Science Education International
Vol. 16, No. 4, December 2004, pp. 333-344

International Council of Associations in Science Education

Acquisition of Scientific Process Skills in Botswana General Certificate Secondary Education Science

CEPHAS DAVID YANDILA (*yandilac@mopipi.ub.bw*) and
SELOI-SEKGETHELO KOMANE (*nini2000zabw@yahoo.com*)
Mathematics and Science Education, University of Botswana, Botswana and Community Junior Secondary School, Botswana

ABSTRACT *The new secondary science syllabuses in Botswana aim at inculcating in students the process skills of: (i) using and organizing apparatus and materials, (ii) observing, measuring and recording, (ii) handling experimental observations and data, and (iv) planning investigations. The purpose of this study was to find out if this was taking place in science lessons. This study was a non-participant observation using a video camera to observe an 80-minute lesson. It involved 22 science teachers randomly drawn from teachers in 11 out of 27 senior secondary schools in the country. Analysis of each recorded lesson on the video involved transcription of what was said and done in each lesson, and categorizing the topic and objectives and process skills inculcated in students. The results showed that the majority of the science teachers were not inculcating the four prescribed process skills in their students.*

KEY WORDS: *acquisition of process skills in senior secondary school science lessons*

Introduction

At the time of gaining independence from United Kingdom, Botswana's secondary school science syllabuses, like other syllabuses, were designed and examined by Cambridge Overseas School Certificate (COSC). The syllabuses placed more emphasis on acquisition of knowledge of science, such as laws, theories, principles and concepts, and less on processes of science. The need to change the syllabuses arose as the country began to be more technological and diversify her economic base. And so the three-year COSC syllabuses were transformed into two-year Botswana General Certificate of Secondary Education (BGCSE) syllabuses. It is made up of Pure Science (Biology, Chemistry, and Physics); Double Science (two-thirds content of Biology, Chemistry, and Physics); and Single Science (one-third content of the Biology, Chemistry, and Physics). In each subject, all students take *core objectives*, but academically able students take *extended objectives also.* In addition to the content, four process skills are included in each syllabus. These are (i) using and organizing techniques, apparatus and materials, (ii) observing, measuring and recording, (iii) handling experimental observations and data, and (iv) planning investigations. With few exceptions, these process skills are to be employed whenever an empirical topic is being taught, so as to encourage the acquisition of hands on experience by students. This does not apply when teaching theoretical content. Instead, models, pictures and videos may be used in which students may not perform any experiment or observe a live demonstration being performed by a teacher. As a rule, whenever an empirical topic is being taught, acquisition of process skills are expected to be taking place through demonstration or practical work.

This characterization of science into content and processes is consistent with the perception of science held by modern philosophers of science such as Hempel (1965, 1966), Kemeny (1959), Carnap (1966), Nagel (1961), Grandy (1973) and science educators, such as Pella (1975), Okatch (1980), Ogunniyi (1977), Rowe (1976), Yandila (1995, 1996), Ogunniyi and Yandila (1993). Due to limited space in this paper, discussion will be restricted to the processes of science, the main emphasis of this study.

According to Yandila (1999), the processes of science or process skills, are methods that scientists employ in their investigations to establish and/or confirm consistencies in nature. Specifically, the processes of science are used to describe natural structures, functions of structures, and phenomena or events, establish consistencies that is functional in explaining and predicting natural structures, functions of structures and phenomena, and develop theories that function in unifying, explaining, and predicting new empirical and theoretical laws/principles.

The processes of science involve what is generally referred to as "*scientific process*" and may include stating of hypothesis, observation, collection of data, verification, confirmation, refutation, falsification, analysis, testing, carrying out experimental procedures, measurement, induction, deduction, intuition, problem-solving (Kemeny, 1959). In the new BGCSE syllabuses, a greater emphasis is being placed on the teaching/learning of selected processes of science, these being: (i) using and organizing techniques, apparatus and materials, (ii) observing, measuring and recording, (iii) handling experimental observations and data, and (iv) planning investigations (Senior Secondary Biology Syllabus, 1997). They transcend the content of every science syllabus, because their acquisition is considered more important than acquisition of knowledge.

