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Nurturing Students' Science Process Skills in Chemistry: A Case of Using the WhatsApp App in Resources-Constrained Secondary Schools in Uganda

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Abstract: *Science process skills are the backbone of science, and innovations in this field. It is critical to inculcate such skills among learners at their early stages of learning science. This study reports on how using the mobile phone WhatsApp-supported instructional resources resulted in improvement in students' science process skills in chemistry, in the context of students in resource-constrained schools. The study adopted the quantitative research approach, taking on a quasi-experimental pretest-posttest non-equivalent group design. Particularly, Solomon's four group design was used, given its high internal and external reliability and validity. Data from a sample of 240 students selected from two experimental and two control schools were analyzed using the independent samples t-tests, to establish if there was a statistically significant difference in students' chemistry process skills test mean scores between the experimental and control schools. The study illuminated that the integration of WhatsApp-supported instructional resources outside the classroom setting and its use improved significantly the students' test scores on chemistry process skills in the experimental schools as compared to the control schools. This has implications for the use of accessible Apps to support teaching and learning in resource-constrained contexts.*

Key Words: *Instructional resources, Resource-Constrained schools,* Science process skills, Mobile phone Apps, WhatsApp, Covid-19, distance education

INTRODUCTION

There is increasing access to mobile phone technology by the general population, even among the less privileged groups in the developing parts of the world (National Information Technology Authority-Uganda [NITA-U], 2018; Altameemy, 2017; Nawi, et al., 2015; Kafyulilo, 2014; Isaacs, 2012). However, a number of studies point to mobile phone technology as having the potential to facilitate teaching and learning, citing among others its ability to transmit electronic instructional resources (Ismail, et al., 2013; Mohammed & Ala' Khalid, 2018; Basal, et al., 2016; Bansal & Joshi, 2014), though it is not yet fully welcome as a tool for teaching and learning in the

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school setting, problematizing it as a distractor to learning the moment it gets into the hands of students (Ott, et al., 2017; Thomas, 2015; O'Bannon, et al., 2017). Blocking this technology from being explored by students for academic purposes while at school has made the majority of them to use mobile phones for mainly entertainment than academics at any given opportunity (Thomas, 2015).

Given the great power of mobile phone technologies in transmitting a variety of information in different formats, for example, audio, visual, audio-visuals, and text among others (Mohammed & Ala' Khalid, 2018), supported by the different application tools (Apps), its potential to facilitate teaching and learning has not been fully exploited by educationists (Ng, Brown, et al., 2016). The raising levels of accessibility to mobile phones by the majority of the population in the developed, developing, and underdeveloped world (Altameemy, 2017), creates an opportunity for mobile phone technology to be used for educational purposes, particularly in circumstances where instructional resources are limited, especially among the developing and underdeveloped countries.

CONTEXT OF THE STUDY

Uganda, a country located in sub-Saharan Africa is one of the countries where access to science instructional resources by the majority of secondary schools in underprivileged communities is still a challenge (Nangonzi, 2016). Amidst this challenge, the government declared science subjects compulsory for all lower secondary school students, in its effort to encourage students to take on science-related careers (Uganda National Council of Science and Technology [UNCST], 2012, Ministry of Education and Sports, [MoES], 2019). The difficulties of having adequate access to science instructional resources by students in resource-challenged schools have been partly cited as one of the explanations for the underdevelopment of key science process skills (SPS) among such students (Komakech & Osuu, 2014).This has negatively impacted their academic performance in science subjects at the national examinations level (MoES, 2019; Nangonzi, 2016; Beaumont-walters & Soyibo, 2001)

This notwithstanding, as revealed in a study conducted by the National Information Technology Authority Uganda (NITA-U, 2018), 70% of Ugandans own mobiles, representing about 24 million people. Indeed, secondary school students own mobile phones which are used largely for entertainment and communication with peers, rather than for academic work (Busulwa & Bbuye, 2018). The WhatsApp App is one of the most popular social networking applications used by youth and teenagers. It supports features such as multimedia messaging and group chatting capabilities, which provide possibilities for sharing multimedia electronic instructional resources for pedagogical purposes.

It was against this background that this study was conducted, to establish if WhatsApp accessed electronic chemistry instructional resources could have any effect on the development of students' science process skills in chemistry, particularly observation, measurement, and communication skills.

