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Teachers' and Students' Experiences of Chemistry Practical in selected Day Secondary Schools in Nyarugenge District, Rwanda

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Abstract

The current study investigated teachers' and students' experiences with chemistry practical in day Secondary schools of the Nyarugenge district of Rwanda. The data were collected and analyzed using a mixed research design. Quantitative data were collected through Chemistry Achievement Test and Likert scale questionnaire, while qualitative data were collected by the interview and open-ended questionnaire. From a district of population of 871, which included 860 chemistry students and 11 chemistry teachers, 184 participants comprising 173 senior two students and 11 Chemistry teachers were purposefully sampled to take part in the study. The results revealed that the use of chemistry practical work increases students' performance ($p < .001$, $df = 171$) at a confidence level of 95%. There was thus a very statistically significant difference in terms of performance between students who learned chemistry practical work and then used the traditional method. Teachers and students also expressed positive perceptions and attitudes toward using practical work in chemistry lessons as it increases the conceptual understanding of students and encourages improvisation, participation, confidence, motivation and problem-solving skills. Some challenges encountered by students and teachers were inadequate equipment, insufficient time allocated to chemistry on the timetable, curriculum coverage and classroom size. As chemistry practical work has an important influences on students' academic performance, the Rwanda Basic Education Board has to avail laboratory equipment and reagents to enable students to conduct experiments in a good atmosphere.

Keywords: chemistry practical; academic performance in chemistry: perception of chemistry; attitudes towards chemistry

Introduction

Chemistry is a scientific discipline that focuses on understanding the make-up and characteristics of matter, as well as how that matter changes and the laws and principles that control those changes (Dillon, 2008). Because there are numerous advantages to learning through laboratory activities. Chemistry practicals are a crucial component of effective science education and science educators (Millar, 2009). As a result, any laboratory experiment is crucial to the learning of chemistry. Chemistry learning is dependent on the type of practice and the approaches or teaching techniques used. The theoretical and practical knowledge of students is closely related to how well they perform in science-based classes like chemistry (Akpan, 2010). Chemistry practical can be done via physical laboratories or Virtual laboratories. The impact of technology

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on chemistry practicals is recognized, it affects student performance, motivation, laboratory experiences, and the changing character of laboratory work. The virtual laboratories, and digital technology are being used in chemistry teaching and practical to enhance students' performance (Nsabayezu et al., 2020; Nsabayezu et al., 2022a; Nsabayezu et al., 2022b; Nsabayezu et al., 2023a; Nsabayezu et al., 2022b). Technology has transformed chemistry practical by boosting experimental precision, efficiency, data processing, and safety (Nsabayezu et al., 2022c; (Nsabayezu et al., 2022d). It enables scientists to investigate complex phenomena, make informed judgments, and gain a better knowledge of chemical processes (Nsabayezu, et al., 2022e).

Students gain an understanding of the method of scientific inquiry and grow in their conceptual understanding when they engage in practical work. The acquisition of knowledge about risks, hazards, and safe working practices is another result of practical work experience, particularly in chemistry (Bialik et al., 2015). And thus, teachers can improve their skills of doing practical via attending various continuous professional development (CPD) (Nunguye et al., 2023). This makes practical work to be more enjoy full for science especially in the chemistry classroom because they help teachers to prepare the student for getting the required 21st-century labour market skills. Besides the provision of a more practical and skills-based approach to learning, a competence-based curriculum orients students towards the requirements skills of the workplace. This means that a competence-based curriculum prepares students to implement what they studied in class in real life, especially in chemistry. The primary goal of chemistry instruction and learning is to encourage students' spirit of inquiry and discovery. These cannot be achieved without a practical-oriented teaching and learning strategy which is recommended in the secondary school curriculum (MINEDUC, 2015).