Mogapi and Yandila (2001) described the characteristics of these four processes of science as conceived in new BGCSE syllabuses. The skill of using and organizing techniques, apparatus and materials consists of two strands-following instructions and using familiar apparatus, materials and techniques. Students are expected to acquire each of these strands in the course of the study and to demonstrate them while performing a procedure outlined in a worksheet. Criteria for successful performance of this skill range from 1-6 marks. The nature of the task given to a student may affect the maximum level that he/she may achieve. For students to earn a mark of 6, they should be given tasks that are complex, involving making a decision at some point in the procedure, and allowing them to demonstrate the awareness of safety procedures.

The skill of observing, measuring and recording consists of two strands-making observations and taking measurements and recording results in an appropriate manner. Students are expected to acquire each of these strands and demonstrate them when being assessed. They may be assessed entirely from their written work or as they are performing tasks in the laboratory. In the latter, students' accuracy of the measurements or observations are assessed. Students may earn from 1-6 marks. If the task and worksheet given to students do not allow higher level of up to 6, then even the very best students cannot be awarded high marks. If the worksheet gives a fair degree of guidance on how to record the results, then the student can be awarded a mark say of 4. Only if the worksheet gives no guidance can the highest mark of 6 be awarded.

The skill of handling experimental observations and data consists of three strands- processing results such as drawing graphs and making calculations, recognizing and commenting on sources of error and drawing conclusions. The results may be obtained from the demonstration carried by a teacher or an experiment carried by an individual student, single group or groups of students in the entire class. The source of the results is not as important as the ability to draw graphs, make calculations, and draw conclusions from the results. The highest mark may be awarded to students who perform all these four operations without assistance from the teacher or in worksheet.

The skill of planning investigations consists of three strands-producing a logical plan for an investigation, controlling variables and evaluating procedure, and modifying plans where possible. It is the most demanding practical skill. It takes place in three sessions. In session 1, the problem is presented to the students, so that they produce their own plan of investigation. The written down plan includes a list of all required apparatus and resources. The list is expected to be checked by the teacher who may make suggestions for improvement. In session 2, students carry out their investigations and collect data. They are expected to work individually, while being supervised by the teacher. In session 3, students write up their investigation to include aim, objectives, materials used, procedure followed observations noted, results, analysis of results, drawing conclusions and discussions of the findings. A student who performs independently the skill may be awarded the highest mark of 6.

According to the stipulations of the new BGCSE syllabuses, in a typical lesson on empirical topic and objectives, students are expected to be actively involved in observing and/or discussing a demonstration that has been carried out by their science teacher, or performing and/or discussing an experiment under any of the four major process skills of: (i) using and organizing techniques, apparatus and materials, (ii) observing, measuring and recording, (iii) handling experimental observations and data and (iv) planning investigations (Senior Secondary School Biology Syllabus, 1997, iii-iv). But the question is whether these activities are taking place in science lessons?

The purpose of this study was to find out if senior secondary school students in Botswana were being given opportunity by their science teachers to acquire any of the four process skills of: (i) using and organizing apparatus and materials, (ii) observing, measuring and recording, (ii) handling experimental observations and data, and (iv) planning investigations while learning empirical topics through laboratory and/or demonstration teaching methods. The best way of establishing this is to carry out non-participant class observation by means of a checklist or video camera.

The significance of this study was that it could serve as a basis for comprehensive investigation to redress problems in the implementation of the new science syllabuses and provide empirical basis for guiding in the revision of the new science syllabuses. It could also provide useful information on teaching/learning of process skills for student teachers as they prepare for school-based teaching practice in tertiary institutions. The videotapes themselves would be a rich source of exemplary lessons to be used in pre- service and in-service science teacher education in Botswana.

Methodology

Research Design

This is a case study looking for actual implementation of the new syllabuses in a particular science class. It is a non-participant observation using a video camera to collect data. Several researchers have developed different instruments to record class observations including Flander (1970), Simon and Boyer (1975), Cohen (1976), Galton (1978), Wragg and Kerry (1978). As Bell (1999) concedes, "...inspite of all the tried-and-tested methods that have been employed by the experienced researchers over the years, there never seems to be an example that is unique for the particular task. Inevitably, you will find you have to adapt or devise a completely new approach, and all new systems need careful piloting and refining in the light of experience.... You will probably need to invent your own system of shorthand symbols and these will have to be memorized. You will need to decide how often to record what is happening (all the time? every three seconds? every five minutes? Every twenty minutes?) and with whom (the entire group? Individuals?" (p. 164). In this study, video recording took take place during the entire 80-minute lesson duration.

