STEP BY STEP GUIDELINES ON IMPROVISING LABORATORY EXPERIMENT MATERIALS

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Abstract

Science education requires observation to internalize the fundamental scientific concepts. One tool among the responsible for observing nature is the science laboratory. However, there is a scarcity of laboratories in many schools, especially in developing countries, and most of the science teachers in those schools lack the skills for improvising materials around their environment. Therefore, in this paper, we have step by step demonstrated how to create and use the cheap and used stuff from our environment in a science lesson. We have provided examples of science improvised materials and have shown their effectiveness in use. The paper recommends teachers to improvise as possible they can to accelerate science education effectively.

Keywords: *improvisation, improvised experiment, improvised material, science laboratory, science teacher*

My experience as a science teacher: I was a tutor of physics and chemistry in teacher training college (TTC) Matimba in Nyagatare district, Rwanda, from 2012 to 2014. I joined this TTC after graduating from the former Kigali Institute of Education (KIE), the current University of Rwanda – College of Education (URCE), after unifying all public education institutions into one university of Rwanda in 2013. In this KIE, I graduated with a Bachelor of Science in physics with education qualified as a secondary school teacher. I also have a background in chemistry as I joined KIE by studying a combination of physics and chemistry with training throughout. After two years, I discontinued chemistry to end with physics with education in the next two years. The TTCs are necessitated to train future primary teachers (teachers to teach in primary schools). The climate in TTC was better than in other schools because of two reasons. I, with my colleagues, were rarely called teachers; instead, we were titled, tutors. Since we had only once cycle of education (year 1, year 2, and year 3), we were more flexible with the teaching load. Despite the respect and low teaching load, however, one challenge I faced was the English and science lab. In Rwanda, we have shifted from French to English as the language of instruction at the end of 2008. In KIE, we started to use English across all the modules in 2009, and I was in my second year. Thus, in 2012 I was at my incubation stage of mastering English compared to my students who were fluent as most of the schools in Nyagatare they studied in were already used to English even before 2008. It was challenging to speak a mixed English-French in front of my students, but I learned a lot from them.

The worrisome was the lack of science laboratory where my students were sleepy in my lessons due to only delivering theory. As a science teacher, specifically chemistry, which requires demonstration of materials and mixing chemicals in laboratory settings, even physics requires observation of natural phenomena, I struggled. We only had a box full of dirty, expired chemicals and rust materials. In addition to this, when I thought that we are training teachers who will also, in return, go to primary schools and teach how they were taught, my head was going crazy. TTC graduates should be given more attention as the ones who will build the foundation of education among little children. They should well be equipped with possible infrastructures, equipment, and standard skills so that we get competent children to upgrade to upper levels of education.

To remedy this challenge, I, with my science workmates, organized a day of cleaning materials and thinking about science teaching strategies. We, together with students, cleaned the possible materials and separated materials from the box. After the cleaning, as teachers, we discussed the problem of science teaching as some teachers were already reported to the principal of the college by students claiming that they do not understand the content, especially my physics! We talked about self-observation to track the real problem, organizing science debates, science clubs, and creating improvised materials. In the next week, we hosted a debate where students guided by tutors started to discuss some topics in science. Together with the director of studies, we scheduled a weekly three hours, one hour for debate and two hours for creating science materials. With the support of school administration, we successfully invited two lecturers from the KIE to our college. Doctor Uwamahoro Jean and Nkundabakura Pheneas visited us to launch the "TTC Matimba science club." They presented insight science demonstration in the presence of tutors and students of the whole college. One topic they presented was energy and the environment. Students were excited and appreciated the visit. Our students also played a drama starring as some well-known scientists such as Avogadro, Newton, and demonstrated some experiments using the equipment they created. One experiment that amazed everyone was the solar system. They made it from rubber balloons, cables, and small soft branches of trees. It was so fantastic. From that day, students never slept in the class. Most of them had a lot of inquiries in the ongoing courses, and the lessons got more of the interest.

In 2014, I joined Hiroshima University with the support of the Japan International Cooperation Agency (JICA) through the Rwanda Education Board (REB) program of improvement of mathematics and science teacher education. In my master thesis proposal, my supervisor, Professor Kinya Shimizu, would have advised me to work on science process skills (SPS) as most of his students do. Still, when I shared my story with him at my college, he let me work on creating and using science improvised experiment materials. It is in this regard; I am going to share in this study some of our work we cooperatively did during my two years at Hiroshima University, Japan. This study will help any teacher like me who faces difficulties in delivering science lessons in the absence of conventional laboratory settings.