LITERATURE REVIEW

For students to perform well in science disciplines, skills such as observation, communication, classification, measurement, and interpretation among others are critical (Ozgelen, 2012). These are referred to as "science process skills". Science process skills are broadly transferable abilities, appropriate for several science disciplines and reflective of the behavior of scientists (Walters & Soyibo, 2014). Such skills are nurtured among students partly by exposing them to science practical activities (Ozgelen, 2012).

Effective participation in science practical activities by students calls for well-equipped science laboratories, with relevant instructional materials such as reagents and apparatuses (Ogal, 2019; Ssenkabirwa, 2013; Musindi, 2011; Musoke, 2015). This provides opportunities for students to develop their observation, analytic, communication, and interpretive skills, shaped by what they have done practically. In light of this, schools that are ill-equipped in terms of science materials pose a great challenge for their students in developing such skills, partly because of the limited or complete absence of opportunities for practical practice (Ozgelen, 2012).

Much as studies on the use of Apps (application tools) to develop science process skills are scanty, some studies have been conducted on Apps, science process skills, and learning in different contexts. For example, Ekanayake and Samarakoon (2016) conducted a study in Sri Lanka, on the use of an Oscilloscope App on mobile phones in a private network for science teaching. Among other findings, it was found that the App enabled students to observe and note how the waves changed according to different students' voices.

Moraes, et al., (2015) conducted a study that required university students of chemistry to use the camera App on their mobile phones to evaluate collision of iron in seawater. By the end of the experiment, it was noted that the camera App enabled students to observe and analyze color changes over time, making it possible for them to develop a procedure for evaluating the corrosion rate of iron in the simulated seawater. Further, in Wishart and Ekannayake's (2013) study on developing teachers' pedagogical practice in teaching science lessons in Sri Lanka, a scenario is reported where a teacher sent a video clip on students' mobile phones using the Bluetooth App, depicting how to construct a simple voltaic cell using a fruit. Students used the video clip to acquire skills that enabled them to set up a voltaic cell using natural fruits themselves.

Karamustafaoglu (2011) carried out a study in Turkey to establish the level of student teachers' science process skills and to determine how efficient I Diagrams were in developing these skills. Pre-test results revealed that student teachers had inadequate science process skills. However, the post-test results showed that student teachers' skills had improved greatly after I-Diagrams were used to develop their skills, pointing to the fact that different strategies can be employed to develop students' science process skills.

Therefore, this study conducted in Uganda, where WhatsApp is the most dominantly accessible mobile phone application, provided some insights as regards integrating the WhatsApp-supported instructional materials on students' science process skills in chemistry. This has contributed to existing literature, specifically regarding the use of mobile phone Apps to support teaching and learning, particularly in resource-constrained circumstances.

Theoretical Framework

This study was informed by the Social Learning Theory (SLT), put forward by Bandura (1962). According to the SLT, learning occurs within a social context, facilitated by observation, imitation, and modeling (Johnson & Bradbury, 2015; Frayne & Latham, 1987). The theory emphasizes that, behavioral, social competencies, and cognitive skills are acquired through observational learning, through which an individual observes the modeled event, forms a cognitive construct ~~which~~ that shapes future behaviors (Devi, et al., 2017).

In this study, the researcher was interested in investigating the effect of integrating the mobile phone WhatsApp-supported chemistry instructional resources in the out-of-classroom teaching and learning of chemistry on students' chemistry process skills, specifically observation, measurement, and communication, in resource-constrained private secondary schools. In relation to the SLT, it was assumed that by students watching the chemistry videos, photos, images, and reading text instructional materials delivered through the WhatsApp App could have an effect on their chemistry process skills. This way of teaching and learning fits in well with the theory principles of observation, imitation, and modeling, hence finding the theory relevant to inform this study

STUDY OBJECTIVE

The study set out to determine the effect of integrating WhatsApp-supported instructional resources in out-of-classroom teaching and learning on students' science process skills in chemistry

RESEARCH HYPOTHESIS

H_1: Integration of WhatsApp-supported instructional resources in out-of-classroom teaching and learning improves students' science process skills in chemistry.