Population and Sample

The population of the study included science teachers in all 27 governments and government- sponsored senior secondary schools in Botswana. To ensure that each of the 11 school regions was represented in the study, a stratified random sample was obtained. One school was randomly selected from each region. Then in each school, the teachers who taught forms 4 and 5 classes of students in Pure, Single and Double Sciences were grouped according to their teaching subjects - Biology, Chemistry, and Physics. In each of these teaching subjects, one teacher was randomly selected, thereby making a stratified sample of three teachers per school, a total of 33 teachers. However, due to scheduling problems, only 22 out of 33 teachers were observed. Therefore, the sample consisted of 22 teachers of which 16 were male and 6 female; 12 were Botswana and 10 expatriates; eight were chemistry, eight biology and six physics teachers; 22 video-recorded lessons in eight chemistry, eight biology and six physics classes, with an average of 21 girls and 19 boys totally of 875 students with an averaging 40 per class. There were 19 Form 4 and 3 Form 5 classes. All but one lesson was held in appropriate subject-specific laboratories. Table 1 also shows the list of topics that were taught by different teachers in different lessons. Except for the lesson on non-ruminant animals, all were held in subject-specific laboratories.

Instrumentation

The classroom activities may be observed using checklist, writing while listening, audio recording or video recording-forms of the case study. All these methods possess some benefits and as well as costs; the teacher's expression (eagerness, aggressiveness) as well as the student expression would be missed out in audio recording.

A video camera was used in this study because of its versatility and accuracy in capturing almost all class activities. It reveals the advantages of audio recording for later analysis, and also adds a record of body language and other useful indicators. It also gives a wealth of material that can later be used to construct a video film that helps to effectively disseminate the results of the study. The researchers recorded the lessons after receiving professional training in how to use them. The training involved focusing on every possible activity as well as the operation of the video camera, its installation and maneuvering in class. Each lesson was videotaped by two researchers.

Tape recording was ruled out, because it only audibly records the activities that are focused on rather than on all the activities that take place in the class during a lesson. Writing on paper in the class was also ruled out, because the researchers would not be able to note all the activities that take place in an 80-minute lesson.

Data Collection

Permission to carry out the study was sought from the headmaster of each school and granted. Once granted, the heads of science departments were contacted to identify and select the sample of teachers. Arrangements were then made with the teachers concerned regarding the location, date and time when their lessons were to be video-recorded by the investigators.

Except in few cases, all recordings were carried out between the first and eighth period and between Monday and Friday school days. All the lessons were of 80 minutes duration. Recording covered the entire 80 minutes without interruption, except for power disruptions. While recording, the lesson was not disrupted by the researchers. They captured and focused on the teacher, the students, and other things, such as practical work, demonstration, charts, and the blackboard work in the course of the lesson. The researchers did not brief the teachers what they were looking for in the lesson. The students were informed in advance that their lesson was being recorded for academic purposes at the University of Botswana.

Class Observation

At the beginning of each lesson, the investigators were introduced to the students. After the investigators settled in the class with the recording equipment, turned on the camera and kept it on throughout the lesson, without interfering with the class proceedings. They did not talk or comment on what the students were doing during the lesson. However, they were free to move around the class to capture various activities that were going on in the lesson.

After recording the lesson, the video tape was rewound and labelled in terms of the name and number of the school, name of the teacher, name of the class, type of science subject, date and time of recording to ensure that videos were not mixed up. The teacher was thanked for co-operation and assured confidentiality of the recorded lesson. Depending on the schedule, the investigators went to the next scheduled lesson in the school. In some instances, there was a period or two between the two lessons being recorded.