Review on Science Improvisation

Science lesson helps learners to understand the nature and be able to solve problems they encounter in daily life (Eren et al., 2015). By science literacy, one of the most vital objectives of science lesson, principles, concepts, laws, and theories of science help us toget scientific knowledge and understand the nature of science. Therefore we develop problem-solving, and we can use scientific methods (Kenar & Balçı, 2012). However, science should be taught by experimentation. According to Adeniran (2006), Science experiments help students to increase their self-confidence, creativity, innovation, imagination, and curiosity, which are essential to science teaching and learning and develop critical thinking since they enhance analysis in mind of students. Sandifer and Haines (2009) revealed that science teachers appreciate the effectiveness of hands-on activities. Teachers perceive that hands-on activities are the best approaches toteach science.

Form the constructivist point of view, Piaget (1970) argues that children learn preeminent through doing and dynamically exploring their environment. This theory shows occuptying pupils and students should teach that sciencewith suitable activities. Constructivism posited the notion that learners create or construct new knowledge. Since learners get information through biological senses, learning should be seen as an experimental and adaptive process instead of knowledge transfer. The creation of new knowledge comes from an interaction between their existing knowledge, experiences from the natural world, or their culture and new ideas faced in daily life.

Since twelve years of basic education policy in 2012 was implemented, not only teachers but also teaching materials became scarce. If science laboratories are insufficient; science lesson faces the problem due to the lack of hands-on activities. For instance, in 2015, there were only five out of 13TTCs having science laboratories in Rwanda (Ndihokubwayo, 2017). The poor performance of students in science in developing countries has the source not only of teaching/learning methods used (Ndirangu et al., 2003) but also the insufficiency of laboratories. In current economic challenges in Africa, almost many schools are facing problems in teaching science. The major challenge to teach science in developing countries takes the source from the cost of imported materials, and the fact that teachers wait for these materials before teaching (DomNwachukwu, DomNwachukwu, 2006). Insufficient funds make it impossible to purchase enough laboratory equipment,making teaching, and learning science difficult. However, teachers should not depend much on these imported industrial laboratory materials. They should not rely on a few laboratories to teach science effectively. Therefore, in such a situation where there is a shortage or lack of the standard laboratory materials, Mboto et al. (2011), have suggested that they can use improvisation. Thus, teachers should create the hands-on equipment from environment locally available and use them to conduct practical experiments. Improvised materials also enhance teaching-learning experiences as conventional ones do. Improvising science laboratory materials enable students to achieve the desired scientific as in laboratory settings.

There is a difference between local production and improvisation. Domestic production is usually a matter of import substitution and is often a trial to meet the demands of the whole school system. On the other hand, improvisation is generally a teacher-centered activity, and its encouragement at workshops and in-service courses can provide an essential means of stimulating a more experimental approach to science teaching. Improvised items produced at such seminars are intended to enable the teacher to explain a particular scientific principle in his or her way.

Let us first understand the related terminologies. (a) Laboratory resources are tools used to experiment, measure, and gather data (Hofstein & Lunetta, 2004). (b) Laboratory work or practical work in science lessons refers to laboratory activities where teachersor students demonstrateor manipulate by real objects, simulate by computer. In contrast, students observe, collect data, and make inferences (Cossa & Uamusse, 2015). (c) Hands-on is doing (touching with your hands) something instead of learning about it from books and lectures. For instance, a learner shouldactively and personally involve in a science experiment. (d) Improvisation is to create something incidentally without pre-planning. This case can be when an individual or group is acting, dancing, playing a musical instrument, creating artworks, or problem-solving. It can also be when one reacts in response to the stimulus of one's immediate feelings. In science lessons, improvisation is making instructional materials by teachers and learners using locally accessible resources (Ndirangu et al., 2003). Improvisation is when teachers or teachers and students select, make and use their own-made equipment. It is to substitute local media obtained within and outside the school environment with industrial-made equipment (Udosen & Ekukinam, 2014). Therefore, science improvisation in this study refers to creating and use of cheap and locally available materials from our environment as a teaching and learning laboratory experiment.

