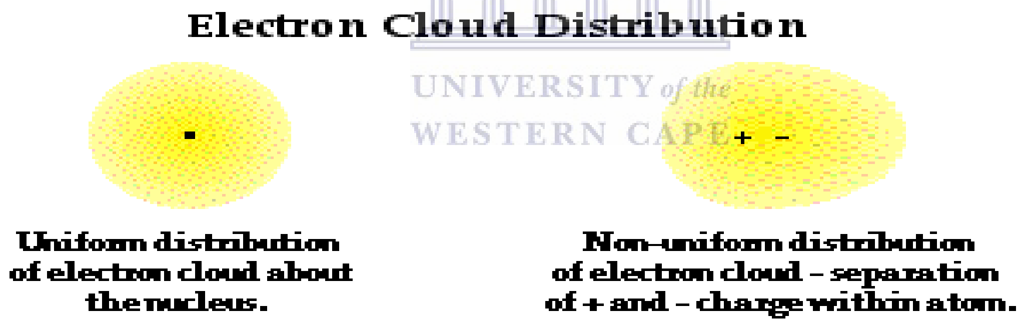

Figure 8: Uniform and Non-uniform electron cloud distribution.

Part (c)

Take your students further and ask them to determine whether or not charges were moved or transferred from one object to another during the polarization of the can. Let the discussion become even more complex by considering the formation of molecules whereby atoms are bonded together. Allow students to do research on this topic and give time in class for them to argue their cases as groups. The form of grouping that shall have been used during this project would be formal cooperative grouping. Try by all means to elicit their understanding; reiterate the acceptable conceptions.

Explain and expand your students' knowledge by making use of models analogy, like the example of a tug-of-war between a wrestler and a toddler and the use of the plastic ball atomic model. In molecules, atoms are bonded together as protons of one atom attract the electrons in the clouds of another atom.

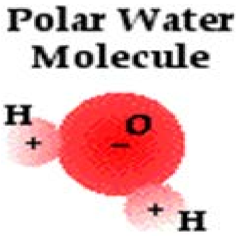

Figure 9: Polar Water Molecule model

This electrostatic attraction results in a bond between the two atoms. Electrons are shared by the two atoms as they begin to overlap their electron clouds. If the atoms are of different types (for instance, one atom is Hydrogen and the other atom is Oxygen), then the electrons within the clouds of the two atoms are not equally shared by the atoms. The clouds become distorted, with the electrons having the greatest probability of being found closest to the more electron-attracting atom. The bond is said to be a polar bond. The distribution of electrons within the cloud is shifted more towards one atom than towards the other atom. This is associated with the ability of an atom to attract the electron shared pair of electrons to itself, which is called electronegativity. This is the case for the two hydrogen-oxygen bonds in the water molecule share its electrons and these two atoms are drawn more towards the oxygen atom than towards the hydrogen atom. Subsequently, there is a separation of charge, with oxygen having a *partially* negative charge and hydrogen having a *partially* positive charge. A dipole is formed and the bond is said to be polar which implies that greater electronegativity difference results in greater polarity.
(*This section was adapted from The Physics Classroom Tutorials written by Tom Henderson since 1996)*

3.4.2.3 The elements of the CL method.

During the lesson presentation, teachers are expected to monitor whether or not students practise the main elements of cooperative learning. In this lesson students were allowed to explore and use their social skills and the teachers working together to achieve the desired goals. These were the aspects that teachers were looking out for:

- *Positive interdependence* whereby students were encouraged to work towards achieving a common goal creating a friendly and accommodating group atmosphere where every group member had an equal opportunity to express himself or herself and was listened to with respect. Students were brought together by means of clear identification of roles as a group and particularly an individual role to understand the content dealt with in class.
- *Face-to-face promotive interaction* was crucial as students had to understand the importance of helping one another learn, applauding effort and success. Helping one another was envisaged to yield promotive interaction whereby students exchanged resources, testing hypotheses together and challenging each other's conclusions but at the end, based on scientific epistemology, arrive at the solution. This was done by means of probing questions that required theory testing and students were urged to clarify to group members by means of known models.
- *Individual and group accountability* put emphasis on individual efforts to make contributions in order to understand the task at hand, which will, in return, endorse individual gains in the process. Each member of the group, to a certain extent, has to contribute to the assigned work so that when assessment is done, every individual is able to demonstrate effort and learning in the interaction process. The teacher had to clearly identify roles and also allow students to give feedback on challenges they had experienced as they were working in their small groups.
- *Interpersonal and small group skills* could defeat the purpose if not gradually fostered and developed as groups depend on them. Communication, trust, leadership, decision making, and conflict resolution skills had to be nurtured by encouraging students to commit to their work so that they could express themselves clearly and with confidence. Each group member was encouraged to view knowing everyone in the group as an obligation, appreciate their individual differences, embrace one another's strengths and, above all, develop their weaknesses into strengths. This would enhance communication and limit conflicts.
- *Group processing* had to be assessed as it would reflect on how well the team was functioning and how it could function even better by giving brief feedback for further improvement and facilitation of cooperative learning skills.

