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A Study of Science Teacher Trainees' Conceptualization of Immunological Processes

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Abstract

This study reports teacher trainees' conceptualization of immunological processes. Data for the study comes from 11 fourth year student teachers who enrolled in science education. The participants answered free response items on immunological processes. Data was analyzed using a qualitative approach. Implications for teacher education programmes are discussed in the light of the findings.

Key Words: *Science teachers, immunological processes, conceptual errors, misconceptions, phenomenographic approach*

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Introduction

Research in science education has placed more emphasis on children's understanding of scientific concepts with less emphasis on teacher trainees' conceptualization of scientific concepts (Linder & Erickson, 1989; Driver, 1989; Yip, 1998). One reason cited for less emphasis on teachers' conceptualization of science concepts is the belief that teachers had extra time at the college/university level to focus on their studies and consequently have acquired an understanding of scientific concepts (Linder & Erickson, 1989).

However, it is becoming increasingly important to investigate teacher trainees' conceptualization of scientific concepts because they will 'talk and explain' science concepts to children. Therefore, it is expected that teacher preparatory institutions would teach teacher trainees in a way that places more emphasis on knowledge construction and with less emphasis on knowledge acquisition. Such a move would help teacher trainees to do the same to learners.

Although some studies have been conducted on teacher' conceptualizations of biological concepts, they are, however, very few indeed (Boo, 2005; Yip. 2007). However, these studies have been very helpful since they indicated biological concepts in which teachers are deficient and possess misconceptions (Boo, 2005). This current study therefore aims at obtaining insights into teachers' conceptualization of immunological processes. In comparison to the wealth of information on some concepts in biology, the research literature on teachers' conceptualization of immunological processes is under-represented yet immunological processes are crucial to the life of all organisms on earth. Teachers therefore should have a clear conception of immunological processes so that they are proficient at explaining them to children. Furthermore, teachers' understanding of immunological processes would help them to explain HIV/AIDS pandemic better.

University/college lecturers tend to equate conceptual understanding with passing examinations, yet many students pass examinations by memorizing sufficient materials (Moore, Mitchell, Bally, Inglis, Day and Jacobs, 2002). It is the researcher's belief that there is a viable method of assessing teachers' conceptualization of biological concepts. The researcher believes that asking teachers to 'talk and explain' immunological processes would reveal their conceptual understanding. The most widely accepted procedure for examining conceptual understanding is the interview technique. Conceptual understanding helps teachers to identify conceptual errors and to correct misconceptions that students may possess. Furthermore, conceptual understanding encourages teachers to teach students scientific concepts for understanding. Teachers who adopt a model of conceptual change in their teaching would help learners to 'talk and explain' biological concepts. In addition, conceptual understanding helps learners to learn scientific concepts relationally, that is learners would relate biological concepts to every day life activity and consequently meaningful learning would be achieved. Therefore, there is a need to promote a

deeper understanding of subject matter knowledge and to make teachers more competent. However, if teachers possess misconceptions, they would influence what is taught in schools and it is likely that they would perpetuate the same misconceptions to students.

Studies conducted on prevalence of conceptual errors by teachers suggest that more research needs be done to assess the extent to which scientific knowledge of teachers is influenced by cultural activities (Barras, 1984; Solomon, 1993; Yip, 1998; Moore, et al, 2002). Solomon (1993) noted that conceptual errors could be a result of the juxtaposition of scientific knowledge to life world knowledge or cultural knowledge. Therefore, when teachers explain scientific concepts, it is likely they would contextualize them with cultural knowledge. Hence the assertion that teachers hold a variety of conceptual errors in their subject knowledge is not surprising (Yip, 1998) because their scientific knowledge is in conflict with cultural knowledge

A study by Martins and Ogborn (1997) on primary teachers' conception of genetics also revealed that conceptual learning could be enhanced by using metaphors when teaching science. Use of metaphors in teaching science is important because it helps students to learn science concepts figuratively and at the same time have the opportunity to 'talk and explain' scientific concepts. Metaphors were found to help teachers to alter and to modify their thinking about scientific concepts (Martins and Ogborn, 1997).

Venville and Treagust (1996) also found that conceptual learning could be achieved if analogies are used in the teaching of scientific concepts. Furthermore, conceptual learning could be achieved when scientific concepts are raised and naïve conceptions are lowered (Venville and Treagust, 1996). This means that learners should be dissatisfied with old conceptions and that new conditions must be accommodating to new concepts being learned. Therefore, analogies help learners to learn science conceptually rather than instrumentally. Instrumental learning interferes with conceptually learning or learning with understanding.

