Journal of Turkish Science Education, 2021, *18*(2), 263-275.
DOI no: 10.36681/tused.2021.64

Journal of Turkish Science Education
http://www.tused.org
© ISSN: 1304-6020

The Effects of "Dance with Fruits" Analogy in Alleviating Alternative Conceptions in Acids and Bases [Case study of Grade 11 Physical Sciences]

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ABSTRACT
This study investigated the effects of the "dance with fruits" analogy on student's alleviation of alternative conceptions among physical sciences high school students in one of the rural province in South Africa. The study used a sequential mixed method research design consisting of quasi-experimental control group pre-test, post-test and semi-structured interviews. The target population of this study was all grade 11 physical science students in all 11 districts of the province. Accessible population included 4 schools in the district close to the researcher. The participants of this study were 117 physical sciences grade 11 students. A research instrument Acid and Base Alternative Conception Test (ABACT) was administered twice as a pre-and post-test to both control and experiment groups. Analysis of pre and post-tests suggested that students strongly held an alternative conception that the strength of acid is related to its concentration and corrosiveness. Molecular drawings of acids and base dissociations revealed notable patterns on how the distribution and ratio of molecules/ions in aqueous solutions are perceived. The results also indicated that the participants in the experimental groups had fewer alternative conceptions as compared to the control groups. The implication of this study for science educators is that correct use of analogies can assist students' understanding of abstract concepts about acids and bases.

ARTICLE INFORMATION
Received: 25.12.2019
Accepted: 25.01.2021

KEYWORDS:
Analogy; acid and base; structure-mapping theory; ph; conductivity; base and target domains.

Introduction

Background to the Study

Acid-bases is recognised as one of the foundations of high school science. Understanding the concepts acids-bases is important as the topic span from primary, high school and university level. In 2014, South Africa changed the physical sciences curriculum from the National Curriculum Statement (NCS) to the Curriculum and Assessment Policy Statement (CAPS). The South African council for quality assurance (UMALUSI) compared the two curriculums and found that two new topics Newton's Laws and Acids and Bases were added into CAPS (Grussendorff, 2014). Acid-Base is an anchoring topic in physical sciences that is related to topics such as electrochemistry, redox reactions and chemical equilibrium. At high school level the acid-base concepts taught are more complex and require the students to visualize at micro-level. According to Cooper, Kouyoumdjian and Underwood, (2016), concepts of acids and bases continue to be a problem for students at all levels of schooling.

The South African CAPS physical sciences chief examiner's report from 2014 to 2017 has also reported conceptual difficulties and alternative conceptions associated with acids and bases. Ionization and dissociation of acids and bases in aqueous has produced alternative conceptions with students failing to comprehend what happens when ions are produced. Common alternative conceptions reported are that acids dissolve and react with water during ionization or dissociation. Understanding the distribution of acid or base ions in aqueous solutions is important since it is related to key ideas such as strength of acids and bases, pH and pOH, acid-base titrations and electrical conductivity of acids and bases. Another common alternative conception that has been reported involves the incorrect use of the pH formula. Students use brackets ( ) instead of square brackets [ ] when using the pH formula and incorrectly use the formula pH = -log [H_2SO_4]. Units are assigned to pH, eg. mol.dm^{-3}. Furthermore, students struggle with the concepts of a reactant in excess and relative strength of acid-base. Most students associate the strength of an acid due to its corrosiveness. Describing any specific observations relating to students' responses on acid-base the chief examiner has concluded that students do not know the theory of acids-bases well enough. The practical visualization of what happens with acid-base in aqueous solutions still lacks among high school students. South Africa attained democracy and freedom in 1994 but its past injustices continue to haunt it in the education system. Subreenduth (2003) a system of institutionalized racial segregation from 1941 to 1991(apartheid) perpetuated a system of poorly resourced rural schools and inadequately skilled teachers. The teacher modus operandi in most rural schools is chalk and talk. Traditional teacher centred instructional approach encourages rote memorization at the expense of deep conceptual understanding (Grove and Bretz, 2012). According to Bodner and Orgill (2003 p 15), "chemistry is full of abstract concepts that are not easy to understand unless they are related to something familiar from our everyday experiences". An analogy transfers a system of relationships from a familiar/base domain (dance with fruits analogy) to one that is less familiar/target domain (acid and bases). Analogy based instruction helps students to visualize abstract acid-base concepts and overcome alternative conceptions (Venville, 2010). The chemistry conceptual understanding learning model suggested by Johnstone (2008), claims that matter is represented at three levels namely: macroscopic, microscopic (particles/molecules) and symbolic (chemistry language and mathematical models). Though students live in the macroscopic world the acid-base concepts require them to be versatile in both microscopic and symbolic levels. Thus, analogies bridge the gap among acid-base abstract concepts and familiar domains through a process called mapping. Matching or mapping involves finding correspondence between two domains. Sarantopoulos & Tsaparlis (2016), reported that analogies help to improve students' curiosity in science by actively engaging them in exploratory activities. There are few studies that have documented the use of analogies in teaching acid-base concepts and identified and characterized alternative conceptions. An in-depth understanding of the acids-bases concepts requires the active participation of the students (Bretz and McClary, 2014). It is clear therefore that robust and innovative ways are required to address student deficiencies in acids-bases. The main objective of this study is to investigate the effects of dance with fruits analogy on students' alleviation of alternative conception on acid-base concepts. Furthermore, the present study sought to identify and characterize alternative conceptions using confidence measures. The study was guided by the following research questions:

