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Using a learning cycle model to improve grade ten students' conceptions of simple electric circuit

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Abstract

The purpose of this study was to improve tenth grade students' understanding of simple electric circuit using a learning cycle model. A research instrument that composed of fifteen-items multiple choice used by Wainwright[24] to explore the persistent misconceptions of electricity was adapted for this study. Since improvement was at the heart of this study, an action research approach was employed for a period of over 8 weeks. Based on the idea of purposeful sampling (N=28), a multi-method approach such as observation techniques, questionnaire and focus group interview were used for the data collection. Using a data triangulation, the findings indicated that the students possessed limited conceptions of simple electric circuit. A majority of the students who revealed to have 'no concept' during the baseline data collection showed an astonishing shift to a category of having 'full concept' after the post-intervention of learning cycle model. A significant affirmative link between the observation and pattern of interview transcripts that were in support of the questionnaire data indicated the positive impact due to the learning cycle model in enhancing students' understanding of simple electric circuit.

Keywords: Simple electric circuit, grade ten, learning cycle model, conceptions, Bhutan.

Introduction

In the perspective of the constructivism, learners construct their knowledge based on the existence of the prior knowledge and understanding[1,2]. They are never like a blank slate but rather preoccupied with their own ideas and beliefs on every subjects. Some of their understandings and beliefs does not match what is known to be scientifically correct, which generally is referred to as alternative conceptions or misconceptions.

Alternative misconceptions are inevitable that its occurrence in the process of teaching learning is a usual phenomenon and science is never an exception too. In fact, the students embraces unusual beliefs and understanding about science that generally have no basis in actual scientific fact.

In view of the principle idea of constructivist learning theory, student's preconceptions that are contradictory with scientific knowledge and poses challenge in learning science have aroused science educators' interest and focus[3] towards plummeting it. In many cases, the presence of such alternative conceptions differ from accepted scientific ideas[4,5] as they are preconceived notions largely built on the influence of either religion and culture or faulty pedagogy. The misconceptions that are unchallenged for a longer duration probably become entrenched[6] if not explored and eliminated at its early phase of discovery.

One area of research on misconceptions in physics is regarding the simp1e electric circuits[5], a concept which forms the basis to understand about electricity and encompass many aspects of our everyday life. Existing literatures such as, Andre and Ding[8], McDermott[22], Sencar, Yilmaz, and Eryilmaz[5], Bull, Jackson and Lancaster[11], Turgut, Gürbüz, and Turgut[12], and Leone[14] supports the existence of such alternative conceptions based on simple electric circuits in varying degrees and settings.

While researchers are familiar with some learning difficulties of students rooted from their preconceptions, an agreed consensus on suitable pedagogical strategies to address such difficulties adequately still doesn't exist[4,15]. Literature has indicated constructivist teaching strategy such as the learning cycle to be effective in constructing concepts and develop more effective reasoning skills about concepts in electricity[4].

With the hands-on experience of teaching physics in grade ten students for several years now, even without the empirical data, common misconceptions on simple electric circuits were often witnessed during the regular classroom interactions. This drew our attention to study the prevalence of misconceptions based on simple electric circuit and remedy with the intervention of learning cycle model.

More importantly, a very little research, if any, was conducted about students understanding of simple electric circuits in our Bhutanese context. Therefore, this action research attempts to investigate the Bhutanese tenth grade students' conceptions of simple electric circuit and use learning cycle model to enhance their understanding regarding it.

Reconnaissance: Reconnaissance in action research is essentially considered as a diagnostic phase that aims to delve deeper into the situation to identify the most strategic point of interest[16]. This study adopted Maxwell's[16] conceptualization of reconnaissance which comprises of *situational analysis*, *competence of the researcher,* and *literature review* as its three critical components as depicted in the Figure-1.

Situational Analysis: Science Education in Bhutan: The scientific knowledge has been accorded a huge significance in the Bhutanese Education System because it helps to accelerate the technological development of the country[18]. The teaching of science in Bhutan was initially started with New Approach to Primary Education (NAPE) system that emphasized the learning of science in our own context.