Analogies have also been found to promote aesthetic appreciations and positive attitudes which are crucial for learning science conceptually. Venville and Treagust (1996) also reported that analogies are pedagogical tools that help students to construct new knowledge by linking it with knowledge cognitive structures they already possess. Therefore, it is easy for new concepts being learned to be easily hooked on cognitive structures.

Conceptual learning is important in learning science for it enables learners to compare unfamiliar concepts to familiar concepts which are part of the learners' everyday experiences. Yip (1998) reported that teacher training programmes focus mainly on educational principles, instructional methodology and teaching practice at the expense of promoting a deeper understanding of subject matter knowledge to make a teacher more competent. In other words, teacher training institutions do not teach for conceptual learning but rather for rote learning. Teacher trainees used in this

study would therefore learn immunological concepts conceptually if they are taught in a way that they would give them the opportunity to 'talk and explain' immunological processes in scientific knowledge. However, it seems to me that if teachers use formal biological knowledge in explaining biological concepts and at the same time indicating conceptual errors associated with our everyday life world knowledge, children will learn biological concepts meaningfully. College science lecturers should teach teacher trainees biological concepts conceptually. This would enable them to be able to identify teacher trainees' conceptual errors, misconceptions and misunderstandings.

Purpose of the study

The purpose of this study is two-fold:

1. To investigate science teachers' conceptions of immunological processes
2. To identify conceptual errors held by science teachers on immunological processes

Research Questions

The research questions are based on the purpose of the study and are as follows:

1. What conceptions are held by science teachers about immunological processes?
2. What conceptual errors are held by teachers on immunological processes?

Statement of the Problem

This study reports on teachers' conceptualization of immunological processes. The main aim of this paper is to describe a set of categories that represent how teachers conceptualize immunological processes, that is how they 'talk and think' about various immunological processes. Furthermore, the study attempted to identify conceptual errors and misconceptions held by teachers on immunological processes.

Methodology

Data Collection

Data were collected using an interview protocol. The protocol consisted of several questions that intended to reveal teachers' understanding of immunological processes. Some interview protocol guide questions are in the appendix. Most of the questions that the interviewee asked were derived from the general questions in the appendix. The questions asked in the interview are not necessarily the ones in the appendix. The questions in the appendix guided the study

Subjects

Eleven science teachers involved in this study were in their fourth year of the bachelor's degree in primary education majoring in science education. In this study, teachers who take all nine science education courses are referred to as science teachers.

The Interview Protocol

The researcher wrote a letter to each of the eleven subjects requesting him or her to participate in the interview. The participants agreed and participated in an interview which lasted for 60 minutes for each subject. The researcher developed interview questions and gave them to two biology educators who validated them. The validators confirmed that interview questions were a true representation of concepts taught in immunology.

The interview protocol questions were developed and piloted using teachers who majored in science and had completed in May, 2008. The results of the pilot study provided information that the helped the author to improve and to change some questions. After the pilot study, the questions were administered to eleven fourth year students who were also majoring in science education. The questions provided an opportunity for the subjects to 'talk biology' as they explore their conceptualizations of immunological processes with the interviewer (Linder and Erickson, 1989). The subjects were assured that interview questions were not posed to intimidate them but rather to investigate how they conceptualize immunological processes.

Theoretical Framework

A review of literature suggests a variety of methods for collecting and analyzing data in the field of teachers' conceptualization of biological concepts (Boo, 2005; Yip, 1998 & Barrass, 1984). Since this study was concerned with investigating teachers' understanding of immunological process, an analytical approach known as phenomenographic perspective was opted for. This approach has been used extensively in research studies that investigated how people conceptualize scientific concepts (Marton, 1981 & 1988; Marton & Booth, 1998). Marton (1981) described phenomenography as a research specialization aimed at studying the different understandings or conceptions of the phenomena in the world around us.

Linder and Erickson (1989) contended that there are two perspectives that researchers could adopt to investigate teachers' conceptualization of immunological processes when using a phenomenographic approach, namely the first and second order perspectives. In the first order perspective (referred to scientific knowledge), the phenomenon of immunology itself is studied, however, this study adopted a second order perspective, the study investigated how teachers conceptualize the phenomenon of immunological processes. In other words, a second order approach investigated how teachers 'talk and think' immunology.