Bhukuvhani et al. (2010) believe that improvised materials can serve asa pedagogical intervention. Therefore, teachers need to be resourceful in making and using locally available materials to substitute the inadequacy and unavailability of conventional equipment. Improvisation provides opportunities to learners for creativity and the development of manipulative abilities in teaching and learning science. To make improvisation as right as in teaching and learning, learners should be a part of creating these improvised materials. Thus, if learners are not taken part in the process of improvisation, their aim will not be successively achieved. When learners participate in the improvisation process, they are exposed to creativity, innovation, imagination, and curiosity, which are essential to science understanding (Adeniran, 2006). DomNwachukwu & DomNwachukwu (2006); and Udosen & Ekukinam (2014) gave some example of improvised materials such as test tube holder using a Y-shape fresh wood, magnifying glass using water into the bare bulb, concave and convex mirrors using empty discarded insecticide cylindrical cans and temporary magnets using a flex wire wound around two nails connected to the top and bottom of a dry touch light battery. Eggshells like the seashells ordinary chicken eggshells can be used to provide a high amount of pure calcium carbonate (CaCO) compounds.

According to cost-effectiveness, Yitbarek (2012) compared improvised and manufactured filtration apparatus and found that funnel, stand and extension clamp, stirrer, beaker, and filter paper cost about 5.35 Birr and 299.59 Birr of the improvised and manufactured device respectively. However, in a study conducted in Rwanda (Ndihokubwayo et al., 2019) found that teaching heat and thermodynamics using conventional experiment or by using improvised materials are with no difference as students get expected achievement. If the teacher is expected to take on the role of facilitator rather than an importer of scientific knowledge; however, there is considerable disparity between programmed expectation and reality. Therefore, they need to engage in producing their own resources from waste materials found in local environment. This practice explainswhy teachers who adapt to local resources were likely to concretize scientific concepts and were able to implement the curriculum at cheapest cost (Ndirangu et al., 2003). Therefore, there is no excuse for any science teacher to associatethe lack of funds with not conducting practical in science teaching. Isaac Newton, Pythagoras of Simos, Galilee Galileo and the rest pioneers in science started building themselves materials from around them to elucidate concepts that are still pertinent to our days (Owolabi & Oginni, 2012).

Science improvised experiments

In this section, we have step by step provided experiments conducted using locally available materials. The materials are not expensive and can be open to any teachers. Teachers may ask students to bring some of these materials. Teachers and students may collaboratively create these materials and use them in experimentation. In this study, we have designed about seven experiments from local hands-on materials; (a) Bunsen burner, (b) lungs model, (c) pinning balloon, (d) water rocket, (e) boat prototype, (f) car prototype, and (g) how the motor works.

Bunsen burner: In a chemistry laboratory, a Bunsen burner is among necessary equipment for heating. The heating equipment, such as Bunsen burners are expensive. The figure shows the Bunsen burner made from an Aluminum can. It can be created and boil water in a few minutes.

Figure 1 : Bunsen burner

To make Bunsen burner, you need Aluminum cans, knife, harmer, and a nail. To light it, you will use concentrated alcohol or petrol(a) Cut a can into two with the knife, (b) introduce the top piece(one with a hole) into the down piece so that it seems close the system using the hammer, (c) make several holes around the top of the system (if the upper piece was inserted top-bottom, make sure the holes are under this piece) using the nail, (d) put alcohol through the whole of the upper piece, and (e) light it on. The fire will come out of the nailed holes; you can heat any object and boil any liquid in any glass or metal container (for more detail, please watch our video at https://youtu.be/8JEzsAu1Ryc, from min 5:04 to 8:15).

Figure 2 : Lungs model

Lungs model: In biology, some concepts are difficult to teach in the absence of conventional laboratory apparatus. Such concepts, such as how lungs function maybe well demonstrated by using rubber balloons and plastic straw instead of trachea and bronchus. The diaphragm is in control of breathing. Commanded by the brain, the diaphragm contracts downward, and we inhale fresh air into the lungs. And the exhalation is a result of diaphragm contracting upward and make the lungs deflate andrelease the used air.

In making this model, you need a clear and transparent plastic bottle, two rubber balloons, one plastic straw, a plate rubber, scissor, and glue.(a) Take a straw and cut it into three pieces and create a y-shape from these pieces using glue. (b) Tie two balloons to twoof the ends of straw with rubber bands so that you remain with only one open end of the straw. (c) Cut the bottom part of the plastic bottle and create a hole into its cap. (d) Pass the open end of the straw through the bottle, passing from the bottom to the neck and the cap. (e) Seal the strawto the closing so that the air will only pass through the open end of the straw and not between closer and straw. (f) Close the bottom of the plastic bottle with aflat rubber and tie it with a rubber band. You will demonstrate the experiment by stretching the flat rubber at the bottomand releasing it. You will figure out that when you stretch, the balloons will fill in the air, and when you realize it, the air will empty the balloons.

