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Impact of 21st-Century Collaboration on Pre-Service Science Teachers' Understandings of Acid-Base Concepts in Selected Science Colleges of Education in Ghana

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Abstract

This study investigated the impact of 21st-century collaboration on pre-service teachers' comprehension of acid-base concepts in selected science colleges of education in the Volta Region of Ghana. A pre-test/post-test quasi-experimental design with a non-equivalent control group was used in this study. The Acids-Bases Chemistry Achievement Test (ABCAT) was adapted from Damanhuri, Treagust, Won, and Chandrasegaran, (2016) to evaluate the extent to which pre-service science teachers in Ghanaian science colleges of education achieved the intended curriculum on acid-base concepts, specifically, concentration in mol/dm^3 or g/dm^3, properties of acids and bases, pH, pOH, neutralisation reaction and titrimetry. A sample of 52 second year pre-service science teachers from two intact science

colleges of education was conveniently selected to participate in the study. An ABCAT comprising 19 items made up of 10 multiple-choice items and nine two-tier multiple-choice items was administered to pre-service science teachers as pre-test and post-test. Students taught with the 21st-century collaboration performed better than those taught using the Lecture method (LM) concerning acid-base conception when one-way between-group analysis of covariance (ANCOVA) and post hoc analysis with a Bonferroni adjustment was conducted on ABCAT. The results suggest that 21st-century collaboration facilitated the conceptual understandings of pre-service teachers in the experimental group.

Keywords: acid-base concepts; 21st-century collaboration, lecture method; multiple-choice and two-tier multiple-choice items; pre-service science teachers

Introduction

The US-based Partnership for 21st Century Skills (hereinafter P21), a coalition of business leaders and educators, proposed a Framework for 21st Century Learning, which identified essential competencies and skills vital for success in twenty-first-century work and life (P21, 2007a, 2011). These included 'The 4Cs' – communication, collaboration, critical thinking, and creativity, which are to be taught within the context of core subject areas and twenty-first-century themes. Research has shown that during collaboration, students have the opportunity to discuss, practice by doing and teaching each other, which ultimately enhances their creative, critical, and innovative skills. Educators in a variety of educational settings have over the years used collaborative approaches to teaching and assessing students. Of late, it has been observed that educators and policy formulators have identified the ability to collaborate as an important outcome in its own right rather than merely a means to an end. This is the reason why the Partnership for 21st Century Skills has identified collaboration as one of several learning and innovation skills that are important for post-secondary education and workforce success. Accordingly, collaborative learning is broadly defined as "a situation in which two or more people learn or attempt to learn something together," and more specifically as joint problem solving (Dillenbourg, 1999, p. 1). Based on this preamble the researchers decided to adopt 21st-century collaboration to teach the topic acid-base concepts to pre-service teachers in selected science colleges of education in Ghana.

Various textbooks have indicated that there are three major classifications of the substances known as acids or bases. The commonest is the Arrhenius definition which states that an acid produces H^+ ions in solution and a base produces OH^- ions in solution (Broderick, Moussa, & Clark, 2020; Wong, 2017). This theory was developed by Svante Arrhenius in 1883. Later, two more sophisticated and general theories were proposed. These are the Brønsted-Lowry and the Lewis definitions of acids and bases. However, in this article, only issues related to the Arrhenius definition has been considered as that relates to the junior high school (JHS) curriculum in Ghana. In 1884, the Swedish chemist Svante Arrhenius proposed two specific classifications of compounds; acids and bases. When dissolved in an aqueous solution, certain ions were released into the solution. An Arrhenius acid is a compound that increases the concentration of H^+ ions that are present when added to water. These H^+ ions form the hydronium ion (H_3O^+) when they combine with water molecules. This process is represented in a chemical equation by adding H_2O to the reactants side (Broderick, Moussa, & Clark, 2020; Wong, 2017).

$$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

In this reaction, hydrochloric acid (HCl) dissociates completely into hydrogen (H^+) and chlorine (Cl^-) ions when dissolved in water, thereby releasing H^+ ions into solution. Formation of the hydronium ion equation:

$$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

Similarly, an Arrhenius base is a compound that increases the concentration of OH^- ions that are present when added to water. The dissociation is represented by the following equation:

$$NaOH_{(aq)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$$

In this reaction, sodium hydroxide (NaOH) dissociates into sodium (Na^{+}) and hydroxide (OH^{-}) ions when dissolved in water, thereby releasing OH^{-} ions into solution.