In this study, the researcher opted for the second order perspective because the researcher wanted to find out how teachers conceptualize immunological processes. The analytical procedure associated with phenomenography is concerned with constructing a range of conceptualizations or a category of descriptions made by teachers. It is known that categories of descriptions differ qualitatively amongst teachers and the intent of using categories of descriptions was to depict teachers' understanding of that which was thought about (Linder and Erickson, 1989). Categories of descriptions delivered by teachers have limitations which are attributed to constraints provided by their linguistic categories or world knowledge which is at variance with scientific knowledge. In this study, the researcher used a phenomenographic research approach to investigate teachers' conceptualization of immunological processes rather than investigating teachers' knowledge of immunology (Linder and Erickson, 1989).

Results of the Study

Since this study adopted a phenomenographic approach, the analysis was divided into three categories depending on the explanation given by the subjects to each interview question. The categories are as follows:

a. Linguistic deficiency: This refers to lack of language used in explaining immunology concepts
b. Conceptual errors: These include mistakes made in the explanation of immunology concepts. Misconceptions (misleading ideas) by the subjects were also treated as part of conceptual errors. The subjects who explained immunology concepts by misinterpretation of facts were regarded as having misunderstandings.
c. Conceptual understanding: In this category, teachers who correctly explained immunology concepts were categorized as having conceptual understanding.

Linguistic Deficiencies

The language used in explaining immunological processes is very complex indeed; consequently the researcher found that most teachers were deficient in this specialized language. In this section, the interviewer is the researcher while the teacher refers to the participant.

Interviewer: 'Explain what you understand by the concept 'immunity'. All subjects responded to this question. However, the researcher identified two who according him were deficient in the language of immunology.

Teacher: Immunity means the ability of an organism to avoid being ill. It is when the body protects itself against some organisms.

Interviewer: What do you mean by some organisms?

Teacher: Not all organisms cause diseases that are why I am saying some organisms because few small things cause disease.

Interviewer: Ok, thank you very much.

Interviewer: How about you sir, what do you understand by the concept 'immunity'?

Teacher: I think it means how our bodies respond to attacks by microorganisms.

Interviewer: Can you give examples of these microorganisms?

Teacher: Yes, they include bacteria, viruses, fungi, protozoa and worms. If your immune system is not strong, then you can easily be attacked by a host of microorganisms.

Interviewer: Why do you say microorganisms?

Teacher: Because they are very small, you cannot see them with your naked eyes.

*Interviewe*r: I thank you very much once more for agreeing to participate in the interview.

Conceptual Understanding

Some teachers showed a clear understanding of the concept, 'immunity'. Such clear understandings are shown by responses below.

Interviewer: What do you understand by the concept immunity?

Teacher: Immunity is a term that describes a state of having sufficient biological defenses to avoid infection, diseases and other unwanted biological invasions. Immunity can either be 'adaptive' or 'innate'. Most organisms' immunity is 'adaptive'. This means the immunity can be .natural' or 'artificial'.

Interviewer: I don't have any further questions. I would like to thank you very much for sparing me your time. Thank you very much.

Interviewer: How about you madam? What do you understand by the concept 'immunity'?

Teacher: Immunity is a medical term that is used to indicate that the body of an organism has the ability to resist a disease. Immunity may exist naturally or as a result of previous infection or passive inoculation. It can either be 'active' or 'natural'. Natural immunity occurs when an organism contacts with a disease causing agent.

Interviewer: Thank you so much for your answers and for agreeing to participate in the interview. I think you understand immunity very well.

Interviewer: John, you can also respond to the question.

John: The word immunity is similar to exemption from military service. Therefore, people who have immunity for some diseases will not be ill again by the same diseases. For example, if one has immunity to smallpox, that individual cannot suffer from smallpox again.

Interviewer: John, then you for your responses. Thank you very much

Conceptual Errors

Interviewer: David, what do you understand by the concept 'immunity'?

David: Immunity is when bacteria fail to attack a person and cause ill-health. You know bacteria can make you ill, but if you have immunity to bacteria, you won't get ill.

Interviewer: Are you saying all bacteria cause illness or diseases?

David: Yes, bacteria release toxins that cause diseases. But they must all bacteria be pathogenic. They attack people all the time. People who do not get ill are those who have immunity to themselves.

Interviewer: I am not ill; does this mean I have immunity to all bacteria?

David: It's because your body produces antibodies and may be you have been injected with immunizing chemicals.

Interviewer: What is an antibody? *David*: An antibody is an antigen. So an antigen is another word for an antibody. *Interviewer*: So they are the same.