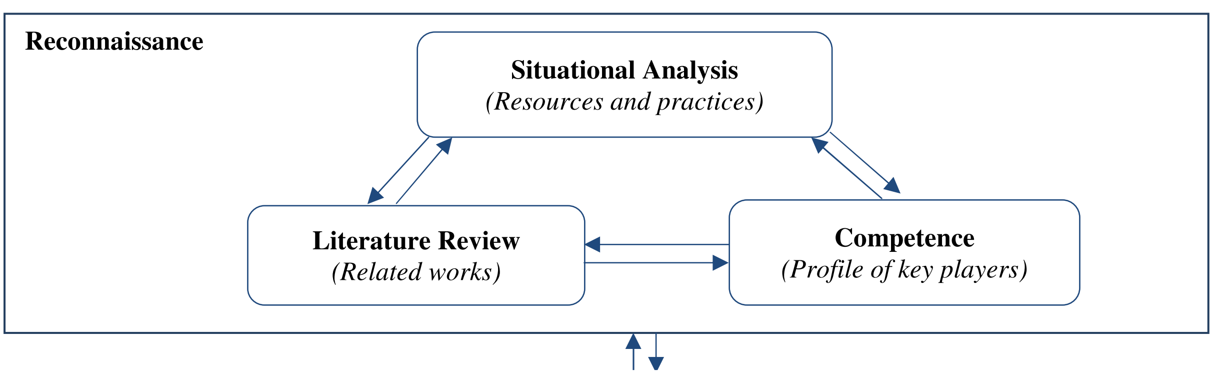
However, after having serious concerns of science curriculum lacking in content, the revision was initiated to generate scientific temper, interest and passion in Bhutanese students so that they can prepare to pursue any endeavor and career opportunities related to science in the future[18]. Hence, the learning of science which is based on the Bhutan National Education Framework (NEF) is classified into four strands:
Strand 1: Working Scientifically.
Strand 2: Life Processes.
Strand 3: Materials and their Properties.
Strand 4: Physical Processes.

Subsequently, the state of science education in Bhutan progressed with profound revisions and editions. While science education is considered important to our students, physics education plays an integral role in science education. It is through this study that facilitate the young and curious minds to seek for higher truth and reveal mysteries of nature[19]. Physics education is not simply gaining of knowledge, but it fosters intensive cognitive abilities that can be useful in other fields of life[20]. The Royal Government of Bhutan strongly emphasizes on delivering quality science education by including physics education as one integral portion.

Physics as a separate discipline is introduced in the middle secondary level from grade IX. This trend of learning science separately is continued next to the higher secondary level (grade XI and XII) till the degree level. The contents included in all the three disciplines of science are highly spiral, interlinked and elaborative in nature as they go on to the next higher grade. The physics curriculum of Bhutan is arranged into different key phases according to the developmental stages of the learners and learning standards that they are expected to accomplish[18]. At every stage, the scientific concepts are linked to each other in a progressive manner. In the lowest phase of kindergarten, the physics concepts are interpreted with the relations to the environment. However, as they approach higher grades, the difficulty with physics concepts is gradually introduced.

Bajothang Higher Secondary School – the Study site: Bajothang Higher Secondary School is one educational institutions that operates under the Bhutanese science curriculum. The school was chosen as the study site of this action research. The day-school which is located less than half a kilometer from the satellite town of Wangdue district caters to 1011 (475 males, 536 females) students from grade seven – twelve. Given the elaborative content of simple electric circuit in grade ten, this action research was designed to focus on grade ten level only. The principal author of this action research study teach physics for grade ten in the school.

Research Problem: In order to achieve the research question, *how can I use learning cycle model to improve tenth grade students' conceptions of simple electric circuit*, this action research was guided by the following research objectives: i. Explore the effectiveness of learning cycle model in teaching the concepts of simple electric circuit for grade ten students. ii. Enhance grade ten students' understanding on the concept of simple electric circuits using the learning cycle model.



Research question
How can I use learning cycle model to improve grade ten students' conceptions of simple electric circuit?

Figure-1: Reconnaissance[16].

Competence: The researchers who are involved in this action research have graduated with Physics as their elective subjects. More specifically, the first author who currently teaches grade ten students has Master Degree in Science and Technology Education and has been teaching physics in grade ten for the last seven years. As an ardent researcher, he has both national and international publications besides having some proceeding papers presented in the national and international seminars and conferences. His wide range of research interests and capacities was even recognized with the best oral presentation award in one of the international conferences held abroad.

The second author has Masters in Science with Physics as her major specialization. Owing to her outstanding performances in physics, she has accolades of academic excellence and recognitions both in Bachelor's and Master's degree level in the subject of physics. She had been teaching physics for middle and higher secondary students for the last eight years. The author has publications both at national and international journals.

Critical friend: In order to avoid research biases and misinterpretation[16], this study is accompanied with a critical friend. Owing to having substantial research background and numerous publications, our critical friend possesses adequate research knowledge to critic our study in many ways possible.

Literature Review: As much as misconceptions are common with the students, so is it with the scientists and philosophers[21]. The inaccurate, inconsistent or misinformed knowledge of the student, referred as alternative conceptions or misconceptions[21,22] differ from accepted scientific ideas[4]. Alternative conceptions are not unusual because it exists during any process of teaching and learning[8]. It simply occurs as mistaken ideas or distorted thoughts in the minds of the children.