However, this seemingly straightforward topic on acids and bases has posed many problems to students of various backgrounds. From as early as several decades ago the topic on acids and bases has been reported to be difficult for high school science students (Burns, 1982) who have as a result held several alternative conceptions about acids and bases (Cros et al., 1986; Hand & Treagust, 1991; Nakhleh & Krajick, 1993). Even until recently, several studies have been documented that refer to alternative conceptions about acids and bases that are held by students and teachers alike (Artdej et al., 2010; Chiu, 2004, 2007; Kala, Yaman & Ayas, 2013; Sheppard, 2006; Drechsler & Van Driel, 2008, 2009). As studies involving students' difficulties in understanding acid-base concepts date back several decades, in this paper we have decided to refer to studies that have identified several alternative conceptions about acids and bases among students and teachers that were conducted within the past four decades.

A review of related literature has revealed that researchers have mainly focused on assessing high school pre-service and in-service chemistry teachers' (e.g. Cetin-Dindar, & Geban, 2011; Karsli & Ayas, 2013) and students' understanding of acid-base concepts (e.g. Kala, Yaman & Ayas, 2013; Sheppard, 2006). Less attention has been paid to junior high school pre-service science teachers' understanding of acid-base concepts (Damanhuri, Treagust, Won, & Chandrasegaran, 2016). Yet when junior high school pre-service science teachers are employed in schools, they teach basic acid-base concepts to students. The pre-service science teachers used in this study are trained to teach science at the junior high school level in Ghana. Nevertheless, research shows that teachers' conceptual knowledge with the subject matter influences their teaching methodologies (e.g. Yilmaz & Bayrakçeken, 2015), and subsequently on students' achievement (e.g. Amponsah, & Mohammed, 2019); Demircioğlu, Ayas, & Demircioğlu, 2005). If these pre-service science teachers have alternative conceptions then these will automatically be transferred to their learners. It is against this backdrop that an investigation into the impact of 21st-century collaboration on pre-service science teachers' understandings of acid-base concepts in selected science colleges of education in Ghana cannot be overemphasised. This paper is structured subsequently by interrogating issues related to the theoretical framework that underpins the study, specifically social constructivism and 21st century collaboration. This is followed by the empirical review which seeks to discuss relevant studies concerning students' conceptions of acids and bases. The purpose and significance of the study are examined and the research question and hypotheses explored. Similarly, the research design discusses the sample and sampling techniques, instrumentation, method of data collection and analysis. The results obtained are discussed based on the research question and hypotheses, and the conclusion made on main findings.

Theoretical Framework

According to the constructivist view of learning, what a learner already knows is a major factor that determines the outcomes of learning (Ausubel, 1968). Students develop their views about scientific concepts and phenomena based on their sensory experiences, cultural backgrounds, peers, mass media as well as classroom instruction (Chandrasegaran, Treagust & Mocerino, 2008). There is a tendency for students to be satisfied with their conceptions because they are often deeply rooted and supported in their daily life experiences (Chandrasegaran, Treagust & Mocerino, 2008). Unfortunately, students' views on science concepts and phenomena could differ from scientifically acceptable conceptions and may cause learning difficulty, especially when the new science concepts are not aligned with their prior experience or conceptual framework. When the new science concepts do not make sense to them, students tend to adhere firmly to their private views. Consequently, it is beneficial to identify students' understandings about various science concepts so that appropriate instructional strategies may be formulated to challenge and facilitate students' understandings of science concepts (Amponsah & Ochonogor, 2018; Chandrasegaran, Treagust, & Mocerino, 2008).