1.What are the prevalent alternative conceptions grade 11 physical sciences students have on acids-bases?

2.To what extent if any does the use of analogy based instruction dance with fruits analogy alleviate alternative conceptions on grade 11 physical science students?

Theoretical Frameworks

The anchoring features of this research are: mapping between familiar and unfamiliar domains, identifying and alleviating alternative conceptions and working within a social group. Anchoring features fits well into dynamic skill theory, structure mapping theory and Johnstone Triangle. Dynamic skill theory (DST) is an extension of social constructivism which claims that skills do not develop in a vacuum and are influenced by social factors (Fischer 2008). Skills develop in three levels of increasing complexity, differentiation and integration being influenced by self, other and environment (Mascolo & Fischer, 2010). DST also claims that cognition develops through levels and tiers. At the age 14 -18 year students operate in the abstract tier. In the abstract tier there are three abstractions namely: single, mappings and systems. Mappings play an important role in analogy based instruction. At the heart of analogy-based instruction lies mapping similarities and differences between the familiar and unfamiliar domains. The structure-mapping theory was developed by Gentner (1983,1993,2004), who suggested that an analogy is a mapping of relations from the base to the target domain. In other words, a familiar situation is used to understand an unfamiliar situation. Gentner's structure mapping theory is explained well in mathematical terms. A is like a B defines a mapping from B to A. A and B represents the base and target domains respectively. Base domain is the familiar one (dance with fruits analogy) and serves as the knowledge source. The target domain is the abstract which is acid-base. Structure-mapping theory is characterised by the mapping of relations between objects from the base/familiar domain to target/abstract domain. The structure-mapping theory was used in this study because it allows one to make differences between the analogy and literal similarity statements. Instructing with analogies was described by Hayashi (2018), as learning new things using comparisons with other familiar phenomena or concepts. The complexity of chemistry concepts was explained by Johnstone (1991, 2008). Chemistry requires a student to operate within three levels of thought, macroscopic, microscopic and symbolic. Macroscopic or descriptive category includes all that people can see, smell and feel with their sensory organs. The sub-microscopic are the atoms, molecules and ions that are dynamic in ionization of acid-base. Representational includes the symbols, equations and mathematical formulae. Johnstone (2009) stated that a trained chemist can operate at the three levels with ease. However, students can struggle to operate at three levels simultaneously and end up having alternative conceptions. In concurrence, Chen (2008) argued that the instruction of chemistry should be limited to only two operating levels at the same time the macroscopic level being the starting point. For this study, the activities of the dance with fruits analogy were carefully planned to avoid the operation of three levels simultaneously.

Review of Acids-Bases Literature

The prevalence of acid-base alternative conceptions among grade 9 students in Singapore was investigated by Hoe and Subraniam (2015), using cognitive confidence measures. A four-tier diagnostic test was used to collect data among 113 participants. Thirty alternative conceptions were uncovered on acid-base strength, pH, pOH and sub-microscopic views of dissociation. Ayas (2013) used Predict, Observe and Explain (POE) activities and interviews to investigate Turkish high school students' understanding of acids-bases. It was reported that most students had alternative conceptions about pH and pOH and had a poor understanding about the strength of acids and bases. Students thought that concentration of acids was directly linked to its strengths. In a similar study, Artdej, Ratanaroutai, Coll and Thongpanchang (2010) investigated common Acs among grade 11 in Thailand. A two-tier multiple choice test was used to collect data. Strong acids do not dissociate in water due to strong hydrogen bonds and all bases are ionic compounds were the most prevalent Acs.

In a study involving grade 12 students in Greece, Demerouti, Kousathana, and Tsaparlis (2004) used multiple-choice and open-ended questions to investigate common Acs on acid-base. The results of their study showed that students had alternative conceptions on: acid-base ionization, acid-base theories, pH and Ka values. Cros, (2006), investigated 400 high school students understanding of states of matter and acid-base concepts. It was reported that students had conceptual difficulties on energy changes during neutralization of acid-base reactions. Furthermore, students had difficulties in visualizing the dissociation of strong and weak acid-base.

