JRIIE Journal of Research Innovation and Implications in Education
Center for Research Implications & Practice

Website:www.jriiejournal.com ISSN 2520-7504 (Online) Vol.7, Iss.2, 2023 (pp. 170 - 179)

Effect of Real-life Application-based Classroom Activities on Engineering Students' Conceptual Understanding of Electromagnetism: A Case of Rwanda Polytechnic, Huye Campus

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Abstract: *The abstract and microscopic character of some physics concepts, make it difficult for pupils to acquire them conceptually. The current study sought to determine how engineering students' conceptual grasp of electromagnetism was affected by learning through real-life application-based classroom activities. Seventy-three (73) students successfully completed the study at IPRC Huye, with 35 in the experimental group and 38 in the control group. In experimental group, the teaching intervention used real-world applications, whereas the control got conventional instruction. Two physics teachers gave lectures on magnetostatics, current electricity, electrostatics, and electromagnetic induction. The conceptual assessment of electricity and magnetism. Independent sample t-test and normalized learning gain were all used in the analysis. Mean mark in pre-test for both control and experimental group are 31.5 and 33.5 respectively and significant value p=0.679 which meant that there was no significant different in conceptual understanding between the groups before the treatment. The mean mark after treatment was found to be 52.44 and 68.5 respectively and significant value p= 0.00 which indicated that there was a significant different in conceptual understanding of electromagnetism between control and experimental group after intervention. Despite being both categorized as being in the medium category, the major findings showed that students in the experimental group increased their conceptual knowledge of electromagnetism more than those in the control group ($g_{av} = 0.520 > g_{av} = 0.31$).The findings of this study concluded that hands-on exercises that linked ideas of electricity and magnetism were noted as the most interesting by students and physics teachers.*

Keywords*: Real-life applications, conceptual understanding, electromagnetism, students' engagement.*

Kabalisa, J., Gapfizi, P., Uwamahoro, J. & Uwayezu, C. J. (2023). Effect of real-life application-based classroom activities on engineering students' conceptual understanding of electromagnetism: A Case of Rwanda Polytechnic, Huye Campus. *Journal of Research Innovation and Implications in Education, 7*(2), 170 – 179.

1. Introduction

Physics education aims to foster critical thinking in students and provides them with knowledge and understanding that will help advance science and technology (Oral & Erkilic, 2022). Other disciplines that provide the foundation of daily life, such as engineering, medicine, and social sciences, also use physics concepts. So, a meaningful education in physics is one that enables students to make connections between the physics ideas covered in these areas and their practical applications. However, several studies globally suggest that due to the nature of the subject, teaching and learning about topics linked to electromagnetism (EM) can be challenging. This is reflected in the various misunderstandings that are frequently held.

Electromagnetism is among physics topics which are mostly discussed in many studies due to its challenging concepts for students, especially in the engineering education. Many concepts in this topic are abstract and complex (Wadana & Maison, 2019). Thus, students may develop wrong conceptions about it and become challenged in daily life where they encounter different applications of the topic. This was noticed in south American engineering students who faced difficulties of conceptual learning in the electromagnetism course due to the lack of direct abstraction (Cutri et al., 2015). Notaroš (2021) argues that, although electromagnetic concepts are fundamental to electrical engineering, this course is the most challenging in the electrical engineering curriculum. However, the use of conceptual questions in the same course has been pointed out as an alternative for abstract concepts and rigorous mathematical description.

In electromagnetism course, students struggle to explain the macroscopically observed phenomena in real-life because the scientific reason behind are from tiny processes which are not directly visible or perceptible (Azaiza et al., 2012; Mbonyiryivuze et al., 2022). This is a problem related to the methods used in the teaching and learning of electromagnetism. Understanding abstract concepts is linked to the knowledge of real-world situations around us (McRae et al., 2018). In this sense, students' experiences in real-life events or situations brought in classroom are the source of knowledge acquired through sensory, motor and affective channels. Thus, traditional methods cannot help while teaching the subjects with many abstract and microscopic concepts. In fact, for these methods, cognitive abilities are not able to handle abstract and microscopic concepts.

