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Enhancing Physical Science Education: The Integration of Digital Practical Work in Teaching Electrodynamics for Experiential Learning

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ABSTRACT

Digital practical work (DPW) has emerged as a highly effective and indispensable component of science education, enhancing and extending traditional laboratory experiences. DPW aims to complement physical laboratory experiments, particularly those that teachers may find challenging to conduct or lack the confidence to perform. In this study, a content training workshop on electrodynamics was implemented to showcase DPW's effectiveness. The workshop was designed to equip in-service physical science teachers with the skills needed for integrating digital tools into their teaching methods. To gather comprehensive data, the study utilized video recordings, discussions, and evaluation reports, providing rich qualitative evidence of DPW's effectiveness. These methods captured teachers' understanding of electromagnetic concepts, their experiences, and their perceptions of DPW. The findings revealed that DPW significantly enhanced teachers' knowledge of electrodynamics and their awareness of effective digital pedagogy. The study strongly recommends integrating DPW into physical science teaching, particularly when traditional laboratory work is impractical. Unlike conventional teaching that merely transmits information, physical science education requires hands-on, practical observation to support theoretical concepts and promote meaningful learning. DPW bridges this gap, ensuring that students receive a robust and engaging science education, regardless of the constraints of the physical laboratory environment.

KEYWORDS

Experiential learning; digital practical work (DPW); physical science teaching; technological pedagogy.

INTRODUCTION

This study explored teachers' experiential learning to evaluate the role of Digital Practical Work (DPW) in physical science classrooms. The study sought to identify ways in which teachers can use DPW to facilitate students' understanding of physical science concepts. To improve learning and knowledge construction of physical science concepts, teachers should take advantage of technological pedagogy’s potential as a teaching tool. The use of technological applications, such as the DPW, was deemed necessary to empower teachers. DPW has proven to be an effective extension of laboratory practice in the teaching and learning of physical science. Practical instructional software applications have been carefully developed based on classroom needs and focused on the dissemination of knowledge to students. Software simulations of skilled tutor behavior, augmented laboratories and many more, were developed as a result of subsequent research on artificial intelligence and digital practice. Development of digital software was intended to bridge the gap between traditional classroom instruction and online instruction (Dorneich, 2002). This study evaluated the effectiveness of DPW in conceptualizing physical science content and electrodynamics knowledge.

DPW is a type of learning activity where learners use digital technology to create, modify, and analyze a physical system. It involves the use of physical materials, software tools, and data to create virtual models and analyze their outcomes (Mulya et al., 2021). Incorporating DPW into physical science teaching offers several potential benefits. DPW provides a safe and controlled environment for students to conduct experiments and explore scientific phenomena that may seem difficult to perform in a traditional laboratory setting. It enables teachers to effectively demonstrate abstract concepts and foster critical thinking skills through simulations and virtual experiments. It has been demonstrated that simulators can improve students' understanding of the material as effectively as real laboratories. It can provide a high level of convenience and flexibility, as well as a better pedagogical basis than other types of laboratories. It can be easily accessible to facilitate safer experiments with hazardous substances. It can also integrate knowledge and training resources to overcome common limitations when necessary. It can support a resilient, inclusive, and sustainable approach to addressing common limitations to laboratory skill training. Virtual laboratories can also be employed for remote learning, providing a platform for students to access learning materials from anywhere in the world. Virtual laboratories can be used to create interactive learning experiences, allowing students to explore and interact with the materials at their own pace (Mulya et al., 2021).

According to (Tüysüz, 2010), it is crucial for educators to enhance their pedagogical choices and instructional practices to attain the desired educational outcomes. It is indispensable for educators to embrace and utilize technological applications, such as Digital Laboratory Practical (DPW), in a purposeful manner to enhance the teaching experiences and actively engage students in reinforcing science theory and interactions within the science classroom. McLoughlin et al. (2007) suggested that educators should use DPW to facilitate the sharing and construction of physical science content. Banu (2011) described physics as an abstract subject that is difficult to understand and conceptualize. Several factors contribute to the status of science, including how it is taught and how it is presented by teachers. Technological programs and applications, such as DPW, appear to be crucial in modifying the instruction provided by educators, with the aim of promoting meaningful learning (Safran et al., 2007).

Algarni and Alahmad (2023) studied the nature of science and placed an emphasis on pedagogical content knowledge and technological innovation. Recommendations were made to encourage scientists to reflect on science teaching methods. Broks (2019) indicated how science education was changing, including changes that are occurring in the digital age, such as the development of the DPW to foster meaningful understanding of scientific theory. Our traditional way of thinking must be changed to obtain general orientation within our current state of education affairs. To develop teachers, skills training and appropriate methodologies are imperative. Physical Science is a practical subject and can therefore be taught and learned through current and relevant teaching methods that incorporate DPW in place of laboratory work.

