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Enhancing secondary school students' engagement in chemistry through 7E context-based instructional strategy supported with simulation

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ABSTRACT

Now days, the level of students' engagement in secondary school chemistry is low. The aim of this study was then to enhance student chemistry engagement through simulation-integrated 7E context-based instructional strategy and compared its efficacy with 7E context-based instructional strategy, simulation-integrated conventional teaching approach, and conventional teaching approach. For the quantitative part, 15-item chemistry engagement scale was utilized to collect data from 229 grade 10 students as part of a quasi-experimental pre-/post-test non-equivalent control group design. Both descriptive and inferential statistics were utilized. Semi-structured interviews were used to collect qualitative data. The study's findings revealed that, when compared to the other instructional strategies, the simulation-integrated 7E context-based instructional strategy was the most successful at raising students' overall engagement and its dimensions. This study implies that implementing a simulation-integrated 7E context-based instructional strategy can boost students' overall and individual levels of engagement in chemistry. Thus, to enhance chemistry learning, teachers may progressively move from the conventional approach to the use of simulation-integrated 7E context-based approach over the other strategies.

Keywords: context-based approach, context-based instructional strategy, 7E learning model, computer simulation, student engagement

INTRODUCTION

Research has demonstrated that actively engaging students in the learning process increases their focus and engagement level (Chans & Castro, 2021; Lancaster et al., 2013). Therefore, the level of engagement in the prescribed activity is defined as student involvement (Plass et al. 2012). Students' level of engagements is also described as focused participation and persistence in the task (Geerdink-Klink et al., 2019). Although it has multiple components, this study measures the three most prominent dimensions (behavioral, cognitive, and emotional engagements) identified in the literature. According to Terrion and Aceti (2012), student engagement is an important component of science education, particularly in chemistry.

Unfortunately, the engagement of most students in chemistry is low (Vaino et al., 2012). Students who are not well engaged do not listen to or pay attention to the learning process. Such a low level of engagement among students in chemistry may be associated with the type of instruction used (Han, 2021). Teachers who incorporate Active Learning into their lessons give students more opportunities to participate, making it easier for everyone to meet learning objectives (Chans & Castro, 2021; Lancaster et al., 2013). To boost students' learning engagement in chemistry, classes may need to use active learning strategies, such as addressing representations (Lancaster et al., 2013; Upahi & Ramnarain, 2019).

Nevertheless, the majority of context-based approach (CBA) studies (Baran & Sozbilir, 2017; Magwilang, 2022), for instance, have not used educational technologies (such as computer simulations) to represent the particulate level of concepts effectively. Simulations are vital for understanding why matter behaves at the macroscopic level (Plass et al., 2012). However, there is a lack of focus on including simulations in context-based chemistry instruction in schools (Plass et al. 2012). Students are unable to connect macroscopic and contextual levels to the particle nature of these CBA instructions. At the microscopic level, they had difficulty interpreting context-based learning (Ibrahim et al., 2014). As a result, many high school students regard chemistry as an

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The present work is based on the doctoral thesis.

abstract subject (Barke et al., 2011). In this instance, simple concepts would appear to be complex, while readily understood topics would appear to be difficult (Demircioglu et al., 2005), resulting in low engagement in chemistry (Vaino et al., 2012).

On the other hand, most simulation-integrated studies did not use contexts; they lacked the contextualization of concepts (Gambari et al., 2016; Tatli & Ayas, 2013). As Klassen (2006) noted, in most parts of the world, chemistry education has been associated with the dominant nature of the decontextualized mode of chemical discourse. This instruction has less power to link the particulate nature of concepts to human activity and the macroscopic level. As a result, secondary school students' participation in chemistry education may be low (Christenson, 2013). Instructions then need to include multiple representations to help students coordinate across representations (Upahi & Ramnarain, 2019). Researchers are thus grappling with ways to increase students' engagement in chemistry. We assumed that combining CBA and simulation could be a solution to this problem as it could improve students' learning outcomes in chemistry (Tatli & Ayas, 2013) and other areas of science education such as biology (Safitri et al., 2017), physics (Nguyen & Williams, 2016), and STEM (Yang & Baldwin, 2020) in general.