METHODOLOGY

STUDY DESIGN

The study took a quantitative approach. The approach was appropriate because much of the relevant collected data were numerical (Creswell, 2014). (A quasi-experimental pretest-posttest nonequivalent control group design was specifically used given its reliability for studying nonrandomized subjects (Creswell, 2014; Wiersma & Jurs, 2004). Solomon's four-group design was used because it is highly recommended for achieving higher internal and external validity in quasi-experiments.

POPULATION, SAMPLING STRATEGY, AND SIZE

The parent population of this study comprised of senior secondary school students, and the unit of analysis was senior secondary three students. The study used purposive, stratified, and simple random sampling strategies. Purposive sampling was used to select the four-day instructional resource-challenged privately owned secondary schools, located in the different municipalities in Wakiso district. The selected schools were located at least fifteen kilometers apart from each other, so that students going to the respective schools cannot easily come into contact. To have equal gender representation, stratified sampling was used, with access to a smart mobile phone as a major inclusion condition for experimental schools. Simple random sampling was then used to select students from each stratum until the desired sample was achieved (Wiersma & Jurs, 2004; Wiersma, 2000; Cohen, et al., 2007). This yielded a total of 240 student respondents.

INSTRUMENTATION

A chemistry process skills achievement tests was used to collect the data. The test was administered as a pretest and posttest for data collection. Both the pretest and posttest were similar in terms of content but differed in terms of arrangement and wording of question items, as well as the physical appearance of the question papers. The tests consisted of tasks testing for observation, communication, and measurement skills. Both the pretest and posttest were validated by a chemistry teacher trainer and a senior lecturer at a university level as well as experienced teachers of chemistry at the secondary school level.

The pretest was administered to students in experimental school A and control school A. The purpose was to determine the most appropriate instructional entry point before the intervention and to establish the students' level of attainment in terms of chemistry process skills, The posttest was administered to all the participating students in the four schools (two experimental and two control schools), for purposes of determining mainly the effect of the intervention.

Data Analysis

The students' chemistry process skills test scripts were marked and scored by an independent teacher of chemistry, who was also an examiner at the Uganda National Examinations Board (UNEB). The resulting quantitative data were analyzed using the Statistical Package for Social Scientists (SPSS) software version 25.0. The independent samples *t*-tests were computed to establish the degree of variance between the groups.

The Intervention

In this study, four teachers of chemistry, each teaching in one specific privately owned resource-constrained day school in Wakiso district were purposively sampled. The sampled teachers had a teaching experience of at least six years. Additionally, they had to be the very teachers who were teaching the targeted students in the preceding class (senior two), as a way of ensuring that both the teachers and the students were already familiar with each other by the time of this study. Each of the teachers was in charge of teaching the targeted students in their respective schools for the entire period of this study.

The study targeted senior three students because being a group preceding senior four, which is the final year transitional class they were expected to be fairly focused academically but at the same time not too busy to be interrupted by the study activities. Schools were randomly assigned to either experimental (A and B) or control groups (A and B).

In the first week of the study, a pretest chemistry process skills achievement test was administered in two schools, that is experimental school A and control school B. The pretest was intended to determine the students' pre-intervention level of achievement on chemistry process skills, focusing on measurement, observation, and communication.

In the second week of the study, three chemistry teachers (at experimental schools A, B, and control school B) out of the four selected teachers embarked on teaching the agreed on topic of study in chemistry, which was qualitative analysis, to senior three students in their respective schools, in the normal classroom setting. Teaching was conducted theoretically, that is without any practical or visual demonstrations on how to use the laboratory apparatuses or reagents, as would be the case for a resource-rich teaching-learning situation.

In addition to the theoretical classroom teaching, students in experimental schools A and B were provided with the electronic chemistry instructional resources in form of video clips, photos, images, text, as well as audio recordings about the topic which the teachers were handling in the classroom. The electronic chemistry instructional materials were shared via the class WhatsApp group platform, which was accessible to students on their mobile phones or those of their guardians while at their respective homes.

Students were expected to interact with the received materials on their WhatsApp platform by reading the text, watching the video clips, observing the images and photos, among others, and relate them to the chemistry content they covered in the classroom while at school. This was aimed at reinforcing the theoretical chemistry content they covered, by carefully studying the photos and demonstrations as depicted in the electronic materials. They were also expected to use the WhatsApp platform for responding to questions or to ask questions to their peers or teachers about what was not clear and any other academic-related interactions about the topic. The teachers and students in experimental schools were provided with internet data bundles by the researcher to enable them to access and share study resources.