Misconceptions in children, according to the existing literature such as National Research Council[7], Andre and Ding[8], McDermott[22] and Kocakulah and Kural[9] asserts that they are considerably rooted to their prior ideas and may inhibit learning certain concepts. The ideas which are strongly held and intensely defended[7] by these students are often different from a conventional scientific view and are thus challenging to transform[12,22].

When these misconceptions are retained unchallenged throughout the time, it is more likely to become entrenched[6]. Subsequently, this poses as a challenge in teaching science that it questions about the prospects of constructing the conceptual change and the way to promote it[12].

While studying the existence of misconceptions is important, realizing how any of these misconceptions impedes the learning is absolutely necessary. Teachers, therefore plays a critical role in not just restoring the already damaged, but also on putting some effective measures in place to eliminate misconceptions in children's learning[6]. When such inadequate and erroneous ideas are not properly attended in the early phase of the instruction, it may persistently settle in minds of the students during the entire course of their learning[11]. Thus, the most fundamental part in enhancing the capacity of children to learn is to assist them confront, restructure and redefine their preceding conceptions[11].

Simple electric circuit is one concept that is vulnerable for student misconceptions. For many decades, this concept has so much attention due to which it remained as the subject of interest for many physics educators.

Several studies have been conducted to investigate the prevalence of misconceptions regarding the simple electric circuits[5,10,11]. The most prominent misconceptions in understanding simple electric circuits were an assumption of a battery as a constant source of current[12]; confusion of charge and energy[13] and closed circuit and electric current[14]. While the occurrence of misconception is natural in the teaching learning process[8], having erroneous understanding in electricity and simple electric circuit could be considered tolerable because these concepts are abstract and complex in nature[24,25].

Although a plethora of studies have investigated the misconceptions of students in different physics contents, a very limited literature is available about Bhutanese high school students' conceptions of the electric current. Therefore, this action research was aimed to investigate tenth grade students' conceptions on simple electric circuit and enhance their understanding using the learning cycle model.

Constructivist-based Teaching Model: The Learning Cycle: With the aim of bringing a reform in student learning, a lot of learning theories have evolved that facilitated the shift of the traditional mindset of accepting the students as a 'sponge' to an 'active builder of the meaning'[26]. Rousseau and Dewey who has done a pioneering success to incorporate the constructivist perspectives into the field of education[1] believes that the learners construct the knowledge[1,2] and that they take into consideration the existence of prior knowledge, understandings and interest[2].

One such model of teaching which is based on constructivism is 'learning cycle' model developed by Robert Karplus in the late 1950s[27, 28]. This teaching procedure basically consists of three essential phases namely (Figure-2): i. Exploration, ii. Concept Development and, iii. Concept Application (33).

Exploration: In this phase, the students are briefly introduced to a topic and then given an activity to complete either on their own or in groups. The lesson is introduced by connecting the activity to prior knowledge and experience. With the activity that engages the students, it provides them to explore the topic further either through data collection, experimentation, problem solving, or group activity using hands-on investigations.

Concept Development: In the concept development phase, instruction is given and the concept is further explained. The students share their understandings and findings from the exploration phase to the class. The teacher facilitates to fill the gap by asking guiding questions that will lead the students to necessary conclusions. Provision of supplementary information to enhance students' understanding are also done in this phase of learning cycle.

Concept Application: At this phase, the students apply the concepts they learned in prior steps of the learning cycle. The teacher provides students with additional opportunities to explore and apply concepts to further enhance their understanding of the concept.

Within these three phases, the learning cycle enhances a thorough understanding and a deeper application of content. While it provides teachers the awareness on the process for instruction, it encourages students to explore a secret formula for learning through inquiry and discovery-based learning.

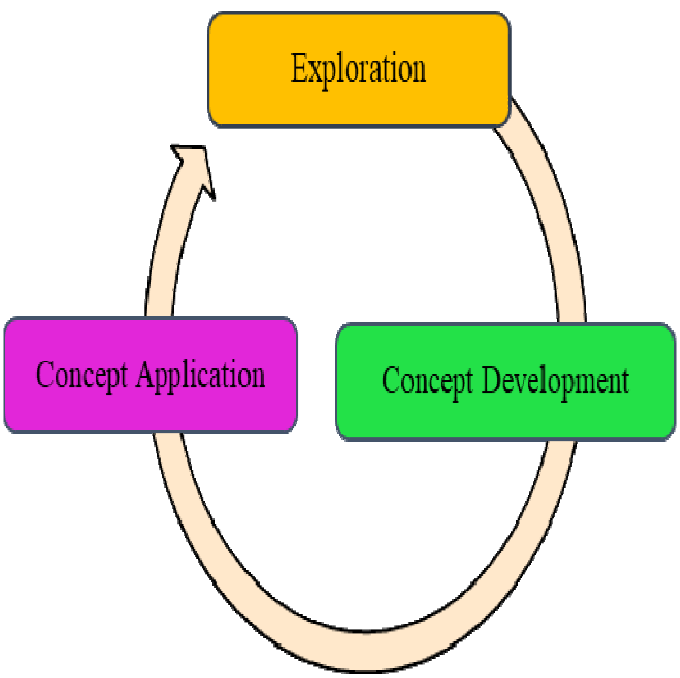


Figure-2: The Learning Cycle model[8].

