Pedagogical Research
2023, 8(4), em0173
e-ISSN: 2468-4929
https://www.pedagogicalresearch.com

MODESTUM

Research Article **OPEN ACCESS**

The effect of simulation-integrated context-based instructional strategy on grade 10 students' achievement in chemistry

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Citation: Demelash, M., Belachew, W., & Andargie, D. (2023). The effect of simulation-integrated context-based instructional strategy on grade 10 students' achievement in chemistry. *Pedagogical Research, 8*(4), em0173. https://doi.org/10.29333/pr/13850

ARTICLE INFO

Received: 17 Jun. 2023

Accepted: 24 Oct. 2023

ABSTRACT

The purpose of this study was to examine whether a simulation-integrated context-based 7E instructional strategy (SICBIS) could increase students' achievement in the chemistry of oxides, acids, bases, and salts (COABS) when compared to context-based 7E instructional strategy (CBIS), simulation-integrated conventional teaching approach (SICTA), and conventional teaching approach (CTA). An embedded mixed-method was employed. For the quantitative part, a 25-item chemistry achievement test was utilized to collect data from 229 grade 10 students as part of a quasi-experimental pre-/post-test control group study design. Both descriptive and inferential statistics were utilized to analyse the data. Semi-structured interviews were used to triangulate it the with quantitative results. Quantitative results demonstrated that although difference was not statistically significant, incorporating computer simulations within CBIS helps students do better than they would have without. SICBIS and CBIS outperformed SICTA and CTA in COABS. Also, implications and recommendations are made.

Keywords: context-based approach, instructional strategy, 7E, simulation, school chemistry, student achievement

INTRODUCTION

The importance of chemistry in development has been acknowledged on a global scale. It is applicable to our daily lives and has played a significant role (Moore, 2019). However, chemistry instruction has frequently been criticized for lacking a constructivist learning environment to adequately represent the levels of chemical concepts (Cigdemoglu & Geban, 2015; Karsli & Yigit, 2017). As a result of this, numerous chemistry educations (Cetin-Dindar & Geban, 2016; Cigdemoglu & Geban, 2015; Demircioglu et al., 2013; Eilks & Hofstein, 2015; Ilhan et al., 2016; Karsli & Yigit, 2017; Kenney, 2021) claimed that students generally believed chemistry was an abstract, complex, irrelevant, and difficult subject (or may be abbreviated as an "ACID"). According to these studies, some students thought that chemistry was neither significant nor relevant to their daily lives or their future societal roles, especially at the secondary school level. Consequently, the achievement of school students in chemistry is unsatisfactory both in many industrialized (Akram et al., 2017; Demircioglu et al., 2013; Utha et al., 2021; Vogelzang et al., 2021; Wiyarsi et al., 2020) and developing (Belay et al., 2016; Hunde & Tegegne, 2011) nations and thus fewer students are pursuing advanced-level chemical studies globally.

This problem might be related to the impelemantation of context-based approach (CBA) and educational technologies separately, or it might be linked to the predominance of decontextualized mode of instruction in schools. In the context of our study, decontextualized instruction is a content-based (conventional teaching) approach, which has less likely to explain concepts with all levels of representations. The teaching of chemistry in schools is often textbook-focused and based on a transmission model that views knowledge as a commodity that can be communicated intact from the teacher to student's mind through telling and teaching process (Vogelzang et al., 2021; Wu et al., 2023). Therefore, the conventional instruction offers little to no interaction between teachers and students, emphasizing the content rather than the context, and they begin to feel bored. These factors may cause students' achievement to be lower in chemistry in general (Utha et al., 2021; Vogelzang et al., 2021) and the chemistry of oxides, acids, bases, and salts (COABS) in particular (Secken, 2010; Tumay, 2016).

This study is derived from doctoral thesis, for which at least two publications in a well-known journal is one of the requirements for graduation at Addis Ababa University.

Cigdemoglu and Geban (2015), Karsli and Yigit (2017), and Osado et al. (2023) thus have suggested the use of innovative pedagogies that can foster secondary school students' achievement in COABS through adequate representations chemical concepts. In response to this, a number of CBA studies (Assi & Cohen, 2023; Cigdemoglu & Geban, 2015; Dori et al., 2018; Magwilang, 2016; Sharma et al., 2019; Vogelzang et al., 2019) have been carried out internationally as a solution, in one hand. These studies have advocated that using CBA helps to make chemistry education relevant and meaningful to students' lives. However, the majority of these studies lacked computer simulations that linked the human elements (contexts) with the other three levels of concepts. For instance, computer simulations were not used by Elmas and Geban (2016), Majid and Rohaeti (2018), Vogelzang and Admiraal (2017), or Vogelzang et al. (2019) to explain the particulate nature of concepts. Additionally, it appeared that previous context-based studies lacked plainly stated teaching methods (TMs) that might have supported the context-based instructional strategies. Therefore, this might not be enough to successfully teach chemistry.

On the other hand, to improve students' achievement in chemistry through effective representation of abstract concepts, a number of chemistry education studies have also been carried out employing simulations incorporated in decontextualized instructions. That is, they lacked a certain type of context-based instructional strategies (5E, 7E, REACT, storyline, and so on) under the umbrella of CBA. Gokalp and Adem (2020) and Kapici et al. (2022), for instance, employed educational technologies (like computer simulations) in their studies to teach secondary school chemistry, but they had not employed CBA rather they integrated these technologies via the existing conventional teaching approach (CTA). As a result, in order to portray the possible levels of chemical concepts fully and more effectively, this form of instruction might not be sufficient.

Therefore, it may appear that most previous chemical research did not make much of an effort to combine the two pedagogies for improved representations. We contend that when developing instructional designs, researchers could not be too far from the four levels of representations–human activity (context), macroscopic, submicroscopic, and symbolic representations. The choice of an approach, instructional strategy (IS), and TMs and the technique of organization could make a difference. Thus, careful selection and adoption of IS and TMs to a particular topic is essential in chemistry education. Previous studies had made only a limited effort to disclose this. This was revealed through our analysis of literature on intervention studies in chemistry education. However, there is only one relevant study (Kunduz & Secken, 2013) that deals with context-based 7E instructional strategy (CBIS) integrated with educational technology. The quasi-experimental design of their study was purely quantitative that focused on developing a computer-assisted instructional material, which involves animations, virtual lab and educational computer applications, based on 7E model towards the topic of "precipitation titrations" using a sample of 89 grade 11 students.

But the design of this previous study was different from the design of our study, including variations in population type and area of chemistry. Besides, our study extends this work through supporting simulations with real in-class and take-home practical activities to address multiple representations. Utilization of kits was essential for teaching both theoretical and practical dimensions of chemistry at the same time in the classroom instead of using the school laboratory at a different time. The present study also addressed other limitation of the study by Kunduz and Secken (2013) by including qualitative part to assess students' feeling about the strategy.

COABS was selected because it occupies a central place in secondary school chemistry curricula. The concepts of the four compounds (oxides, acids, bases, and salts) are sturdily related to each other and they can also be connected with a shared context (Demircioglu et al., 2013). Besides, the chemical concepts of these compounds are very related to everyday activities and hence they are potentially applicable in a context. It is also one of the abstract and poorly contextualized areas of chemistry (Demircioglu et al., 2013). According to these evidence, secondary school students perform poorly. The low performance of students might be related to their misconceptions in oxides (Sesen & Tarhan, 2011), acids (Mulyani et al., 2023; Sesen & Tarhan, 2011; Tumay, 2016), bases (Mulyani et al., 2023; Sesen & Tarhan, 2011; Tumay, 2016), and salts (Secken, 2010; Tumay, 2016). Specially, Sesen and Tarhan's (2011) study revealed 54 misconceptions that were observed in some common terminologies such as 'acid and base theories', 'properties of metallic and nonmetallic oxides', 'acid and base strengths', 'neutralization reactions', 'pH and pOH', and 'acid and base indicators'. Furthermore, these studies have also appealed that the misconceptions of students might often be resulted from the regular teacher-centered instructions in schools.