Hand and Treagust (2010) investigated prevalent alternative conceptions among 60 high school students. The intervention on experimental groups was based on the conceptual change theory versus the traditional teacher centred instructional approach on control groups. The results showed that students taught by using the conceptual change theory approach performed better than those taught by using traditional approach. Thus changing instructional strategies really affect performance. Sheppard (2006) reported that out of 16 American grade 11 students who took part in his study only four students were able to provide the correct formula for pH. The rest of the students (n = 12) thought that pH was a linear scale. Most of the students failed to explain the difference between pH 3 and 5. The literature explored has shown that high school students starting from grade 9 to 12 have similar Acs and students struggle with the microscopic view of acid-base dissociation.

Methods

Research Design

The study employed a mixed-methods sequential explanatory research design. The sequential explanatory design uses both quantitative and qualitative approaches (Creswell, 2015). The quantitative method is dominant over qualitative (Quan-qual). In this study a quasi- experimental, non-randomized Pre-and-Post-test control group and semi-structured interviews were used in a sequential design. The rationale for this approach is that the quantitative data analysis provides a general understanding of the research problem. The qualitative data and their analysis refine and explain those statistical results by exploring participants' views in more depth (Gay & Mills, 2016). Kumar (2014) suggests that the overarching goal of a quasi-experimental research lies in attempting to find the effectiveness of a treatment or intervention. Does a treatment or intervention of using (Dance with fruits) analogy based instruction have an impact on students' performance on acids-base?

Participants

The participants involved in this study were 117 Grade-11 students (age range 16-18 years) who were studying physical sciences. Convenience sampling was used to select four schools readily accessible to the researcher. Four schools (A = 30, B = 34 C = 26, D = 27) were randomly assigned to two experimental and control groups. Intervention for group A and C was the dance-with-Fruits analogy while B and C was traditional teacher centered approach.

Instrumentation

A diagnostic questionnaire Acid-Base Alternative Conception Test (ABACT) was administered as both a pre-test, post-test to both experimental and control groups. The first stage of the instrument development involved defining the content boundaries of acid-base. The South Africa's high school National Curriculum Statement (NCS) for physical sciences (Acid-Base) was used to define the content scope of the study, encompassing: acid-base theories (Questions 1-5), strength of acids-bases, pH and pOH (questions 6-11) and electrical conductivity (Questions 12-15). Identification of alternative conceptions by reviewing literature was the second stage that was used to select distractors in the instrument. Accordingly, distractors in the multiple-choice questions were based on alternative conceptions related to acid-base (Ozmen, Demircioğ̌lu, Burhan, Naseriazar, Demircioğ̌lu. and Test, (2012); Artdej, Ratanaroutai, Coll and Thongpanchang (2010); Hoe and Subraniam (2015); Huang, (2004). The ABACT was a three tier (multiple choices, reasoning and confidence level). The reasoning tier sought to elicit students' justification of the multiple choice tier. One of the questions of the ABACT and the interview schedule are shown below:

1.12 Consider the following solutions of hydrochloric acid:

SOLUTION A	SOLUTION B
0.1 $mol.dm^{-3}$ hydrochloric acid	1.0 $mol.dm^{-3}$ hydrochloric acid

Which ONE of the following statements about the solutions is CORRECT?

A. A is a weaker acid than B and more dilute.
B. A is more dilute than B but a stronger acid.
C. A is a weaker acid than B but more concentrated.
D. A is less concentrated than B and both A and B are strong acids.

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

Question 2

Identify and explain which of the following are strong and weak acids [0.1M HCL, 0.6M HCL, 0.9M CH_3CHOOH].

Two chemistry lecturers and three high school educators checked the content validity of the instrument. The ABACT was piloted with the sample of 52 grade 11 students outside the sample space. Reliability of the test was calculated using Cronbach alpha coefficient of 0.74. The fifteen questions instrument difficult indices ranged from 0.38 to 0.68. A semi-structured interview (Gay & Mills, 2016) data collection instrument was used to gain insight into how the use analogy based instruction alleviates acid-base alternative conceptions. Reliability and validity of interview data have always been a problem in research. Creswell (2009: 153) claimed that interview reliability is elusive. Interviews have poor reliability because they are prone to many types of bias, particularly when the researcher makes comparisons between data sets (Millward, 2001). To maintain the validity and reliability of the interview process, the researcher avoided asking leading questions. A pleasant environment was created by assuring the students that the results will be used for research purposes only.