Methodology

Research Plan: This action research was conducted within a span of 8 weeks subsequently to the approval from the Ministry of Education and the school administration (Table-1). The entire procedures for the study was embedded within the phases of action research such as planning, acting, observing and reflecting[30,32,33]. The students' consent to participate in this action research was formally sought prior to commencement of the study.

Table-1: Timeline for the action plan.

Activities	Week
Collection of baseline data (interview and observations)	1, 2
Implementation of the learning cycle's three phases: a) Exploration b) Concept Development c) Concept Application	3, 4, 5, 6
Post intervention data (interview and observations)	7, 8

Data Collection: This study was conducted in a regular classroom setting with those students who were taught by one of the authors. A multi-method approach employed for collecting the data are briefly mentioned below:

Observation techniques: Participant observation was employed as one of the means to collect data on how students learn while using the learning cycle model. A dated field notes and observational records (in the form of tally mark and frequency) were maintained both by the authors and the critical friend in their diaries for a comparative study on the degree of improvement in learning the concept of simple electric circuitusing the learning cycle model.

Questionnaire: A questionnaire used to study the misconceptions of simple electric circuit by Wainwright[24]was adapted for this study. The questionnaire which was in the form of multiple-choice format was administered twice: before the intervention of the learning cycle model and after the intervention of the learning cycle model. The responses were classified into three levels of understanding: sound understanding, partial understanding and no understanding.

Focus group interview: A focus group of 6 students based on the idea of purposive sampling was employed so that the group represented members of the entire sample involved in this study. The information gathered were audio-recorded and transcribed for the content analysis.

Data Analysis: Based on the concepts embedded in the questions of the questionnaire, two scenarios were created for the data analysis. Those questions that possessed the same concept were grouped under the same theme and three criteria were employed to classify the students' understanding on simple electric circuit. When the responses for all the items under the same theme were correct, students' understanding was labeled as having *Complete Concept*. Likewise, when the responses for any of the items under the same theme were incorrect, it was grouped under *Partial Concept*. The incorrect responses to all the items were classified as having *No Concept*. The ten questions of this category were grouped under four themes numbered 1, 2, 3 and 4 as shown in Table-2.

Similarly, for the question that contained its own concept, two criteria were employed to catalog students' understanding. When the response to the item was correct, the level of understanding was marked as having *Complete Concept*. For the incorrect response to the item, it was labeled as No Concept. There were four items (item 8, 10, 11 and 13) for this category.

The data recorded in the diary and records obtained through observation by the authors and the critical friend were analyzed in the form of tally mark and frequency. The information collected based on the focus group interview were audio-recorded and later transcribed. During the analysis, this study emphasized to find the trends and patterns by comparing the words stated based on its emphasis and intensity. The data obtained using these three methods were analyzed using a data triangulation.

Results and discussion

Pre-Intervention: Baseline Data: The baseline data for this study was obtained by administering a questionnaire used to study the misconceptions of simple electric circuit by Wainwright[24]. The responses gathered (Figure-3) were classified into three levels of understanding: sound understanding, partial understanding and no understanding. The findings revealed that the students possessed a very limited conceptions of simple electric circuit. The highest percent of students having complete concept was 21.4% (N=6) for the theme 'brightness of the bulb' while it was only 3.5% (N=1) for 'consumption of energy'. 32.1% (N=9) students were revealed to have partial concept on 'complete circuit'. However, as high as 96.4% (N=27) of students showed to have no concept on the theme 'consumption of energy'.

Participant observation as a systematic approach for data collection was employed starting from week 1 to week 8. The observation details were noted in the dated diaries to compare during the post-intervention. An interview for the focus group of 6 students were administered during the phase of reconnaissance (week 1 and 2) to identify the issues related to this study.

Table-2: Themes and the corresponding item number.