Lahti et al. (2014) reported that physical science teachers lack methodological skills that are relevant and effective for the 21st century. In teacher training institutions, limited methodologies, which exclude technological pedagogies, such as the use of DPW, are overlooked and excluded from the curriculum. Technological pedagogy is rarely included in methodology courses at most training institutions, to prepare them for the digital age. As a result, graduates may not be fully equipped for in-service teaching and may not be relevant to current science practices. As a result, teachers are unable to keep up with the current and new methodologies, resulting in the need for teacher training workshops. Developing DPW is an essential soft skill in the teaching and learning of physical science, and teachers have difficulty developing these skills. Lahti et al. (2014) suggest that teachers who lack the skills, confidence, or resources to perform practical work may benefit from technological pedagogy.

The purpose of this study was to facilitate teachers' reflection on their experiences as well as their perceptions of effective, current, and relevant teaching practices. This study was conducted to determine the effectiveness of DPW in science classrooms. It was designed to provide practical instruction to in-service Physical Science educators about Digital Practical Work as a critical skill for teaching and learning science. By introducing instructional teaching methods that improve content knowledge, the intent was to motivate teachers and enhance science pedagogy. A study evaluated the effectiveness of DPW in stimulating motivation, intensifying conceptual understanding, improving teaching and learning practices, and enhancing improved knowledge (de Vries, 2019). It was necessary for the study to demonstrate the value of DPW in science classrooms and to enhance the relevant science practices, skills, and knowledge. To raise awareness of the effectiveness of DPW in science education, a workshop was conducted to demonstrate its application.

General Background

Based on experiential learning theory and technological pedagogy, DPW was used to present an effective physical science teaching method. Experiential learning theory emphasizes the importance of hands-on experiences, active engagement, and reflection. By incorporating these principles into the physical science teaching method, DPW enables students to actively participate in the learning process, explore scientific concepts through real-world applications, and reflect on their own experiences to deepen their understanding. Slavich and Zimbardo (2012) recommend that instructors prepare lessons and content based on the students' needs, interests, and learning styles relevant to the digital age. In the teaching of electrodynamics, DPW was used to expose and motivate teachers to reflect on their learning process, and to provide feedback. Experiential learning in this study was based on the notion that personal experience is the best means of learning. To retain skills and recall practical experiences for science classrooms, Cherry (2019) suggests that teachers acquire skills through experience. In this study, experiential learning theory was applied to the teaching and learning of electrodynamics. This was in an effort to raise awareness among physical science teachers about the effectiveness of the DPW through participant engagement.

Research Problem

In the fourth industrial revolution, teaching physical sciences has presented significant challenges for teachers, particularly those with long service in the education system. The advancements in computing, simulations, and animation are transforming educational practices. Integrating digital practical work (DPW) is crucial to enhancing performance and developing 'practice-readiness' among teachers. Even though Physical Science is a practical subject, experiments to reinforce theories are infrequently conducted due to teachers' lack of confidence and content knowledge. The study identified electromagnetic theory as a particularly challenging topic and proposed DPW as a means of facilitating understanding. Physical Science will continue to be viewed as a challenging subject unless teachers are equipped with technological pedagogies. It is therefore vital that teachers are prepared and made aware of the benefits of integrating DPW with traditional laboratory practices.

Research Focus

In technological pedagogy, advancing technologies such as DPW constantly evolve and influence teaching and learning, which is an accepted scientific practice. To ensure the successful integration of DPW into classrooms, a teacher training workshop was proposed to provide educators with the tools, resources, and motivation necessary to implement DPW as a digital strategy. Thorne et al. (2015) regarded DPW as an ideal alternative for laboratory practical work due to its precision, accuracy, error-free process, and successful execution. There was a need to demonstrate the effectiveness of DPW in improving science teaching and learning as a practical subject and to produce teachers who arouse students' scientific curiosity. To raise awareness of the application of DPW in science teaching and learning, a content workshop was required to demonstrate the effectiveness of DPW. Study was conducted on instructional methods that would position DPW at the forefront of practical work in the 21st century. To examine how DPW can improve physical sciences teaching and student performance, the study used electrodynamics as an example.

LITERATURE REVIEW

An overview of digital learning and teacher education is presented in this section to set the background for using virtual laboratories in the science classroom. Lab work is an important component of the teaching and learning of physical science, but there are hindrances to this important process such as availability of tools to enhance experimental processes, problem solving and critical thinking skills (Altalbe, 2019). Several South African schools do not have adequate science labs and equipment, which affects the quality of teaching and learning. This challenge can be solved by introducing virtual labs, which are cost effective because they do not require expensive maintenance and equipment's such as chemicals. Available tools are limited in number compared to the ratio of students, while in some schools they are no tools at all. Sometimes these challenges are influenced by the high cost of lab materials and equipment, at times limited due to extreme hazardous materials which can have a negative impact towards learners' outcomes and performance (Bursztyn, et al., 2021). The digitalization of practical laboratory work has been demonstrated to be an effective alternative to practical laboratory work, particularly when practical laboratory work is not possible.