Vygotsky (1962, 1978) defined social constructivism as a sociological theory of knowledge that applies the general philosophy of constructivism into social settings. He indicated that social constructivism has three components: (a) knowledge and knowing to originate in social interaction; (b) learning proceeds from the inter-psychological plane (between individuals) to the intra-psychological (within an individual) plane with the assistance of knowledgeable members of the culture; and (c) language mediates experience, transforming mental processes. Additionally, Mercer (2002) emphasised that science teachers should understand the importance of constructivism especially in terms of the discourse that happens. A couple of the forefront principles of Vygotsky's theories on cognitive development: the More Knowledgeable Other (MKO) and the Zone of Proximal Development (ZPD) have been used in classroom settings to enhance student achievement. According to McLeod (2014), the MKO is indicative of someone who is equipped with a comparatively superior understanding or otherwise a superior range of abilities for the particular task, process, or concept. McLeod argued that MKO can refer to a teacher or an older adult, or the peer group of students, or subsequently an adult who has acquired pertinently more knowledge and also experience. McLeod went further to indicate that MKO need not be indicative towards an existent individual. E-Tutors may be used in the education set-up to expedite and also direct the students through the requisite learning procedure. In summary, a common denominator is indicative of the proposition that MKOs should wield more knowledge than the learners about the particular topic being taught to them. Furthermore, the idea of MKO is inextricably linked to the Zone of Proximal Development. ZPD relates to the pertinent contrast between the extent to what can be achieved by a student in an individual context as opposed to what are the horizons of an individual's achievement endowed with the necessary counsel as well as fortification garnered in association with a skilled partner (McLeod, 2014). Research in chemistry has indicated that consensus-building during discourse results in what they term as the concept of *knowledge creation*, which can be construed as '*the production of knowledge*

that adds value to the community' (Bereiter & Scardamalia, 2010; Scardamalia & Bereiter, 2006). "This model of knowledge building postulates that knowledge advancement is the collective work of a community, analogous to scientific communities and that knowledge is improvable through discourse" (Chan, Lam & Leung, 2012, p. 201-202). Even though it is believed that comprehensive classroom discourse can improve students' achievement, some researchers have indicated that some students still perform poorly as a result of their inability to connect various concepts of solving science problems (Ahmad, & Che Lah, 2012; Amponsah, Kotoka, Beccles, & Dlamini, 2018).

Empirical Framework

Understandings of acid-base concepts

In another study using POE activities and interviews with 27 high school students, Kala, Yaman, and Ayas (2013) investigated their understandings of acids and bases. "Some of the students were found to have alternative conceptions about pH and pOH. In one of the POE tasks, the students were required to predict the pH and pOH sequence for substances like tap water, lemon juice, and HCl. The expected sequence of $pH_{HCl} < pH_{lemon\ juice} < pH_{tap\ water}$, with the reverse order for pOH, was provided by 21 of the students, but only one student gave the correct explanation for the reason for the sequence. At the same time, only four students provided partially correct reasons for the prediction. In conclusion, most students believed that pH was associated with acids and pOH with alkalis" (Yaman & Ayas, 2013, p. 1).

A study on identifying students' misconceptions of acid-base concepts using a three-tier diagnostic test: a case of Indonesia and Thailand, was conducted by Mubarokah, Mulyani and Indriyanti (2018). The results revealed that "most of the students had misconceptions of such concepts as acid-base theories, the strength of acids and bases, pH concept in electrolyte and non-electrolyte characteristics of acids and bases. The results also shed more light on students' conceptual understanding. It was concluded that students should be encouraged to overcome their misconceptions and change their scientific conceptions" through using specific teaching strategies (Mubarokah, Mulyani, & Indriyanti, 2018, p. 1). Similarly, an investigation was conducted into students' misconceptions of acid-base titration assessments using a two - tier multiple-choice diagnostic test. The results revealed that the students lacked deep understanding of acid-base reactions which consequently affected their performance in learning acid-base titrations (Supatmi, Setiawan, & Rahmawati, 2019). Pohan and Syahwin (2017) conducted a research on identification of acid-base concept understanding using the assessment of a two tier multiple choice diagnostic ınstrument. At the end of the research it was seen from the results of the scores of students that as much as 47% had low understanding level and 53% had medium understanding level of concepts related to acids and bases. Regrettably, in the high category none of the students had high level of understanding (Pohan & Syahwin, 2017).