Although one of the most important goals of chemistry education is to help students navigate between the four levels of representation (Plass et al., 2012; Upahi & Ramnarain, 2019), most previous research has not made much effort to integrate the two pedagogies to better represent concepts and improve student engagement. We argue that when developing chemistry instructions, researchers should not be too far from the four levels of representations: human elements, macroscopic phenomena, submicroscopic representations, and symbolic representations. To address these issues, the choice of approach, instructional strategy, and topic-specific participatory teaching methods may play a significant role. However, previous studies have made limited efforts to achieve this goal.

The design of our study differs in multiple ways from that of previous studies. Our study extends previous work by supporting simulations with real in-classroom and take-home practical experiments. Practical work was conducted in the classroom using locally made laboratory kits. The use of these kits was critical for teaching both theoretical and practical aspects of chemistry in the classroom while learning concepts, rather than using the school laboratory at different times. In addition to distinctions in population type and area of chemistry, the current study addressed another drawback of prior studies by examining students' opinions on the strategy using qualitative data.

The chemistry of oxides, acids, bases, and salts was used because this topic occupies a central place in the chemistry curricula. Their concepts are too abstract to be understood by secondary school students (Barke et al., 2009; Ross & Munby, 1991; Sesen & Tarhan, 2011) and poorly contextualized (Demircioglu et al., 2005). Consequently, students engaged and performed poorly in this area of chemistry. In addition, the low level of engagement of students might be related to their misconceptions of oxides (Sesen & Tarhan, 2011), acids (Hans-Dieter et al., 2009; Ross & Munby, 1991; Sesen & Tarhan, 2011), bases (Hans-Dieter et al., 2009; Ross & Munby, 1991; Sesen & Tarhan, 2011), and salts (Hans-Dieter et al., 2009; Secken, 2010). Furthermore, these studies have also argued that the misconceptions and low engagement levels of students might often result from teacher-centered instruction in secondary schools in which students passively participate in learning.

In summary, our study fills the empirical gap in that simulation-integrated context-based instructional strategy might improve grade 10 students' engagement in chemistry of oxides, acids, bases, and salts. We also investigated how simulation-integrated 7E context-based instructional strategy affects secondary school students' engagement in chemistry of oxides, acids, bases, and salts in comparison with 7E context-based instructional strategy, simulation-integrated conventional teaching approach, and conventional teaching approach. Our argument is that it is insufficient to simply compare the impact of simulation-integrated 7E context-based instructional strategy on students' engagement in chemistry of oxides, acids, bases, and salts with conventional teaching approach, because even a few adjustments to conventional teaching approach may have a significant impact on students' learning outcomes. This study also revealed which TSPTMs are used in conjunction with simulation-integrated 7E context-based instructional strategy to increase students' engagement in chemistry of oxides, acids, bases, and salts.

Theoretical Framework

This study's theoretical foundation is based on social constructivism. Lev Vygotsky introduced social constructivism as a learning theory in 1968 (Liu & Matthews, 2005). In the 1980s, social constructivism was a popular theory that was used to guide teaching, learning, and research in the field of science education (Pritchard, 2009). It underlines the need to begin knowledge with what learners already know about. This implies that learning occurs through contact between the learner and others.

This learning framework assumes that students actively construct meaning while engaging in a self-directed role in their learning, with the teacher serving as a facilitator rather than passively absorbing it (Johnson, 2019; Opara, 2013; Suryawati & Osman, 2018). They come to class with preconceived thoughts and prior concepts rather than as empty bottles waiting to be filled by their teachers (Johnson, 2019; Opara, 2013; Schunk, 2020; Suryawati & Osman, 2018). As a result, every student has prior knowledge that the teacher links with new knowledge for long-term learning through social constructivist learning activities such as context-based and technology-integrated instruction (Akpan et al., 2020; Haryadi et al., 2016).

Accordingly, a CBA (De Jong, 2008; Gilbert, 2006) and computer simulation (Suits & Sanger, 2013) build on social constructivist learning theory that helps learners construct meanings from contexts using macroscopic and abstract concepts. Hence, simulation-integrated 7E context-based instructional strategy can also be viewed as a social constructivist environment. This implies that this study was guided by the social constructivist theory. Therefore, it might be reasonable to assume that dynamic student–teacher and student–student interactions would be helpful in improving students' engagement in chemistry of oxides, acids, bases, and salts.