According to a study by Bursztyn et al. (2021) virtual labs contribute to increased study activity and motivation among students which overall improves their performance in the subject content. Digital practical works have lots of advantages and can be considered the classroom of the future which involves DPW in addition to teaching and learning tools. Students have the advantage of doing virtual experiments at any time and can be a useful tool for teachers. So, this means that DPW can be used as an additional tool to already existing resources such as physical laboratory. With the introduction of 4IR, teachers are faced with an even greater challenge in the areas of computing, simulations, DPW, etc. (Deloitte Access Economics, 2017).

As a nation seeking to develop, it is important to ensure that science education is not neglected in its educational structure (Sondlo & Ramnarain, 2018). According to Opere (2021), practical e-learning, such as DPW in this study, was not sufficiently organized to facilitate the proficiency to produce an envisioned educational goal in practical subjects such as physical science. Teaching-learning activities are centered on teachers, and teachers should receive exposure to technological practices (Syahabuddin et al. 2020). Teachers' skills in teaching and learning Physical Sciences are a key component of a teaching and learning program. A teacher's choice of teaching and learning activities, especially practical activities relevant to science lessons, has a direct impact on the learning process, conceptual development, and knowledge acquisition of students (Copriady, 2014). Physical Sciences teacher competency is predicted by PCK and is related to students' learning outcomes). Teachers' educational backgrounds, their practices and competence, and the use of technological pedagogy have been found to affect science teaching, thereby impacting students' learning outcomes (Blömeke et al., 2016).

Various practical activities have been incorporated into the science curriculum to assist students in understanding the complex concepts of science (Oguoma, 2018). In addition to strengthening learners' content knowledge, these practical activities provide them with the skills necessary to succeed in an increasingly complex world (Banu, 2011). Through participation in DPW, students acquire skills such as watching, observing, and recording procedures (Ghartey-Ampiah et al., 2004). The development of DPW is aimed at addressing a wide range of topics, including safety precautions, a lack of practical skills, a lack of confidence in performing practical work, natural disaster escapes, etc. DPW's precision, accuracy, and error-free practical process are essential to its successful implementation in science classrooms for teachers who lack confidence in conducting practical work. In general, DPW are designed for specific purposes (practical work in this study) following a specific procedure and achieving a specific goal, so they can be used in a variety of science related fields (Taupiac et al., 2019).

Through virtual laboratories, students can conduct DPW to explore concepts and theories without stepping foot in a physical science laboratory. The digitization of practical work is an essential part of creating a virtual environment and content for the teaching of Physical Science as well as for meaningful learning. With the help of digital practical work, students can test, observe, and revise their understanding to improve their scientific literacy. When DPW is designed and implemented in a manner that addresses learners' needs, it has been shown to enhance learning outcomes. DPW is described by Gunawan et al., (2017) as software that simulates a laboratory environment and combines data with a series of activities to generate experimental results. DPW allows students and teachers to perform experiments remotely using real laboratory apparatus connected to computers. Students can also learn through experience by using the DPW and have access to systems which would otherwise be difficult to access due to factors such as safety, cost, and size (Bursztyn et al., 2021).

The use of technology in education can be defined as the operative use of technological pedagogy in teaching and learning. In the current technological environment, educators can engage in self-directed professional development activities with minimal support from their institutions by using computer applications (Khoza & Mpungose, 2018). As described in this framework, professional development entails knowledge, practice, skill development, and individual abilities to effectively teach. Teaching and learning are facilitated by utilizing and managing relevant technological practices and resources. Teaching and learning of practical subjects can be enhanced with educational technology, and this study suggests application of DPW. Physical science teachers could gain significant benefits from using DPW, including improved digital literacy and competence. The integration of computers into physical science education has not consistently translated into practical applications. This gap is being addressed by ongoing efforts to improve preservice teacher education programs and professional development for teachers.

