Physics and Southern African Biology

Jan JA Smit
North-West University, Potchefstroom Campus, South Africa
nwtjjas@puk.ac.za

Abstract

The presentation starts with a demonstration of sparks produced with a Van de Graaff generator. In the Socratic style students are asked to predict what happens in the spark. The answer is that different oxides of nitrogen are produced. This leads to atmospheric lightning and the question why, as experienced in South Africa plants grow well after severe electric storms? It is also experienced that plants in regions in Southern Africa where lightning is absent also grow well on rainwater. The nitrates that come through rain water in the soil are thus not the only factor to stimulate growth. What else can contribute? A simple experiment provides the key to this question: Heat cold tap water in a glass beaker with a gas flame. It is observed that gas bubbles form on the inside and on the bottom of the beaker, long before the water boils. What accounts for this? Through further direct questioning students arrive at the explanation: the solubility of air in water decreases with rise in temperature. Of what significance is this fact? Cold water favours biological life. More oxygen and nitrogen is dissolved in cold rain water and in the cold Atlantic Ocean West of Africa. In the water of the warmer Indian Ocean at the east coast less air is dissolved. This accounts for the rich fish life in the Atlantic along the African coast. Plenty examples that link physics to Southern African biology exist.

Introduction

In School curricula, textbooks and presentations nature is often fragmented. When for example electricity is presented it is mostly done in the context of physics, ignoring other relevant areas of occurrence and application. The fact that there is only one nature and that biological, geographical, physical and chemical phenomena are mostly closely related is often ignored. With the announcement of Outcomes-based Education in South Africa in 1997 [1] a holistic approach to Science teaching was introduced. In the new approach the importance of local content in Science is emphasized. Attention to local content, to phenomena learners experience regularly is expected to make science more relevant and acceptable to learners. This would comply with the principles of constructivism. The sample lesson presented in the next section and further examples illustrate how physics and biology can be integrated in science teaching in the Southern African context.

1 Physics and the growth of plants

The lesson starts with a stretched hand over a charged Van de Graaff dome. The spark is related to a flash of lightning between a thunder cloud and the Earth. The class discussion is then directed in a Socratic style by questions:

Q1. What happens to the air in the region of the flash of lightning?

A1. It is pointed out to learners that the huge current of about 100 000 A causes the temperature of the atmosphere to rise to about 30 000 °C. At this high temperature nitrogen and oxygen combines to form nitrogen oxides.

Q2. What happens to the nitrogen oxides when it starts raining?

A2. It combines with the rainwater to form acids like nitric acid. The rainwater carries it down to the Earth.

Q3. Account why plants grow better from rainwater than from tap water.

A3. The nitrogen oxides are ingredients of fertilizers that cause plants to grow well.

It is a well-known fact that plants grows well from rainwater even in regions where there are no thunderstorms. How would you account for this? To direct learners' speculation a glass beaker filled with cold tap water is heated on a gas flame. The observation is that gas bubbles start to form at the bottom and sides of the beaker long before the water boil.

Q4. How do you explain this observation?

A4. The tap water was exposed to air and air dissolves in the water till saturation is reached. When the temperature of the water is raised it becomes over-saturated with air and the air appears as bubbles at the bottom and sides of the beaker.

Q5. How would you, with this knowledge at hand, explain why plants grow well from rainwater where there is no thunder?

A5. When falling through the atmosphere a raindrop cools due to evaporation. The colder water can take more dissolved air. As 80 % of air is nitrogen abundant nitrogen gets into the soil to feed plants.

Now consider the map of Southern Africa. At the east coast is the warm Indian Ocean and at the west coast the cold Atlantic.

Q6. At which coast is more fish? Explain why.
A6. The cold Atlantic has plenty of oxygen and nitrogen in solution. The nitrogen favours the growth of plankton that serves as food for fish, even the big whales. The abundant oxygen makes it comfortable for fish to live.

2 More examples

There are abundant examples to illustrate the relationship between physics and Southern African biology [2]:
Antelope and predators [3]: African antelope like springbuck, impala and blesbuck have the ability to convert when running kinetic energy into potential energy that is stored in the muscles and bones. This happens at the end of each leap when the animal is running. For the next leap the potential energy is converted back to kinetic energy. The conversion kinetic to potential energy and back continues for leap after leap. This ability makes these antelope very economic runners. On average about 80 % of the kinetic energy for successive leaps comes from the potential energy stored this way. Predators like lion and hyena do not have this ability. The energy for every leap needs to come from bodily chemical energy. Predators can run fast for a couple of hundred meters and then tire out. If it wasn't it for this difference in ability to convert and store kinetic energy as potential energy while running the ecology between predators and antelope would have been disturbed.

Crickets [4]: Why is it very difficult to locate a cricket by means of its sound? A South African Rob Toms researched this question and came up with three explanations: a cricket emits its sound in a specific direction and some South African crickets keep turning around when they chirp. The loudness of the chirps thus varies and one cannot tell how far the cricket is. A second reason why it is difficult to find a cricket has to do with the frequency of the sound it emits. The human ear is incapable of determining accurately from which direction sounds with frequencies higher than 3 000 Hz come. Generally the frequencies of cricket sounds are higher than this value. The third reason Toms gives is that crickets often chirp in a chorus. When one cricket senses danger it suddenly stops while another continues heartily. Later the first one will begin to chirp again while one of the others will stop. In this way the enemy is completely confused.

The Bonsmara breed of cattle [5]: Prof Jan Bonsma a South African cattle breeder bred the Bonsmara by applying principles of electrostatics and heat. Through research Bonsma established that the causes why European cattle races like the Hereford and Shorthorn suffers from a disease called tropical degeneration is simply because those animals overheat in the very hot summers of Southern Africa. He further established that these cattle races have two layers of hair. A short one near to the skin that is always electrical positive and a long layer that is uncharged in fair weather conditions. These two layers give the hair the quality of a fur coat. These animals were thus wearing fur coats in summers and it is thus not surprising that they overheated and consequently developed tropical degeneration. Through selective breeding Bonsma eliminated the short layer of hair and decreased the skin thickness. The final result is a breed of cattle that is extremely well adapted to the Southern African climate. What is more is that the skins of these animals produce a waxy substance that acts as a natural "block-out' for the hard African Sun's ultra-violet rays. For more examples on the physics Southern African biology relationship refers to the booklet: *Quarks, Crickets and Catfish… through the eye of a physicist* [2].

Conclusions

The author's experience is that by relating biological phenomena the South African child is familiar with to physics creates interest in physics and enhances understanding. The relationships are not limited to biological phenomena only. Examples from geography, atmospheric phenomena, the human body, astronomy and even religious believes and perceptions were gathered and implemented with great success in teaching learners ranging from Grade 8 to Grade 12.

References

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