Data Analysis

The nature of the research design of this study dictated the method of data analysis, which in this case was qualitative analysis. To do this, preliminary processes were carried out and included the following stages:

- Identification of the recorded videotapes according to schools, teachers, classes and science subjects, date and time of recording. This was necessary to ensure that the tapes were not mixed up while analysing them.
- Preview of each videotape in order to ensure that the entire lesson was recorded accordingly. Had this not been the case, the lesson would have to be re-recorded.
- Transcribing each video, so that every event that took place in each lesson was written down. This included everything that was said by the teacher and the students, questions and answers, discourse and activities that the teacher and the students undertook.
- Identifying and recording class activities of both teacher and students. These included things like bringing equipment trolley into the class/laboratory, teaching aids, performing certain process procedures such as demonstration, investigation, writing on the blackboard, handing out or receiving assignment, test answers or practical reports, group and individual work, supervision of student work, copying notes from the blackboard, teacher's handout or reading from book or other printed materials, etc.
- Noting whether the lesson was teacher- centred or learner-centred.
- Noting which of the four process skills were the students involved in, if the lesson was a demonstration or practical.
- Noting whether the students were learning or being assessed to acquire any of the four process skills and describing the activities.

Table 1 shows the initial analysis of the data. There were 21 empirical and one theoretical topics being taught. The topics were of a wide variety from biology, chemistry, and physics. Twelve empirical topics were taught empirically and the rest, though some were empirical, were taught theoretically. Except one, all the lessons were conducted in appropriate science laboratory.

Out of 22 lessons, 19 were involved in providing students with some hands-on experience in carrying out practical work. There were no laboratory assistants to assist teachers before and during the lessons. The teachers set up the laboratories before students came in and cleared them after the students left. In few cases, a few students offered to help their teachers to clear the laboratories. The lessons were conducted using appropriate teaching materials and equipments in 13, but not in 9 lessons.

Demonstration Lessons

Table 2, shows the list of five lessons and topics taught through demonstration teaching method. These were: Acceleration, Redox Reactions, Sound, Total inter-

Table 1
Topics Covered in the 22 Lessons and Teaching Methods Employed

Topic	Type of Topic	Teaching Method Used	L	E	T	1	2	3	4
1. Abuse & Disabuse of Drugs	Empirical	Lecture + Discussion	√	X	X	X	X	X	X
2. Abuse & Disabuse of Drugs	Empirical	Lecture + Discussion	√	X	X	X	X	X	X
3. Acceleration	Empirical	Demonstration	√	√	X	√	√	√	√
4. Acids, bases and salts	Empirical	G. Practical	√	√	X	√	√	√	√
5. Alloys	Empirical	Lecture	√	X	X	X	X	X	X
6. Calculations in Electrolysis	Empirical	G. Practical	√	√	X	√	√	√	√
7. Chemical Bonding	Theoretical	Lecture	√	√	X	X	X	X	X
8. Digestion in Humans	Empirical	Lecture + Discussion	√	X	X	X	X	X	X
9. Digestive System	Empirical	Lecture + Discussion	√	X	X	X	X	X	X
10. Electrolysis	Empirical	G. Practical	√	√	X	√	√	√	√
11. Exchange of Materials: Capillaries & Tissues	Empirical	Lecture, Discussion	√	X	X	X	X	X	X
12. Food Tests	Empirical	G. Practical	√	√	X	√	√	√	√
13. Methods of preparing Salts	Empirical	G. Practical	√	√	X	√	√	√	√
14. Non-Ruminant Animals	Empirical	Lecture	X	X	X	X	X	X	X
15. Reaction Rates	Empirical	Lecture	√	X	X	X	X	X	X
16. Redox Reactions	Empirical	Demo+G.Practical	√	√	X	√	√	√	√
17. Resistance	Empirical	G. Practical	√	√	X	√	√	√	√
18. Sexual Reproduction in Flowering Plants	Empirical	G. Practical	√	X	X	√	√	√	√
19. Sound	Empirical	Demo + Lecture	√	√	X	√	√	√	√
20. Total Internal Reflection	Empirical	Demo	√	√	X	√	√	√	√
21. Waves	Empirical	Demo+ G. Practical	√	√	X	√	√	√	√
22. Good emitters of heat	Empirical	Practical	√	X	√	√	√	√	√
	20 Empirical 1 Theoretical	√-20 X 1	√-9 X 13	X 22	√-14 X 8	√-14 X 8	√-14 X 8	√-14 X 8	√-14 X 8

Key:

Process Skills: 1-using and organizing techniques, apparatus and materials, 2-observing, measuring and recording, 3-handling experimental observations and data and 4-planning investigations. **Laboratory Factors:** L= Laboratory, T= Technician, E= Materials and Equipment, X= Not available √= Available.

nal reflection, and Waves. The common features of the lessons were that in each case, the teacher treated the lesson as if the students were the ones carrying out their own group experiments such that all four process skills of (i) using and organizing techniques, apparatus and materials, (ii) observing, measuring and recording, (iii) handling experimental observations and data, and (iv) planning investigations were manifested. Some students assisted the teacher in bringing required materials and equipments from the storeroom for use in the demonstration, assembling the apparatus, performing the demonstration, collecting and analyzing data. But as in all cases of demonstration, most students were passive observers of what the teacher and a few students were doing.