Through the application of PCK, the study illustrates the ability of teachers to interact and engage with students in a digital environment. By accepting PCK as a method for connecting content knowledge with teaching methods in science education, it encourages teachers to use technology to create meaningful learning experiences for students. It also provides a framework for teachers to reflect on their teaching practices and make necessary improvements (Ball & Forzani 2009); Gudmundsdottir & Shulman, 1987). In the context of this study, it was necessary to explore a refined construct, technological pedagogy. Technological pedagogy refers to the teacher's knowledge of how to digitally transform science topics into effective learning platforms that facilitate learners' understanding when accessed. In this study, the objective was to expose and motivate teachers to the application of DPW to teach electrodynamics and to improve the standard of physical sciences teaching. Teachers would have the opportunity to understand how DPW resources can be used to improve teaching. As one of the professional knowledge bases to be developed in ICT, PCK is highly valued in the science education community (Mavhunga, 2014), despite its lack of implementation. In this paper, the importance of becoming a part of the 4IR by shifting towards technological pedagogy was emphasized. As a result, the study sought to demonstrate the importance of technological pedagogy, with specific reference to DPW for conceptual understanding of electrodynamics. By creating virtual assistants that adapt human behaviors to conduct hands-on experiments, DPW has the potential to be a collaboration partner in Physical Science teaching and learning. To guide this process, a demonstration of technological pedagogy was required, and the researcher applied DPW to the teaching and learning of electrodynamics (Becker et al., 2019).

The theoretical background of this study involves creating dynamic relationships between teachers, students, and a shared body of knowledge to promote student improved content knowledge for meaningful learning. This discussion has been informed by previous research exploring how instructors can make classes more engaging and interesting for learners. Slavich and Zimbardo (2012) suggest that solutions and advancements integrate multimedia, such as DPW in this study, to improve learners' attention in class. The advances have had a significant impact on how instructors teach and on how students learn (Slavich & Zimbardo, 2012). A framework was used in the study to consider aspect of experiential learning theory, social constructivism and social cognitive theory. As part of the design of digital learning environments, it was expected that teachers would engage socially to construct knowledge of electrodynamics, through experiential learning and use of DPW. Social cognitive theory addresses fundamental aspects of how learning occurs and is thus critical for all approaches to classroom instruction, including experiential learning to build understanding. The experiential theory of Kolb indicates that experiences, including cognition, environmental factors, and emotions, play a significant role in learning. As a result of experiential learning, students gain a deeper understanding of concepts, can synthesize, and discuss ideas in a way that advances conceptual understanding and are able to identify areas for improvement.

As highlighted by Lee and Dickson (2010), experiential learning can assist educators in acquiring valuable soft skills in an environment that is rapidly changing. Participating in this study provided teachers with the opportunity to go and apply what they learned in a practical setting. Experiential learning allows teachers to discover their values, demonstrate socially responsible behaviour, develop intellectual skills and competencies, and prepare for work. A study by Slavich and Zimbardo (2012) found that interactive teaching methods such as DPW improve student learning, conceptual understanding, and engagement. It is the purpose of experiential learning activities to engage teachers in activities that allow them to experience subject matter firsthand, such as DPW, which took place during a content capacity workshop for teachers. Experienced learning takes many forms, including observing course-relevant phenomena, conducting experiments, playing simulations, etc. In addition to improving self-confidence and self-concept, experiential learning programs can increase practical knowledge, skills, and enhance employment opportunities (Lee & Dickson, 2010; Slavich & Zimbardo, 2012).

Teachers are conceptualized as agents who exercise authority over their activities and over the educational environment. This study contributed to teachers' understanding of the importance of DPW in science lessons, influencing attitudes, perceptions, and knowledge (Linnansaari et al., 2015). An individual's ability to develop knowledge, skills, practices, and abilities in teaching pedagogies was encompassed within professional development. By using the framework developed in the study, educators will be able to present physical science content in a way that engages and motivates students. Best practices were shared for motivating teachers to make use of DPW resources through experiential learning (Cherry, 2019). For a general understanding of the limitations of quality teaching and learning, it was imperative that possible solutions to physical science problems be considered. The study demonstrated how Physical Science teachers can use DPW creatively in the classroom to remain competitive during the digital era. To enhance teachers' technological pedagogy, a professional development workshop was conducted to explore the potential of DPW in the teaching of electrodynamics. Consequently, the study presented DPW during an intervention workshop for physical science teachers to provide guidance on its use. As a result of the digital era and the methodologies that accompany it, science educators need to have appropriate competencies to offer a science education that is as effective as possible.

Research Aim and Research Questions

Aim: Assessing the effectiveness of DPW in enhancing teachers' adaptations to 21st century science classrooms through experiential learning.

Research question: Is experiential learning an effective way for teachers to explore the effectiveness of DPW relevant to 21st century classrooms?

RESEARCH METHODOLOGY

This study highlighted the importance of practical work utilizing DPW in Physical Science classrooms. It was demonstrated during the intervention that DPW in Physical Science classrooms has a significant effect on learning outcomes. Data collection took place in three phases: before, during, and after intervention. A workshop was conducted during which instructional materials were provided, discussions were facilitated, and participant feedback was collected to demonstrate the effectiveness of DPW. Qualitative data was collected using participatory observation, discussion, and evaluation reports to assess the effectiveness of DPW. Participant engagement was intended to ensure that they were self-sufficient in the application of DPW, in guiding and facilitating the experiential learning process of science teaching. The intervention workshop was videotaped to observe and analyze teachers' participation. As part of preparation for the workshop, the lecturer prepared the slides for presentation and downloaded DPW for electrodynamics. A researcher conducted the intervention and facilitated it to gather first-hand information, accurate and reliable data. This allowed the researcher to gain a deeper understanding of the intervention's outcomes and the impact it had on the participants.