David: Yes, they are

Interviewer: Tell me. What are immunizing chemicals?

David: Tablets that are taken in by people so that they do not become ill.

Interviewer: David, are ARVs immunizing chemicals?

David: Yes, because they make people who are HIV positive a bit strong and healthy, so they are immunizing chemicals.

Interviewer: Thank you, David for responding in detail to my questions

Linguistic Deficiencies

There were instances where teachers showed linguistic deficiencies when answering some immunology questions.

Interviewer: Folks, here is another question. Why is it that people get ill?

Teacher: There are many microorganisms that make people ill. So people are constantly being attacked by these microorganisms. There are cells in the body whose task is to fight microorganisms. If these cells are not strong enough, microorganisms can make people ill.

*Interviewe*r: Tell me, is there a general name given to organisms that make people ill?

Teacher: Yes, they are called bacteria or viruses

Interviewer: Let me thank you for providing me with valuable information

Conceptual Understanding

Interviewer: How do people get ill?
Teacher: I think people get ill if foreign microorganisms enter their bodies freely. The immune system should attack and destroy these pathogenic organisms. It uses a variety of strategies to neutralize invaders. If one of the strategies fails to stop pathogens from entering the body, the person gets ill. If the organs of the immune system do not work together, then the chances of pathogens entering the body become high.

Interviewer: What a detailed response! Thank you for enlightening me on how people get ill. I am very impressed.

Conceptual Errors

Interviewer: Teachers, I am having one more question to ask you. *Can you explain to me how immunological processes work to defend the body against disease causing organisms?*

Teacher: I think the blood is the key tissue in the immune system. The blood carries immune cells and circulates them in the body, where there are unwanted organisms, the blood releases chemicals or toxins that fight organisms and kill them. The blood cells could fail to kill the harmful organisms if white blood cells are not produced in large quantities.

Some dead organisms and unwanted chemicals have to be discarded. Its kind of a complex process, you know. As far as I know white blood cells are the key immune cells, without them, an organism is killed.

Interviewer: Can you say more about how the immune system defends itself against pathogenic organisms.

Teacher: I think what I have already said is clear enough. There is a bunch of organs that work together to defend an organism. One of them is the liver, the heart and the spleen.

Interviewer: So the heart also defends the body against microbes that cause diseases.

Teacher: Yes, it heart.

Interviewer: In what way?

Teacher: It sends blood where it is needed and if blood finds these organisms, it kills them

Interviewer: Thank you for your answer.

Conceptual Understanding

Few teachers showed a conceptual understanding of immunological processes taking place within an organism.

Interviewer: Explain how the immune system work to defend itself against organisms that cause illness

Teacher: The immune system is a group of cells, tissues and organs that must work in harmony to defend the body against pathogens. If pathogenic organisms manage to enter the body, massive defensive mechanisms and processes are launched. Pathogenic organisms that manage to escape the skin (acidic sweat and oils) will not be left to room around. Other organs launch attacks. The invaders will induce an immune response from T-cells, B-cells and macrophages. T-cells will help B cells to recognize the invaders. B. cells will produce antibodies which will hold pathogens and fiercely pin them down for macrophages to finish them. All the organs of the immune system produce toxins which will run to the pathogens and attach them until pathogens are neutralized. This happens only to pathogenic bacteria, it does not happen to viruses. You see immunological processes are very difficult to explain.

Interviewer: Thank you very much; you have been very articulate in your explanation of how immunological processes work. Thank you once more.

Discussion of the Results

From a few excerpts above, it is clear that some immunology concepts were not well understood by teacher trainees. Conceptual errors and linguistic deficiencies tend to be dominant amongst teacher trainees' responses. An observation for the occurrence of such errors suggests that teacher trainees still learn scientific concepts by memorization rather than conceptually. This is evident in the responses to interview questions in which teachers memorized definitions of certain concepts used in immunology rather than 'talk and explain' those concepts.

Learning science conceptually has been identified by research as the best way of learning because it enhances meaningful learning (Driver, 1987). According to Driver, (1987), the goal of science teaching should change from knowledge acquisition to knowledge construction. In other words, learners should have the opportunity to learn science conceptually, that is, they should 'talk and explain' science.

In this study, very few subjects showed conceptual understanding of immunological processes. One barrier to conceptual understanding is the fact that teachers equate passing exams with conceptual understanding (Moore, et al, 2002). So, students memorize scientific concepts to ensure that they pass exams so that they please teachers. While passing exams is important, it is equally important to ask students to explain scientific concepts in a test.