Figure 3 : Ghost balloon

Pinning balloon: Can you pin the aired balloon without busting it? Yes! In mechanics, the concepts of friction forces and stress are discussed. When you put air in the balloon and pin it with a well-pinned material on the side part, it busts.

However, in the picture in the figure above, it was successful in pinning the balloon without busting. How was this made? Well, if you look well, the pinned load was introduced at the bottom of the balloon to it,tyingthe end. In these two places, the rubber material is not stretched, allowing the pin inter without busting. Thus, the friction between pin and material is higher than at the side of the balloon (for more detail, please see Goto, 1999).

Water rocket: The third law of motion among Newton's laws shows how things react to the active forces. Actual rockets use gases to launch the satellites in the space. We can, however, demonstrate a similar concept using the water rocket.

Figure 4 : Water rocket

To launch the rocket using water, you need two big plastic bottles, scotch, timber, closer, water, and pump. (a) cut and remove the bottom part of one bottle, (b) connect the cut bottle to another bottle (one which is not cut) with scotch, (c) close the cut bottle with its cap, (d) put water into the whole bottle and close it with a close which can go inside the mouth of the bottle (the cap should do not be used as it has screws), (e) creates a hole into that closer and connect it to the pump, (f) place it on an inclined surface of 45 degrees such that the part containing waterad connect to the pump is downward. When you pump the air in, air will fill in the water and water will push the closer, while water flows out, the rocket will fly in the opposite direction.

Boat prototype: In mechanics, there many phenomena explaining many concepts such as force, pressure, and density. The working principle of the boat able to float and moves on water uses both of the above concepts. In making a boat, two major considerations should be taken into accounts. We need to make the boat into a heavy object so that its density will be lower than that of water, and it floats. We then need to design the propeller accurately. The propeller is made ofrotor blades that move the water so that the latter pushes the boat forward. Therefore, each blade should be made considering the pitch or different angles across its surface to make the propeller powerful.

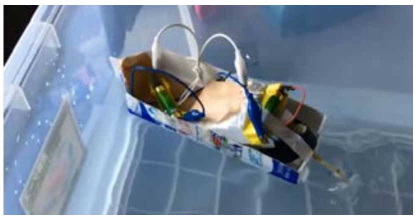

Figure 5 : Boat making.

The prototype with the propeller behind is floating on the water in the big bucket. To make the boat, you will need a cell battery to rotate the electric motor, wires to connect battery to the battery, and the electrical motor to rotate the propeller. You can use any other materials such as styrofoam, carton box, or hard paper to make body partsof the boat as long as it floats on the water. Make sure you load the battery, wires, and the motor inside the body part. The propeller is made up ofstrong blades and ax (load connecting the blades to motor). Seal the part connecting the motor and the propeller to avoid water entering the boat. Make them part of the blade deep into the water behind the boat. (for more detail, please watch our video at https://youtu.be/OIXuQtYwvcs)

Car prototype: In mechanics, the motion of an object is at all of the questionable phenomena among many people. How does the car move, for example? The energy concept is more crucial to make an object move. However, this energy may be in different forms. In our experiment, we made a car using an electric motor. While some cars use petrol to turn the motors, in our case we used a cell battery.

Figure 6 : Car making

The gears are shown under the tire. The car is shown upward down as the maker is installing the motor.To make a car, you need any materials such as plastic, styrofoam, or paper boxes to make car body, battery to turn the motor, motor to turn the small gear, small gear to turn the big gears, and big gears to turn the tires or wheels. You also need four tires made from any object such as plastic, wires, and two metal or wood sticks. Connect the one stick to the bottom of the car body on the front side and another on the backside. Make sure they smoothly move around. Tie a wheel to each end of the stick with glue such that two wheels are stack to their stick and move together. Depending on the number of motors you have, install them near the wheels. Depending on the number of wheels, tie the big gear to each tire, tie the small gear to each motor, and install the motor near the tire such that the small gear is connected side by side with the big gear under the car. Put the battery inside the car or somewhere and connect it to the motor (s) with wires. The car moves without any difficulty (for more detail, please watch our video at https://youtu.be/_MU63mPZ-lE, from min 18:45 to 25:42).

How motor works: Electricity and magnetism are the most branches of physics, which are really interconnected. For example, we can use electricity to make objects magnet, and we can use a magnet to produce electricity.