Population and sampling

A sample of in-service teachers from the Northwest province of South Africa were studied. This study involved thirty-one (31) high school in-service teachers from the Ngaka Modiri Molema district. Participants included 16 females and 15 males, with 14 teachers aged between 31 and 40, and 17 above 41. Most of the participants had more than three years of teaching experience and held bachelor's degrees, so they were qualified to teach science. The schools studied were in remote, secluded areas that shared the same contextual characteristics. To determine the similarity of contextual factors, schools were profiled by province, as quintile 1 or no fee schools. All teachers reported that the computer was not an integral part of their teaching. They preferred to use traditional methods such as textbooks and lectures. The teachers were also not familiar with many of the online tools available for virtual experiments.

Instrument and Procedures

DPW was evaluated qualitatively over three days. Video recordings, evaluation reports, and discussions were used to collect data before, during, and after intervention.

At the beginning of the intervention (phase 1), the researcher facilitated a discussion to uncover and identify teachers' preconceptions about electrodynamic concepts. Teachers' preconceived knowledge was identified and addressed to assess conceptual understanding. The participants were asked to share their thoughts regarding electromagnetic concepts that they found challenging or difficult to explain to their learners. Part of the discussions was that teachers give reasons why they believed the concepts were difficult to conceptualize. Teachers were further asked to indicate if they utilized or incorporated laboratory practical work to teach physical/technical science, as well as the reasons why it was not used or presented during teaching and learning in science lessons.

In the next phase of the intervention (phase 2), digital practical work (DPW) was evaluated as a strategy for conceptual development and understanding of electrodynamics. The researcher utilized video and simulations to explore the effectiveness and participants' observation to evaluate understanding of the topic through the application of DPW. All activities were video recorded, transcribed and coded to identify common themes and patterns. Using electrodynamics as an example of the FET syllabus, the intervention aimed to meaningfully engage teachers to develop competence in the application of DPW, as well as working in groups to download DPW that were more relevant to their classrooms.

To conduct virtual electrodynamics experiments (DPW), participants used a workbook developed by the researcher, and each participant received a copy. It included DPW and detailed instructions of electrodynamics experiments for teachers to download. In conjunction with the DPW, a workbook was developed to effectively record data from DPW observations and findings (Ramnarain, 2010).

To gain a deeper understanding of DPW's effectiveness and teachers' experiences learning electrodynamics during intervention, video recordings of classroom observations were used. A participatory observation method was used to analyze the participation, interactions, and discussions during the intervention, as well as how teachers interacted with the DPW to conceptually understand science concepts (Crabtree & Miller, 2022). DPW was evaluated as a complement to physical laboratory practice in science classrooms.

Teachers were also given the opportunity to evaluate the workshop. The teachers were asked to provide honest opinions or descriptive feedback regarding the impact of the workshop. The data was subsequently analyzed to gain a deeper understanding of the participants' perceptions of the effectiveness of the DPW. Furthermore, discussions with teachers were conducted to obtain their attitudes and perceptions regarding digital practical work. This allowed for a better understanding of how teachers perceived the workshop. The data and insights gained from these discussions were invaluable in ensuring that the DPW was effective in meeting the needs of the participants.

Data Analysis

Based on the qualitative analysis, DPW provided participants with the opportunity to actively engage with the material, making it more meaningful and memorable for them. To ensure the validity and reliability of the study, a variety of data collection techniques were used. These included interviews, observations, workshop evaluations and discussions. These techniques provided a deeper understanding of participants' experiences, perceptions, and outcomes. The study findings were analyzed and interpreted, presenting a comprehensive overview of the study's results. The findings were then used to make recommendations for future practice and research.

RESEARCH RESULTS

Discussion before intervention

During the intervention, electrodynamics was used as an example to demonstrate the application of DPW in the teaching and learning of the physical and technical sciences. As part of the second phase of data collection, participatory observation was used to evaluate the efficiency of DPW. From the preconceived knowledge discussed, the following were identified as difficult to teach and unclear to teachers. As examples of challenging concepts, the following examples were provided.

Lenz's law and Faraday's law: Participants had difficulty explaining these two laws to learners because the concepts were also difficult for them to understand. There was a lack of understanding and familiarity with the concepts and laws, which contributed to difficulties explaining them to learners.

Differences between a generator and a motor: This is a direct application of Faraday's law and is fundamental in understanding how motors and generators work. This principle is essential for understanding how generators and motors work, and why they are so fundamentally different.