In summary, our study would fill the empirical gap on the generalization that CBA supported with computer-assisted instruction may improve learning outcomes of school students in science in general and chemistry in particular. Besides, we investigated how the design of simulation-integrated context-based 7E instructional strategy (SICBIS) affects students' achievement in COABS in comparison to CBIS, simulation-integrated conventional teaching approach (SICTA), and CTA. Our argument is that it is insufficient to just compare the impact of SICBIS on students' achievement in COABS with the usual teaching approach because even little adjustments to this approach may have a significant impact on students' learning outcomes.

Theoretical Framework of the Study

This study's theoretical framework was social constructivism. According to its concept, students actively construct meanings while taking a self-directing role in their learning, with the teacher acting as a facilitator (Suryawati & Osman, 2017). Outside of the school compound, learning takes place through interactions with the environment. This framework's guiding principles state that students should construct knowledge rather than passively receive it. Accordingly, a CBA (Assi & Cohen, 2023; Dori et al., 2018) and computer simulation (Al-Balushi et al., 2016; Suits & Sanger, 2013) build on a social constructivist theory, which helps learners to construct meanings from contexts using macroscopic and abstract concepts. Hence, SICBIS can also be viewed as a social constructionist environment. This implies that the study was guided by social constructivist theory. Therefore, it might be very reasonable to assume that a dynamic student-teacher and student-student interactions would be helpful to improve students' achievement in COABS.

Table 1. Pre-/post-test nonequivalent-groups quasi-experimental design of the study

Group	Pre-test	Treatment	Post-test
IG_1	Pre-test	SICBIS	Post-test
IG_2	Pre-test	CBIS	Post-test
IG_3	Pre-test	SICTA	Post-test
CG	Pre-test	—	Post-test

Table 2. Table of specifications for COABS (Anderson & Krathwohl, 2001)

Instructional (behavioral) objectives					
Course content	**Recall of information**	**Understanding of concepts**	**Application of cconcepts in new situations**	**Analysis of concepts**	**Total /percent**
Introduction		1			1/4
Oxides	1	1	1		3/12
Acids	2	1	3	2	8/32
Bases	2	2	3	1	8/32
Salts	1	2	1	1	5/20
Total/percent	6/24	7/28	8/32	4/16	25/100

Aim of the Study & Research Questions

The main objective of this study is to determine how SICBIS affects students' achievement on COABS topic and to compare its effectiveness to that of other active instructional strategies (i.e., CBIS and SICTA) in improving their achievement in the area. CBIS, SICTA, and CTA would also be compared with one other. Thus, this study addressed the following research questions:

1. Does SICBIS have a statistically significant impact on students' achievement in COABS as compared to CTA?
2. Does SICBIS have a statistically significant impact on students' achievement in COABS as compared to CBIS and SICTA?
3. Do CBIS and SICTA have a statistically significant impact on students' achievement in COABS as compared to CTA?
4. How do students perceive SICBIS has affected their achievement in chemistry?

RESEARCH METHODOLOGY

Research Methods & Design

Kunduz and Secken (2013) conducted a purely quantitative analysis. Their study ignored students' perceptions/feelings that simulation-integrated context-based instruction had helped them achieve more. Because of this, as no single data set could sufficiently address all of the study questions, we chose a concurrent embedded mixed-method approach for our work (Bunce & Cole, 2008; Creswell & Creswell, 2013). This method was then utilized to determine how students actually felt about the influence of SICBIS on their COABS achievement. The qualitative findings were used to support and consolidate the quantitative findings (Creswell & Creswell, 2018). The quantitative part of the study was carried out according to the quasi-experimental pre-/post-test control group research design (**Table 1**). Chemistry achievement test (CAT) was used to gather quantitative data, and semi-structured interviews (SSIs) were used to gather qualitative data from students who had been exposed to SICBIS.

Research Participants

The sample of this study consisted of 229 grade 10 students in four different groups (study group one [IG_1], study group two [IG_2], study group three [IG_3], and comparison group [CG]) at four different public secondary schools in Borena zone, Ethiopia. All the participants in the schools had similar socio-cultural backgrounds and experienced in similar academic environments. The four schools received official approval from the Borena educational office. Random sampling technique was applied to choose all intact research groups, one from each school, for the quantitative strand. SICBIS, CBIS, SICTA, and CTA were then randomly assigned to these groups having 60, 58, 56, and 55 students, respectively. Six students (two from each achiever level) from SICBIS were randomly chosen for the qualitative section.

Data Collection Tools

Quantitative data: Chemistry achievement test

CAT was developed by the researchers based on the recommendation of Cigdemoglu and Geban (2015) through formation of question pool, selection of questions using the table of specifications, measuring reliability and validity of the test, and administration of the test having 25 items to the four students groups (see **Appendix A**). Based on the curriculum's content and learning objectives for COABS, the item questions were taken from the students' textbooks and other related context-based chemistry materials like and Güth and van Vorst (2023) and Karsli Baydere (2021). The test was then constructed based on the table of specifications (**Table 2**) using the format suggested by William and Lehmann (1991). The table of specification contains the course contents in COABS that simultaneously relates to instructional objectives to Bloom's revised taxonomy (Anderson & Krathwohl, 2001). Three seasoned secondary school chemistry teachers, two university teaching staff from the department of chemistry, and other subject experts were consulted to assess the validity of the items' face and content as well as their suitability for students' cognitive levels according to Bloom's revised taxonomy (Krathwohl, 2002).

Table 3. Item analysis of chemistry achievement test

Item	Difficulty index	Discrimination index	Item	Difficulty index	Discrimination index	Item	Difficulty index	Discrimination index
1	.34	.21	10	.35	.62	19	.46	.54
2	.31	.27	11	.59	.34	20	.33	.43
3	.44	.38	12	.64	.44	21	.45	.65
4	.68	.76	13	.52	.68	22	.38	.71
5	.57	.30	14	.60	.37	23	.70	.38
6	.65	.66	15	.47	.59	24	.56	.22
7	.43	.54	16	.46	.18	25	.36	.23
8	.69	.41	17	.37	.70			
9	.68	.63	18	.66	.42			

To avoid non-homogenous items, the difficulty and discrimination indices of each question were also examined (**Table 3**). The items with average indexes for the study were kept, while those with difficulty and discrimination indices outside of acceptable ranges were deleted. As a result, two items–one easy and one difficult–were completely removed. The remaining 25 test items, which had difficulty and discrimination indices between 0.30 and 0.70, and 0.20 and 0.70, respectively, were maintained and used as a pre- and post-test to gather the main data, as indicated by Kara and Celikler (2015). Additionally, CAT's Kuder-Richardson-20 (KR-20) reliability coefficient was found to be 0.86, indicating that the test is a dependable instrument (Prins et al., 2018).

Semi-structured interviews

To complement and confirm the quantitative results from the study's quantitative strand, the qualitative data were gathered using SSI. The interviewing process included a few leading questions to investigate how SICBIS affected students' performance in chemistry. We developed SSI after reviewing previously published related studies (e.g., Bennett & Lubben, 2006; Dori et al., 2018; Karsli & Yigit, 2017; Magwilang, 2016). By obtaining professional opinions from the professors in the Department of Chemistry Education at the University, the validity of SSI was strengthened. During the interview, students were grilled to get rich data for the study (Newby, 2014). The questions were, as follows:

1. Tell me about your experience of COABS during SICBIS. Explain your opinion.
2. Do you think that learning of COABS via SICBIS relates to your daily life? Why?
3. After learning of COABS through SICBIS, is there any improvement on your achievement? Tell me what you think of your improvement on this topic in the test. If any difference occurs in your achievement, please explain the underlying reasons.
4. Do you think that you have been benefitted from SICBIS? How do you feel about it?
5. Would you like to learn chemistry by conventional/existing or SICBIS? Why? Please explain.

The qualitative data were collected via a one-on-one in-person interview with six of SICBIS students using semi-structured protocols using video recorder. The six participants were selected in such as way that two students would be in each of the achiever levels (higher, middle, and lower) based on their mean values of pre- and post-test scores in the achievement test. These participants were labeled as P1, P2, P3, P4, P5, and P6.