The condition of laboratories in general and chemistry laboratories in specific is not satisfactory in day secondary schools (Jabeen et al., 2020). Most Rwandan teachers emphasized that certain CBC content calls for materials that cannot be made up as needed, particularly in science subjects, and is therefore taught theoretically (Nsabayezu et al., 2022a). Regarding this, it notes that, primarily in twelve-year basic education schools, a lack of laboratories, reagents, and materials prevented the majority of teachers from carrying out planned experiments. Enhancing scientific abilities, attitudes, and inquiry-based learning are all achieved through practical work in science, which is crucial for the growth of scientific knowledge. Hofstein and Luneta (2003) Describe science practical activities as learning opportunities where students collaborate with materials or models to observe and comprehend the natural world.

Despite widespread recognition of the importance of chemistry labs in school science, the laboratories' design must support both teaching and learning (Dillon, 2008). Science process skills include practical knowledge of chemistry. Cognitive and psychomotor skills are used in problem-solving as part of science process skills. They are the abilities that sciences employ for problem identification, unbiased investigation, data collection, trans-formation, interpretation, and communication. Practical work requires more than just assembling an apparatus; it also requires planning, designing a problem, coming up with a new method and procedure, as well as combining well-known elements in a novel way (Akinbobola & Afolabi, 2010).

Research Theory

Constructivism is the theory upon which this study is based, which provides a perspective on how science is taught and learned in classrooms. According to the constructivism theory, a student's understanding of the world and the meaning of information is based on their reality. As a result, humans gain knowledge through conversation, observation, and interpretation, transforming information into unique knowledge (Alves, 2014; Mohammed et al., 2020). Students learn more effectively when they can apply what they've learned and create personal meaning (Forster, 2011; Sjøberg, 2010).

Constructivism argues that for students to learn, active learning experiences are preferred to passively absorb information. Since knowledge cannot be imparted to students directly, teaching aims to provide experiences that contribute to knowledge creation. Encourage students to evaluate new information and re-evaluate their prior understanding (Taber, 2018). Through activities, students should be able to compare their current schema to novel situations. Quizzes, small-group discussions in class, and presentations are a few examples of potential activities (Nsabayezu et al., 2022b). New knowledge is developed with the learner's prior knowledge. Give them challenges and tasks to complete, then assess their performance. As students overcome challenging obstacles, they change their pre-existing schemas and encounter new issues, which aids in knowledge development. Encourage students to analyze new material and review prior knowledge (Dagar, 2016). The activities ought to allow for a comparison of prior knowledge with the new situation. Many different activities can be done, including presentations, class discussions, and quizzes. Permit students to show you and themselves what they have learned.

Throughout this study, students were assigned laboratory tasks to complete. In a lab activity that was supervised by a teacher, students were able to participate and then report their findings. Their knowledge and skills were developed as a result. The students engaged in the required activity and learned new information as a result. Students must have the capacity to independently develop new ideas and concepts. The learning process is made active for students who would typically be passive consumers of information. Scientific knowledge is developed more thoroughly thanks to assessment and active learning in structured learning environments (Kirshner, 2015).

Relevance of the study and its contribution to the existing literature

The study's findings will be beneficial to chemistry instructors, specifically those who are trying to devise a worthwhile approach for supporting students in performing to the best of their abilities in chemistry practical. The study's conclusions suggest that students will become more motivated, self-assured, and positive about learning chemistry. The creation of information will help with better curriculum development, teaching and learning, the use of instructional media, and school administration. Encouragement to think critically, assess oneself, and raise the calibre of one's efforts will inspire students to take charge of their education. The findings of this investigation will be added to the existing publications on chemistry teaching and learning strategies for future use by various academics, and additional research will be conducted.

Research questions

The questions that follow guided this investigation:

1. What are the significant differences in the mean between students learning chemistry with and without practical?

2. What are teachers' and students' attitudes and perceptions towards the utilization of chemistry practical works?
3. What are the challenges encountered by chemistry teachers and students while conducting practical during chemistry lessons?