3.4.2.4 Benefits of sharing content knowledge and conceptual understanding amongst teachers

The historical background of cooperative learning has shown it to be an unusually strong psychological success story. From being discounted and ignored in the 1940s through the 1970s, cooperative learning is now a standard and widespread teaching procedure that has been adopted by many countries when developing their curriculum, hoping for skill development and preparing them for the work place. According to Gillies & Ashman (2003) the approach has been recognized for its importance, in contrast to the traditional classroom, as an effective approach to teaching.

Through cooperative workshop activities, teachers were exposed to the practice of content sharing, without shame or fear of being judged, for the purpose of personal development and that of a group. During this exercise they were able to negotiate meaning about their work, thus developing shared goals of fostering students' higher level of thinking skills and creativity- adopting specific instructional strategies for specific purposes. The programme then adopted and introduced the peer coaching and co-teaching resonate in the teaching and learning setting as suggested by Goodnough, K., Osmond, P., Dibbon, D., Glassman, M. & Stevens, K. (2009). Teachers often complained that professional development learning experiences were not in line with everyday teaching situations; as a result, the learning experiences do not have meaningful effects on their teaching practice. In cases like this, peer coaching and co-teaching became meaningful as the teachers understood the actual science teaching practices.

The mentoring programme avoided the traditional mentoring relationship where the authority imparts knowledge to the novice; instead, it took a partnership form where both team members could learn with and from one another. The intention was that of shifting one member's conceptual knowledge about teaching, which was something that could not be attained in the short time period available during a workshop presentation. Participants were advised to draw from Matlin & Carr (2014) as they recommended in their study that the co-teacher should be chosen thoughtfully; they also raised the importance of making sure that you and your team teacher complement one another in multiple areas, where members would want to create a partnership in which each person can play off one another's strengths, from a disciplinary, personality, or teaching style perspective. Geographic considerations could be an issue of concern but still, co-teachers had to put careful thought into choosing a mentor.

The programme guided the teachers in how to implement co-teaching during a lesson, taking its key aspects into consideration.

Co-teaching

Co-teaching is the instructional arrangement in which a general education teacher and a special education teacher deliver core instruction along with specialized instruction, as needed, to a diverse group of students in a single physical space. Co-teaching partnerships require teachers to make joint instructional decisions and share responsibility and accountability for student learning. Teachers are both teaching the same information, but they divide the class into equal groups and teach simultaneously. This allows for more support, more supervision and greater participation from students.

Implementation

Students are divided into equal-sized groups similar to cooperative learning groups whereby each teacher teaches the same content in the same amount of time.
Instructional methods may differ and groups do not rotate.

Opportunities

Students have an increased opportunity for response and participation due to lower student-to-teacher ratio. In this model both teachers play an active role in instructing the students.

Challenges

Schools and teachers may face challenges with this model as they need to identify appropriate physical space and must have adequate knowledge of content and pedagogical skills to provide equally effective instruction. However, having two teachers instructing at the same time may be distracting, especially when the students are not used to this kind of instruction, but if well planned, students cope with it quite well.

3.4.2.5 Instructional Practices and Teacher Perceptions

Before the end of the mentoring programme, the researcher aspired to obtain the perceptions of the participants with regard to the instructional strands which the programme followed. On the last day of the workshop, the participants were requested to evaluate the workshop with the aid of an evaluation form. The evaluation form was designed in a manner that would enable the researcher to easily analyze data according to themes. Data were collected using this instrument and analysed later.