At control school B, much as there was teaching of the selected topic for this study, students were not provided with any supplementary electronic chemistry instructional resources, as was the case for students in experimental schools. Students only depended on theoretical classroom teaching and the notes given to them by their teacher for revision. At control school A (pure control group), students were not exposed to the content on the selected topic (qualitative analysis) for the entire study period. The teacher just proceeded with a different topic he had earlier planned to cover with those students.

After four weeks of the intervention in experimental schools, a posttest chemistry process skills achievement test was administered in all four schools. Table 1 shows the summary of the experiment setup with the corresponding sample size of students in the brackets.

Table 1
Adapted Solomon's Four Group Design experimental setup

Group	Pretest	Intervention	Posttest
E_A	T_1 (s79)	X	T_2 (s36)
E_B	-	X	T_2 (s57)
C_A	T_1 (s47)	-	T_2 (s33)
C_B	-	-	T_2 (s57)

Where, E=Experimental group, C= Control group
T_1 = Pretest T_2 = Posttest
X = WhatsApp-supported chemistry electronic instructional resources (Experimental Treatment)
S = Sample size

From Table 1, posttest (T_2) results of groups E_A and C_A were compared to investigate if there was a statistically significant difference in students' chemistry process skills achievement test mean scores between the two schools. The posttest results of groups E_B and C_B that did not sit for the pretest were used to validate the contribution of the treatment or intervention on the students' scores.

Posttest results of groups C_A and C_B were used for investigating if there were any testing effects in the study. The posttest results of groups E_A and E_B were compared with the posttest results of groups C_A and C_B to validate the results of testing effects in the study. By carrying out these tests, it was possible to rule out the major internal and external threats to validity of the results, common in quasi-experimental studies.

Results and Discussion

In order to run the parametric analysis, data were tested for normality, and the results are presented in Figure 1.

Figure1
Histogram for posttest chemistry process skills achievement test scores

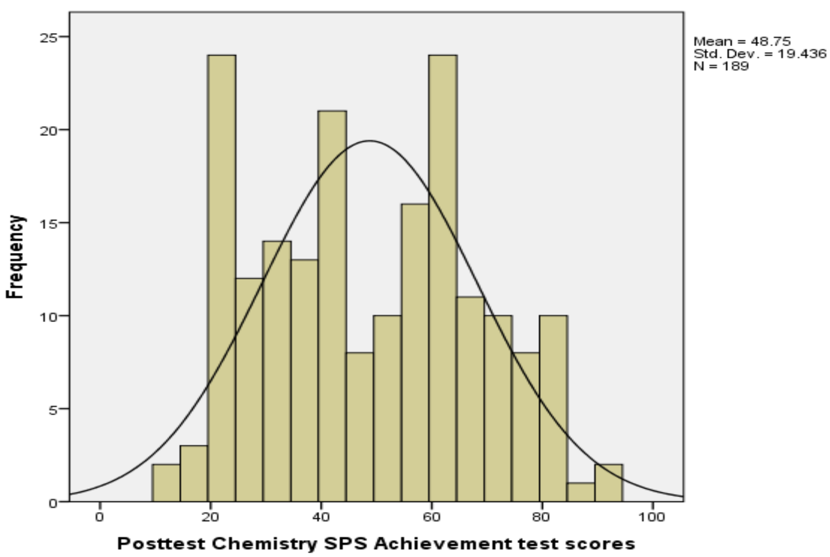

Figure 1 indicates that students' posttest scores in chemistry process skills achievement test were approximately normally distributed. Therefore, the data were fit for parametric tests.

The main research hypothesis for this study stated, H_1: Integration of WhatsApp-supported instructional resources in the out-of-classroom teaching-learning process improves students' science process skills in chemistry. To effectively address the stated hypothesis, the following null hypotheses were tested.