During demonstration, the teacher and a few students performed the procedures, while the rest observed and only contributed after the data had been collected. For that matter, the lessons cannot be said as providing students with the opportunity of acquiring all four process skills. The demonstration lessons were on

Table 2.
Topics that Were Taught Empirically in Which the Major Four Process Skills Were Inculcated in Student by Means of Demonstration

Topic	Type of Topic	Teaching Method Used	L	E	T	1	2	3	4
1. Acceleration	Empirical	Demonstration	√	√	X	√	√	√	√
2. Redox Reactions	Empirical	Demo+G.Practical	√	√	X	√	√	√	√
3. Sound	Empirical	Demo + Lecture	√	√	X	√	√	√	√
4. Total Internal Reflection	Empirical	Demo	√	√	X	√	√	√	√
5. Waves	Empirical	Demo+ G. Practical	√	√	X	√	√	√	√
	5 Empirical	5 Demo	5√	5√	5X	5√	5√	5√	5√

Key:

Process Skills: 1-using and organising techniques, apparatus and materials, 2-observing, measuring and recording, 3-handling experimental observations and data and 4-planning investigations. **Laboratory Factors:** L= Laboratory, T= Technician, E= Materials and Equipment, X= Not available √= Available.

acceleration, redox reactions, sound, total internal reflection and waves. As the videos show, only a few lucky ones acquired one or two of the four process skills by assisting the teacher in performing the demonstration. It is for this reason that the demonstration should not be an end in itself unless the equipments are delicate or the procedure is dangerous. Another notable problem is that in each lesson there was no trained laboratory assistant to help the teacher. As a result, teachers serve the roles of laboratory assistant of setting up the demonstration and putting things away after the lesson.

Using and organizing techniques, apparatus and materials

In each case, teachers ensured that students in the laboratory were able to observe and hear what was being done and said. The teacher involved several students in setting up the apparatus, such as a water rocket on acceleration, performing redox reactions, and measuring sound waves. In the cases of the experiments on acceleration, sound and waves, and total internal reflection, several students were asked to repeat the procedures several times after the teachers had demonstrated them. These students acquired the skill of using and organizing techniques, apparatus and materials. Unfortunately, the majority of the students who laid their hands on the demonstration were boys. The majority of girls were observers.

Observing, measuring and recording

In all five demonstrations, while the teacher or student carried out the demonstration, certain students recorded the results on table or chart. They were recording the results as if they themselves had performed the demonstration. Each class was treated as one group.

Handling experimental observations and data

In each demonstration, the class discussed the results after they had been analyzed, the teacher serving as a member of the group. The teacher announced that the groups would treat the data in a similar manner after they perform their own investigation in future.

Planning investigations

The five lessons on Acceleration, Redox Reactions, Sound, Total Internal Reflection and Waves were carried out in the laboratories. However, the lesson on acceleration was carried out partly in the physics laboratory where the teachers outlined the principles of acceleration and partly in the school field where the demonstration was carried out. The common features of these lessons are that the teacher planned the investigations before the lesson and only presented them to the class. As a result, students were denied the opportunity of planning.

Group Practical Work

Table 3 below, shows the list of eight lessons and topics taught through practical work teaching method. The topics were: acids, bases and salts, calculations in electrolysis, electrolysis, food tests, methods of preparing salts, resistance, sexual reproduction in flowering plants. The common features of the lessons were that groups of students were encouraged to acquire some of the four process skills of (i) using and organizing techniques, apparatus and materials, (ii) observing, measuring and recording, (iii) handling experimental observations and data, and (iv) planning investigations by carrying out experiments, while the teacher walked around providing some assistance.