Although Posner, Strike, Hewson and Geerzog (1982) and Driver (1987) advocated for conceptual teaching a long time ago, it seems this has not been the case in Botswana. The researchers emphasized that students should 'talk and think' the concepts they are being taught. In this study, not all teachers were able to 'talk and think' immunological concepts so that conceptual errors, misconceptions and naïve explanations are identified.

From excerpts, it is very clear that conceptual learning is a demanding task which requires more time. Teacher: *I think if we are going to teaching science by allowing children to talk scientific concepts that we teach, it's good, but this kind of teaching will help children relate what they are learning to everyday life situation. But where do we get time for this? Government wants children to pass National Exams.*

In this study, teacher trainees were answering interview questions and at the same time constructing knowledge. As I interviewed teacher trainers, I realized that asking them to explain their responses helped them to realize their conceptual errors and consequently correct them. Hope and Townsend (1983) are of the view that

teachers who talk and explain' scientific concepts would realize where errors are made and would attempt to correct them. This could happen when they are probed further with questions that ask them to explain their answers. Such teachers are considered to be engaged in the learning.

From few teachers who exhibited conceptual understanding, it could be concluded that they will be able to engage children in both the construction of knowledge and the use of scientific language, in this case biology. This suggests that those subjects who answered immunology questions conceptually are more likely to become agents of conceptual change. Research suggests that teachers who teach science conceptually use a variety of methods that promote conceptual understanding (Mintzes, Trowbridge, Arnaudin and Wandersee, 1991). As a result one would expect college lecturers to use a variety of instructional strategies that would promote conceptual learning. However, in this study, some responses from science teacher trainees showed conceptual errors. It is these conceptual errors that should be corrected to avoid a situation where the same conceptual errors would be perpetuated by these teacher trainees in the classroom.

Implications for Science Teacher Education Programmes

There is no science training policy document in Botswana which articulates how teachers should be trained in science education. Such a document is necessary to guide teacher trainers on how to train teachers in science so that they are proficient at explaining scientific concepts conceptually. There is a policy document in education called the Revised National Policy in Education of 1994 and is popularly known as RNPE, 1994 (Republic of Botswana, 1994).This policy document is not on science education per se but on education in general. However, the policy document calls for strengthening science education in Botswana so that it is of high quality. The policy paper also calls for regular review of science programmes so that they are up to date and relevant for the 21st century which is scientifically based. The policy document opines' training institutions should undertake regular employment surveys of their graduates to ascertain the relevance of their training' (p.31). The policy document does not offer any model to be followed by teacher trainers, however, research indicates that a model called teaching for conceptual change is essential for training teachers in science and has become popular in science education.

The increasing importance of conceptual learning makes it essential that those who prepare teachers should develop more coherent science education programmes which would include the opportunities for student teachers to learn scientific concepts conceptually. Furthermore, programme developers should ensure that learning science conceptually goes beyond basic education and lays a firm foundation for learning science at higher levels of education (Byrne & Sharp, 2006). In developing programmes that emphasize conceptually learning, the use of incorrect science language should not be comprised. Some subjects used in this study were found to deficient in the language of immunological processes. Terms such pathogens, antibody and antigens were not understood by the participants yet they are critical for

teaching immunology. Graf and Berck (2006) are of the view that teacher trainees are unable to learn such concepts because the concepts are too many yet teacher trainees are expected to learn them within a short period of time. Teacher trainees learn concepts that are most important and interesting to them. Teacher trainers should realize that unlike other scientific concepts, immunology concepts are not part of our cultural language and hence a lack of an understanding of these concepts.

Conclusion

Graf and Berck (2000) posit that knowing the concepts of a subject is a prerequisite for understanding it. They contend 'Without them there is no understanding of facts and theories and no way to apply them in wider contents' (p.3). Therefore teacher trainees should have a clear understanding of immunology concepts if they are to teach it effectively. Gagne (1977) asserts that the acquisition of concepts is the first step for instruction.

The conclusion drawn from the results of this study suggests that our teacher trainees will not be able to teach children immunological concepts conceptually because they are deficient in immunological processes. So, in training our science teachers, emphasis should be placed on conceptual learning rather than on rote learning. Conceptual learning helps learners to make meaning out of what is being taught.

Understanding immunological processes is of paramount importance to teachers since they have to explain to children the threats posed by HIV/AIDS to their survival. However, the explanations by teachers could be articulated if teachers have a holistic understanding of immunological processes

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