Data Collection

Quantitative data was collected followed by the qualitative data to provide insight about students' acid-bases alternative conceptions. The experimental group was instructed using analogy based instruction dance with fruits analogy and the control group traditional teacher centered instructional method. Post-test mean scores were compared to the pre-test mean score after a two-week intervention. Six students were purposively selected to ensure gender balance for interviews. Interviewees were drawn two from each of the following performance score bands namely: high, medium and low. The fruit and dance activity based analogy suggested for this study was designed by the author. Five tall girls joined hands with five short boys. A girl represented Cl and boy represented H. The joining of hands and with two oranges represented a polar covalent bond between HCl and the shared electrons respectively. The dancing around of all learners represented the constant motion of the HCl atoms in solution. Breaking up of the bonds resulting in each student standing on her/his own represented dissociation (complete) strong acids-bases. Partial dissociation would occur when two boys and girls break up and the other three remain joining hands. Extent of dissociation was used to explain the strength of the acid/base. During dissociation the two fruits will be taken by the girls and when a potential difference is applied they migrate to the anode and boys to the cathode. To avoid the mechanical breakdown of the analogy teachers led students in mapping the similarities and differences between the abstract and familiar domains.

Table 1

Mappings Between Familiar and Unfamiliar Concepts

Familiar	Unfamiliar concepts
Girl & Boy	Cl and H
Joined hands	Polar covalent bond
Fruits	Electrons
Dancing	Movement of atoms in solution

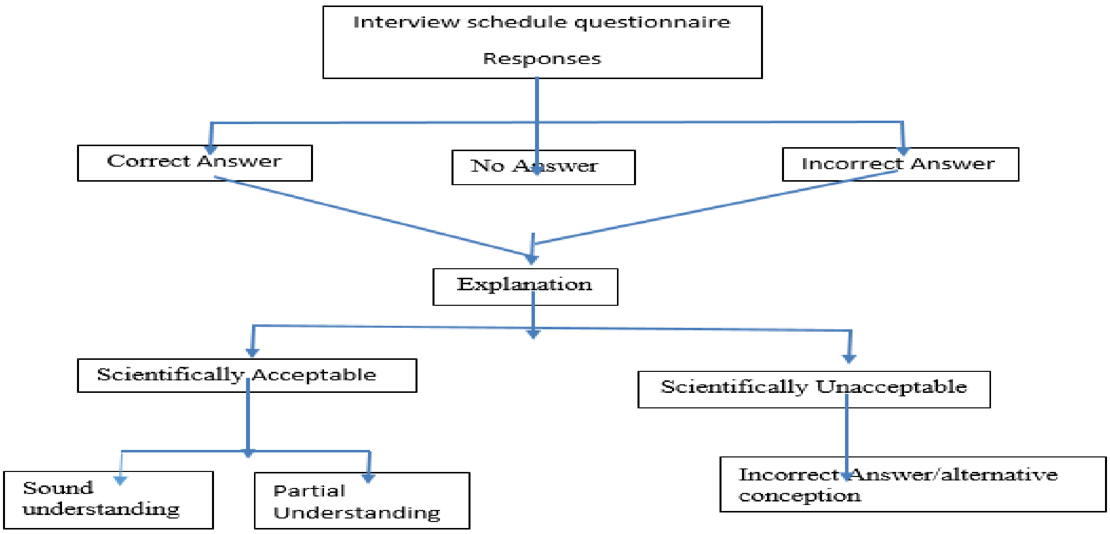
The control groups were taught using a traditional teacher method, five hours per week, for two weeks. Lessons were presented using the chalk and talk. During lessons, the important concepts of acids-bases were explained and important points were noted on the whiteboard. Participants were recommended two textbooks for further reading. Revisions were held as scheduled, once per week, for an hour. In the lessons, the students solved questions in workbooks and they were allowed to finish homework at home.

Method of Data Analysis

The data collected from students' pre-and post-tests was analyzed using SPSS. The data collected through semi-structured interviews was analyzed qualitatively using idiographic and nomothetic method (Kumar, 2014) Figure 1. The interviews were tape recorded and transcribed.