APPENDIX C: EVALUATION FORM

Name:					
After the workshop, how do you rate your	Low	Medium		High	
1. Level of satisfaction with the workshop	O 1	O 2	O 3	O 4	O 5
2. Understanding of what cooperative learning is	O 1	O 2	O 3	O 4	O 5
3. Eagerness with regard to the use of cooperative learning	O 1	O 2	O 3	O 4	O 5
4. Skill to work with cooperative learning groups	O 1	O 2	O 3	O 4	O 5
5. Ability to assign roles in cooperative groups for functionality	O 1	O 2	O 3	O 4	O 5
6. Ability to facilitate learning in cooperative learning groups	O 1	O 2	O 3	O 4	O 5
7. Skills to encourage students to interact in a classroom using their social frameworks	O 1	O 2	O 3	O 4	O 5
8. Views of teaching nature of science to secondary school science students	O 1	O 2	O 3	O 4	O 5
9. Knowledge with regard to using NOS as an instructional method	O 1	O 2	O 3	O 4	O 5
10. Ability to use nature of science to diagnose student's areas of difficulty	O 1	O 2	O 3	O 4	O 5
11. Ability to teach students not only what scientists know but also how they know it.	O 1	O 2	O 3	O 4	O 5
12. Eagerness to share scientific developments and teaching strategies	O 1	O 2	O 3	O 4	O 5
13. Content knowledge development on the topics dealt with during the workshop	O 1	O 2	O 3	O 4	O 5
14. Attitute towards teaching science for scientific literacy	O 1	O 2	O 3	O 4	O 5
15 Views in terms of improved performance when teaching NOS to secondary school students	O 1	O 2	O 3	O 4	O 5

APPENDIX D: GRADE 11 LESSON PLAN

TOPIC: *ELECTRIC FIELD AT A POINT*

LESSON OBJECTIVES

- Define the magnitude of the electric field at a point as the force per unit charge
- Deduce that the force acting on a charge in an electric field is F = Qe
- Calculate the electric field at a point due to a number of point charges, using the equation $E = k\frac{Q}{r^2}$ to determine the contribution to the field due to each charge.

2. LESSON DEVELOPMENT

2.1 Introduction

a) PRE-KNOWLEDGE students need understanding of the following:

(i) Coulomb's Law

(ii) Electrostatic force

(iii) Magnetic Field

2.2 Main Body

(a) Demonstrate the relations between electric field, magnetic field and gravitational field.

(b) Introduce potentials, a concept essential to electromagnetics as electric field at a point.

(c) Work with calculations related to the electric field at a point.

2.3 Conclusion

Recall that fields exist even if there are *no* test charges around to probe them. That means that we don't need to use *actual* charges to measure a field—we could simply image a "what if?" scenario, and determine the field by *pretending* that a test charge (of arbitrary and unknown charge "*q*") were present, and computing the force per unit of imaginary charge. Since we are dividing out the value of *q*, it won't even matter that *q* itself *doesn't actually exist!*

Student activities

1 Calculate the magnitude and direction of the electric field at a point P which is point charge Q = −3.0 μC.

2 Two point charges are separated by a distance of 10.0 cm. One has a charge of −25 μC and the other +50 μC.

(a) What is the direction and magnitude of the electric field at point P in between them that is 2.0 cm from the negative charge?

PART OF THE NOTES GIVEN TO STUDENTS

I. Force & Coulomb's Law: Coulomb's Law is an empirical rule describing the force between charged particles. (By "empirical", we mean that the law is a principle inferred from *experimental* observation and measurement.) The two most important preliminary issues we must realize are: **(1) Coulomb's Law only applies between *pairs* of charged particles**; and **(2) Coulomb's Law is only accurate if the charges involved are *point like*. (3) The forces implied by Coulomb's Law are always along the direct line joining the two charges.** If they are *like* charges, the force is repulsive, while if they are *unlike* charges, the force is attractive………

Technically, *every* charge is simultaneously a source charge and a test charge, since every charge creates its own electric field, and every charge experiences forces due to the fields created by *other* charges. However, **no charge *ever* creates a field that exerts a force back on that same charge.** (Equivalently, "No charge ever exerts an electrostatic force on itself."—can you see *why* this must be true*?)* In practice, for any particular charge, it's an "either/or" distinction—*either* we are interested in the field which that charge creates, *or else* we are concerned with how that charge responds to a field that already exists.