Table 3.
Topics Taught Empirically in which Students Acquired the Major Four Process Skills by Means of Group Practical Work

Topic	Type of Topic	Teaching Method Used	L	E	T	1	2	3	4
1. Acids, bases and salts	Empirical	G. Practical	√	√	X	√	√	√	√
2. Calculations in Electrolysis	Empirical	G. Practical	√	√	X	√	√	√	√
3. Electrolysis	Empirical	G. Practical	√	√	X	√	√	√	√
4. Food Tests	Empirical	G. Practical	√	√	X	√	√	√	√
5. Methods of preparing Salts	Empirical	G. Practical	√	√	X	√	√	√	√
6. Resistance	Empirical	G. Practical	√	√	X	√	√	√	√
7. Sexual Reproduction in Flowering Plants	Empirical	G. Practical	√	√	X	√	√	√	√
8. Good emitters of heat	Empirical	G. Practical	√	√	√	√	√	√	√
	8 Empirical	8 Group Prac	√ Lab	8 X	8-7	√-8	√-8	√-8	√-8

Key:

Process Skills: 1-using and organising techniques, apparatus and materials, 2-observing, measuring and recording, 3-handling experimental observations and data and 4-planning investigations. **Laboratory Factors:** L= Laboratory, T= Technician, E= Materials and Equipment, X= Not available √= Available.

Using and organizing techniques, apparatus and materials

The results showed that in all seven lessons, students were given some instructions on carrying out the investigations. They spent some time reading them before they began their investigations. They also assigned duties to each other. In each group, one member was selected to serve as group leader. One or two group members went to collect apparatus, equipments, and in some cases reagents from either the teacher's table or a designated place within the laboratory. After the apparatus were set up, the teacher was asked to come and certify that they were set up properly. In most cases, teachers helped the groups to set the apparatus properly. Because the teacher had to check every apparatus, the last groups to be inspected started their investigation 10-15 minutes later than the first group.

Observing, measuring and recording

The results showed that there was division of labour among group members. In each of the experiments, one or two students performed the experiment, one or two calling for the results, and one recording them on a table of results. In the case of food tests, methods of preparing salts and acids, bases and salts, when the test was repeated students exchanged their roles in order to give each other opportunity to experience the exercise. In the case of reproduction in flowering plants, group members swapped responsibilities of making sections of the flower for observation on the microscope and hand lenses.

Common problems included absence of a trained laboratory assistant, lack of adherence to safety rules by students. Although students were constantly reminded of the need to take safety precautions, they did not seem to care. They did not wear laboratory coats, safety goggles, and gloves. When mixing reagents in test tubes or when heating they did not always point the test tubes away from people. They did not handle properly blades or scalpels when cutting sections of flowers. Most students had difficulties in using the microscopes. In some cases, when mounting a fresh specimen, they wet the microscope. This could be a source of electrical shock. Another problem is the fact that a class of about 40 students was manned by one teacher who was unable to efficiently supervise it. This caused some anxious moments among members of different groups, as the teacher could not be available to them when his/her input was badly required in a particular procedure.

Students were excited whenever they obtained expected results, particularly those that involve colour change in acid and base reactions, and in various food tests.

Handling experimental observations and data

The results showed that in the food tests experiments, the teacher prepared a table of results on the board into which group members were to record their findings and discuss them during plenary session. However, each group prepared table of results in either their notebooks or on papers. The results were being recorded as the investigations progressed. It was well done. In the cases of redox reactions, acid bases and salts, and methods of preparing salts, groups recorded their various results on appropriate table of results that they had designed. In the case of experiments on electrolysis and resistance, groups designed tables to record their results on. In almost all cases one or two group member designed the table and entered the results as they became available.

Planning investigations

The results showed that in all cases, the teacher announced the topic and objectives of the lesson at the beginning of the lesson. In most cases, written worksheets outlining the aim and objectives of the practical, list of equipments, chemicals, and other materials were presented to groups. In few cases, these were written on the chalk board. Groups were then asked to plan for their investigations and to modify their plans if necessary. They were told to ask for any material they required, if they had not been placed on the work tables. They were told to call for the teacher once they had completed making their plans. Good examples of planning investigation were the lessons on food tests and acids and bases and salts, and methods of preparing salts.