Figure 1

Analysis of Interview Responses



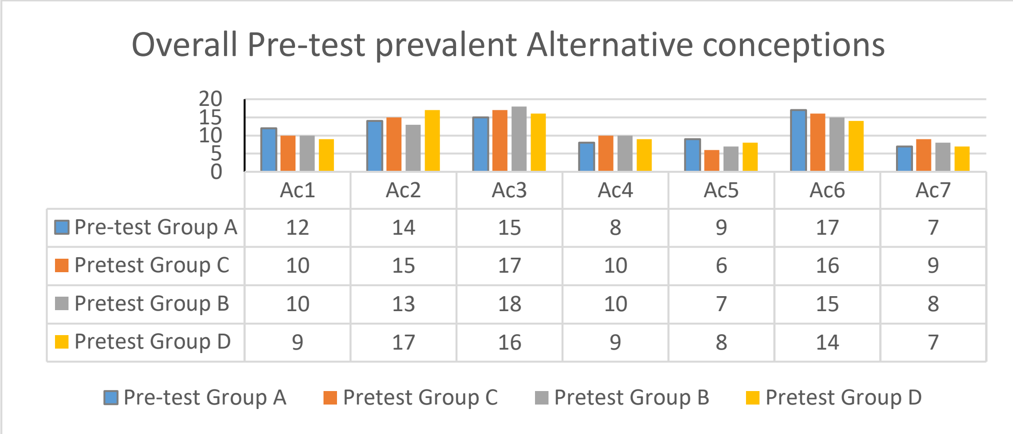
Findings and Discussion

Identification and Characterizing the Significance of Prevalent Alternative Conceptions

The first step in analyzing the data was to identify the overall prevalent Acs among all the four groups. Subraim and Yan (2017) suggested that prevalent Acs should be focused on those responses chosen by 10% of the participants. The overall frequency per group of the prevalent Acs are presented in Figure 2 below. From the responses of the pre-test seven misconceptions were identified. The most prevalent were Ac2 (Strength of an acid or base is determined by its concentration), Ac3 (Concentration determines the strength more than Ka values) and Ac6 (Mixing corrosiveness with pH). The full list of the Acs together with confidence measures is presented in Table 2.

Figure 2

Pre-Test Prevalent Alternative Conceptions



The significance of the identified alternative conceptions was calculated using the confidence ratings associated with the specific alternative conception (SAC). Caleon & Subramaniam (2010) suggested that confidence expressed on alternative conception (CAC) by the student can be used to measure the strength of the alternative conception prevalent among students. CAC values enable the researcher to shed light on the conceptual difficulties, errors and genuine alternative conceptions. CAC is calculated by adding the average confidence ratings of the answer and response tiers and then divide by the total number of students who chose the same answer and response tier. Confidence ratings were used to calculate CAC values which were then grouped into three categories, based on the classification proposed by Caleon & Subramaniam (2010), Yan & Subranaim (2017) as follows:

- Spurious ACs: CAC < 3.5 (expressed due to lack of knowledge or guessing, low confidence)
- Moderate ACs $4.0 <$ CAC ≥ 3.5 (expressed with medium level of confidence)
- Strong ACs: CAC ≥ 4.0 (due to lack of understanding or wrong reasoning accompanied by high level of confidence)

The ACs of all the groups in the pre-test were combined and presented in the Table 2 below. From Table 2 strong Acs with a CAC greater than or equal four were three. Ac5 and Ac6 had CAC ≤ 3.5 implying a lack of knowledge or guessing.

Table 2

Confidence Measures of Prevalent Acs on Acids-Bases

Alternative Conceptions		CAC
Acid and Base Theories		
Dissociation or Ionization of acids and bases		
Ac1	Concentration is directly proportional to the dissociation of an acid or base.	4.6
Ac2	Strength of an acid or base is determined by its concentration.	4.1
PH and Strengths of Acids and Bases		
Ac3	Concentration determines the strength more than Ka values	3.9
Ac4	Strong acids do not contain OH^-	4.6
Ac5	Mixing pH and concentration	3.2
Ac6	Mixing corrosiveness with PH	2.9
Ac7	Acids conduct electricity more than bases	3.3

Acid and Base Theories

The dissociation of acids was tied to the concentration of the acid. Question 1 required the students to identify 0.1 HCl as a strong or weak acid. Most students realized that it was a strong acid but the justification showed an alternative conception. Since the concentration was low about 40% of the students thought there will be complete ionization but low concentration of [H_3O^+]. The justification in the pre-test showed that students used concentration to determine the extent of ionization. Question 1.13 required the students to determine whether an acid was strong or weak given both concentrations of the solution and [H_3O^+]. Students responses revealed that the alternative conception of using concentration of [H_3O^+] to determine whether the acid is weak or strong. Since the concentration of [H_3O^+] was low the students thought it was a weak acid with low ionization. These findings support previous research studies done by (Yalçin & Bayrakçeken, 2010). From Table 2 the responses of the students showed that the Ac1 and Ac2 students were highly confident with their answers (CAC = 4.6) and they are strong alternative conceptions (SAc).