APPENDIX E: GRADE 10 LESSON PLAN

TOPIC: Gravitational Potential and Mechanical Energy

LESSON OBJECTIVES

Define gravitational potential energy

Determine gravitational potential energy of an object

Determine the mechanical energy

2. LESSON DEVELOPMENT

2.1 Introduction

a) PRE-KNOWLEDGE students need understanding of the following:

(i) Different forms of energy

(ii) Potential energy of an object

2.2 Main Body

(a) Gravitational potential energy is the energy an object has due to its position in a gravitational field relative to some reference point. Gravitational potential energy (Ep) is a scalar quantity and is measured in Joules (J). * Some books use the symbol PE or U for gravitational potential energy

where

Ep= gravitational potential energy (measured in joules, J),

m = mass of the object (measured in kg) g = gravitational acceleration (9,8 $m \cdot s^{-2}$)

h = perpendicular height from the reference point (measured in m)

Reference point is the zero energy level. Example of this reference point is the ground.

Gravitational potential energy (EP) of an object is directly proportional to the mass of an object. EP α m; and

Gravitational potential energy (EP) of an object is directly proportional to the height of an object EP α h

Example

A brick with a mass of 2kg is lifted to the top of a 5 m high roof. It slips off the roof and falls to the ground. Calculate the gravitational potential energy of the brick

a) at the top of the roof

b) on the ground once it has fallen.

(b) Mechanical energy (EM) is the sum of the gravitational potential energy and the kinetic energy of a system. Mechanical energy is mathematically written as:

$Emech = E_p + E_k$ which can be expanded to $E_{mech} = mgh + {}^{1}/_{2}\, mv^2$

The symbols E and I are sometimes used to denote mechanical energy, but for this lesson Emech will be used. Mechanical energy is measured in Joules (J), the same unit as gravitational potential energy and kinetic energy. NB. It is scientifically wrong to mix symbols in an equation e.g. Emech = PE + K. Though each symbol represents the correct energy, the symbols were used inappropriately.

Example 2

Calculate the total mechanical energy for a ball of mass 0, 15 kg which has a kinetic energy of 20 J and is 2 m above the ground.

2.3 Conclusion

Student activities

1) Climbing a vertical rope is difficult. You have to lift your full body weight with your arms. If your mass is 60 kg and you climb 2.0 m, by how much do you increase your gravitational potential energy?

2) A block of bricks is raised vertically to a bricklayer at the top of a wall using a pulley system. If the block of bricks has a mass of 24 kg, what is its weight when it is raised 3, 0 m? Calculate its increase in gravitational potential energy when it reaches the top of the wall.

3) Frank, a San Francisco hot dog vendor, has fallen asleep on the job. When an earthquake strikes, his 3, 00 X 102 kg hot dog cart rolls down Nob Hill and reaches point A, 3 m above the ground at a speed of 8, 00 m·s-1. Calculate the mechanical energy of the cart at A.

4) A stone with a mass of 50 g is thrown vertically upwards into the air. At a height of 8 m above the position it was thrown, the stone has a velocity of 6 m· s-

1. Determine the mechanical energy of the stone at a height of 8 m

APPENDIX F: PRACTICUM REVIEW QUESTIONNAIRE

The questionnaire included a small number of scales (5), each containing a relatively small number of items. A Likert scale was used to obtain the responses to the items. The Likert scale ranged from 1 to 5, with 1 for the most negative perception that represents not at all, 2 represents sometimes, 3 represents often, 4 represents generally, and 5 for the most positive perception, which represents almost always.

Items	Rating				
1. I was more patient while being part of a small group.	1	2	3	4	5
2. Working in a group helped me to overcome my shyness.	1	2	3	4	5
3. I enjoyed helping my group members with what I am good at.					
4. My group was more organized than the rest of the groups in my class.	1	2	3	4	5
5. Everyone in the group wanted to contribute towards the assigned tasks.	1	2	3	4	5
6. Members in my group benefited from my contributions to learn the material.	1	2	3	4	5
7. The learning material is easier to understand when working with other students	1	2	3	4	5
8. I view nature of science as the way of knowing	1	2	3	4	5
9. The knowledge on the development of science with regard to the lesson was irrelevant in this lesson	1	2	3	4	5
10. Teachers were able to identify my areas of difficulty	1	2	3	4	5
11. I understand how scientists arrived at the scientific conclusions for this particular concept.	1	2	3	4	5
12. The lesson has taught me that science changes with new observations and evidence.	1	2	3	4	5
13. I understand the concept better now.	1	2	3	4	5
14. I have learnt that there is no one way method of arriving at scientific conclusions	1	2	3	4	5
15. The lesson has made me realize that scientific laws and theories are derived from human curiosity.	1	2	3	4	5
16. The lesson presented encouraged further individual physical science related research.	1	2	3	4	5
17. I learnt that science can be learnt from social contexts.	1	2	3	4	5