The researchers observed two common problems. All the teachers did much planning for their students who were only allowed to make minor modifications, and some of the members did not make meaningful contribution in planning for their investigations. They relied on their peers who seem good planners.

Conclusion

The results showed that:

- Ten lessons on empirical topics were taught theoretically in which lecture and discussion were the dominant teaching methods, something not recommended in the new Botswana General Certificate of Secondary Education of 1997.
- Eight lessons on empirical topics were taught empirically by laboratory method encouraging students to acquire some of the recommended process skills of using and organizing techniques, apparatus and materials, observing, measuring and recording, handling experimental observations and data, and planning investigations.
- Five lessons on empirical topics were taught empirically by demonstration method in which a few students had opportunity to acquire any of the recommended process skills.
- Most students did not seem to have an opportunity to acquire all four process skills because they do practical work in groups.

Recommendations

The study recommends that the Departments of Science in senior secondary schools should insist that science teachers teach empirical topics empirically, so that students are encouraged to acquire the four process skills of using and organizing techniques, apparatus and materials, observing, measuring and recording, handling experimental observations and data, and planning investigations. It also recommends that Teacher Education institutions in Botswana should place great emphasis in training teachers on the teaching/learning of process skills of using and organizing techniques, apparatus and materials, observing, measuring and recording, handling experimental observations and data, and planning investigations.

REFERENCES

BELL, J. (1999). Doing Your Research: A guide for first-time researchers in education and social science (3rd Ed.). Buckingham: Open University.

CARNAP, R. (1966). *Philosophical Foundations of Physics.* New York: Basic Books Inc.

Cohen, L. (1976). *Educational Research in Classrooms and Schools: A Manual of Materials and Methods.* London: Harper & Row.

Flander, N. A. (1970). Analysing Teaching Behaviour. Cambridge, MA: Addison-Wesley.

Galton, M. (1978). *British Mirrors. Leicester: University of Leicester School of Education.*

Grandy, R. E. (1973). *Theories and Observations in Science.* Englewood Cliffs. N. J.: Prentice Hall. Inc.

Hempel, C. G. (1965). *Aspects of Scientific Explanation.* N. Y.: The Free Press. A Division of Macmillan Company.

Hempel, C. G. (1966). *Philosophy of Natural Science.* Englewood Cliffs. N. J.: Prentice Hall. Inc.

Kemeny, J. G. (1959). *A Philosopher Looks at Science.* New York: D. Van Nostrand C. Mogapi, M., & Yandila, C. D. (2001). *Assessment on the New Senior Secondary School Syllabuses. A Paper presented at the Biannual National Conference on Teacher Education, held at Tonota College of Education in August, 2001.*

Nagel, E. (1961). *The Structure of Science.* N.Y: Harcourt, Brace and World, Inc. Ogunniyi, M. B., and Yandila, C. D. (1993). Perception of the Language of Science held by Nigerian and Botswana Secondary School Science Teachers. *The Beacon, 2, 51-56.*

Ogunniyi, M. B. (1977). *Conceptualizations of Scientific Concepts, Laws and Theories held by Kwara State Secondary School Science Teachers.* PhD Thesis, University of Wisconsin-Madison.

Okatch, B. O. (1980). The School Science Project as an Example of the Process of Tanzanian Educational Policy Determination for Curriculum Development. Unpublished PhD. Thesis, University of Calgary.

Pella, M. O. (1975). *Concept of Concept.* Madison University of Wisconsin.

Republic of Botswana, (1997). *Senior Secondary School Biology Syllabus.* Government Printer. Gaborone

Rowe, R. E. (1976). Conceptualizations of the Nature of Scientific Laws and Scientific Theories held by Middle School and Junior High School Teachers in Wisconsin. Unpublished Thesis University of Wisconsin-Madison.

Simon, A., & Boyer, E. (1975). *The Reflective Practitioner.* New York: Basic Books.

Wragg, E. C., & Kerry, T. L. (1978). *Classroom Interaction Research.* Rediguide 14. University of Nottingham School of Education.

Yandila, C. D. (1995). *Teaching Science in Botswana.* Printing & Publishing: Gaborone

Yandila, C. D. (1999). *Implementation Hiccups of Senior Secondary_Syllabus in Botswana.* Paper presented at the eighth Symposiúm of International Organization for Science Technology Education held in Durban, 1999.