In order to improve the conceptual learning in an electromagnetism course, several creative teaching and learning methodologies have then been suggested by authors of physics education research. For dealing with abstract concepts in electromagnetism, some of them suggest using hands-on activities (Bozzo et al., 2022; Kittiravechote, 2020), others suggest using virtual experiments(Escobar et al., 2016; Harun et al., 2020), while still others consider computer simulations as an option (Dantic & Fluraon, 2022; Hartanto et al., 2023; Uwambajimana & Minani, 2023). All of these options have been crucial in helping students understand the concepts of electromagnetism. However, for students pursuing technical courses, these approaches should be handled with a focus on real-world applications, exposing them to how things function in practical situations.

The problem of misconceptions about electricity and magnetism in Rwandan society has already been recognized. In the study regarding lightning myths against science facts (Ndihokubwayo & Nkundabakura, 2019), it was discovered that few educated intellectuals in Rwanda, as well as old, uneducated people, have unscientific views about the phenomena of lightning. This demonstrates that understanding the ideas of electromagnetism in relation to our everyday lives is a problem that affects all societies, including Rwanda. Although it is asserted in this study that people's preconceptions about the topic are dispelled as they become more educated, lightning is a naturally occurring electrical event that is presented using abstract notions, which can make it difficult to teach and learn about.

Notwithstanding the fact that there is a dearth of technical and vocational education and training (TVET) data from Rwanda linked to physics teaching and learning, the material that is now available suggests that TVET and general education classes should include real-life applications. Mbonyiryivuze et al. (2022) carried out a study to determine what misunderstandings Rwandan ordinary level secondary school students had about electromagnetism. It was found that many students held incorrect views about the core concepts of electromagnetism and using real-world application questions in evaluations was recommended over usual memorization questions. Extensive use of memorization learning lead to students being bored. For example, students at the integrated polytechnic regional college (IPRC) of Kigali claimed that they are overwhelmed by theoretical courses and prefer to take many practical sessions (Rwamu, 2019).
The main objective of the current study was to assess the effect of real-life application-based classroom activities on level six engineering students' conceptual learning in electromagnetism. The research question was formulated to guide the study:

Is there a significant difference between the experimental and control groups in the conceptual understanding of electromagnetism after the treatment?

2. Literature Review

Conceptual change theories presuppose that during the learning process, pupils' knowledge expands and is restructured (Thurn et al., 2020). It is also asserted in the study by Dega (2019) that conceptual change is a complex process that calls both knowledge and intervention. The teaching and learning of electromagnetism should be founded on conceptual change theories because the subject is filled with microscopic and abstract notions. Physics instructors must take into account the naïve theory and knowledge in pieces theory when planning their lessons. Knowledge in pieces refers to the idea that other students' information is formed in real-time within the exposed context, as opposed to naïve theory, which assumes that some students' starting knowledge about the subject is stable and coherent but not scientifically valid (Bao & Koenig, 2019). Finding effective teaching and learning strategies that can effectively address this discrepancy, particularly for conceptual learning because of potential students' misconceptions in electromagnetism, is made clear by this.

Yet, numerous investigations into electromagnetism courses around the globe have revealed various issues. Students develop misunderstandings regarding the charge on a body, for instance, because electric charges are invisible in most real-world situations. Several students seem to believe that a neutrally charged body has no electrical charge attached to it (Addido et al., 2022). Students often struggle to understand an object's charge neutrality on an intuitive level. Despite this, for pupils to fully comprehend electrical materials, they need to develop thinking skills on a macroscopic, microscopic, and symbolic scale (Yanti et al., 2019).