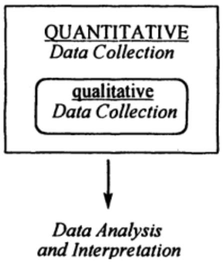

Figure 1. Scheme of embedded mixed method of the study (Bunce & Cole, 2008; Creswell, 2014)

Table 1. Quasi-experimental design of the study

Group	Pre-test	Treatment	Post-test
IG1	Pre-test	Simulation-integrated 7E context-based instructional strategy	Post-test
IG2	Pre-test	7E context-based instructional strategy	Post-test
IG3	Pre-test	Simulation-integrated conventional teaching approach	Post-test
CG	Pre-test	-	Post-test

Aim & Research Questions of the Study

The objective of this study is to determine how simulation-integrated 7E context-based instructional strategy affects students' engagement in chemistry of oxides, acids, bases, and salts and to compare its effectiveness with 7E context-based instructional strategy, simulation-integrated conventional teaching approach, and conventional teaching approach in improving their level of overall engagement and dimensions. Thus, this study addressed the following research questions:

1. Would students in grade 10 who received simulation-integrated 7E context-based instructional strategy treatment have significantly higher mean scores for overall engagement across groups towards chemistry of oxides, acids, bases, and salts than conventional teaching approach?
2. Would students in grade 10 who received simulation-integrated 7E context-based instructional strategy treatment have considerably higher overall engagement with chemistry of oxides, acids, bases, and salts than students who received 7E context-based instructional strategy and simulation-integrated conventional teaching approach?
3. What impact would simulation-integrated 7E context-based instructional strategy have on each of these three dimensions?
    a. Would each engagement dimension weigh equally at the overall level of student engagement?
    b. Would there be a significant mean difference between groups for each dimension level?
    c. Would students in grade 10 who were exposed to the simulation-integrated 7E context-based instructional strategy have the highest mean scores with respect to each dimension?
4. Do students believe that simulation-integrated 7E context-based instructional strategy positively affects their engagement in chemistry?

METHODOLOGY

Research Method & Design

A concurrent embedded mixed method was used in this investigation. The scheme of this mixed method (Bunce & Cole, 2008; Creswell, 2014) is presented in **Figure 1**. The results from the two methods were merged throughout the discussion phase to ensure complementarity (Creswell & Creswell, 2018). The pre-/post-test non-equivalent-groups quasi-experimental design was adopted in the investigation (**Table 1**). To collect quantitative data, the chemistry engagement scale (CES) was used. Six students (P1-P6) who had been exposed to simulation-integrated 7E context-based instructional strategy were interviewed in semi-structured interviews (SSIs) to collect qualitative data to better understand how the strategy impacted their level of engagement.

Research Site, Population, & Participants

The Oromia Region of Ethiopia's Borena Zone served as the study's location. For quantitative strand, a sample of 229 grade 10 students from four public secondary schools (at different towns) made up participants of the study. Four intact research groups, one from each school, were randomly chosen using lottery method for this quantitative part. Three of these groups (SICBIS, CBIS, and SICTA) were chosen at random to be the intervention groups, while the remaining group was chosen to be the comparison group (CTA). Based on this lottery method then Shaleqa Jateni Ali Secondary School, Kobole Secondary School, Dubuluk Secondary School, and Mega Secondary School were assigned to be SICBIS, CBIS, SICTA, and CTA treated group, respectively. Every group of students at these schools experience the same academic environment and comes from a similar sociocultural background. There were 60, 58, 56, and 55 students in the groups for SICBIS, CBIS, SICTA, and CTA, respectively. Six students (two from each achiever level: higher, medium, and lower) from SICBIS group were randomly chosen for qualitative strand of the study.

Data Collection Tools

Chemistry engagement scale

In this study, CES was used to evaluate the engagement level of students in chemistry in all the groups. The three components of the scale were emotional engagement, cognitive engagement, and behavioral engagement. The scale consisted of 15 items. A 5-point Likert scale was used to rate each item: always (4), usually (3), sometimes (2), rarely (1), and never (0). The adaptation was made in accordance with the literature (Appleton et al., 2006; Dogan, 2014; Veiga, 2016). The English version was translated into the local language (Afaan Oromo) by an Afaan Oromo language specialist. The reason for translating the instrument's English form into the local tongue was that the scale was seen to be better understood by students than its English version. The two linguists (one English and one Afaan Oromo language) back-translated the scale into its English version. A different English specialist attested to the fact that the new and original versions were identical.