Data Analysis

The quantitative data obtained from CAT were analyzed using descriptive and inferential statistics by using IBM SPSS version 20. The threshold for significance level was fixed at .05. After verifying its assumptions, an ANOVA analysis was performed to determine how the groups' CAT pre-test scores differed from one another. The differences among pre-CAT scores of the four groups were covariated and the difference among post-CAT scores were analysed using ANCOVA when its assumptions were assumed. Despite the fact that there were no significant mean differences between the groups for pre-CAT scores, it was nevertheless beneficial to take it into account as a covariate (Field, 2013) to *partial out* any of its effects. This would assist us to evaluate how a treatment affects the dependent variable, which would increase our confidence in F-test statistics. The research questions pertaining to post-CAT scores would therefore be addressed using ANCOVA. Verbatim were used to examine the qualitative data.

Implementation

At first, participatory TMs that may establish a constructivist learning environment such as classroom and take-home practical activities, three- to four-membered small group discussions, and questioning-and-answering were chosen. A suitable IS (i.e., 7E) that could support CBA and TMs was selected (Gill & Kusum, 2017). Suitable contexts were then identified based on a set of guiding principles recommended by academics (Assi & Cohen, 2023; Bennett & Lubben, 2006; Dori et al., 2018). These contexts were prudently linked with the contents of COABS, and thus the two context-based intervention materials, SICBISM for SICBIS and CBISM for CBIS were developed. Besides, SICTAM for SICTA was also developed. But, for the case of CG, the intervention material was the existing teacher's guide prepared by the Ministry of Education.

To conduct in-classroom experiments, a nearby carpentry shop prepared two lab kits (see **Appendix B**) on demand (for SICBIS and CBIS-treated groups). Instead of using the school laboratory at a different time, these kits were potentially important for teaching both theoretical and practical aspects of chemistry in the classroom at the same time. A lab report would be written based on the prescribed format provided by the teacher. This report could be submitted to the teacher in groups. Questioning-and-answering was another TM used in SICBIS and CBIS.

Table 4. COABS topic & sub-topics are identified in allocated time

Topic	Sub-topic	Lesson	Time allocated	
			Period	Total period
COABS	Introduction	Introducing organic & inorganic compounds	1	18 (six weeks)
	Oxides	Introducing oxides & acidic oxides, basic & amphoteric oxides, & neutral oxides & peroxides	3	
	Acids	Arrhenius, Bronsted-Lowry, & Lewis definition, classification & general properties of acids, strength & concentration of acids, pH value & its relation with strength & concentration, preparation of acids, & uses & effects of acids	6	
	Bases	Definition & general properties of bases, strength & concentration of bases, pOH & its relationship with pH, strength, & concentration, & preparation & uses of bases in everyday life	4	
	Salts	Definition & classification of salts, properties of salts, preparation of salts, & applications of salts	4	

Table 5. A sample of context & activity of SICBIS & CBIS intervention materials

Context	Activity
Wood smoke	(a) Ask your mothers &/or elder sisters/brothers what they felt on their eyes during cooking using wood fuels due to smokes. What causes irritated sensation in eyes? (b) Hold a wet blue litmus paper above a smoke & notice any color change. Why color of blue litmus changes so? Why did litmus paper need to be wet? Write a report & present to class.
Stomach acid & lemon juice	(a) Assume that two cups contain equal amounts of HCl & lemon juice. Which one might have a lower pH level? (b) What causes heartburn in people? How does drinking more water make him feel better? How does consuming an antacid, ($Mg(OH)_2$, affect pH of stomach? Why? Report to your class.
Shampoo & conditioner	Why do people use conditioner to cleanse their hair after using shampoo? Report to your class.
Wood ash & turmeric papers	Sprinkle a small amount of water over wood ash. Using turmeric paper that researchers have prepared, check for any color changes.
'Megado' & 'tambo'	(a) Why Borena people mix 'megado' with 'tambo' in their mouths? Why not they mixed it with common salt or sugar while using? (b) Use Megado to wash your hands while trying to feel any sensations. Did you get a soapy/slippery feeling? What does this feeling mean? Observe, record, analyze, & report results to your class.

SICBISM and CBISM were developed to have the seven learning stages of 7E (engage, explore, explain, elaborate, extend, exchange, and evaluate). CBISM resembled SICBISM, except the integration of simulations. Computer simulations were integrated at the 'explain' and "presentation" phases of SICBISM and SICTAM, respectively. The other types of participatory TMs were applied at the appropriate time/place at all phases of the strategy in SICBISM. SICTAM was comparable to the existing teaching material of CTA that have four stages (introduction, lecture, summary, and evaluation) with the exception of integrating the PhET interactive simulations.

The seven learning stages of 7E were incorporated into SICBISM and CBISM, as well as the responsibilities of teacher and students. Except for simulation, CBISM was similar to SICBISM. Computer simulations were integrated into SICBISM and SICTAM *explain* and *presentation* phases, respectively. With the exception of incorporating the PhET interactive simulations, SICTAM was comparable to the material used to teach CG. We used "PhET interactive simulations for science and math" software (University of Colorado Boulder, 2019), which was designed specifically for COABS. The following are some examples of PhET simulations utilized in this study: preparation and properties of oxides and salts; preparation of acids and bases; concentration and strength of acids and bases; relationship between pH and pOH; relationship between concentration and pH/pOH; and relationship between strength and pH/pOH. Finally, to validate the materials, we obtained insightful inputs from university professors and secondary school chemistry teachers.

Three school chemistry teachers attended training on SICIS, CBIS, and SICTA after intervention materials had been developed. Information about the instructional strategies was also provided to these groups. Then, the interventions were put into actions.

COABS has been arranged in the curriculum as the second unit of the grade 10 chemistry course. This topic is divided into four major subtopics: oxides, acids, bases, and salts. **Table 4** lists the topic, subtopics, and permitted time (period). Each regular class time lasts 40 minutes.

Examples of contexts and activities utilized during the intervention of SICBIS and CBIS groups are provided in **Table 5**.

Study Group One

IG_1 was exposed to SICBIS using the intervention material (SICBISM). The teacher prepared daily lesson plans derived from SICBISM (see sample lesson plan in **Appendix C**). The teacher was able to initially *engage* (elicit prior knowledge, rouse, and motivate) pupils and connect past and present concepts using context-based inquiries, question-and-answer approaches, and small group discussions. In the second stage (*explore*), the teacher gave pupils the opportunity to observe, record, and analyze results to provide answers to the questions posed in the first stage. This was accomplished through hands-on activities in the classroom and/or at home (based on take-home practical tasks).

The teacher then discussed concepts in the third stage (*explain*) with the help of PhET interactive simulations using desktop computers conveniently available in information and communication tecnology rooms to relate contexts to concepts and concepts to concepts. This was done following students' presentation of their results from *explore* phase. In *elaborate* phase (where detailed discussion of concepts to link concepts to concepts was made), the teacher gave students opportunity to relate previously learned ideas (stages one through three) to other related concepts by asking questions and/or by providing practical activities. At this stage, learners were anticipated to acquire a deeper and broader understanding through new experiences.

Table 6. ANOVA results for pre-CAT scores

Variable	Sum of squares	df	Mean square	F	p-value
Between groups	44.955	3	14.985	2.463	.065
Within groups	1,369.097	225	6.085		
Total	1,414.052	228			

Table 7. Descriptive statistics for post-CAT scores

Group	n	Mean	Standard deviation	Adjusted mean after ANCOVA
IG1	60	16.90	3.91	16.42
IG2	58	14.61	4.07	14.80
IG3	56	11.83	3.46	11.51
CG	55	9.54	2.92	10.23

Extend phase was then performed. This phase entailed applying concepts and experiences to similar contexts. At this point, learners were given real-world examples from their surroundings and asked to produce concepts in response to them. During the *exchange* (or sharing) phase, a space was created for students to discuss newly acquired knowledge with their peers. Finally, students were given the opportunity to assess their learning at the *evaluate* phase.

Study Group Two

This group taught COABS using CBIS, CBISM, and lesson plans (see a sample lesson plan in **Appendix C**). The teacher employed a CBA using 7E IS. The teacher and students' responsibilities are nearly identical to those in IG_1. The sole difference between these groups is in the third phase (explain), where the PhET simulation was not used.