Application of DPW: Teachers engaged in learning how to download DPW. To demonstrate the effectiveness of DPW, the researcher prepared presentation slides and linked them to DPW that were downloaded.

Analysis of video recording during intervention workshop

A video recording of all the activities associated with the intervention was made. The qualitative analysis utilized participatory observational data, examining video recordings to determine whether DPW enhanced teachers' conceptual understanding (Crabtree & Miller, 2022). Observations and analyses of video recordings were conducted by the researcher using participatory observatory data. Video recordings were transcribed and thoroughly analyzed to evaluate the effectiveness of the DPW. It was through the transcriptions that conceptual change/refinement and the application of DPW through experiential learning were identified. The participants worked in groups to download an electromagnetic experiment, present a simulation, and answer related questions from the workbook. DPW uploads and findings were then presented to the entire participant cohort. In the workshop, DPW downloads were retrieved from PHET simulations and YouTube videos, as presented below.

Examples of Magnetic field around a conductor

Figure 1.
Magnetic field around a single conductor

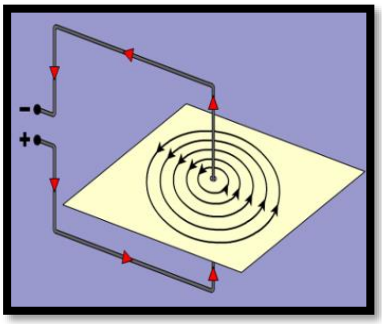


Figure 2.
Magnetic field around a single coil

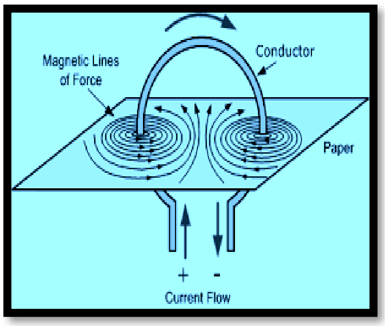


Figure 3.
Magnetic field around a solenoid

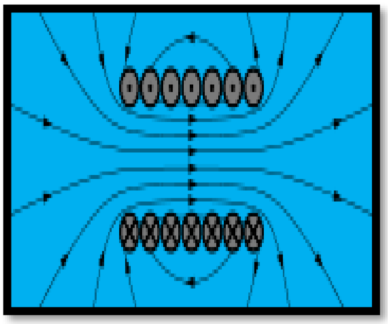
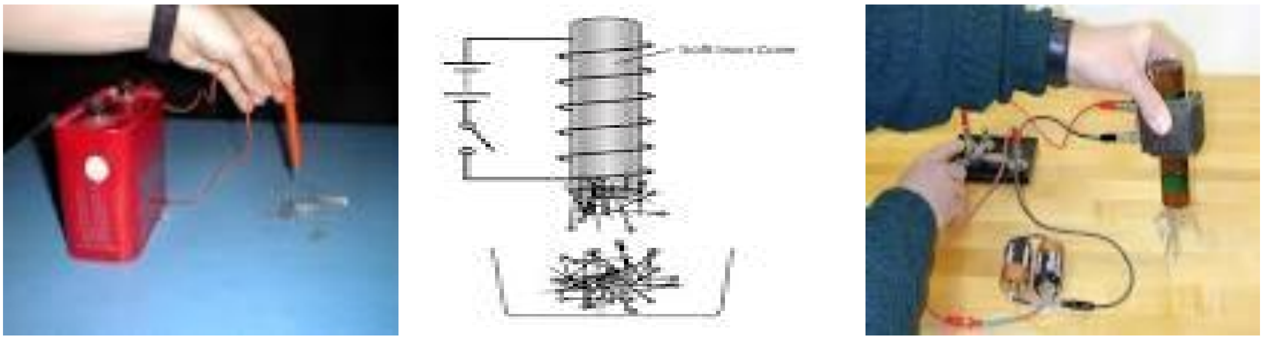


Figure 4.
Examples of electromagnets



Electrodynamics: Applications of electromagnetism

Figure 5.
Motor

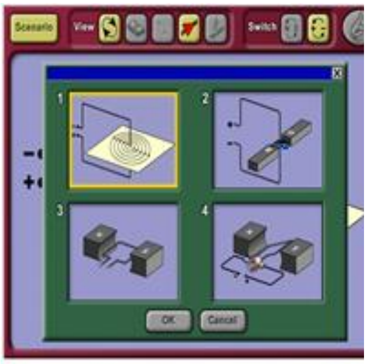


Figure 6.
Generator

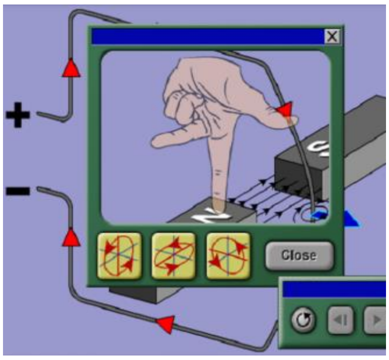
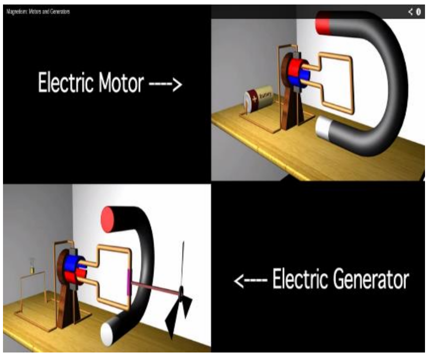