Themes	Item number
Complete Circuit	1, 2, 8
Magnetic deflection due to the flow of current in wire	3, 6
Origin of charges	4, 11
Brightness of bulb in series and parallel circuit	5, 13, 14
Short circuit	7
Consumption of energy	9
Function of ammeter	10
Function of voltmeter	12

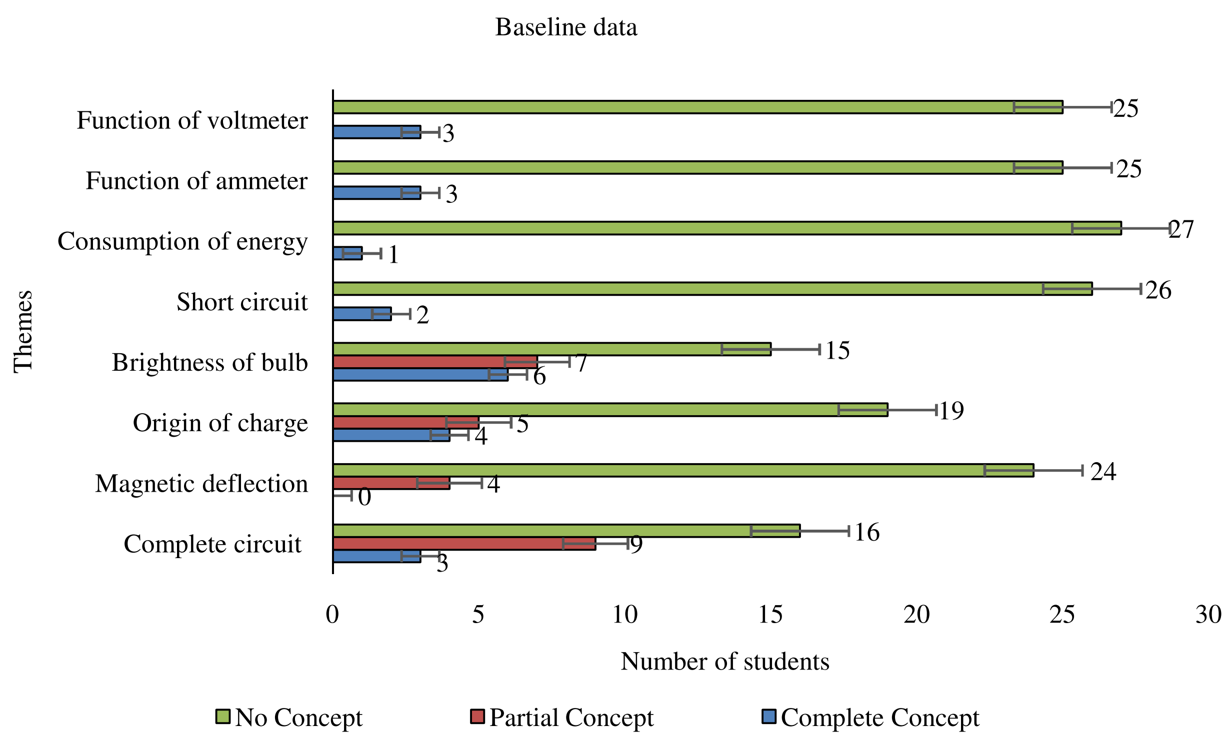


Figure-3: Baseline data

Intervention: During the intervention phase from week 3 to week 6, the students were taught about the simple electric circuit based on the three stages of learning cycle model. Within these phases of the learning cycle model, some hands-on activities and collaborative assignments were embedded to elicit and enhance the understanding on simple electric circuits.

Post Intervention: After the intervention of a learning cycle model for a period of four weeks, the same questionnaire was administered to determine the degree of variation in understanding simple electric circuit. The findings revealed that 100% (N=28) of students possessed a complete concept on the themes such as 'function of voltmeter', 'function of ammeter', 'consumption of energy' and 'short circuit'. The lowest percent of students having a complete concept was 89.2% (N=25) for the themes 'origin of charge' and 'magnetic deflection'. While the percent of students having partial concept ranged from 3.5% (N=1) to 10.7% (N=3), there was no students who possessed no concept on simple electric circuit (Figure-4).

Observation techniques to examine the setting of the class was extensively used by the critical friend as well as the authors to record on how the instructional hour embedded with the tenets of learning cycle model effected students' learning. Based on the observations recorded in the diary, it was identified that most of the students were hesitant and unwilling to share openly during the team learning. It was particularly observed during the 'concept development' phase of the learning cycle where each student was required to share their findings based on the activity provided during the 'exploration phase'. As the lesson progressed, from week 1 to week 2, the students were observed to engage themselves in the activity. The role of the teacher was reduced to a mere facilitator. In one of the diary notes maintained by the critical friend he wrote:

"Those students who were inactive in the beginning weeks [e.g. a girl sitting next to the window in the last row] gradually opened themselves and took active role in the group discussion. The otherwise hesitant and shy student was observed debating her opinions" (Diary notes, 13/09/2018).