Methodology

Research paradigm

This study followed the pragmatism paradigm. The principle of pragmatism state that "Actions must be interpreted to generate beliefs, and beliefs must be interpreted to generate actions" (Morgan, 2014). Pragmatism combines both qualitative and quantitative data (Maarouf, 2019). This research combines qualitative analysis from the interview and quantitative analysis from achievement tests and questionnaires. The utilization of mixed-method was useful to ensure the potential validity and reliability of the current investigation.

Research design

The study utilized a mixed research design in which data were collected and analyzed sequentially (exploratory sequential design). The vital objective of this design was to identify the boundaries of the environment in which problems and situations of interest are likely to exist, as well as the prevailing factors. It is also useful when there is no earlier research to which references can be made for information (Islamia, 2014). In this design, the researcher started with collecting and analyzing qualitative data, then the obtained information was used to build into a second phase of quantitative data. John (2014). Before using chemistry practical work, all the students did the pre-test, then the researcher integrated a new approach to teaching and learning, and thereafter students did the post-test. The interview provided qualitative data, while the questionnaire and Chemistry Achievement test provided quantitative data.

Population and sample

A population is a gathering of elements that meet certain aspects and to which the research's findings are to be based on (McMillan & Schumacher, 2006). In this investigation, the population was a group of senior two students because they have basic knowledge about chemistry and Chemistry teachers from four-day secondary schools of Nyarugenge district, Rwanda. The total population of this study was 871 and included 860 chemistry students and 11 chemistry teachers from GS Camp Kigali, GS Akumunigo, GS Epa St Michel and GS Sainte Famille. However, a sample is a subset of a population that characterises the population's individualities (Kabir, 2016). In this study, both purposive and random sampling strategies were used. Agreeing with Kothari (2004), the purposive sampling technique entails a deliberate or intentional selection of specific participants in the universe to constitute a sample that represents the universe. This sampling strategy was employed to choose a sample of chemistry students and teachers who participated in this research. Thus, 184 participants were purposively sampled and included 173 senior two students and 11 chemistry teachers from four-day Secondary Schools of Nyarugenge District. Secondly, it was random sampling. Random sampling has the advantage of collecting unbiased information because each of the possible samples has the same probability of being chosen in the case of a finite universe (Kothari, 2004). This sampling strategy was used to get students who participated in the interview. Based on the experience of the selected teachers, 18.2% have 1-2 years of, 36.4 have teaching experience of 3-5 years and 45.4% are above 5 years of teaching experience.

Research instruments

Chemistry achievement test: A test can help to assess students' comprehension of concepts (Sener & Tas, 2017). The chemistry achievement test was used in this research to evaluate students' performance in chemistry laboratory activities. The test consisted of twenty questions with multiple choices and two open-ended questions. The test was based on the practical content of the Rwandan basic education Ordinary Level chemistry curriculum. The content covered were types of chemistry reactions, preparation of salts, and identification of ions. The test was marked out of 22 marks. Before using the chemistry practical work, the school were grouped into two (control and experimental). All the selected student did a pre-test to measure their prior chemistry performance and then a post-test to evaluate the effectiveness of practical work on their academic performance.

Questionnaire

A questionnaire, as defined by Munn and Drever (2010), is a group of thoughtfully crafted questions that are created and given to respondents to collect information that can be documented in writing. The main benefits of using questionnaires, in their opinion, are standardized questions, anonymity (for the respondent), the potential for a high return rate, and effective time management. Concerning this study, the questionnaires composed of 11 multiple choices and one open question were deployed to eleven chemistry teachers to investigate their perceptions, attitudes and challenges faced by them when conducting chemistry practical lessons.

Interview

The interview is used to learn one's thoughts of participants (Alshenqeeti, 2014). In this investigation, a structured interview was utilized to obtain additional information from chemistry teachers and students. In addition, the interview was used to get a deep insight of students and teachers about using practical work in chemistry lessons. In this study, six chemistry teachers and 14 students selected randomly participated in the interview.