Figure 7.
Motor and a Generator



Evaluation of DPW

After intervention, participants were asked to complete an evaluation form, followed by discussions that gave feedback about the learning experience. The points listed below provide feedback regarding teachers' perceptions and learning experience on the application of DPW in conceptualizing electrodynamics.

Table 3.

Evaluation and discussions of the intervention (see Appendix)

In the evaluation forms completed by the in-service teachers at the end of the workshop, teachers strongly recommended that computer simulations be included in physics teaching. The participating teachers highlighted the importance of providing students with the opportunity to learn through DPW, which can help them gain a better understanding of the concepts. Teachers say the DPW makes teaching physical science easier and more efficient. They also gained confidence in their ability to teach electrodynamics effectively and fine-tuned their own teaching strategies. Finally, they gained insight into the various educational resources available to support their learning.

DISCUSSION

The emphasis of this study and teachers' perceptions reflects the widely held belief that DPW integration effectiveness depends on the proficiency of both teachers and students. The study also highlighted the need for teachers to be adequately trained and supported to effectively implement DPW as an extension of laboratory work. The teachers further emphasized the need for students to be well-prepared for DPW and the general application of Information and Communication Technology (ICT), as well as providing adequate technical support in classrooms as they implement to teach topics that are perceived as difficult such as the ones identified under the pre knowledge discussions. Teachers perceived a better understanding of how to effectively involve students in the learning process and facilitate meaningful learning. They gained insight into the importance of providing students with opportunities to practice and apply their skills and knowledge in science classrooms.

As a result of participating in an intervention workshop for experiential learning, teachers improved their understanding of electrodynamics. Additionally, they improved their ability to view science teaching expectations realistically, their ability to take initiative, their ability to adapt to change, and their methodological skills. Among all of the potential benefits available to in-service teachers participating in an experiential learning program, learning outcomes were of utmost importance. Therefore, the effectiveness of the program was primarily measured by its learning outcomes. Based on the findings of the study, the researcher became convinced that teachers' methods of teaching and skills could not be acquired better and more effectively without experiential learning. Those who engaged in experiential learning in this study reported significantly higher levels of satisfaction and efficacy. These are precisely the ways in which experience-based learning enhances teacher education. This suggests that experience-based learning is an effective method for advancing teacher education. The study concluded that experiential learning was the most effective means for in-service teachers to develop their skills and improve teaching methods. Based on the technology acceptance model, a model explaining teachers' acceptance of the application of DPW was tested and validated as perceived by the teachers. Furthermore, the model indicated that teachers' acceptance and effective use of DPW was positively influenced by their perceived ease of use and usefulness (Lee & Dickson, 2010).

Through the application of DPW, it was shown to be effective in reconstructing the participants' preconceived knowledge and to empower them with the correct and sufficient scientific knowledge to teach the topic effectively. By providing an interactive learning environment through experiential learning, DPW enabled the participants to gain a deeper understanding of the topic, ultimately enabling and preparing them to teach it with confidence. Therefore, DPW proved to be an invaluable tool for teaching as it not only equipped the participants with the knowledge they needed, but also gave them the confidence to teach it. It appears that teachers' preference for DPW in the classroom was directly influenced by factors such as effectiveness, efficiency, user-friendliness, and learning options.

The findings of this study could be used to improve physical sciences teaching, revitalize teacher confidence, and enhance learner curiosity and interest in physical sciences classrooms. Based on the teachers' perceptions, the findings would enhance and improve student performance as well as address the resources needed to deliver effective classroom activities. If teachers gain confidence in teaching physical sciences and are equipped with varied methods of transferring knowledge to learners, they will most likely improve the teaching of physical sciences, increasing the number of science learners in the country. Providing quality science education to learners should be the country's collective goal, and this is dependent on the effectiveness of teaching physical sciences. To achieve this goal, teachers must receive the necessary training and support to effectively teach physical sciences. This will empower students to develop a deeper understanding of science and its practical applications. To ensure this goal is achieved, we must prioritize equipping teachers with the resources and support necessary to teach physical sciences in a way that encourages students to engage with the content on a deeper level.