Demircioğlu, Ayas, and Demircioğlu (2005) used a conceptual conflict instructional strategy to remediate alternative conceptions that were held by 88 grade 10 students (aged 16-17 years) from a high science college of education in Turkey. They utilised a pretest-posttest control group-experimental group design, where two different teachers taught two groups (control

and experimental) that were each made up of two classes. “Part of the study involved using a Concept Achievement Test (CAT) consisting of 20 multiple-choice items on acid-base concepts that was administered before and after instruction. During instruction of the students in the experimental group, the teacher attempted to help the students to recognise and resolve the conflict between their knowledge and scientific knowledge using worksheets, analogies, and practical work. The control group students, on the other hand, were instructed in a traditional manner involving chalk-and-talk and some practical work. There was no significant difference in the pretest mean scores of the two groups indicating that the students in the two groups were equivalent. However, when the mean posttest scores of the two groups were compared after instruction using an independent samples t-test, there was a significant difference in the scores with the students in the experimental group achieving higher mean scores [(experimental group: $M = 73.9$, $SD = 12.7$); (control group: $M = 60.0$, $SD = 15.9$); $t = 4.50$, $p < 0.001$]. Before instruction, the percentage of misconceptions held by students in the experimental group ranged from 18% to 84%, while that in the control group it ranged from 20% to 95%. After instruction, the results showed that the percent performance for the experimental group ranged from 0% to 23% and that for the control group from 2% to 43%” (Demircioğlu, Ayas, & Demircioğlum 2005, p. 1). This finding suggests that the conceptual change teaching strategy used for the experimental group facilitated their conceptual understanding.

Correspondingly, a study was conducted on high school students’ understanding of acid-base concepts: an ongoing challenge for teachers (Damanhuri, Treagust, Won & Chandrasegaran, 2016). “The researchers used a quantitative case study design to develop the Acids-Bases Chemistry Achievement Test (ABCAT) to evaluate the extent to which students in Malaysian secondary schools achieved the intended curriculum on acid-base concepts. Responses were obtained from 260 Form 5 (Grade 11) students from five schools to initially create the two-tier multiple-choice items. After pilot testing, the final version of the ABCAT consisting of 19 items, 10 multiple-choice items and nine two-tier multiple-choice items was administered to 304 students in Form 4 (Grade 10) from seven secondary schools when 12 alternative conceptions were identified by at least 10% of the students. Of these alternative conceptions, three were displayed by less than 15% of students. The data from the study suggest that the ABCAT has shown the extent to which the teaching has reduced the incidence of students’ scientifically inappropriate understandings; for example, in nine of the 19 items, no alternative conceptions were displayed by the students” (Damanhuri, Treagust, Won & Chandrasegaran, 2016, p.1).

Purpose of the study

The study used 21st-century collaboration as a teaching strategy to determine its effect on pre-service teachers’ comprehension of acid-base concepts in selected science colleges of education in Ghana. The study focused on the outcome of students’ negotiation during collaborative learning.

Significance of the study

First, this study will illuminate the sources of pre-service science teachers' misconceptions, miscomprehension, and difficulties of acids and bases. It will promote comprehensive discourse in the problem areas among pre-service science teachers to generate positive cognitive conflicts that will enhance conceptual comprehension, conceptual change, problem-solving capabilities, and the resultant improvement of students' performance. Secondly, the study will unearth and document practices and situations in both the control and the experimental groups, which might give some insight into the factors contributing to the low performance of students in acids and bases. This study will also provide useful information as to the processes that students go through in solving a particular problem through collaboration to finally come up with a plausible solution.