Study Group Three

Using SICTAM intervention material, IG_3 was treated with SICTA using daily lesson plans (see a sample lesson plan in **Appendix C**). The group's IS was comparable to that of CG. The sole variation was use of PhET interactive simulation. During the *presentation* phase, the teacher integrated and used simulations. The teacher prepared and used daily lesson plans to teach this topic.

Study Group Four

CTA was used to teach CG in accordance with the curriculum. In this group, the teaching process began with the chemistry topic and may or may not have moved on to the context (see **Appendix C**). This was due to the fact that in the existing curriculum, the context was either provided incorporated as examples in the text, at the end of the textbook, or not at all.

Controlling Mechanisms

To ensure that the interventions were carried out as planned as or not, the researchers carried out triad classroom observations during implementation for all groups using observation checklists. The researchers attempted to follow the advice given by Creswell and Creswell (2018, p. 243) in response to the threats to internal validity. Each group had an own list of observations to make (see a sample checklist for SICBIS group in **Appendix D**). During the course of the observation, the researchers had made some notes. We provided input to teachers for each classroom observation to improve implementations.

RESULTS

Because this embedded mixed-methods study starts with a quantitative approach, the quantitative findings are reported first, followed by the qualitative results, in the next result section. With a focus on how the qualitative findings assist in explaining the quantitative findings, the inferences made from the integration of the two data sets are also included.

Quantitative Results

The average results of the observation checklists obtained from the three researchers were above 85.0% in each study group and the whole groups as well. This showed each IS in each group was implemented successfully as it was planned as. The groups were compared with their pre-CAT scores whether they were different regarding to their prior achievement using ANOVA. The assumption of normality of the data (using shapiro-wilk's test of significance, skewness and kurtosis, boxplots, normal Q-Q plots, and histograms), and homogeneity of variance (using Levene's test) were assumed. After checking the assumptions, pre-CAT scores of the four study groups were compared via ANOVA (**Table 6**). According to these results, there was no statistically significant mean difference, at the level of 0.05, among the study groups. The result thus suggests that students in all groups had approximately closer prior knowledge on COABS concepts.

After controlling for the pre-test scores, the post-test scores were compared through ANCOVA. Pre-CAT scores did not differ significantly on average between the groups, but it was nonetheless beneficial to take it into account as a covariate (Field, 2013) to assist us raise our confidence in the results of F-test statistics. Using shapiro-wilk's tests, visual inspection of histograms, boxplots, normal Q-Q plots, and skewness and kurtosis values, the assumption of normal distribution of post-CAT scores was found tenable. Besides, the homogeneity of variance, using Levene's test ($p>.05$), and homogeneity of regression slopes were also assumed. Post-CAT mean scores of the groups (**Table 7**) were then compared with ANCOVA (**Table 8**).

Table 8. ANCOVA results for post-CAT scores

Source	Sum of squares	df1	F	Sig.	Partial η^2
Treatment	289.433	3	45.100	.000	.380
Pre-CAT	152.486	1	38.085	.000	.124
Error	984.249	221			
Total	25,250.000	229			

Table 9. Bonferroni post-hoc pairwise comparison outputs for post-CAT scores

(I) Group	(J) Group	Mean difference (I-J)	Standard error	Significance	95% confidence interval	
					Lower bound	Upper bound
IG_1	IG2	1.6	.58	.033	0.07	3.16
	IG3	5.0	.58	.000	3.43	6.54
	CG	6.3	.62	.000	4.61	7.93
IG_2	IG3	3.4	.57	.000	1.86	4.89
	CG	4.7	.58	.000	3.12	6.19
IG_3	CG	1.3	.59	.164	-0.28	2.84

As can be seen in **Table 7**, post-CAT mean scores of SICBIS group were found to be the highest from the mean scores of the other groups treated with CBIS, SICTA, and CTA. Depending on ANCOVA results, there was statistically significant difference among the adjusted post-CAT mean scores of SICBIS, CBIS, SICTA, and CTA, after controlling for the effects of pre-CAT. Partial η^2 of .38 indicates that the treatment has fairly large effect size according to Cohen (1988). In a plain language, 38.0% of the variability in post-CAT scores was explained by the variance in IS.

From these results, it was clear that there would be at least one pair of groups that had statistically significantly different adjusted post-CAT mean scores. This led us to the post hoc multiple pairwise comparisons using the Bonferroni methods at the .008 (.05/6) against .05 alpha level. The results of Bonferroni methods are presents in **Table 9**.

These results showed that SICBIS treated group (IG_1) had significantly (Bonferroni adjusted $p<.008$) the highest adjusted mean scores relative to SICTA and CTA groups (IG_3 and CG, respectively). But the adjusted mean of IG_2 (CBIS) was not statistically different from the adjusted mean of IG_1 (SICBIS). The adjusted mean scores of IG_2 were significantly different from IG_3 and CG groups. Moreover, the difference between post-CAT mean scores of IG_3 and CG was not statistically significant (Bonferroni adjusted $p>.008$). Thus, CBIS was found to be as better as SICBIS. This indicates that SICBIS and CBIS are more effective in enhancing students' achievement in COABS than SICTA and CTA.

Qualitative Results

This section presents the findings from grade 10 students' perceptions and experiences with the unit of COABS after learning it through SICBIS. It was analyzed in order to support results acquired from quantitative data (CAT). Thus, the fourth study question will be addressed.

Participants were asked to provide feedback on SICBIS. Each participant stated how they felt SICBIS enhanced their COABS performance. They responded that using SICBIS to learn COABS was extremely interesting and enjoyable. Students frequently utilized the following arguments to support their opinions about SICBIS while discussing their performance in COABS. They claimed that the following strategy aspects or features–the relevance of chemical topics; simulation of abstract concepts; participation in experimental activities; and interaction with peers and teachers–were responsible for their increased achievement. Students claimed that by employing this IS, they will be able to learn chemistry and score better on post-CAT more easily. Based on these features, the results would be provided in the following paragraphs.

Relevance of chemistry topics

An in-depth interview with students found that chemistry was irrelevant to everyday life context when taught using CTA, making it difficult to attain satisfactory high marks in chemistry. Concepts and processes are difficult to visualize in static textbook diagrams, common classroom visual aids, and decontextualized instructions were challenging to grasp (Suits & Sanger, 2013). All participants (P1 through P6) believed that SICBIS aided their chemistry learning in real-world contexts. They also stated that they began to relate chemistry with everyday life and valued it:

> When we learn chemistry through conventional method, chemical concepts were very abstract and very hard to visualize. After SICBIS, everything makes more sense. I found chemistry is quite relevance to my life. Hence, I understand chemistry better than before and my result in post-CAT will be beter than pre-CAT.

Students also explained their appreciation having for SICBIS IS in relation to their scores in chemistry topic learnt through this strategy. Moreover, three of the participants (P1, P2, and P5) in particular stated their views about chemistry and believed that they had been living immersed in contexts that have used the concepts of chemistry:

> It was very astonishing because it presented chemistry contents by linking the concept with daily life experiences. The new strategy assisted me what is chemistry really mean. I believe that I will score better results in the post-test than what I usually scored in previous teacher-made assessments. Thus chemistry is what we see, smell, and touch.

Students who participated spoke openly about the notion of COABS chemistry with respect to two native chemicals (tambo and megado). Prior to our research, students had no understanding of why Borena people used megado with tambo instead of normal salt or sugar. According to this study, tambo has an acidic behavior, whereas megado has an alkaline property (backing soda, $NaHCO_3$). Megado (a white powder) is superior to the neutral compounds of common salt and sugar for dissolving tambo (powdered leaves) due to neutralization. As a result, they believe the concept of chemistry is simple, which helped them do better on the chemistry post-test than on the pre-test. P1, for example, stated:

> I know megado is popular traditional chemicals in Borena. The society has been using it for different purposes. But I did not know the concept of chemistry behind why Borena people have been taking 'megado' with 'tambo'. However, after learning COABS through SICBIS all these questions have got answers.