- H_{01}. *There's no statistically significant difference in students' pretest chemistry process skills achievement test mean scores for experimental school A and control school A.*
- H_{02}. *There's no statistically significant difference in students' posttest chemistry process skills achievement test mean scores for experimental school A and control school A.*
- H_{03} *There's no statistically significant difference in students' posttest chemistry process skills achievement test mean scores for experimental school B and control school B.*
- H_{04}. *There's no statistically significant difference in students' posttest chemistry process skills achievement test mean scores for control school A and control school B.*
- H_{05}. *There's no statistically significant difference in students' posttest chemistry process skills achievement test mean scores for experimental school A and experimental school B.*

Tests on each of the stated null hypotheses were conducted and the results are presented as follows.

Hypothesis H_{01}. *There's no statistically significant difference in students' pretest chemistry process skills achievement test mean scores for experimental school A and control school A.*

The rationale behind testing this hypothesis was to establish if students from experimental school A and control school A were relatively at the same level, regarding achievement in science process skills in chemistry before the intervention. Results are presented in Tables 2 and 3.

Table 2

Pretest chemistry process skills achievement test mean scores for experimental school A and control school A.

	School category	N	Mean	Std. Deviation	Std. Error Mean
Pretest chemistry PS	Experimental school A	72	27.93	10.368	1.222
	Control school A	47	27.68	9.220	1.345

Table 2 shows that the mean test scores for the two schools were almost the same and the standard deviations dispersed almost equally (experimental school A- M=27.93, SD=10.368 and control school A- M=27.68, SD=9.22). To test if there was any significant difference between the two means, the independent samples *t*-test was computed and the results are presented in Table 3, followed by the corresponding effect size (R^2).

Table 3

Independent samples t-test for pretest chemistry process skills achievement test mean scores for experimental school A and control school A

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
Pretest Chemistry PS	Equal variances assumed	.905	.343	.134	117	.894
	Equal variances not assumed			.137	106.344	.891

Source: Primary data

As shown in Table 3, the computed independent samples *t*-test indicates that there was no statistically significant difference in students' pretest mean scores between experimental school A and control school A (sig. 2-tailed 0.894). The computed R^2 =0.000 also points to a very small difference effect, hence accepting the null hypothesis $\boldsymbol{H_{01}}$. This implies that students from both schools were at relatively the same level, in terms of achievement on chemistry process skills before the intervention.

Hypothesis H_{02}. *There's no statistically significant difference in students' posttest chemistry process skills achievement test mean scores for experimental school A and control school A.*

The purpose of this hypothesis test was to establish if there was a statistically significant difference in students' posttest chemistry process skills achievement test mean scores between experimental school A, where the mobile phone WhatsApp-supported instructional resources were used and control school A, where the instructional resources were not used. Results are presented in Tables 4 and 5.

Table 4
Students' posttest chemistry process skills achievement test mean scores for experimental school A and control school A group statistics.

	School Category	N	Mean	Std. Deviation	Std. Error Mean
Posttest Chemistry PS	Experimental school - A	53	64.08	13.508	1.855
	Control school - A	33	24.27	5.513	.960

Table 4 displays a higher posttest mean score for experimental school A (M=64.08, SD=13.508) as compared to that of control school A (M=24.27, SD=5.513). To test if the difference in mean scores were statistically significant, the independent samples *t*-test was computed. The results are presented in Table 5, followed by the corresponding effect size (R^2), to establish the magnitude of the difference.

Table 5
Posttest independent samples t-test for chemistry process skills achievement test mean scores for experimental school A and control school A

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
Posttest Chem. PS	Equal variances assumed	26.862	.000	16.085	84	.000
	Equal variances not assumed			19.054	74.840	.000

Source: Primary data

As shown in Table 5 the computed independent samples *t*-test reveals that there was a statistically significant difference (sig. 2-tailed 0.000) in the posttest mean scores between experimental school A and control school A. The computed R^2=0.81 indicates a very large difference effect, hence rejecting the null hypothesis H_{02}.

In reference to Table 3, there was no statistically significant difference in the pretest mean scores between the two schools before the intervention. Therefore, the significant difference in scores between the two schools, with the experimental school having a higher mean score, suggests that the use of mobile phone WhatsApp-supported instructional resources could partly explain the difference. To confirm these results, a comparison was made with schools where the pretest was not administered, as indicated in hypothesis H_{03}.