The same focus group of 6 students were interviewed to explore whether their understanding on the concept of simple electric circuit was enhanced using the learning cycle model. The collation of data gathered from the observations and interview transcriptions were analyzed basically into two themes by knitting the patterns of the words as indicated below:

***Intervention strategy – learning cycle model*:** 5 out of 6 interviewees expressed that the concept of simple electric circuit was confusing and challenging as compared to other aspects of learning physics.For instance, one of them said that the most of items rated in the questionnaire before the activity [intervention of the learning cycle model] was just superficial. Another agreed when she said that, *"I know that the scores of the first test [questionnaire administered during pre-intervention] would be very less compared to the second test [questionnaire administered post intervention] because I had very less ideas on each questions asked"*. She further added, *"After the engaging in various group activities [intervention of the learning cycle model], my understanding on many items were better"*. Another asserted, *"The class in general was interesting because all the activities that we were engaged in, made us to think a lot"*. The data was supplemented by the baseline and post-intervention data obtained from the questionnaire. During the collection of the baseline data, most of the students possessed no concept on simple electric circuit. However, in the post-intervention, majority of the students had complete concept. This indicates that the learning cycle model has helped the students to enhance their understanding on simple electric circuit.

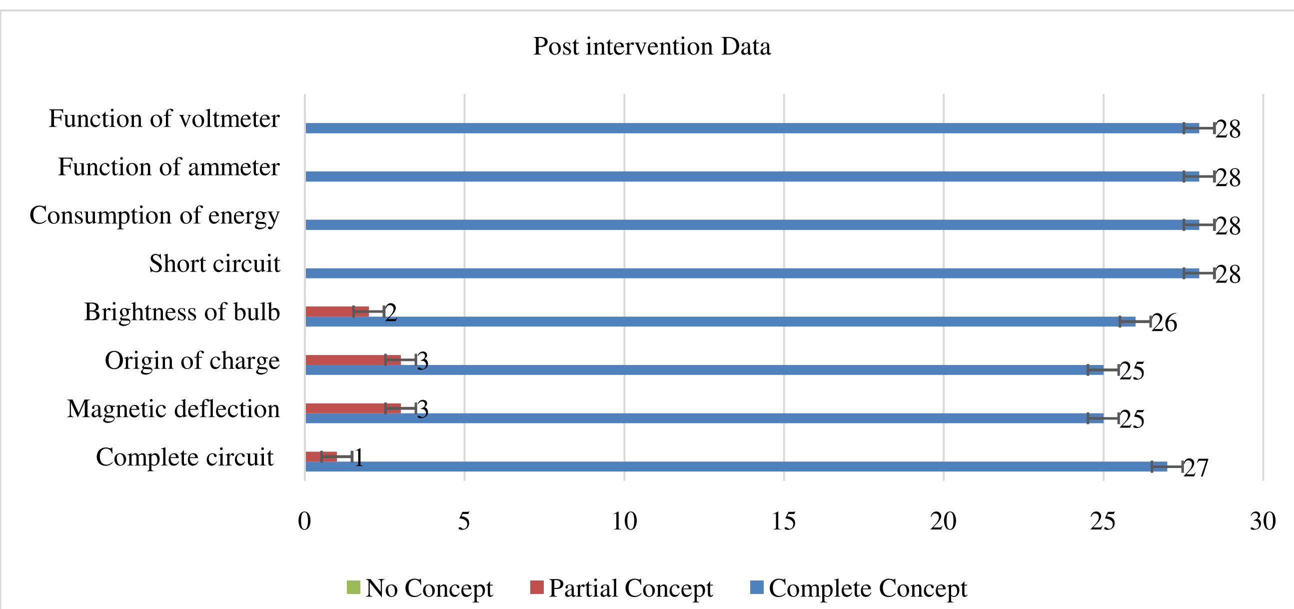


Figure-4: Post intervention data.

The content – simple electric circuit: Initially before the intervention, the students were of the view that the concept on simple electric circuit was abstract and broad. Consequently, they were reluctant to open up for the interview protocol fearing to respond to the questions associated with the concept of simple electric circuit. However, after the post-intervention of the learning cycle model, they were noticed being comfortable and confident to respond in a faster pace. Some of the relevant and supporting responses the students gave on simple electric circuit were, *"I was not very confident to speak about this concept. But after attending the activities in each class, I could understand it better"; "My understanding of the simple electric circuit was much better due to the way I was taught in the class"* and, "*The lesson was interesting and useful. Now, I can not only understand about simple electric circuit but I can also explain to my friends about it"*.

Discussion: The finding of this study, based on the data triangulation using observation techniques, questionnaire and focus group interview revealed that the students' understanding of simple electric circuit was improved using a learning cycle model. The majority of the students who demonstrated to have no concept on simple electric circuit before the intervention of a learning cycle model later revealed to have complete understanding of the simple electric circuit. Similar findings on bringing a conceptual change in students due to the learning cycle model was also reported[4,29,15,34].