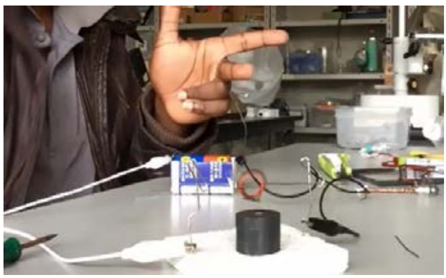

Figure 7 : Working principle of a motor

To create a motor, you will need only two valuable materials; copper (or any other) wire and a magnet (even from dead post radios). You may also requirethe cell battery as a source of energy, paper clips to lift the copper wire over the magnet, and a lamp to test the flow of current.Take copper wire and create the coil using your finger, make it so that you reserve two wingers (ends) in both side of the wire, hang two paper clips to support the two ends of the wire, and place a magnet under the coil (down and between the paper clips) such that the coil part is in meddle and faces the magnet.Connect two paper clips to the battery and disturb the coil to start the motion. If it does not move, grab the end of the wire (where it attach to paper clip) to remove the insulator substance, which avoids copper wire to rust. The coil will move, turning around itself due to the magnet under it. Thus, the magnet will induce the motion of the coil. And this is how the motor we used in the boat and car prototypes is working, and it can also be improvised. To test if the current is flowing, you can connect the bulb lamp to both ends of paper clips. The bulb lightsto show that there is the presence of electrical current (for more detail, please watch our video at https://youtu.be/_MU63mPZ-lE, from min 8:00 to 16:23, and 26:10 to 26:35).

Recommendations

The National Curriculum Development Centre in Uganda is responsible for the development of low-cost teaching aids and the training of teachers in their production (Angus & Keith, 1992); therefore, in Rwanda too, REB can take this task. Teachers need to be psychologically prepared to improvise as well as to have the necessary practical skills to do so. Teacher educators should be involved in science kit development projects from the beginning. In some cases, there have been attempts to provide in-service training through radio, television, and video.

Ministry of education should encourage the following institutions to engage in laboratory material production. (a) Workforce development force; since this institution is in charge of vocational training, it is easy to take action for improvised experiment materials since their daily work deals with wood, metal, electric as well as electronic materials. (b) Integrated polytechnic regional center (IPRC); since they are distributed in the whole country, plus they study technical courses, they can do this duty locally to help nearby primary and secondary school. University of Rwanda-college of education; since this college is in charge of developing teachers, it can also hold this duty using students, teachers, and hiring carpenters and other technicians to work together for the production of these materials. Private institutions can also engage in making improvised materials and sell to schools. However, the ministry should have a committee of experts and science teachers for periodical evaluation working hand in hand with Rwanda standards board.

Conclusion

Improvisation of materials helps teachers teach science contents, buildsthe gap existing inthe curriculum, and substitute teacher-centered instruction. Most of science laboratory equipment is very expensive in terms of importation, purchase, and maintenance. However,we may substitute them by locally creating inexpensive materials in a way to bring about a cost reduction in education as well as a better suit to the climatic conditions of our local environment (Udosen & Ekukinam, 2014). Improvisation serves manyeducationalpurposes,such asreducing the money spent on the purchase of equipment for schools. It allows the teacher to demonstrate his/her creative abilities and encouragelearnersto developcreativity, the ability of inquiry, discovery, and investigative methods. This insight enablesthe teachers to think of cheaper, better, and faster methods of making the teaching and learning processes easier for learners, and familiarize them with resources in their environment as well as a way of environmental protection and recycling.

Learners benefit from experimenting themselves. For instance, concrete experiments help students observe nature and understand the scientific concepts. Owolabi and Oginni (2012) advise that students should be given the opportunity to discover and invent things. Since learners achieve more when they are allowed to manipulate the apparatus instead of listeningto or observing teachers, therefore, teachers should allow them acquire skills that will make them learn on their own. In conclusion, a lack of laboratories should not be a challenge in this modern and digital world. Through workshops organized by educational organizations, teachers can be trained on how to create improvised materials since the lack of skills is a core challenge, and this will serve as motivation to teachers to use these improvised experiments, get rid of rote learning as well as save the environment. In this study, we have crafted the improvised materials such that any teacher can follow step by step to make them on him/herself. Teachers can also learn from the presented experiments and get an idea of creating other experiment materials. We used some of the experiments presented in our study in 2015 during teaching electrostatics and workshop with TTC teachers (Ndihokubwayo et al., 2018; Ndihokubwayo et al., 2019). We have found that improvised experiments excite students because they participate in, and teachers appreciated the role of improvisation. Science activities were done more in physics and through science clubs as well as borrowing materials from other schools are strategies of schools without laboratories.

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