Hypothesis ***H_{03}***. *There's no statistically significant difference in students' posttest chemistry process skills achievement test mean scores for experimental school B and control school B.*

The purpose of testing this hypothesis was to establish if there was any significant difference in students' posttest chemistry process skills achievement test mean scores between e experimental school B and control school B, where students never sat for the pretest. The results are shown in Tables 6 and 7.

Table 6

Posttest chemistry process skills achievement test mean scores for experimental school B and control school B group statistics.

	School Category	N	Mean	Std. Deviation	Std. Error Mean
Posttest Chemistry PS	Experimental school -B	46	63.85	10.226	1.508
	Control school -B	57	36.49	9.042	1.198

As displayed in Table 6, the posttest mean score for experimental school B (M=63.85, SD=10.226) is greater than that for control school B (M=36.49, SD=9.042). To establish if the difference in mean scores was statistically significant, the independent samples *t*-test was computed and the results are presented in Table 7.

Table 7

Independent samples t-test for students' posttest chemistry process skills mean achievement test scores for experimental school B and control school B.

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
Posttest chem. PS	Equal variances assumed	.760	.385	14.396	101	.000
	Equal variances not assumed			14.207	90.687	.000

Source: Primary data

The computed posttest independent samples *t*-test for the two schools was statistically significant, sig. 2-tailed 0.000 (Table 7). The computed R^2=0.67 shows a very large difference effect, hence rejecting the null hypothesis ***H_{03}***.

Given that students from both schools (experimental school B and control school B) did not write the pretest, but the only difference was the utilization of the mobile phone WhatsApp-supported instructional resources in experimental school B, the results confirm that the electronic instructional resources contributed to the difference in mean scores, given that experimental school B had a higher mean score.

***Hypothesis H_{04}.** There's no statistically significant difference in students' posttest chemistry process skills achievement test mean scores for control school A and control school B.*

The purpose of testing the stated hypothesis was to establish if teaching students chemistry theoretically in the classroom had a significant effect on the posttest results. The results were also used to test for any testing effects in the study. Results are indicated in Tables 8 and 9.

Table 8

Students' posttest chemistry process skills achievement test mean scores for control school A and control school B group statistics

	School Category	N	Mean	Std. Deviation	Std. Error Mean
Posttest Chem. SPS	Control school - A	33	24.27	5.513	.960
	Control school - B	57	36.49	9.042	1.198

As displayed in Table 8, the posttest mean score for students from control school A (M=24.27, SD=5.513) was less than that for students from control school B (M=36.49, SD=9.042). Students from control school A sat for the pretest but did not receive any teaching about the topic of interest in this study (qualitative analysis). Students from control school B did not write the pretest but received the theoretical teaching, though without the additional support of the WhatsApp-supported instructional resources. To test whether the difference in mean scores was statistically significant, the independent samples *t*-test was computed and results are presented in Table 9.

Table 9

Independent Samples t-test for students' posttest chemistry process skills achievement test mean scores for control school A and control school B

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
Posttest students' chemistry PS	Equal variances assumed	6.837	.011	-7.033	88	.000
	Equal variances not assumed			-7.962	87.716	.000

Source: Primary data

As shown in Table 9 , the computed independent samples *t*-test reveals that there was a statistically significant difference (sig. 2-tailed = 0.000) in students' posttest mean scores between control school A and control school B. The computed R^2=0.02, pointed to a very small difference effect, hence rejecting the null hypothesis H_{04}.

Given that students from control school B received the theoretical teaching, yet those from control school A did not, it points to the contribution of teaching for effective learning to occur, explained by a higher mean score for students in control school B as compared to control school

A. Secondly, the results provide support to rule out any testing effects in the posttest results. This is evidenced by a low mean score for students in control school A, who sat for the pretest, as compared to control school B, where students did not. The testing effects would have been reflected by control school A having a higher mean score compared to control school B, which was not the case.

Hypothesis $H_{05.}$ *There's no statistically significant difference in students' posttest chemistry process skills achievement test mean scores for experimental school A and experimental school B.*

The rationale for testing the stated research hypothesis was to establish if there were any learning effects in the posttest results of chemistry process skills achievement test for experimental school A whose students participated in the pretest. Results are presented in Tables 10 and 11.

Table 10
Posttest chemistry process skills achievement test mean scores for experimental school A and experimental school B group statistics.