Another issue is a lack of knowledge regarding the magnetic field for various current elements, such as current-carrying wires and current coils (Jelicic et al., 2017). Students in this study, for instance, were unable to depict the shape of the magnetic field produced by the two current elements mentioned. If students do not have a thorough comprehension of these features, it is very difficult for them to comprehend and describe electromagnetic phenomena that include the magnetic fields produced by currents. Parallel to this, it was discovered in another study that most students failed to use the proper right-hand rule, resulting in incorrect answers when they were asked to determine the direction of the magnetic field around a current-carrying wire (Özdemir & Coramik, 2018).

Confusion over how to describe an electric field and a magnetic field can lead to conceptual issues with magnetic fields of currents in various other circumstances. To distinguish between electric and magnetic phenomena in nature, these fields must be properly distinguished from one another. The mistake of depicting the magnetic field vectors produced by an electric current as radial fields from the wire was one of the mistakes demonstrated by engineering students at one Mexican university (Campos et al., 2021). This research has demonstrated that there was a misunderstanding among students regarding the vector representations of magnetic and electric fields.

Students learn physics more effectively when engaged in hands-on activities that develop higher-order cognitive skills. Nevertheless, without connections to real-world circumstances, laboratory activity alone cannot be sufficient for the meaningful learning of science disciplines (Shana & Abulibdeh, 2020). To prevent this, for instance, teaching and understanding the idea of electromagnetic induction (EMI) has been successful when using inquiry-based explorative hands-on activities with the Predict-Observe-Explain (POE) technique (Bozzo et al., 2022). The conceptual grasp of the EMI phenomena has significantly enhanced as a result of the students' transition from the phenomenological explanation to the formalization procedure.

Past research has demonstrated that electromagnetism presents difficulties for both classroom instruction and practical application. In the study regarding lightning myths against science facts (Ndihokubwayo & Nkundabakura, 2019), it was discovered that few educated intellectuals in Rwanda, as well as old, uneducated people, have unscientific views about the phenomena of lightning. This demonstrates that understanding the ideas of electromagnetism in relation to our everyday lives is a challenge that exists in many countries, including Rwanda. Mbonyiryivuze et al. (2022) have studied EM misunderstandings among Rwandan secondary school students at the ordinary level in the classroom. In this study, it was discovered that many students have false beliefs regarding the fundamental ideas of EM. The use of real-life application questions in formative and summative evaluations is preferable to route memorization questions, according to the researchers' recommendations. The utilization of PhET simulation activities, however, has been demonstrated by Uwambajimana and Minani (2023), to be a successful teaching method when dealing with abstract electrostatic ideas.

3. Methodology

Research Design

This research used a quasi-experimental design. This design enabled the role of real-world teaching application methods to be established. As a result, data analysis included both the experimental and control groups. The experimental group was taught using a real-life application approach, whereas the control group was taught using a traditional approach that did not involve the learners in hands-on activities.

Population and Sampling Techniques

The population composed of 81 students in two classes of level six students from the department of electrical and electronics engineering at IPRC Huye. Multiple sampling techniques were used. First simple random sampling was used to select IPRC Huye in 8 IPRCs that are in Rwanda. Purposive sampling was used to select level six students in the department of electrical and electronics engineering at IPRC Huye. There was no further sampling procedure used to obtain the participants. Nonetheless, classes were chosen at random and experimental group and control group to create two groups. In the experimental group were forty-one (41) students studying electrical technology, while the control group contained forty (40) students studying electronics and telecommunication engineering. Also, two physics instructors were hired to assist with the teaching intervention.

Data Collection Procedures and Instruments

Data on performance was collected using the Electricity and Magnetism Conceptual Assessment (EMCA) in both pre and post-tests. The researchers designed the questionnaire by adapting questions from books used to teach electromagnetism in Rwanda **Polytechnic, Huye Campus.** The questionnaire was composed of 30 multiple choice questions. The questions were admitted to other polytechnic during piloting period for reliability and Cronbach alpha was found to be $\alpha=0.75$ which is in the accepted range (Cohen, 1988). The experts from the University of Rwanda Department of Physics and the participating teachers established content and checked for validity.