Simulation of abstract concepts

According to Al-Balushi et al. (2016), chemical phenomena are first explained at the macroscopic level (Suits & Sanger, 2013). However, these phenomena are typically explained utilizing the submicroscopic characteristics and behavior of molecules. Thus, from this perspective, the students interviewed stated that computer simulations had some advantages for them. They believed that by simulating abstract concepts in relation to macroscopic phenomena (contexts and real-world applications), they had enhanced their chemistry grades. According to what these students believe, combining computer simulation with a context-based IS increases students' achievement. Particularly from P3 and P4, this was clear:

> I knew some concepts of COABS in lower grades. During that time, chemistry was very theoretical, difficult, and my result was very low. But now, the abstract concepts were understood with the help of computer simulations that made the macroscopic phenomena to be understood at the particulate level.

Almost all of the participants believed that computer simulations may help them understand chemical concepts at the molecular level, avoid misconceptions, and connect their practical work to underlying submicroscopic notions. According to their perspectives, this strategy assisted them in understanding things learned in context through real practical activities (macroscopic phenomenon). They praised SICBIS since it provides chemistry with a diverse variety of chemical representations. Their COABS post-test performance appears to be much improved. Furthermore, one of the participants agreed that SICBIS will improve their chemistry achievement. This participant stated that incorporating computer simulations into a context-based 7E IS can improve their chemistry performance. P6 provided the following evidence:

> I need always to learn chemistry in the same way in the future. Computer simulations amalgamated into CBA help me to grasp the context and macroscopic level of concepts through visualization of particulate level that would assist to boost my achievement in chemistry.

In-depth interviews with students were also done to find out what they had learned from simulations and how it linked to their achievement. The interview revealed that simulation was extremely useful for simulating what necked eyes could not perceive and for truly understanding abstract concepts that could improve students' achievement in chemistry. P1, P2, P4, and P5 in particular expressed:

> We compared concentration of HA, $H3O^+$, A^- for strong and weak acids when more amount of an acid was added to the solution with associated change of pH. These simulations helped me to understand more about the difference between strong and weak acids. We have also prepared concentrated and diluted solution of battery acid and orange juice using simulations. These also assisted me to comprehend concentrated and diluted solution of acids with change of pH. Similarly, we had simulated for strong and weak bases. These helped me enhancing my achievement.

Performing experiments

Participants also stated that using SICBIS to learn COABS enhanced their chemistry performance. They were then questioned about why this was the case. They attempted to link their ideas to SICBIS, which clarified the concept of chemistry at both the macroscopic and contextual levels. Students also remarked that COABS was made meaningful for them by combining theoretical concepts with experiments in the classroom using laboratory kits made in the area. These participants, especially, P3, said that "it was greatly appreciated that the theoretical and practical aspects of chemistry were taught simultaneously in the classroom as we learned the chemical concepts, using locally made laboratory kits." All participants remarked that

> Using SICBIS, the abstract concepts of chemistry were not such difficult with the help of hands-on activities and demonstrations using locally vailable materials. The concepts were sensed with our organs by relating them with daily life contexts what are available in our surrounding. Usually, learning was made simple as the theoretical and practical futures of chemistry topics were presented concurrently during instruction.

Interactions with peers & teachers

Because it is built on interaction, discussion, and knowledge sharing among learners (Sithara, 2017). In regard to this principle, SSI revealed that students worked in groups to share ideas and solve problems in the natural environment, with the teacher serving as a facilitator and learner. Students have claimed that knowledge was interestingly constructed from the learning environment through interactions with their teachers, peers and parents a result of these. Sample quotation (by P4) is stated as

"SICBIS had enabled me to construct meaning by own. It was very participatory, which made me to interact and discuss with my friends and teacher."

As a result of our qualitative findings, we can conclude that all participants shared the belief that their achievements in COABS had increased since SICBIS made chemistry concrete, simple, and authentic to their daily lives. Students expressed a favorable assessment of SICBIS, which helped them get better chemistry outcomes since it can connect abstract concepts with everyday activities and is supported by real experimental activities. Participants found learning COABS with SICBIS to be highly interesting and fun. This kind of instruction helps learners to solidify theoretical concepts and get better results.

DISCUSSION

In this section, the effectiveness of SICBIS in improving students' achievement in COABS in relation to CBIS, SICTA, and CTA is discussed. The effects of SICBIS, CBIS, SICTA, and CTA on students' learning achievement were examined via findings obtained by CAT. When post-CAT scores of groups were compared via post hoc Boneferroni procedures, SICBIS enhanced students' achievement as good as CBIS. This result was also supported by the qualitative results. Both of these CBAs brought better changes on students' achievement than did by non-context-based instructional approaches (i.e., SICTA and CTA).

The reason might be lack of teaching and learning experiences of teacher and students of this group through computer simulations (Younis, 2017). The two groups also shared similar approach, IS, and TMs (except the presence of computer simulation in SICBIS). When compared to CTA, the results of this study support those of a previous study by Kunduz and Secken (2013) on the benefits of computer-assisted context-based instruction on students' achievement in the chemistry of precipitation titration. As a result, SICBIS may be thought of as more effective than SICTA and CTA.

Contrarily, in accordance with the current curriculum, SICTA and CTA used the same approach (content-based approach), which have had four stages: introduction, presentation, consolidation, and evaluation (see **Appendix C**). The presentation (lecture) phase takes up 25 (62.5%) time of the overall 40 minutes, with the introduction, consolidation, and evaluation phases lasting five (12.5%) minutes each. This means that the lecture phase takes up the majority of the allocated time. The incorporation of computer simulations for COABS concepts during SICTA's presentation phase is the only distinction between it and CTA. Within the allotted 25 minutes for SICTA, the teacher lectures and uses simulations. This teaching approach is based on the present chemistry curriculum, which begins with the content and places a strong emphasis on it. The context may be provided at the end of the textbook as a stand-alone unit or referenced as examples during the presentation phase somewhere in the text. Students in these two study groups therefore do not have the opportunity to recognize the interdependence between the context and content of chemistry, unlike those in SICBIS and CBIS groups. The idea that contexts and contents are two sides of the same chemical coin (Garcia-Martinez & Serrano-Torregrosa, 2015) then has not been applied in SICTA group

Besides, SICTA is also not better than CTA in increasing students' achievement in COABS. This particular result appears to contradict with the claims of Al-Balushi et al. (2016), Gambari et al. (2016), Kapici et al. (2022), and Younis (2017) that simulation-integrated instruction enhances students' achievement level in learning chemistry. The reason might be similar to SICBIS-treated group. The experiences and self-confidence of both the teacher and students in this group might be very limited in using computer simulations (Younis, 2017). Chemistry teachers may have little experience of using computer simulations. Thus, in order to improve implementation, teachers should get ongoing training on how to integrate and use computer simulation in context-based chemistry education.

However, SICBIS-treated group remarkably claimed that strategy enables them to raise their achievement in COABS. SICBIS has the ability to present abstract concepts in a way that is connected to context, macroscopic, submicroscopic, and symbolic representations. This result agrees with that published by Enero Upahi and Ramnarain (2019). Multiple representations, according to these authors, support students' constructivist learning in chemistry education. SICBIS can then offer a conducive learning environment to students in achieving better in COABS. This indicates that students' construction of knowledge is connected to the constructivist theory, which holds that learning cannot be transmitted from teacher to student but rather requires students develop a comprehension on their own (Suits & Sanger, 2013). This supports the notion that the main goal of teaching and learning chemistry is to promote meaningful learning rather than learning by rote (Sithara, 2017).

It could be started by posing questions and employing the small group discussions at the first stage of 7E (*engage*). The real chemical experiments may be conducted next to this stage in the 'explore' phase. These experiments may be carried out in-class and/or take-home experimental activities. It is advantageous for students that local chemicals are mild and noncorrosive substances. Moreover, the computer simulations, students' presentations, and group discussions can be used in the *explain* stage. By relating concepts to other concepts and to contexts, the teacher might offer a brief lecture. Similar participatory TMs can be used in the remaining phases (*elaborate*, *extend*, *exchange*, and *evaluate*) depending on how well they work for that particular phase. The sample lesson plans (see **Appendix C**) present TMs employed in each stage of IS.