Research question

One research question was framed for this study:

1. What is the impact of 21st-century collaboration as a teaching strategy on pre-service science teachers' comprehension of acid-base concepts?

Hypotheses

The following hypotheses were framed for this study:

1. **Ho$_1$**: There is no significant interaction effect between the lecture method and 21st-century collaboration concerning pre-service teachers' comprehension of acid-base concepts (post-test scores).

2. **Ho$_2$**: There is no statistically significant mean difference between post-test and pre-test mean scores of pre-service science teachers taught with 21st-century collaboration and those taught with the lecture method concerning their comprehension of acid-base concepts.

Method

Research Design

The researchers found that a quasi-experimental design was suitable for the research as it was impossible to casually allocate pre-service science teachers to a specific class division; hence the researchers employed the convenience sampling technique (Gliner, Morgan, & Leech, 2011). For instance, in the research science college of educations, the researchers did not casually allocate students as individuals to investigative groups and control groups as the science college of education timetable could not be altered for the current research. For example, all students in a specific classroom were casually allocated as an intact group to act as the Experimental Group (EG) or Control Group (CG). The main research employed two pre-established or intact groups (classes), made up of two science colleges of education in the Volta Region of Ghana. One of the colleges was conveniently sampled as the EG and the other, the CG.

Sample and Sampling Technique

The sample of the study consisted of fifty-two second year pre-service science teachers, which was randomly selected using the table of random numbers from four science colleges of education in the Eastern and Volta Regions. One of the colleges formed the experimental group and the other formed the control group. Table 1 presents the distribution of the sample with respect, college-type, and age range.

Table 1. Distribution of the sample across college-type and age range

Variables	Subscale	Freq.	Percent %
College-type	Control group	25	48.1
	Experimental group	27	51.9
Age Range	17-19	25	48.1
	20-22	24	46.1
	23-25	2	3.9
	26 or more	1	1.9

These two schools were randomly selected from four colleges using the table of random numbers. The experimental group consisted of 27 pre-service science teachers who followed the designed teaching sequence called 21st-century collaboration whilst a baseline class of 25 pre-service science teachers served as a comparison group and followed a similar curriculum but used normal classroom teaching termed lecture method. Regarding the age range, it was observed that the majority (48.1%) of the students were aged between 17 and 19. A few (1.9%) of the pre-service science teachers were more than 26 years.

Instrumentation

The data collected in this study was mainly focused on the responses in the post-diagnostic test. The instrument used is Acids-Bases Chemistry Achievement Test (ABCAT) and was to evaluate the extent to which pre-service teachers in Ghanaian science colleges of education achieved the intended curriculum on acid-base concepts. Some parts of the instruments were developed by the researchers and some adapted from (Damanhuri, Treagust, Won, & Chandrasegaran, 2016) and validated by some experienced chemistry tutors at the colleges. In this paper, only the data on ABCAT in the pre and post-diagnostic tests are presented. The final version of the ABCAT consists of 19 items, 10 multiple-choice items, and nine two-tier multiple-choice items. The first tier of each pair of questions was based on procedural knowledge and the second tier was based on conceptual knowledge, with the pre-service teachers choosing a reason for their choice in the first tier. This type of questioning has the potential to distinguish between procedural knowledge and conceptual knowledge when examining student work (Treagust, 1988).

Method of Data Collection

Of the two schools selected for the research, one school represented the control group and was taught using the lecture method and the other school represented the experimental group taught using 21st-century collaboration. The ABCAT was administered as a pre-test in the

fourth week of September 2018, before instruction began in the fifth week of September 2018. The post-test was administered after treatment, precisely in the second week of November 2018. The ABCAT involved a pencil and paper test on acid-base concepts for the post-test. Two chemistry tutors from each of the research science colleges were trained by the researchers for the study.