CONCLUSIONS AND IMPLICATIONS

Educators are constantly confronted with challenges related to ICT as well as practical methods. As society changes, new demands are placed on the content and methodology of science education. To prepare students for science and a technological society, it is essential to incorporate digital competencies into science curricula. In spite of this, teachers may find it difficult to integrate technology in order to fulfill these obligations. Physical science teachers must understand how to integrate DPW into the curriculum and how to meet the practical requirements of the physical science curriculum. To prepare science learners for the 21st century, educators must integrate DPW into laboratory practical work.

For better results, ICT integration, digital pedagogy and teacher training on how to use DPW strike a balance between theoretical concepts and practical work. The research study offered and provided modern ideas on how to approach Laboratory practical work effectively and progressively. DPW used in this study presented an approach and solutions for effective extension of physical laboratory practical work. The impacts of DPW of the topic electrodynamics as it was displayed in this study had implications toward the teaching and learning of physical science, and pivotal to teachers' methodologies and applications. Based on the research results and the literature review of this investigation, recommendations have been made.

To incorporate DPW effectively into their teaching methods, educators must undergo specific training. If teachers are not properly trained or exposed through direct experience, they may not be able to make full use of these tools. The study found that through the integration of virtual and physical practical work, teachers can foster students' self-efficacy, self-confidence, and practical skills. This study concluded that experiential learning can be considered a synergistic process when it involves both virtual and physical practical work, since the combined effect is more powerful than either function alone. The researcher foresees DPW in science classrooms as transformation towards teachers' PCK that enhance the quality of teaching, equip Physical Science teachers in the 21st century teaching practices, and ultimately improve performance. The overall conclusion of this study was that DPW is an effective complement to physical laboratory practical.

Ethical aspects of research

Permission to conduct the research was obtained from the North-West Department of Basic Education of South Africa, the principals of the selected schools and the teachers. The University of North-West's independent ethics committee approved the study. The researcher informed the participants (the physical science teachers) about the nature and purpose of the research and the ethical considerations that guided the research. The participants were informed of voluntary participation, confidentiality of information, and the purpose of the research.

Limitations

Limited hands-on experiment, as DPW cannot fully replicate the physical and tangible experience of handling real equipment and chemicals. Learners miss out on the sensory aspect of science experiments, leading to lack of real-world challenges, which is not provided by DPW.

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APPENDIX

Table 3.

Evaluation and discussions of the intervention

Questions	Participant response
Was the workshop run smoothly and the facilitator well prepared?	All participants (100%) agreed that the workshop was well organized, and the facilitator was well prepared.
Was the workshop successful in meeting your expectations?	All participants (100%) indicated that the workshop met their expectations. Comments indicated that the workshop addressed their general frustrations and challenges. They were also able to gain a better understanding of concepts they struggled with.
Was the workshop able to address challenges and alternative conceptions of electrodynamics that were discussed prior to the intervention?	The participants (100%) were all satisfied with the way in which various challenges were addressed, and some were specific about alternative conceptions. The participants provided detailed feedback on their challenges, indicating that the solutions were effective and satisfactory.

What impact has DPW had on your understanding of electrodynamics? Specify as much as possible.	"They made difficult concepts understandable and clarified them". "They brought concepts to life, made them real, and cleared misconceptions."
What did you enjoy most?	Simulations of practical work and facilitation were highlighted in the feedback. The simulations were praised for providing an opportunity for in-service teachers to practice and fine tune their skills and knowledge in a risk-free environment. An engaging facilitator and exposure to experiential learning of concepts and phenomena, which was well-designed.
In your opinion, what could have been done better by the facilitators?	There was a need to repeat the topic at school, so teachers requested that before school begins teaching the topic, intervention workshops should have been conducted earlier. In addition, they suggested that the workshop should have lasted at least a week in order to allow more time for experiments.
What improvements would you suggest?	Teachers suggested more time for experiments. The emphasis was placed on the possibility of conducting future workshops on other challenging topics, based on diagnostic analysis. This meant that DPW positively impacted teachers' knowledge gain, hence they requested more workshops.
Do you have any experience using DPW in educational settings?	Most participants stated they have not participated in any training related to DPW educational use
In your opinion, what are the main benefits of integrating theory and DPW?	Students' engagement is identified as the primary benefit of DPW integration in science classrooms. Additionally, participants emphasized the importance of accessibility and flexibility in learning, as well as real-world learning experiences.
When it comes to integrating DPW into your teaching, what factors influence your decision?	Experiential learning of the effectiveness of DPW for improving knowledge and meaningful learning.
Did you find the workshop to be engaging for the teachers?	All participants agreed on a maximum level of participation. There was a great deal of appreciation and enthusiasm for this level of participation. It was evident that the participants were eager to learn from the workshop, as they asked questions and requested clarifications.