Likewise, the results of this study are consistent with the conclusions drawn by previous context-based chemistry studies on different chemistry topics (Baran & Sozbilir, 2017; Celestina et al., 2020; Gambari et al., 2016; Ilhan et al., 2016; Magwilang, 2016; Majid & Rohaeti, 2018; Younis, 2017). For instance, it was indicated that CBA was superior to existing non-context-based instructions by Baran and Sozbilir (2017) (thermodynamics), Celestina et al. (2020) (chemical kinetics), Ilhan et al. (2016) (chemical equilibrium), and Magwilang (2016) (matter and chemical reactions). In general, it can be said that CBA instruction, with/without computer simulations, is very helpful to achieve better results in secondary school chemistry, particularly in COABS, than using conventional mode of teaching with/without simulations.

CONCLUSIONS & IMPLICATIONS

It is clear that using a CBA, computer simulation, or very limited purely quantitative computer-assisted CBA instructions in secondary school students' chemistry in general, and in some topics in particular, has a positive impact on their academic achievement when compared to students who receive conventional instruction. In this embedded mixed-method study, it was discovered that grade 10 students (average age 17) who were taught using a 7E context-based IS that included computer simulation did better in COABS than those who were not, even if the difference was not statistically significant. The achievement of these students was found to be significantly different from that of students who received a CTA with or without computer simulations. It implies that these student groups comprehend COABS better than their counterpart student groups. This finding was supported with the opinions of students obtained through semi-structure interview that was not did by related previous studies. It appears that students' perception of chemistry as ACID are gradually changed into conception of chemistry as relevant, less abstract, complex, and difficult.

Other important aspect of this study was that COABS specific TMs and IS within a constructivist CBA were identified boldly to improve grade 10 students' achievement. Those TMs were determined primarily based on the four levels of chemical concepts, and they were amalgamated via the seven-stages of 7E IS to improve students' achievement. It is therefore difficult to picture teaching chemistry today without considering relevant contexts and integrating them with computer simulations in order to properly address the levels of chemical concepts and increase secondary school students' achievement in chemistry.

The implication of this study, for chemistry teachers, is that simulation integration within 7E context-based IS supported with real experiments and other topic-specific TMs can be used to improve achievement of students in COABS especially in secondary schools. As a result, a gradual shift in chemistry teachers' teaching styles from the conventional, context-based-, or simulation-only teaching approach to the use of simulation-integrated 7E context-based IS with a careful selection and integration of TMs in their IS may be considered for the improvement of COBS chemistry instruction.

Limitations & Directions for Future Research

This study, like many others, has some limitations. The research data for this study were not gathered from teacher participants; teachers had not taken part in the study as research subjects. Besides, there were no qualitative data collected from CBIS and SICTA treated groups to compare with SICBIS groups. Similarly, open-ended questions were not used in the study to collect rich qualitative data from a large sample of students. However, to lessen this concern, we employed SSIs with six students who had varying degrees of academic achievement. However, future research in this area must take these limitations into account. Further studies with different population and different topics should also be undertaken to generalize the findings.

Author contributions: MD: design, data analysis, interpretation, & writing & **WB & DA:** directed & commented on study from beginning to end. All authors have agreed with the results and conclusions.

Funding: This study was supported by Addis Ababa University.

Acknowledgements: The authors would like to thank Addis Ababa University for funding & Department of Science and Mathematics Education for assistance & facilitating with this study. The authors would also like to thank the colleagues & friends who provided valuable comments & insights in various stages of production of this study based on their rich experiences.

Ethical statement: The authors stated that an official letter (protocol code: Ref. No. SMED/459/2014-22, approved on 19 September 2022) was received from Addis Ababa University. This letter was given to the study area district education office and obtained a letter of permission (protocol code: Ref. No. WBG/225/12/35, approved on 30 September 2022) from the office to get access to the school authorities, teachers, and students as well. Written informed consents were obtained from the participants.

Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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APPENDIX A: CHEMISTRY ACHIEVEMENT TEST

Instruction

1. This test paper contains 25 multiple-choice questions. Each test item has four alternatives. Circle the letter of your choice to answer each question.
2. The information obtained will be used only for study purpose, and it will be kept confidential.

Questions

1. Which of the following locally available substances is composed of inorganic compounds?
   a. Beeswax
   b. Common salt
   c. Lemon juice
   d. Benzene
2. If an oxide tends to react with **both** an acid and a base, then it is
   a. an acidic oxide
   b. a basic oxide
   c. an amphoteric oxide
   d. a neutral oxide
3. What may be produced if you add water to a wooden ash at your home?
   a. Acidic solution
   b. Saline (salt) solution
   c. A basic solution
   d. Oxide
4. In a **concentrated** solution of **weak** acid (HA),
   a. undissociated HA is not present while H_3O^+ and A^- ions are high in concentration
   b. all HA, A^- & H_3O^+ species are present, but HA is more in concentration than A^- & H_3O^+
   c. all HA, A^- & H_3O^+ species are present, but HA is less in concentration than A^- & H_3O^+
   d. H_3O^+ and A^- ions are not totally present.
5. Which one of the following is **wrong** about acids?
   a. Acids can be prepared by direct combination of elements.
   b. Acids can react with bases to form salt and water.
   c. Acids can be formed when acidic oxides dissolve in water.
   d. Acids are bitter in taste.
6. Which one of the following is **correct** about the method of preparation of a salt?
   a. A salt can be formed when a basic oxide reacts with acidic oxide.
   b. A salt can be formed when a basic oxide reacts with water.
   c. A salt can be formed when an acidic oxide reacts with water.
   d. A salt can be formed when a neutral oxide reacts with a base.
7. Which one of the following alternatives describes correctly about the property of a nonmetallic oxide?
   a. A nonmetallic oxide is also called as a basic oxide.
   b. A nonmetallic oxide changes wet red litmus paper to blue.
   c. A nonmetallic oxide can produce an acid when it dissolves in water.
   d. A nonmetallic oxide can react with an acidic oxide to give a salt product.
8. When you add extra amount of a **strong** base (MOH) to its solution,
   a. undissociated MOH does not exist in the solution
   b. OH^- ion concentration decreases in the solution
   c. M^+ ion concentration decreases in the solution
   d. undissociated MOH also increases in the solution

9. A person was holding a blue litmus paper over a burning wood to check the acidity of the smoke. But the blue color of the litmus was not changed. This was because
    a. the litmus paper was dry so that H^+ was not formed
    b. the litmus paper was wet so that H^+ was not formed
    c. blue litmus paper does not change its color with an acid
    d. wood smoke does not contain acidic oxides
10. According to the Arrhenius definition, a base is a substance that
    a. donates a lone pair of electrons
    b. gives OH^- ions in water solution
    c. accepts a proton
    d. accepts H^+ ions in water solution
11. Traditionally, some people living in Borana zone swallow a solution of megado to get relieve from heartburn and sometimes they also use it for washing purpose as well as to rinse and clean their mouths. This indicates that megado might be
    a. a basic salt
    b. an acidic oxide
    c. a neutral salt
    d. a nonmetallic oxide
12. What are you going to do if you were being stung by **mosquito** and **wasp** to neutralize and get relief from the effects?
    a. Apply a solution of megado, soap, or ash onto the skin stung by both insects.
    b. Apply a solution of megado, soap, or ash onto the skin stung by mosquito and apply a lemon or vinegar solution for wasp stinging area.
    c. Apply a lemon or vinegar solution onto the skin stung by both insects.
    d. Apply a lemon or vinegar solution onto skin stung by mosquito and apply megado, soap, or ash solution for wasp stinging area.
13. Which of the followings is a **basic (an alkaline**) substance?
    a. Soft drink
    b. Lemon juice
    c. Vinegar
    d. Toothpaste
14. When we add more amount of water to an orange fruit solution,
    a. its pH value increases
    b. its H^+ ion concentration increases
    c. its volume decreases
    d. its orange color becomes red
15. Which one of the following would **NOT** be used as a pH indicator of a solution?
    a. Filter paper
    b. Turmeric paper/solution
    c. Litmus paper
    d. Methyl orange
16. What happens to the pH of a stomach when a person swallows an antacid like $Mg(OH)_2$?
    a. Increases
    b. Decreases
    c. Does not change
    d. Impossible to judge
17. Which one of the following compounds is considered as a **strong** base?
    a. $Mg(OH)_2$
    b. NH_3
    c. $Al(OH)_3$
    d. KOH