Data Analysis Procedure and Issues of Validity and Reliability

Analyzing data involves looking at the information obtained and drawing conclusions (Kombo & Tromp, 2006). In this investigation, the descriptive with inferential statistics was employed to examine the quantitative data. To compare the means of the experimental and control groups, data from the pre-and post-test were checked employing descriptive statistics and inferential statistics (independent t-test). Questionnaires were also checked by utilizing descriptive statistics like mean, percentage and standard deviation. The SPSS version 23 was utilized to analyze quantitative data. Qualitative data from the interview were checked by using interpretive and descriptive analyses. For interpretive and descriptive analysis, the researcher continually used word text to understand the meaning and directive data from participants.

The ability of a research instrument to gauge what it is intended to measure is referred to as its validity. Conferring to Kumar (2005), the determination is that an instrument is estimating what it is supposed to measure. In this study, the triangulation and validation from others were used. Triangulation is the process of analyzing a study of a single phenomenon using two or more data sources, methodologies, researchers, theoretical aspects, and approaches (Bashir et al., 2008). For the validation from others, an independent check of the data is utilized by others which are in the same domain (Hayashi et al., 2019). In this investigation, to ensure the content validity of the research, research instruments were confirmed by the guide and team of experts in research and chemistry education from the UR-CE.

The accuracy degree is necessary in order to get predictable and reliable results in any investigation (Kothari, 2004; 2005). The research instruments were piloted at another school located in Nyarugenge District which has the same aspects as the school under the investigation. The reliability coefficient of the test item was quantified by utilizing a split-half coefficient and found to be 0.743. The reliability coefficient of the questionnaire was estimated by using the Cronbach coefficient and 0.83 was noticed and was acceptable.

Ethical statement

The investigator obtained an introductory letter from the UR-CE in the unit of research, and an authorization letter from Kigali city and Nyarugenge district. The researcher obtained consent forms for all participants that were involved in the research. The consent form included information on key aspects of the research such as the purpose, procedures, time, benefits, and method of data storage, as well as a clause stating that participation is voluntary and that participants have the right to draw out from the investigation. All the participants' voluntarily signed the consent form and agreed to participate in the research. The researcher also obtained research permission from the head teachers of the schools for students below 16 years old. The information gathered from the study subjects was only confidentially utilized for the present investigation. All the participants got an equal chance to participate in the research.

Results and Discussion

Effectiveness of chemistry practical on student's academic performance

To investigate the effectiveness of chemistry practical work towards students' academic performance, the Chemistry Achievement Test was for two groups. An independent t-test was utilized to check the difference in mean between the two groups in the pre and post-test. Table 1 shows the independent t-test results of the pre-test of the experimental and control groups.

Table 1 Independent t-test results of the pre-test scores

Group	N	Mean	Std. Dev.	t	df	Sig. (2-tailed)
Experimental	92	15.8744	2.2250	-0.076	171	0.631
Control	81	14.5421	2.3270			

t-value significant at $p < 0.05$

The results in Table 2 indicate the experimental group's mean score as M = 15.8744 and the control group's as M = 14.5421, out of 22, with p = 0.631; p>.05. This showed that before using chemistry practical work, there is no statistically significant

Table 2 Independent t-test results of the post-test scores

Group	N	Mean	Std. Dev.	t	df	Sig. (2-tailed)
Experimental	92	18.3254	2.5311	-6.320	171	.001
Control	81	15.8730	2.6321			

t-value significant at $p < 0.05$

difference between the scores of the control and experimental groups. Meaning students in both groups had similar performance in the pre-test. After exposing the experimental group to chemistry practical work in teaching types of chemical reactions, preparation of salts, and identification of ions, while students in the control group learnt without practical work, the post-test yielded the results presented in Table 2.