A study conducted by Ates[4] in Turkey found out that the students' understanding of the main aspects associated with the concepts of direct current circuits were enhanced using the learning cycle model as compared to the traditional method. Similarly, the learning cycle model was observed to be more effective in identifying students' preconceptions about direct current electricity and teaching the interrelated but different aspects direct current electricity[15]. In another study by Aboagye et al[34], it recommends the use of the learning cycle model after it was observed to have promoted students' understanding of direct current electricity for senior secondary students.

The impact of having a complete concept of simple electric circuit by the students in this study may be attributed to students' active participation at every stage of the learning cycle model. Throughout these stages, the students were engaged in examining their preconceptions, exploring it further by applying to a newly constructed situations, and evaluating to judge if their conceptions were in consistent with scientific understanding. Another possible reason for the students to have complete concept on simple electric circuit using the learning cycle model may also include value associated in acquiring scientific knowledge using alternative ways which is deemed as one of the key features of the learning cycle model[29].

The intent of this action research study was not simply limited to the exploration of grade ten students' understanding of the simple electric circuit. But, it also delved into eliminating or remedying their misconceptions of the simple electric circuit using various conceptual change activities embedded in the learning cycle model. While most of the students' misconceptions on simple electric circuit were deduced to have remedied, a handful of them still possessed a resistant to change. For some of the concepts such as 'brightness of bulb', 'origin of charge', 'magnetic deflection' and 'complete circuit', there were still negligible number of students who possessed partial concept only. This is because misconceptions once formed in the students are very difficult to get rid of and therefore possess negative impact on understanding scientific concepts[35].With majority of the students' having correct conceptions of simple electric circuit using the learning cycle model in this action research study, in the light of these findings, the learning cycle model was considered effective strategy to enhance students understanding conceptions.

Conclusion

This action research which was undertaken for a stretched period of over 8 weeks revealed the improvement in grade ten students' conceptions of simple electric circuit using a learning cycle model. Keeping in mind the series of misconceptions stated in the literature regarding the simple electric circuit, this study attempted to remedy and enhance the students understanding of the simple electric circuit. The data triangulation approach indicated an effective impact due to the learning process in teaching the concept of simple electric circuit.

In order to promote meaningful learning – a process where students have conception that are scientifically acceptable and accurate, educators need to explore devising alternative teaching strategies. The success of implementing any noble teaching strategies would depend on how well the teacher is familiar with students' prior knowledge and its preconceptions that tends to deter their learning. Recognizing such learning hitches in the students and remedying with specific strategies such as the learning cycle method or any other constructivist approaches of teaching would be an enriching teaching phenomenon.

The learning cycle approach that employs the idea of constructivism must be encouraged in the instructions of scientific concepts. The activities embedded in each phase of the learning cycle model provides students extra opportunities to explore, discuss, challenge and test their pre-existing ideas about concepts before formal instruction[34]. The learning cycle model as an approach to teaching-learning process maximizes the probability of engaging students into the kind of thinking process that constructivists considers to be crucial for thinking productively.

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References

1. Boethel M. and Dimock K.V. (1999). Constructing knowledge with technology: A review of the literature. *Southwest Educational Development Laboratory*. Available from: http://files.eric.ed.gov/fulltext/ED431398.pdf.

2. McLeod G. (2003). Learning theory and instructional design. *Learning Matters*, 2(3), 35-43.

3. Küçüközer H. and Kocakülah S. (2007). Secondary school students' misconceptions about simple electric circuits. *Journal of Turkish Science Education,* 4(1), 101-115.

4. Ates S. (2005). The effects of learning cycle on college students' understanding of different aspects in resistive DC circuits. *Electronic Journal of Science Education,* 9(4).

5. Sencar S., Yilmaz E.E. and Eryilmaz A. (2001). High school students' misconceptions about simple electric circuits. *Hacettepe Journal of Education,* 21(21), 113-120.

6. Gooding J. and Metz B. (2011). From misconceptions to conceptual change. *The Science Teacher,* 78(4), 34.

7. National Research Council (1997). The dynamics of sedimentary basins. National Academies Press.

8. Andre T. and Ding P. (1991). Student misconceptions, declarative knowledge, stimulus conditions, and problem solving in basic electricity. *Contemporary Educational Psychology,* 16(4), 303-313.

9. Kocakulah M.S. and Kural M. (2010). Investigation of conceptual change about double-slit interference in secondary school physics. *International Journal of Environmental and Science Education,* 5(4), 435-460.

10. Çepni S. and Keleş E. (2006). Turkish students' conceptions about the simple electric circuits. *International Journal of Science and Mathematics Education,* 4(2), 269-291.