Analysis of Data

After meeting all the assumptions for the use of ANCOVA, the data obtained to answer research question one were analysed using descriptive statistics specifically means standard deviations and standard scores. This was because the research question sought to investigate the extent to which the teaching strategies have influenced pre-service teachers' conceptual understandings of acids and bases. One-way analysis of covariance (ANCOVA) was used to test the null hypothesis. The intent was to test whether pre-service teachers differ in terms of the teaching strategy used or whether there was an interaction effect on the teaching strategies used.

Results and Discussion

The researchers used mean and standard deviation to find out whether the 21st-century collaboration used in the study impacted on the performance of pre-service science teachers. One of the two colleges formed the experimental group, whereas the other formed the control group of a major study. The 21st-century collaborative discourse was used to ascertain its effectiveness on pre-service science teachers' achievement on acid-base concepts. The interaction term was not included in the ANCOVA output in Table 5 as the presumption of homogeneity of regression slopes has already been validated in the scatter plot.

Research question 1: What is the impact of 21st-century collaboration as a teaching strategy on pre-service science teachers' comprehension of acid-base concepts? To answer this question, the mean and standard deviation for pre-service science teachers were found. Table 2 presents the post-test means and standard deviations of pre-service science teachers, taught using collaboration and lecture method.

Table 2. Mean and Standard Deviation for the experimental and control group

Teaching Method	Mean	Standard deviation	N
Experimental group	61.85	6.225	27
Control group	48.00	4.787	25
Total	55.19	8.909	52

The results from Table 2 indicate that the mean post-test ABCAT score (61.85 ± 6.23) for the experimental group was higher than the mean post-test ABCAT score (48.00 ± 4.79) for the control group. This suggests that 21st-century collaboration facilitated acids-bases concept achievement in the experimental group compared to the control group.

A Bonferroni adjustment was executed to conduct a Post hoc evaluation as shown in Table 3 to find out whether the mean differences are statistically significant.

Table 3. Pairwise comparison between experimental and control groups

Science college of education	Type	Mean Difference	Std. Error	Sig.
experimental group	control group	11.095*	1.534	.0005
control group	experimental group	-11.095*	1.534	.0005

** The mean difference is significant at the .05 level.*

From Table 3, the experimental group had the highest post-test scores, which was statistically significantly greater than the post-test scores of the control group ($p < .001$), with a mean difference of 11.095. The pairwise comparison showed that there was a significant disparity amongst the post-test mean scores of the experimental group and control group concerning the comprehension of acid-base concepts.

Ho_1: There is no significant interaction effect between the lecture method and 21st-century collaboration regarding pre-service science teachers' comprehension of acid-base concepts (post-test scores)**.** To test for an interaction effect between the type of teaching strategy, it was presumed that the pre-test shared a linear correlation with the post-test, for all groups of the independent variable, teaching method. A scatterplot of the post-test against the pre-test grouped on the type of teaching method was plotted. The result is as shown in Figure 1, which indicates a linear correlation between pre-test and post-test scores for each intervention type for the type of teaching method, as evaluated by visually examining the scatterplot. Furthermore, the interaction effect was statistically tested by determining whether there is a statistically significant interaction term, type teaching method*pre-test. In other words, there should be no interaction between the covariate, pre-test, and the independent variable, type of teaching method.