The results from above indicated the mean score of the experimental group was 18.3254, while the control group was 15.8730 with p = .001; p<.05, indicating that chemistry practical work has a significant effect on students' performance than using the traditional method. This means that using chemistry practical work increases students' performance in chemistry concepts. Therefore, the p-value (.001) was less than the expected value (.05), which indicates to rejection of the null hypothesis in favor of the alternative hypothesis. It means there is a statistically significant difference in terms of performance between students who learnt chemistry practical work and then used the traditional method. Thus, the outcome from the statistical analysis discovered that chemistry practical work meaningfully influences students' educational performance in chemistry concepts (types of chemical reactions, preparation of salts and identification of ions).

Table 3 Teachers' agreement to statements on their perception of chemistry practical work

Statement	Mean	Standard Deviation
a. Chemistry practical increases student understanding	3.0909	.0802
b. When we are dealing with a chemistry experiment, I do it myself and students watch carefully what I am doing	2.4545	.82020
c. Lab experiments are carried out in the chemistry course	3.0909	.70065
d. Practical work in chemistry leads to skills acquisition by the students	3.5455	.52223
e. I organize students to improvise equipment which is not available	2.2727	.46710
f. I provide the improvisation when laboratory standard equipment is not available	3.0909	.53936
g. Through practical work, students' participation and confidence to solve real-life problems were increased	3.3636	.50452

Teacher's perception towards the utilization of chemistry practical work

This section contains teachers' ratings of statements about their attitudes toward the use of laboratories in chemistry instruction. On a 4-point Likert scale, the teachers were asked to rate their agreement to statements about their attitudes toward the utilization of laboratories in teaching and learning chemistry. The results of the teachers' ratings are shown in the Table 3.

The majority of teachers at the $\bar{x}$ = 3.0909 with .0802 reported that the use of practical work in chemistry increases knowledge and understanding of chemistry concepts. Students watch carefully the experiment demonstrated by their teachers at $\bar{x}$ =2.4545 with an SD of .82020. Most of the teachers at the $\bar{x}$ of 3.0909 and SD of .70065 agree that they conduct laboratory experiments in the chemistry lessons. The study proved that chemistry practical work leads to the acquisition of knowledge at the $\bar{x}$ = 3.5455 with SD = .52223. Teachers at the $\bar{x}$ = 2.2727 and SD = .46710 reported that they organize students to improvise practical when laboratory materials are not available. In addition, most of the teachers at the $\bar{x}$ = 3.0909 and SD of .53936 agreed they improvise materials when materials are not available. Chemistry practical work encourages participation and confidence to solve the real-life problem at the $\bar{x}$ 3.3636 with SD = .50452. The study found teachers have a positive perception of using practical in chemistry lessons because it increases the conceptual understanding of students, and encourages improvisation, participation, confidence, motivation and problem-solving skills.

Table 4. Teacher's response on challenges of conducting chemistry practical work

Statement	Number	Mean	Standard Deviation
a. The school timetable is an obstacle to syllabus coverage	11	3.4545	0.52223
b. Chemistry practical are an obstacle to syllabus coverage	11	3.1818	0.60302
c. School laboratories have inadequate equipment	11	3.5325	0.5122
d. Large number of students in class is an obstacle to chemistry practical work	11	3.6364	0.50452

Student's perceptions and attitudes toward the utilization of chemistry practical work

To examine students' perceptions and attitudes towards the utilization of chemistry practical works, the incorporation of students' opinions from the interview was utilized. The investigation found that students have positive perceptions and attitudes towards the utilization of chemistry practical works in chemistry lessons. All students (100%) reported that learning chemistry through practical work is interesting and joyful. One student in the interview said that" *chemistry is an interesting subject and easy to understand when we learnt it by experimenting*". Another student reported that "when *you see things and you do it yourself you remember, but when you just write it down you forget".*

Challenges faced by teachers through conducting chemistry practical work

To identify difficulties encountered by teachers during chemistry practical work, a 4-point Likert-scale questionnaire and structured interview for eleven chemistry teachers were used. The Table 4 shows teachers' responses to challenges faced by them during chemistry practical work.