Data Analysis Techniques

Data was treated through the independent sample t-test which helped to test the two hypotheses. The analysis started by comparing the mean score of the experimental and the control groups prior to treatment. After the treatment, the mean scores of the two groups were tested again to determine whether the real-life application approach had any effect on the students' conceptual understanding of electromagnetism.

Validity and reliability

To ensure high validity, the research instrument for the current study was chosen after carefully examining the literature on comparable studies examining the conceptual understanding of electromagnetic. This led the researcher to choose two tools, including a structured interview, and the EMCA two well used instruments. To determine if it was appropriate to test conceptual understanding of electromagnetism considering learning objectives in the topic of engineering electromagnetics and wave optics, some physics education specialists and physics teachers conducted a second review of the EMCA. The physics education specialists also reviewed the interview questions. The reliability of the common instruments EMCA had already been examined, according to studies in the literature. The rules for giving and scoring the conceptual assessment in the current study, however, must be followed. The researcher was able to utilize these equipments appropriately and precisely to obtain valid data thanks to these recommendations, which are also available on https://www.physport.org. Techniques for appropriate data analysis were also used.

4. Results and Discussion

The study's findings are presented in this part. The study's results are also expanded upon using literature.

Demographic Characteristics

Among 73 students who completed the research, 20(27.39%) were girls and 53 (72.6%) were boys.

Impact of Using Concept Tests Initial Stage Results

To assess the effect, the researchers distributed the questionnaire to the control and experimental groups, resulting in the initial scores shown in table 1.

Table 1: Pretest score

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Score	Group1	38	31.5000	11.33936	1.83949
	Group2	35	33.7143	12.31348	2.08136

According to table 1, the mean score for the control group was 31.5 with a standard deviation of 11.33, while the mean score for the experimental group was 33.71 with a standard deviation of 12.31.

Table 2: Independent sample test for pretest

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	sig	t	df	Sig.(2-tailed)	Mean difference	St. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Score	Equal variances assumed	.172	.679	.800	71	.426	-2.21429	2.76822	-7.73397	3.30540
	Equal variances not assumed			.797	69.111	.428	-2.21429	2.77773	-7.75554	3.32697

On the other hand, Independent sample t- Test for Equality of Variances in Table 2 shows a Sig of.679, which is greater than the critical value, leading us to accept the null hypothesis and maintain that there is no significant difference in the level of study habits before treatment between the experimental and control groups. As a result, the two groups were homogeneous in nature, which means that they had comparable conceptual understanding before treatment.

Change in students' conceptual understanding in electromagnetism

The teaching intervention was a process of teaching and learning using real-life application-based teaching and learning strategies in the experimental group and usual teaching methods in the control group. It started immediately after the pre-test and lasted for one month. Based on the conceptual framework, this teaching intervention focused on exposing students on how things work in real-life through demonstrations, hands-on and experimental activities, and computer simulations. In the subject of engineering electromagnetics and wave optics, the topics which are related to the current study were covered and included electrostatics, direct current electricity and electromagnetic induction.

In the control group, teaching and learning of these topics was done using the usual competence-based training (CBT) used at all IPRCs which involves many learner-centred approaches. However, they were not provided the opportunity to experience how things work in real-life scenarios. On the other hand, participants in the experimental group were exposed to learning activities involving real-life applications for the overed topics. Apart from implementing CBT techniques, students in the experimental group were taught some of the topics in the electrical and electronics workshop where demonstrations and experimentations were performed whereas some other working principles were demonstrated using computer simulations.

In the workshop, students in the experimental group had the experimental and demonstration activities including the making of series and parallel resistance network where they were observing the difference in electrical bulbs' brightness. For the sake of deep conceptual understanding about this topic, hands-on in the workshop has been conducted in parallel with a PhET simulation to allow students understand the change in electrical resistance as well. Figure 2 indicates both the hands-on and PhET simulation learning activities conducted.