11. Bull S., Jackson T.J. and Lancaster M.J. (2010). Students' interest in their misconceptions in first-year electrical circuits and mathematics courses. *International Journal of Electrical Engineering Education*, 47(3), 307-318.

12. Turgut Ü., Gürbüz F. and Turgut G. (2011). An investigation 10th grade students' misconceptions about electric current. Procedia-Social and Behavioral Sciences, 15, 1965-1971. DOI:10.1016/j.sbspro.2011.04.036

13. Loughran J., Berry A. and Mulhall P. (2012). Electric Circuits. *In: understanding and developing science teachers' pedagogical content knowledge,* Springer, 159-188. Available from: http://link.springer.com/chapter/10.1007/978-94-6091-821-6_8

14. Leone M. (2014). History of physics as a tool to detect the conceptual difficulties experienced by students: the case of simple electric circuits in primary education. *Science and Education*, 23(4), 923-953. DOI: 10.1007/s11191-014-9676-z.

15. Aboagye G.K. (2009). Comparison of learning cycle and traditional teaching approaches on students' understanding of selected concepts in electricity. Doctorate Thesis. Ghana: University of Cape Coast.

16. Maxwell T.W. (2003). Action research for Bhutan. *Rabsel-the CERD Educational Journal,* 3, 1-20.

17. Department of Curriculum Research and Development (2011). Science Curriculum Framework PP-XII. Ministry of Education: Thimphu.

18. Trivedi R. and Sharma M.P. (2013). A study of students' attitude towards physics practical at senior secondary level. *International Journal of Scientific and Research Publications,* 3(8), 1-4.

19. Machold D.K. (1992). Is physics worth teaching?. *Science and Education,* 1(3), 301-311.

20. Barke H.D., Hazari A. and Yitbarek S. (2009). Perceptions of Ancient Scientists. *In Misconceptions in Chemistry,* Springer, Berlin, Heidelberg, 9-20. Available from: http://www.springerlink.com/index/10.1007/978-3-540-70989-3_2.

21. Dega B.G., Kriek J. and Mogese T.F. (2013). Categorization of alternative conceptions in electricity and magnetism: The case of Ethiopian undergraduate students. *Research in Science Education*, 43(5), 1891-1915. DOI: 10.1007/s11165-012-9332-z.

22. McDermott Lillian C. (1993). Guest Comment: How we teach and how students learn—A mismatch?. 295-298.

23. Burgoon J.N., Heddle M.L. and Duran E. (2011). Re-examining the similarities between teacher and student conceptions about physical science. *Journal of Science Teacher Education*, 22(2), 101-114.

24. Wainwright C.L. (2007). Toward learning and understanding electricity: Challenging persistent misconceptions. Available from: http://fg.ed.pacificu.edu/wainwright/Publications/MisconceptionsArticle.06.pdf.

25. Hart C. (2008). Models in physics, models for physics learning, and why the distinction may matter in the case of electric circuits. *Research in Science Education,* 38(5), 529-544. DOI: 10.1007/s11165-007-9060-y.

26. Wilson S.M. and Peterson P.L. (2006). Theories of learning and teaching: What do they mean for educators?. Washington, DC: National Education Association. Available from: http://beta.nea.org/assets/docs/mf_ltreport.pdf.

27. Fuller R.G. (2003). "Don't tell me, I'll find out" Robert Karplus—A science education pioneer. *Journal of Science Education and Technology,* 12(4), 359-369.

28. Karplus R. and Butts D.P. (1977). Science teaching and the development of reasoning. *Journal of research in science teaching*, 14(2), 169-175.

29. Lawson A.E. (2001). Using the learning cycle to teach biology concepts and reasoning patterns. *Journal of Biological Education*, 35(4), 165-169.

30. Gaffney M. (2008). Participatory action research: An overview–what makes it tick?. *Kairaranga,* 9, 9-15.

31. Kemmis S. (2009). Action research as a practice based practice. *Educational Action Research,* 17(3), 463-474. DOI: 10.1080/09650790903093284.

32. Kemmis S. and McTaggart R. (1988). Communicative Action and the Public Sphere.

33. McTaggart R. (1994). Participatory action research: Issues in theory and practice. *Educational Action Research*, 2(3), 313-337. DOI: 10.1080/0965079940020302.

34. Aboagye G.K., Ossei-Anto T.A. and Johnson E.A. (2011). Effectiveness of Learning Cycle in Exploring Students' Preconceptions on Selected Concepts in Direct Current Electricity. *Journal of Science and Mathematics Education*, 5(1), 11-24.

35. Mioković Ž., Ganzberger S. and Radolić V. (2012). Assessment of the university of Osijek engineering students' conceptual understanding of electricity and magnetism. *Tehnicki Vjesnik/Technical Gazette*, 19(3).