While probing challenges encountered by teachers when conducting chemistry practical work, the study found that the challenge that had the teachers' highest rating was "school timetable is a an obstacle to syllabus coverage" in chemistry with mean rating ($\bar{x}$ = 3.4545 and SD = 0.52223; this is followed by "chemistry practical are an obstacle to syllabus coverage" with mean rating $\bar{x}$ =3.1819 and SD = 0.60302. The third challenge rated was "school laboratories have inadequate equipment" with mean rating $\overline{x}$ = 3.5325 and SD = 0.51220; and the fourth was "large number of students in class is an obstacle to chemistry practical work" with mean rating $\overline{x}$ of 3.6364 with SD = 0.50452. In addition, interviewed teachers reported that the lack of laboratories and laboratory manuals, chemicals, and laboratory technicians is a challenge that hinders the effective teaching of chemistry through practical work.

The challenges identified are inadequate equipment, insufficient time allocated to chemistry on timetable, curriculum coverage and classroom size. The results obtained concur with those of other authors. The results of a study conducted by Mwangi (2016) on the influence of chemistry lab works on students' performance in Machakos and Nairobi secondary schools of Kenya revealed a positive correlation between the use of Chemistry experiments and students' achievement in chemistry. The achievement of the learners who were taught using chemistry practicals also improved following the intervention. In addition, an importance significance between the achievement scores was noticed for experimental and control groups, when practical work is considered. Its effect on students' science attainment, according to the mean score comparison, using chemistry practical work has a significant effect on student's academic attainment (Shana & Abulibdeh, 2020).

In this investigation, an important significance in the attainment scores was seen for the experimental groups, in comparison to the control groups. Chemistry practical work enhances students' interest and scientific attitude and hence supported more academic achievement in Chemistry in senior secondary schools (Of et al., 2019; Shana & Abulibdeh, 2020). The results are in line with those of Mahdi (2014) who noticed a positive link for students carrying out practices. In addition, chemistry is not a boring subject. According to Hofstein and Mamlok-Naaman (2011), the main objective of chemistry teachers is to develop a positive attitude toward chemistry learners. The research showed that learners have a positive attitude toward chemistry when they conduct practical work. Similar observations were reported (Yunus & Ali, 2012).

The present results were also confirmed by Feyzioğlu et al. (2011) who found that experienced teachers have a positive attitude toward practical work and availability of school laboratories is another aspect that increases teachers' perception. Akani (2015) discovered that the use of the laboratory aids in the development of scientific attitudes in students toward chemistry learning, particularly practical chemistry. Those study results are also in line with those of Halim et al. (2012) who reported that teachers thought that the learning environment that lab students encountered was productive.

Other studies about challenges that hinder effective teaching and learning chemistry through practical work were conducted. The current findings support the findings of Olufsen et al. (2015), who noted that a lack of chemicals and equipment, a lack of time, and a large class size prevent effective teaching of chemistry through practical work. According to Shitaw's (2017) study, a lack of laboratory materials has an impact on how chemistry concepts are taught and learned. According to Chala (2019), the biggest obstacles to the instruction of chemistry practical activities are a lack of lab supplies, equipment, manuals, and space, as well as large class sizes and limited access to ICT.

Conclusion and Recommendations

The findings of this study revealed that chemistry practical work significantly influences students' academic performance in chemistry concepts (types of chemical reactions, preparation of salts and identification of ions). It also showed that teachers and students have positive perception and attitudes toward using practical in chemistry lessons because it increases the conceptual understanding of students, and encourage improvisation, participation, confidence, motivation and problem-solving skills. During practical work, the challenges faced by teachers and students to conduct an effective practical work include inadequate equipment, insufficient time allocated for chemistry practical on timetable, curriculum coverage and classroom size. Thus, the study recommends the following: chemistry teachers have to conduct experiments in chemistry lessons to enhance chemistry instruction and learning standards; school administrators have to help teachers to find chemicals to be used in the practical lessons; and the Rwanda Basic Education Board which is in charge of curriculum development and training has to provide training of teachers, laboratory technician, and laboratory equipment in the schools.

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