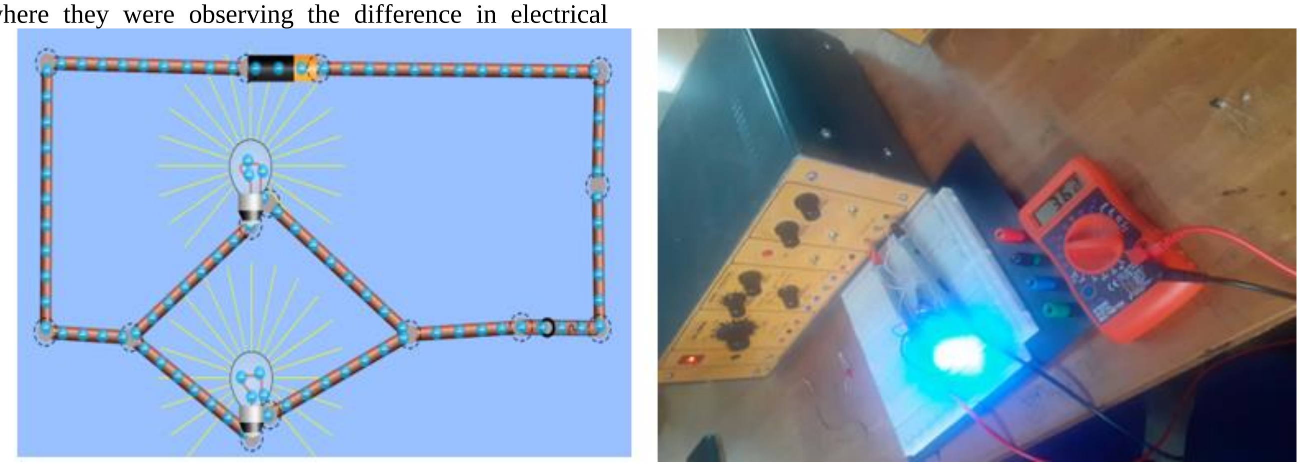

Figure 1: Construction of two bulbs in a parallel circuit using a PhET simulation and Hands-on in the workshop.

In this topic of direct electricity, the experimental activities have also been conducted about ohm's law. On the part of electrostatics, PhET simulations were used to understand quantitatively and qualitatively the coulomb's force between two charged particles whereas a demonstration using a golden leaf electroscope was used to help students understand electrical charging. Moreover, GeoGebra simulations have been used to demonstrate electric phenomena which cannot be done physically. Figure 3 shows a GeoGebra simulation about electric force that a charged particle experience in a uniform electric field. Students were given examples of deflecting plate systems in the Cathode-Ray Oscilloscope (CRO).

Table 1: Descriptive statistics for post-test

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Score	Experimental group	35	68.5429	14.16571	2.39444
	Control group	38	52.4474	17.39633	2.82206

According to table 3, the mean score for the control group was 52.4 with a standard deviation of 17.39, while the mean score for the experimental group was 68.5 with a standard deviation of14.165.

Table 2: Independent sample t-test for post-test

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Score	Equal variances assumed	1.259	.266	4.312	71	.000	16.09549	3.73237	8.65335	23.53762
	Equal variances not assumed			4.349	69.980	.000	16.09549	3.70099	8.71405	23.47693

On the other hand, independent sample t- Test for Equality of Variances in Table 2 shows a Sig of.00, which is less than the critical value, leading us to accept the null hypothesis and maintain that there is no significant difference in the level of study habits before treatment between the experimental and control groups. As a result, the two groups were homogeneous in nature, which means that they had comparable conceptual understanding of electromagnetism after treatment using real -life application approach.

The initial objective of this study was to assess the effect of using real-life application-based teaching and learning strategies to level six engineering students' conceptual understanding in electromagnetism. The following formulation was used to create the research question: : What is the change in level six engineering students' conceptual understanding in electromagnetism when taught with real-life application-based teaching and learning strategies compared to traditional methods? The EMCA test was employed, and average results as well as normalized learning gains were provided.