	School Category	N	Mean	Std. Deviation	Std. Error Mean
Posttest Chem. SPS	Experimental school – A	53	64.08	13.508	1.855
	Experimental school – B	46	63.85	10.226	1.508

Table 10 reveals that students from experimental school A performed slightly better (M=64.08, SD=13.503) than students from experimental school B (M=63.85, SD=10.226). To establish if the difference was statistically significant, the independent samples *t*-test was computed. The results are presented in Table 11.

Table 11
Independent sample t-test for posttest chemistry process skills achievement test mean scores for experimental school A and experimental school B

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
Posttest chemistry process skills	Equal variances assumed	5.462	.021	.093	97	.926
	Equal variances not assumed			.095	95.321	.924

Source: Primary data

Table 11 shows that the computed independent samples *t*-test of sig. 2-tailed = 0.924 was not significantly different. The computed R^2 =0.00, shows a very small difference effect, hence accepting the null hypothesis H_{05}This rules out any testing effects in the study, because if there were any such effects, students from experimental school A who participated in the pretest would have had a higher mean score as compared to those from experimental school B who did not write the pretest.

The findings from this study have indicated that the students' mean test scores on chemistry process skills were higher in experimental schools as compared to those in control schools. This implies that the repeated watching of the videos and observing photos on how specific practical procedures were conducted contributed to students' improvement in observation, measurement, and communication skills. This study finding is largely in agreement with studies conducted by Ekanayake & Samarakoon, 2016, Moraes, et al., 2015, Wishart & Ekannayake, 2013, although their studies were conducted using different Apps. While the ideal learning environment that can enable students to develop the appropriate science process skills is that with a well-equipped science laboratory (Ozgelen, 2012), this study findings point to the possibility of exploring Apps such the WhatsApp for purposes of sharing electronic instruction resources, in circumstances where access to well-facilitated science laboratories is a challenge to students. The WhatsApp App specifically is of an advantage, given its popularity among teenage students (Alsleem, et al., 2019). The App also has the capacity to share a variety of multimedia instructional resources, which allows learners ample time to interact with the learning resources as often as they wish for learning purposes, at the comfort of their mobile phones and during times when they do not have lessons, for example, while at home (Durgungoz & Durgungoz, 2021). The WhatsApp group platform equally created a window for peer academic interactions, through which they asked relevant questions in the group and got feedback at any time. This minimized the limitations to asking questions while in the physical classroom setting by students, such as shyness and fear among others. (Hamidy, et al., 2015).

CONCLUSION

We have argued that the use of the electronic chemistry instructional resources supported on the mobile phone WhatsApp App by students improves their science process skills in chemistry, particularly in the case of students in secondary schools where access to adequate physical science instructional resources is a challenge. The improvement in skills is partly attributed to students' taking advantage of the App for receiving and sharing instructional resources in a variety of formats, for example, text, pictures, audio, and videos, which they can read, listen to and watch repeatedly until when the desired skill is achieved. However, we emphasize that a well-resourced science laboratory is the best learning environment for students to develop key science process skills. But in situations where such resources cannot be easily accessed by students, particularly in the underdeveloped and developing parts of the world, teachers and students can take advantage of mobile phone technology, along with the associated Apps such as WhatsApp to facilitate teaching and learning.

LIMITATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

This study bears some limitations that need to be considered while interpreting the results of the study. This study was conducted during the COVID-19 period. This affected the initial design of the study, specifically in terms of choice of teachers who were to teach students in the schools. The initial teaching strategy was to have only two teachers participate in the study, whereby each teacher was to teach in two schools (an experimental and a control school). This was intended to control the teacher-related characteristics, such as teacher experience, personality, and teaching style among others, which have an impact on students' learning. But, the Ministry of Health guidelines on teaching in schools barred teachers from teaching in more than one school, as one of the strategies for minimizing the spread of the COVID-19 virus. This forced the researcher to engage four chemistry teachers, with relatively the same years of teaching experience, each to teach in one school. The difference in teachers' teaching performance could have affected the study results in one way or another.

Therefore, a study with well-controlled teacher factors is highly recommended, to establish if it could yield similar findings. Secondly, a replica study in other science subject areas such as physics and biology among others is equally recommended.

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