PH and Strengths of Acids and Bases

Pre-test responses showed that 42% of the students associated PH and strength of the acids to its corrosiveness. Battery acid which most students encounter in their daily lives was deemed as the strongest acid. Linking the corrosiveness of battery acid to pH is in agreement in the DST an extension of social constructivism which claims that skills do not develop in a vacuum but are influenced the environment. Lack of knowledge about the dissociation of acids and bases led students to justify their answers as guessing. The Ac on PH and strength could not be justified as a strong Ac but lack of conceptual understanding (CAC = 3.5). Strength of bases remained a challenge to students as they failed to relate to real life examples. The ACs reported here were similar to those identified by (O¨zmen, 2009 & Artdej, 2010). Strong acids were deemed to have [H^+] ions only by 38% of the respondents. The Ac might have come from the incorrect use of the Arrhenius acid base theory. Physical sciences textbooks define an acid as a compound that produces hydrogen ions (H^+) in an aqueous solution. Bases produces hydroxide ions (OH^-) ions in aqueous solutions.

Electrical Conductivity

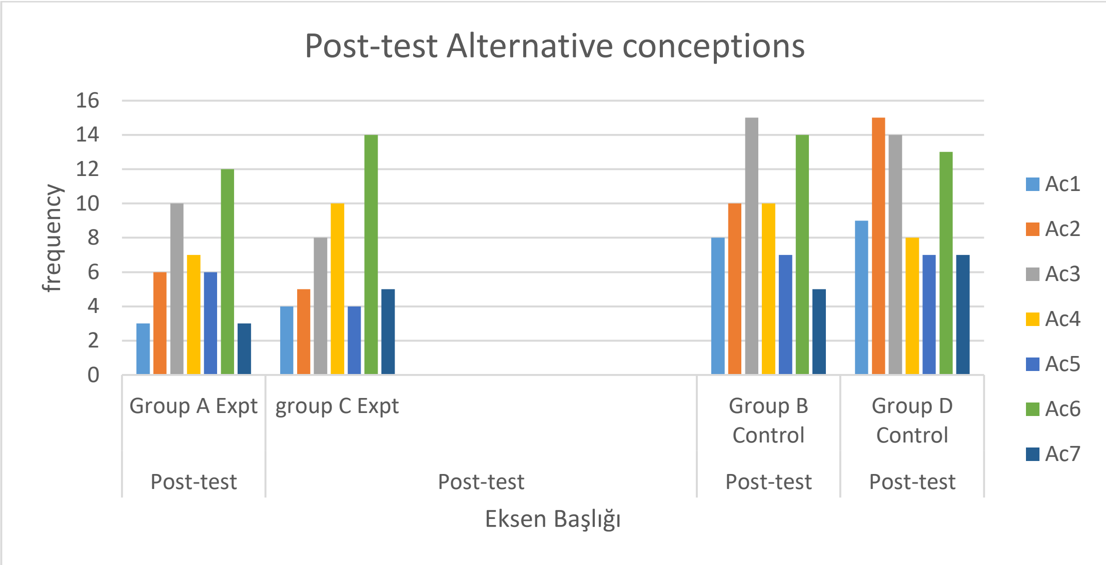
About 30% of the participants thought that acids conduct electricity more than bases. Most of the responses were left blank indicating that the participants had conceptual difficulties with the movement of ions migrating to the electrodes when a potential difference is applied. The CAC values was 3.3 indicating lack of knowledge in both groups.

The Effectiveness of the Dance-With-Fruits Analogy in Ameliorating Students' Acs

Descriptive and inferential statistics were used to illustrate the distribution and extent of students' alternative conceptions, before and after the two respective interventions. The dance with fruits analogy alleviated some of the Acs and improved conceptual understanding of acids and bases. Three Acs namely, Ac1, Ac2 and Ac7 were greatly reduced in the experimental groups as compared to the control groups in the post-test as shown in Figure 3 below. In the post-test Ac1 dropped from 12 and 10 to 3 and 4 respectively for the experimental groups, while in the control groups there was slight difference of 2 and 1. The decline in the experimental groups of Ac1 can be attributed to the visualisation and conceptual understanding of dissociation of acids-bases using the dance with fruits analogy. Complete dissociation was also linked to high Ka values and strength of acids-bases which is independent of the concentration. On the other hand, low Ka has low dissociation which is characteristic of weak acids-bases. The other Ac **7** on electrical conductivity was greatly reduced in the experimental groups from frequency of 16 to 7. The use of fruits to indicate electrons during dissociation and movement of ions when a potential difference has been applied might have helped to improve the conceptual understanding of electrical conductivity of acids-bases.

Figure 3

Post-Test Alternative Conceptions



Mappings from the familiar to unfamiliar domain might have improved the conceptual understanding of acid–base. The students in the experimental groups according to the DST where in the range of 14 -18 years which enabled them to operate in the abstract tier. The abstract tier involves mappings which were crucial in alleviating alternative conceptions in acid-base. The structure mapping theory claims that for an analogy to be effective students must use familiar representations to understand the target domain. The dance with fruits analogy used familiar objects to relate to abstract acid-base concepts. However, Ac3 and Ac6 remained the almost the same in both pre-test and post-test. The alleviation of alternative conceptions requires time and manipulation of complex abstract mappings Mascolo (2015). The alleviation of some of the Acs is similar to those reported by (Geban and Bayır, 2000; Pabuccu and Geban ,2006) involving conceptual change instructional strategies in alleviating alternative conceptions in chemical reactions and chemical bonding, respectively. Some Acs were greatly reduced while others remained the same.