The main data gained from the EMCA analysis of pre-test and post-test scores include the average scores (M=33.71, SD=12.28) in the pre-test and (68.5, SD=14.16) in the post-test for the experimental group. For the control group these values were (M=52.46, SD=17.36) in the post-test whereas these scores are (M=31.49, SD=11.33) in the pre-test. The average normalized gain was $g_{av} = 0.520$ and $g_{av} = 0.31$ in the experimental and control group respectively. It can be seen that the scores in the experimental group for both pre-test and post-test are higher compared to those in the control group. However, due to the nature of the current study, these scores have only helped to find the average normalized gains.

The average normalized learning gain in the experimental group is greater than that in the control group (0.52>0.31) although both are in the medium category. Since the normalized learning gain is a measure that is not affected by any difference between groups, these results indicate that participants in the experimental group have improved their conceptual understanding in electromagnetism topics better than those in the control group. It implies that, using real-life application-based teaching and learning strategies has helped students to understanding the concepts in the topics including electrostatics, direct current electricity, magnetostatics and electromagnetic induction.

These findings are in line with those of earlier studies by Bozzo et al.(2022) on the use of inquiry-based exploratory hands-on activities to improve students' conceptual understanding of electromagnetic induction, Kittiravechote (2020) on the use of hands-on activities and demonstrations to clarify the right-hand rule for the magnetic field concept, and Hartanto et al. (2023) on the improvement of students' conceptual understanding of electromagnetic induction using PhET simulations and POE strategies. The teaching and learning techniques utilized in these earlier researches are comparable to those in the current study, and they are recognized to aid in student learning by making connections between electromagnetic ideas and how things function in everyday life. For instance, after engaging in practical exercises with magnetic needles, students have independently developed the accurate knowledge of the magnetic field surrounding a current-carrying wire (Bozzo et al., 2022). As with the current study, this activity was presented in class as a real-life context.

The constructivism theory of teaching and learning lends credence to the results of the current investigation.

Constructivism learning theory defines instruction as the process of presenting students with learning situations, environments, and tasks that accurately reflect the inherent complexities of the real world. These techniques assist students in producing abstractions and learning concepts in a meaningful way (Kola, 2017). Engineering students are able to interact with the everyday electromagnetic materials and equipment thanks to the instructional intervention in the current study. This has demonstrated the distinction between the experimental group and the control group. Even yet, the normalized learning gains that were achieved on average were not exceptional. This indicates that more work must be done.

5. Conclusion and Recommendations

5.1 Conclusion

Based on the findings, the research concludes that real-life application teaching and learning approaches are more successful than traditional teaching and learning approaches in improving learners' conceptual understanding of electromagnetism topics. This conclusion was based on the fact that students who were taught using the real-life application learning approach had significantly higher mean scores than students who were taught using the conventional learning strategy, which did not involve hands-on activities among learners in the process of teaching and learning.

5.2 Recommendation

Based on the findings and limitations in this research, the following recommendations are provided.

To physics teachers: Physics teachers are recommended to use effective teaching and learning strategies which involve real-life applications to help students improve their conceptual understanding by connecting the real-life and physics concepts. By doing so, they must make sure that students are engaged in the learning process. Physics teachers at IPRCs and TVET schools in general, can look for how to use the usual technical workshops to teach some fundamental science subjects but with appropriate strategies.

To Rwanda Polytechnique: From the findings drawn from this study, Rwanda Polytechnique should collaborate with education partners to get fund for buying the educational teaching aid to enhance the real-life application-based teaching and learning strategies on engineering students' conceptual understanding in electromagnetism. Secondly, Rwanda Polytechnique has should train teachers on how to find some online teaching resources such as PHET and other Virtual Laboratories.

TO Further Researchers: The findings of this study suggest that the following further studies should be carried out:

1. To investigate the effect of pairing between physics teaching methodologies and TVET students' characteristics on their conceptual learning in physics.
2. To investigate the teachers' perception on real-life teaching application methods to enhance conceptual understanding of electromagnetism in IPRC and TVET.

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