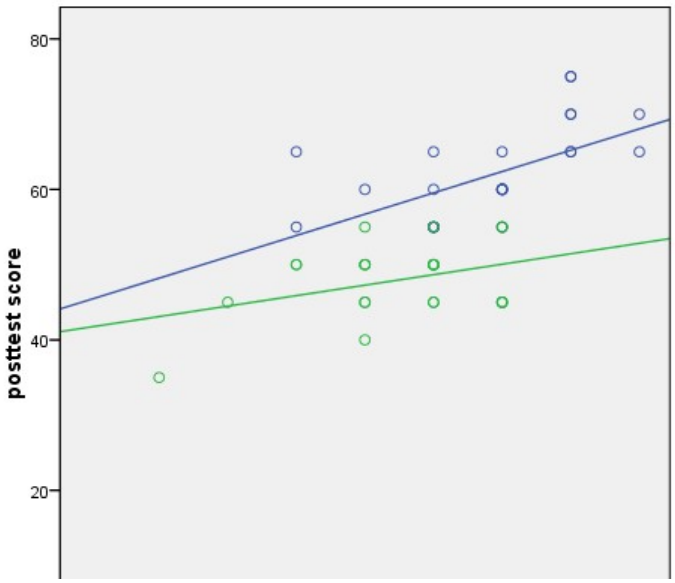

Figure 1. Scatterplot of post-test against pre-test grouped on type of Science College of education

To do this, a general linear model univariate analysis was conducted. The result showed that the interaction term was not statistically significant indicating that there was homogeneity of regression slopes, F (1,48) = 1.801, p = .186. This suggests that the regression lines in the Scatterplot must be parallel.

Table 4. Test for homogeneity of regression slopes

Source	Type III Sum of Squares	df	Mean Square	F	Sig	Partial Eta Squared
Corrected Model	2906.643[a]	3	968.881	40.744	.000	.349
Intercept	1180.789	1	1180.789	49.655	.000	.310
tm	1.069	1	1.069	.045	.833	.039
pre	367.358	1	367.358	15.448	.000	.254
tm * pre	42.820	1	42.820	1.801	.186	.007
Error	1141.434	48	23.780			
Total	162450.000	52				
Corrected Total	4048.077	51				

a. R Squared = .718 (Adjusted R Squared = .700)

When the Explore procedure was run, the results generated indicated that post-test scores were normally distributed for both the experimental group (p=.061) and the control group (p=.058), Thus, standardized residuals for the interventions were normally distributed, as assessed by Shapiro-Wilk's test (p > .05). Similarly, an evaluation by Levene's Test of Equality of Error Variances indicated that there was also a homogeneity of variances,

(p = .736). It tests the null hypothesis that the error variance of the dependent variable is equal across groups.

Levene's Test of Equality of Error Variances

F	df1	df2	sig
.115	1	50	.736

H_{02}: There is no statistically significant mean difference between post-test mean scores of experimental and control groups for science pre-service teachers' comprehension of acid-base concepts. In running the ANCOVA, the dependent variable represented the science pre-service teachers' comprehension of acid-base concepts (post-test scores), whereas the covariate depicted the students' pre-test scores. The independent variable showed the science college of education type, experimental or control groups. The results are presented in Table 4.

Table 5. ANCOVA Summary on Comprehension acid-base concepts for experimental and control groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2863.823[a]	2	1431.912	59.247	.000	.707
Intercept	1205.164	1	1205.164	49.865	.000	.504
pre	373.154	1	373.154	15.440	.000	.240
tm	1263.788	1	1263.788	52.291	.000	.516
Error	1184.254	49	24.168			
Total	162450.000	52				
Corrected Total	4048.077	51				

a. R Squared = .707 (Adjusted R Squared = .696)

After adjustment for pre-test scores, there was a statistically significant difference in post-test scores between the interventions, F (1,49) = 52.291, p < .0005, partial η^2 = .516. The strength of the relationship between the type of Science College of education and comprehension of acid-base concepts as shown in Table 5 was very strong. From Table 5 it is observed that the type of teaching method accounted for 51.6% of the variance of the dependent variable when the pre-test is controlled as a covariate.