To fully understand the alleviation of the Acs of the students the mean scores (Table 3) of the groups were recorded. Gay and Mills (2016) claimed that as ANCOVA increases, so does the strength of a quasi-experimental design. It takes into account the lack of randomisation by adjusting initial differences between groups. This study used non-equivalent intact groups. ANCOVA is powerful and versatile in situations where basic ANOVA assumptions, particularly randomisation, are violated (Campbell & Stanley, 2015). The one-way ANCOVA is used to determine whether there are any significant differences between two or more independent (unrelated) groups on a dependent variable. Table 4 show the findings of the one way ANCOVA, in which the post-test mean scores were the dependent variable, and the pre-test scores which were a covariate to correct for any differences in the control or comparison and experimental groups. The table shows a statistically significant result (F= 0.57345; $p < .0001$). The value of p showed that there was a very small probability of this result occurring by chance, under the null hypothesis of no difference between pre-and post-test scores. Based on the results of the ANCOVA, the null hypothesis was rejected in favour of the alternative hypothesis, since $p < 0.05$. This is an indication that the dance with fruits analogy intervention was more effective, resulting in higher post-test scores, in comparison to the traditional-based groups.

Table 4

One Way ANCOVA Analysis of the Pre-and-Post-Tests Mean Scores of Experimental and Control Groups

Source of variation	Sum of squares	Df	Mean squares	Ratio-F	Value-P
Between groups	486.987	3	3947.731	0.57345	.0001
Within groups	7251.507	114	7895.46		

Table 5

Pre-and–Post-Tests Mean Scores

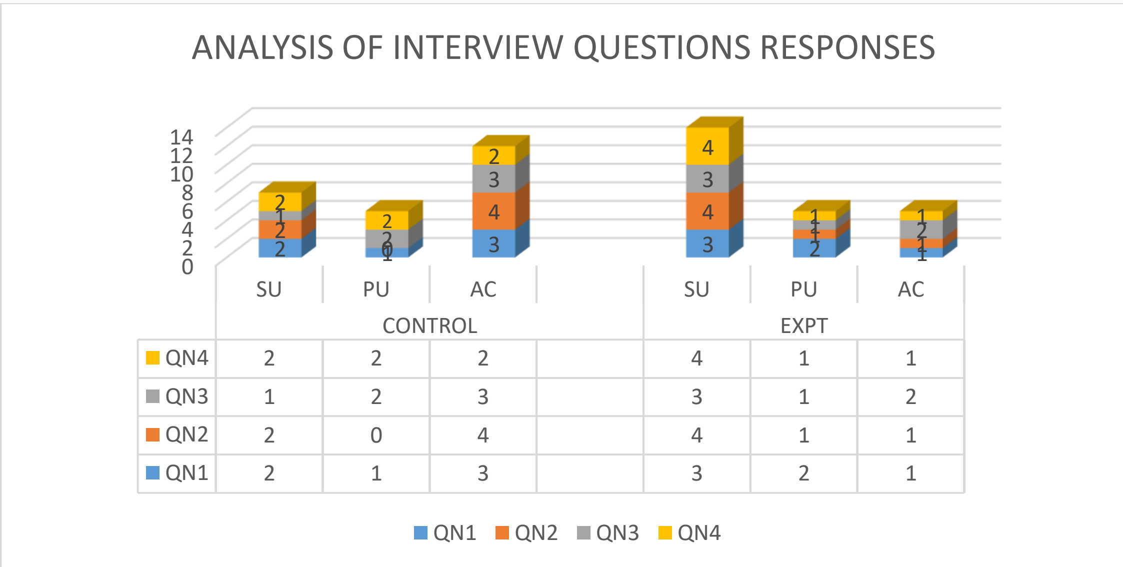
Groups	Pre-test	Post-test	No of students
Group A	58.6	66.3	30
Group C	56.2	68.8	26
Group B	55.3	60.1	34
Group D	57.2	62.5	27

Qualitative Data on the Students' Alternative Conceptions

Interviews were done to complement the results obtained using the quasi experiment pre-test-post-test design. Interviews were conducted using purposive sampling of students in the lower, middle and upper groups of performance. Six students were interviewed at each school taking into conscience gender balance three boys and girls. Pre-tests responses of the control groups were compared to post-test responses after instruction and the students were selected for interviews. The results of semi-structured interviews are presented in Figure 4. For students in the experimental group, their responses were mainly in the scientifically acceptable category (Sound Understanding SU and Partial Understanding PU). Alternative conceptions (ACs) from the interview responses were 5 in the experimental group as compared to 12 from the control group. The ACs were similar to the ones reported from the quantitative data analysis. Thus, it may be concluded, as it was from quantitative data, that the use of the dance and fruits analogy ameliorated ACs in acid-base.