18. A sample of **vinegar** has a pH of **5**, and a sample of **rainwater** has a pH of **6**. Which of the following statements describes these two substances?
    a. Both samples are bases, but vinegar is more basic.
    b. Both samples are acids, but vinegar is more acidic.
    c. Both samples are bases, but rainwater is more basic.
    d. Both samples are acids, but rainwater is more acidic.
19. Among the following, which one is **wrong** about a salt?
    a. A salt is composed of a cation coming from a base and anion coming from an acid.
    b. A salt solution is a nonconductor of electricity.
    c. A salt can be prepared from a reaction between acidic and basic oxides.
    d. A salt can be classified as acidic, basic or normal salt.
20. A compound, which contains only two types of elements (oxygen and another element) is
    a. an acid
    b. a base
    c. an oxide
    d. a salt
21. Why do some people rinse their hair with vinegar (or conditioner) after washing with shampoo?
    a. To neutralize the acidic shampoo and maintain the basic nature of hair.
    b. To neutralize the basic shampoo and maintain the basic nature of hair.
    c. To neutralize the basic shampoo and maintain the acidic nature of hair.
    d. To neutralize the acidic shampoo and maintain the basic nature of hair.
22. Which salt is derived (formed) from calcium hydroxide and sulfuric acid?
    a. $Ca(NO_3)_2$
    b. $CaSO_4$
    c. $MgSO_4$
    d. MgS
23. Wood smoke irritates (burns) our eyes when it gets (enters) to eyes. This is because
    a. SO_2, CO_2, & NO_2 in the smoke mix with water in the eyes and form neutral solution.
    b. SO_2, CO_2, & NO_2 in the smoke mix with water in the eyes and form acidic solution.
    c. SO_2, CO_2, & NO_2 in the smoke mix with water in the eyes & form amphoteric solution.
    d. SO_2, CO_2, & NO_2 in the smoke mix with water in the eyes and form basic solution.
24. When more amount of a base is added to a solution, its
    a. pH value decreases
    b. pOH value increases
    c. OH^- ion concentration increases
    d. H^+ ion concentration increases
25. When a person eats food, HCl is released/secreted more and
    a. the concentration of OH^- increases
    b. the concentration of H^+ decreases
    c. the pOH value decreases
    d. the pH value decreases

APPENDIX B: LOCALLY MADE CHEMISTRY LABORATORY KITS

Figure B1. External view of locally made lab kits (Source: Authors' own Elaboration)

Figure B2. Internal view of locally made lab kits (Source: Authors' own Elaboration)

APPENDIX C: SAMPLE LESSON PLANS

Table C1. A sample lesson plan for SICBISM

General information

Subject: *Chemistry*	**Grade:** *10th*
Unit-2: *Chemistry of oxides, acids, bases, & salts*	**Teacher's name:** ……………………........
Lesson title: *Introducing oxides & discussion on acidic oxides*	**Duration:** *40 minutes*

Prerequisite/prior knowledge: *Students may be familiar with general classifications of compounds into organic & inorganic, & into oxides, acids, bases, & salts based on their compositions & properties.*

Learning objectives of the lesson

Upon completion of this lesson, students will be able to:

1. Define term oxide & state different classifications
2. Define an acidic oxide & explain their formation methods
3. Give examples of acidic oxides available in real-life situations
4. State physical & chemical properties of acidic oxides
5. Describe impact of acidic oxides in real life situations

Materials & technology: Desktop computers, PhET simulation software, LCD projector (if accessible), chalk & board, chemistry textbook, & intervention material (SICBISM)

7E instructional strategies & learning tasks

Phase	**Activity description**	
	Teacher	**Student**
Engage (5')	Begin lesson with following questions: Ask students some questions such as what are some common examples of oxides/acidic oxides in your locality? How could you define these oxides? What are their impacts on human health & on environment? Let students to discuss in their groups.	1. Listen to teacher's questions 2. Being activated to prior knowledge 3. Respond to the questions asked by the teacher 4. Raise questions for unclear ideas
Explore (10')	Students need to analyze data that were (a) obtained from their mothers/elders (home assignment & lesson-1) & from their own feeling when smokes get into their eyes & (b) obtained from color change of wet blue litmus paper.	1. Ask parents including your experiences at home about irritating/tearing effect of smokes, record, & analyze data. 2. In analysis, students may discuss on (a) composition of wood smokes, (b) reason why smokes irritate our eyes, (c) reaction equations occurring in our eyes, (d) color change of litmus paper, & (e) purpose of using wet litmus rather than dry.
Explain (10')	1. Let students to present their results obtained from explore phase. 2. Discuss concepts of oxides & acidic oxides by linking contexts to concepts on textbook with help of computer simulations. For example, discuss definition & classification of oxides, acidic oxides, real-life examples of oxides, physical & chemical properties of acidic oxides, & their impacts on real life. **PhET interactive simulations:** 1. Formation of SO_2 from S and O_2 2. Formation of CO= from C and O_2 3. CO_2 dissolve in water to form H_2CO_3 4. SO_2 dissolve in water to form H_2SO_3 5. N_2O_5 dissolve in water to form HNO_3	1. Present analysis results to class 2. Listen to teacher & watch on PhET simulations & try to understand sub-microscopic concepts 3. Take notes properly 4. Compare ideas with what you have worked before 5. Ask questions for unclear ideas 6. Respond to questions
Elaborate (4')	Ask questions like write a balance chemical equation: 1. When P burns with O_2? 2. When NO_2 dissolves in water? 3. When SO_3 dissolve in water? 4. When Cl_2O_7 dissolve in water?	1. Actively participate within learning groups 2. Give balanced chemical equation
Extend (4')	Ask some questions such as ☞Decide whether each compound is an oxide or not: (a) P_4O_6 (b) H_2O (c) KOH (d) Ga_2O_3 (e) H_2SO_4 (f) Na_2O ☞Complete & balance following chemical equations: (i) $CO_2 + Na_2O \rightarrow$ **?** (ii) $SO_3 + CaO \rightarrow$ **?**	1. Actively participate within their learning groups 2. Answer the questions asked by the teacher 3. Transfer previously learned concepts to other concepts & contexts
Exchange (5')	Let learners to exchange what they have learned about acidic oxides with their peers. Probed them to discuss what they have learned & understood about acidic oxides with their neighbors.	Share your knowledge about acidic oxides within your learning groups.
Evaluate (2')	What would you like to tell to your families about impact of fuel woods on their health while using as an energy source? Why? ***Take-home assignment*:** (a) request students to ask their mothers & elders what they felt on their eyes during cooking using wood fuels due to smokes & (b) give a piece of blue litmus paper for students to notice any color change. Note: Tell students to make wet litmus paper into pure water before using.	1. Actively participate in individual & group works 2. Put down plausible answers to questions

Teacher's name: ______________________________	Department head name: ______________________	V/Principal name: ____________________________
Signature: __________________________________	Signature: __________________________________	Signature: __________________________________
Date: ______________________________________	Date: ______________________________________	Date: ______________________________________