Discussion

The primary purpose of this investigation was to ascertain the effectiveness of 21st-century collaboration and lecture method (LM) on pre-service science teachers' comprehension of acid-base concepts. The post-test mean scores of CG and EG pre-service science teachers were evaluated, by employing ANCOVA analysis. The inferences showed that there was a statistically significant difference in the post-test mean scores of students learning with LM and those learning with 21st-century collaboration in conjunction with their conceptual understanding of acid-base concepts (Cetin-Dindar, & Geban, 2011; Karsli & Ayas, 2013). Pre-service science teachers in the EG achieved better compared to students in the CG on

post-test (ABCAT) scores, which shows that 21st-century collaboration was more successful in addressing pre-service science teachers' alternative conceptions and conceptual understanding of acid-base concepts. These inferences are endorsed by other researches (Chiu, 2004; Demircioğlu, Ayas, & Demircioğlu, 2005; Huang, 2004: Kala, Yaman & Ayas, 2013; Sheppard, 2006), which shows that conceptual change teaching strategy such as 21st-century collaboration was more successful for pre-service science teachers' conceptual comprehension of acid-base concepts.

Usually planned chemistry instruction depends on declarative knowledge, which is factual knowledge, where pre-service science teachers were presumed to remember elementary details. Comparatively, teaching depending on the conceptual change teaching strategy, using, for instance, 21st-century collaboration preferred advancement of procedural knowledge, which in other words was known to be knowledgeable about knowing how to conduct specific exercises. Pre-service science teachers in the EG used their knowledge linked to acid-base concepts, with the use of 21st-century collaboration to analyse their reasoning and alternative conceptions. This may have resulted in the variation in the post-test scores of pre-service science teachers in the CG and EG. Pre-service science teachers in the CG were unable to provide subsequent conceptual meaning even though they were able to answer factual questions. On the other hand, the EG pre-service science teachers employed their procedural knowledge by using their knowledge on fundamental conceptions on acids-bases in conjunction with 21st-century collaboration and attained meaningful learning.

Conclusions

This study looked at the use of 21st-century collaboration and lecture method to teach the topic of acid-base concepts, specifically concentration in mol/dm^3 or g/dm^3, properties of acids and bases, pH, pOH, neutralisation reaction and titrimetry, in the Science Colleges of Education curriculum. The study has indicated that pre-service science teachers have several alternative conceptions related to acids and bases, and these alternative conceptions affect students' comprehension of chemistry conceptions. Thus, it is crucial to seek techniques to rectify these alternative conceptions to fulfill meaningful learning. The inferences of the current research showed that 21st-century collaboration assisted pre-service science teachers in the remediation of their alternative conceptions as their comprehension of acid-base concepts was improved by the increase in their post-test scores.

On the contrary, pre-service science teachers from science colleges of education (experimental group) performed better than the control group from Science Colleges of education on their post-test scores. The former showed a greater understanding of acid-base concepts compared to the latter that utilised the lecture method when they were examined after the instruction. The data presented from the mean, standard deviation, Post Hoc analysis, and ANCOVA were able to show the differences between the experimental group and control group on pre-service science teachers' performance on ABCAT. The results indicated that there were differences in the conceptual understanding of control and experimental pre-service science teachers.

From the findings obtained on the analysis of the results, the evidence shows that pre-service science teachers in the experimental group developed a better conceptual understanding, in comparison with pre-service science teachers in the control group suggesting that the experimental group benefitted more from 21st-century collaboration compared with the control group. Thus, there must be some aspects of the 21st-century collaboration that contributed to these differences in the achievement of the groups. Drawing from this, the effectiveness of the collaboration can be determined according to whether or not pre-service science teachers in the experimental group had developed a better conceptual understanding after teaching in the comparison to control group.

This study contributes to the research on alternative conceptions in acids and bases regarding pre-service science teachers' understandings of acids-bases concepts. This is relevant as these teachers are trained to teach science at the JHS (grades 7-9) level, where students form most of their conceptions concerning science. These teachers can easily pass the misconceptions to students at this level hence the need to undertake this study to help mitigate and possibly eradicate pre-service teachers' alternative conceptions in acids and bases.

Recommendations

Collaboration is a 21st-century skill, used in this study can be used as a tool in the Science Colleges of Education classroom to help improve students' conceptual comprehension of acids-bases as shown in this research. Chemistry tutors are encouraged to determine important concepts in the chemistry curriculum and apply relevant instructional strategies that will help increase pre-service science teachers' achievement.

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