Figure 4

Analysis of Interview Responses



Excerpts from Interviews

Researcher (R): In your responses in both pre-test and post-test you have maintained that 0.1 M HCL is a dilute strong acid with incomplete dissociation.
SC_b (student in control group B): HCl is a strong acid and 0.1 M shows it's not concentrated. Since its' 0.1M it undergoes complete dissociation yes but very little [H_3O^+] are produced cause its' already dilute.
(R): If it was 1M how would you compare its dissociation?
SC_b: *It dissociates more*.

The excerpt above shows the student continued to hold to his initial conceptions about concentration even after instruction. A student in the similar group but in the experimental group was interviewed.

Researcher: The responses in the pre-test and post-test with regards to question 1 changed. What made you to change the response?

SE_a (student in experiment group): I had some vague idea about acids and bases. To me the car battery acid was the strongest because of what it does to clothes. I had no basis whatever about the strength of acids and bases and how they dissociate. The analogy made me to understand and think in other terms.

Re: What difference if any was made by the use of analogy dance with fruits

SEa: I learnt that dissociation of acids and bases is the key to understanding PH, strength (Ka and Kb) and conductivity. Impartial and complete dissociation play a crucial role in conceptually understanding the concepts. Honestly I never knew where-the positive and negative signs came from. The above response shows how the analogy managed to enhance conceptual understanding of acids and bases.

(R): Coming to your response in the pre-test you had 0.1M HCL being a dilute strong with impartial dissociation.

SEa: I now know that dissociation of a strong acid is independent of its concentration.
The interview excerpts show that students in the experimental group conceptual understanding of acids-bases concepts improved after intervention with the dance with fruits analogy.

Conclusion

This study summarised the effects of the dance-with-fruits analogy in alleviating alternative conceptions in acid-base. A total of 7 ACs were identified using the 15-item Three-tier Multiple Choice test (3TMC). Prevalent ACs found in this study were on PH and strength of acids-bases and acid-base theories. Lack of knowledge and guessing characterised ACs on the electrical conductivity of acid-base. Students associated corrosiveness with the strength and pH of acid and bases. The study has shown that the conceptual understanding and visualization of the dissociation of acids-bases using the dance with fruits analogy improves alleviation of alternative conceptions. ACs (AC1, AC2, AC5 and AC7) were greatly reduced in the experimental group because the analogy unlocked and greatly improved the visualization and conceptual understanding of the dissociation of acid-base. A quote from one of the students who was interviewed sums it all "*I learnt that dissociation of acids and bases is the key to understanding PH, strength (Ka and Kb) and conductivity*". Electrical conductivity of the acid-base can be extended to redox reactions. The findings confirm that intervention using analogies (Çalık and Ayas, 2005; Çalik, et al., 2010) is a powerful instructional method that alleviates ACs. The dissociation of acid-base is difficult to grasp, as there are no analogues from everyday life that can be used to illustrate the dissociation at molecular level. Comprehending this invisible and non-intuitive dissociation requires concrete representation for students to conceptually understand the concept. The use of the dance with fruits analogy might have caused a shift in students' mental models about the dissociation of acid-base. The findings of this study have shown that abstract concepts must be related to analogies to improve students understanding. Analysis of pre-test responses shows that both groups had difficulties in articulating the anchoring concept in acid-base dissociation. One of the students in the control group had this to say "*I now know that dissociation of a strong acid is independent of its concentration*" indicating a shift from the previously held ideas. Despite, the reduction of ACs some of the persisted. According to the DST first year students are in the abstract systems stage where they link abstract mappings to form related abstract ideas. In order for students to conceptual understand acid-base concepts multiple abstractions must be meshed to form a system of abstractions. The complex abstract mappings are influenced by maturation of an individual from 9-25 years. The ability to form complex mappings fully develops above 25 years. As Mascolo (2010) contends as people matures their thinking become increasingly abstract, complex and integrated. Thus, the persistence of alternative conceptions might be that students are still building complex schemata required for abstract system thought. This study has shown that the use of the dance with fruits analogy provided students with concrete familiar domains mappings that were used to create new knowledge on existing structures. It is recommended that teachers should use well documented analogies to enhance the understanding of abstract topics such as acids and bases.

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