Table C2. A sample lesson plan for CBISM

General information		
Subject: *Chemistry*		**Grade:** *10th*
Unit-2: *Chemistry of oxides, acids, bases, & salts*		**Teacher's name:** ………………….…..…
Lesson title: *Introducing oxides & discussion on acidic oxides*		**Duration:** *40 minutes*
Prerequisite/prior knowledge: *Students may be familiar with general classifications of compounds into organic & inorganic, & into oxides, acids, bases, & salts based on their compositions & properties.*		
Learning objectives of the lesson		
Upon completion of this lesson, students will be able to: 1. Define term oxide & state different classifications 2. Define an acidic oxide & explain their formation methods 3. Give examples of acidic oxides available in real-life situations 4. State physical & chemical properties of acidic oxides 5. Describe impact of acidic oxides in real life situations		
Materials & technology: Chalk & board, chemistry textbook, & intervention material (CBISM)		
7E instructional strategies & learning tasks		
Phase	**Activity description**	
	Teacher	**Student**
Engage (5')	Begin lesson with following questions: Ask students some questions such as what are some common examples of oxides/acidic oxides in your locality? How could you define these oxides? What are their impacts on human health & on environment? Let students to discuss in their groups.	1. Listen to teacher's questions 2. Being activated to prior knowledge 3. Respond to the questions asked by the teacher 4. Raise questions for unclear ideas
Explore (10')	Students need to analyze data that were (a) obtained from their mothers/elders (home assignment & lesson-1) & from their own feeling when smokes get into their eyes & (b) obtained from color change of wet blue litmus paper.	1. Ask parents including your experiences at home about irritating/tearing effect of smokes, record, & analyze data. 2. In analysis, students may discuss on (a) composition of wood smokes, (b) reason why smokes irritate our eyes, (c) reaction equations occurring in our eyes, (d) color change of litmus paper, & (e) purpose of using wet litmus rather than dry.
Explain (10')	1. Let students to present their results obtained from explore phase. 2. Discuss concepts of oxides & acidic oxides by linking contexts to concepts on textbook with help of computer simulations. For example, discuss definition & classification of oxides, acidic oxides, real-life examples of oxides, physical & chemical properties of acidic oxides, & their impacts on real life.	1. Present analysis results to class 2. Listen to teacher & watch on PhET simulations & try to understand sub-microscopic concepts 3. Take notes properly 4. Compare ideas with what you have worked before 5. Ask questions for unclear ideas 6. Respond to questions
Elaborate (4')	Ask questions like write a balance chemical equation: 1. When P burns with O_2? 2. When NO_2 dissolves in water? 3. When SO_3 dissolve in water? 4. When Cl_2O_7 dissolve in water?	1. Actively participate within learning groups 2. Give balanced chemical equation
Extend (4')	Ask some questions such as ☞Decide whether each compound is an oxide or not: (a) P_4O_6 (b) H_2O (c) KOH (d) Ga_2O_3 (e) H_2SO_4 (f) Na_2O ☞Complete & balance following chemical equations: (i) $CO_2 + Na_2O \rightarrow$ **?** (ii) $SO_3 + CaO \rightarrow$ **?**	1. Actively participate within their learning groups 2. Answer the questions asked by the teacher 3. Transfer previously learned concepts to other concepts & contexts
Exchange (5')	Let learners to exchange what they have learned about acidic oxides with their peers. Probed them to discuss what they have learned & understood about acidic oxides with their neighbors.	Share your knowledge about acidic oxides within your learning groups.
Evaluate (2')	What would you like to tell to your families about impact of fuel woods on their health while using as an energy source? Why? ***Take-home assignment*:** (a) request students to ask their mothers & elders what they felt on their eyes during cooking using wood fuels due to smokes & (b) give a piece of blue litmus paper for students to notice any color change. Note: Tell students to make wet litmus paper into pure water before using.	1. Actively participate in individual & group works 2. Put down plausible answers to questions
Teacher's name: ______________________________ Signature: ______________________________ Date: ______________________________	Department head name: ______________________ Signature: ______________________________ Date: ______________________________	V/Principal name: ___________________________ Signature: ______________________________ Date: ______________________________

Table C3. A sample lesson plan for SICTAM

General information			
Subject: *Chemistry*		**Grade:** *10th*	
Unit-2: *Chemistry of oxides, acids, bases, & salts*		**Teacher's name:** ……………………........	
Topic: *Introducing oxides & discussion on acidic oxides*		**Duration:** *40 minutes*	
Objectives			
Upon completion of this lesson, students will be able to: 1. Define term oxide & state different classifications 2. Define an acidic oxide & explain their formation methods 3. Give examples of acidic oxides available in real-life situations 4. State physical & chemical properties of acidic oxides 5. Describe impact of acidic oxides in real life situations			
Stage	**Teacher's activity**	**Student's activity**	**Remark**
Introduction (5')	1. Start lesson through reminding previous lesson 2. Then introducing lesson of day	1. Listening 2. Participation through giving answers & posing questions	
Presentation (25')	Discuss concepts of oxides & acidic oxides on textbook with help of computer simulations. Simulate following concepts using PhET interactive simulation software: 1. Formation of SO_2 from S & O_2 2. Formation of CO_2 from C & O_2 3. CO_2 dissolve in water to form H_2CO_3 4. SO_2 dissolve in water to form H_2SO_3 5. N_2O_5 dissolve in water to form HNO_3	1. Give attention & actively participate during lecturing 2. Watch on simulations & try to understand sub-microscopic concepts 3. Takes notes 4. Ask questions for unclear ideas	
Consolidation (5')	Summarize main points of lesson	Carefully listening and ask questions when necessary	
Evaluation (5')	Assess students whether they understood new information correctly by using oral questions, classwork, homework, etc.	Actively participate to questions	
Teacher's name: ______________ Signature: ______________ Date: ______________	Department head name: ______________ Signature: ______________ Date: ______________	V/Principal name: ______________ Signature: ______________ Date: ______________	

Table C4. A sample lesson plan for CTAM (comparison group)

General information			
Subject: *Chemistry*		**Grade:** *10th*	
Unit-2: *Chemistry of oxides, acids, bases, & salts*		**Teacher's name:** ……………………........	
Topic: *Introducing oxides & discussion on acidic oxides*		**Duration:** *40 minutes*	
Objectives			
Upon completion of this lesson, students will be able to: 1. Define term oxide & state different classifications 2. Define an acidic oxide & explain their formation methods 3. Give examples of acidic oxides available in real-life situations 4. State physical & chemical properties of acidic oxides 5. Describe impact of acidic oxides in real life situations			
Stage	**Teacher's activity**	**Student's activity**	**Remark**
Introduction (5')	1. Start lesson through reminding previous lesson 2. Then introducing lesson of day	1. Listening 2. Participation through giving answers & posing questions	
Presentation (25')	1. Giving lectures about topic 2. Explain concepts in detail	1. Give attention & actively participate during lecturing 2. Takes own notes 3. Ask questions for unclear ideas	
Consolidation (5')	Summarize main points of lesson	Carefully listening and ask questions when necessary	
Evaluation (5')	Assess students whether they understood new information correctly by using oral questions, classwork, homework, etc.	Actively participate to questions	
Teacher's name: ______________ Signature: ______________ Date: ______________	Department head name: ______________ Signature: ______________ Date: ______________	V/Principal name: ______________ Signature: ______________ Date: ______________	

APPENDIX D: CLASSROOM OBSERVATION CHECKLISTS FOR SICBIS (IG_1) GROUP

School: _______________

Section: ______________

Time: ________________

Date: ________________

Questions (this teaching strategy is evaluated on 7E learning cycle [engage, explore, explain, elaborate, extend, exchange, & evaluate]):

1. Did the teacher start the instruction from the context at the 1st (*engage*) stage?
2. Did students actively participate in groups and respond to questions raised by the teacher at the 1st stage?
3. Did the teacher link contexts to concepts via hands-on activities at the 2nd (*explore*) stage?
4. Did students do hands-on activities and observed, recorded, and analyzed data at the 2nd stage?
5. Did the teacher discuss concept of chemistry (COABS) by linking with contexts based on the textbook at the 3rd (*explain*) stage?
6. Did the teacher explain concepts with the help of computer simulation (when necessary) at the 3rd stage?
7. Did students present their analysis results to the class at the 3rd stage?
8. Did students give proper attention and actively participate when the teacher presents concepts with computer simulations (e.g., giving attentions, watching on or run simulations, take notes, and ask questions) at the 3rd stage?
9. Did teacher discuss concepts in detail to relate previously concepts to other concepts by asking questions at 4th (*elaborate*) stage?
10. Did students actively listen to teacher & participate for questions asked by teacher either individually or in groups at the 4th stage?
11. Did teacher ask questions for students to apply/transfer the new obtained knowledge to new situations at the 5th (*extend*) stage?
12. Did students actively participate for the questions asked by the teacher either individually or in groups at the 5th stage?
13. Did teacher develop an environment for learners to exchange what they have learned within their groups at 6th (*exchange*) stage?
14. Did students share their knowledge between groups at the 6th stage?
15. Did the teacher assess students' learning by asking open-ended questions at the 7th (*evaluate*) stage?
16. Did students try to respond to the questions asked by the teacher?
17. Extra notses, comments, suggestions, & remarks given by researcher: ____
    ____
    ____
    ____