To evaluate the validity of the measure, it was sent to two experienced university professors (one in chemistry education and one in psychology). The stratified Cronbach's alpha of the instrument's reliability was also revealed by the pilot study. The stratified Cronbach's alpha of CES as a whole was .90. Moreover, the reliability coefficients for behavioral engagements were .80, for cognitive engagements were .79, and for emotional engagements were .82. These all turned out to be within permissible bounds (Creswell & Creswell, 2018). The Afaan Oromo version of the scale was then used for a pre- and post-test, which were given before to and following the six-week intervention.

Semi-structured interviews

SSI was used to collect the qualitative data, which served to supplement and validate the quantitative findings. In order to look into how simulation-integrated 7E context-based instructional strategy affected students' engagement in chemistry, SSI included a few leading questions. After examining earlier, related studies that had been published, the researchers of the current study created SSIs (Gilbert, 2006). The three university professors' expert comments were obtained, which increased the legitimacy of SSI. We provided five sample questions, as follows:

1. Tell me about your experience of the chemistry of oxides, acids, bases, and salts (COABS) during SICBIS. Did you like it or not? Why? How? Please explain.
2. Do you think that learning of COABS via SICBIS relates to your daily life? Why? How?
3. After learning of COABS through SICBIS, is there any improvement (change) on your engagement? If any difference occurs in your engagement, please explain the underlying reasons.
4. In general, do you think that you have been benefitted from the SICBIS? How do you feel about it? Please explain.
5. Would you like to learn chemistry by conventional/existing instructional strategy or by SICBIS? Why? Please explain.

Data Analysis

MANCOVA, follow-up ANCOVA, DFA-discriminant function analysis, and Bonferroni procedures were used to analyze the quantitative data in IBM SPSS version 20. Since follow-up ANCOVA overlooks the correlations between dependent variables, it is inefficient for investigating what the MANCOVA tests indicated (Field, 2017). DFA, on the other hand, may provide rich information by accounting for correlations between the dependent variables. Therefore, both ANCOVA and DFA were utilized, as follow-up analyses in order to adequately interpret the data in this study (Field, 2017; Hahs-Vaughn, 2017).

A significant threshold of .05 was chosen. After assessing the assumption, an ANOVA analysis was used to determine how the pre-test scores for the overall level of engagement and the levels of dimensions varied from one another. ANCOVA and MANCOVA were used to analyse the difference between pre- and post-test scores when the assumptions were met (Field, 2017). Six students' qualitative data (P1, P2, P3, P4, P5, and P6) were analysed using verbatim.

Implementation

First, participatory instructional methods were selected, which have the potential to create a constructivist learning environment. These include real practical activities that students can complete in class and at home, group discussions, student presentations, and question-and-answer sessions (Hasanova et al., 2021). It was decided to use 7E context-based instructional strategy as it was aligned with the chosen participatory instructional methods and CBA (Gill & Kusum, 2017; Hasanova et al., 2021). Then, on the basis of guiding principles suggested by academics (De Jong et al., 1998; Gilbert, 2006), appropriate contexts were determined.

These contexts were carefully connected to the chemistry of oxides, acids, bases, and salts content, leading to the development of the two context-based intervention materials for 7E context-based instructional strategy and simulation-integrated 7E context-based instructional strategy. Additionally, the simulation-integrated conventional teaching approach intervention material was developed. However, in the instance of conventional teaching approach, the Ministry of Education's pre-existing teacher's guide served as the intervention material.

For use in-class experiments, two lab sets, one for each group exposed to simulation-integrated 7E context-based instructional strategy and 7E context-based instructional strategy were made by a local wood workshop. These kits could be helpful for teaching both the theoretical and practical aspects of chemistry in the classroom at the same time, as opposed to using the school lab at a different time. Depending on the time allotted, practical tasks were given in class as demonstrations. In contrast, the take-home experiments were entirely hands-on; students carried them out independently with materials that could be found locally, and then presented their findings to the class. There were three to four students assigned to each small group.

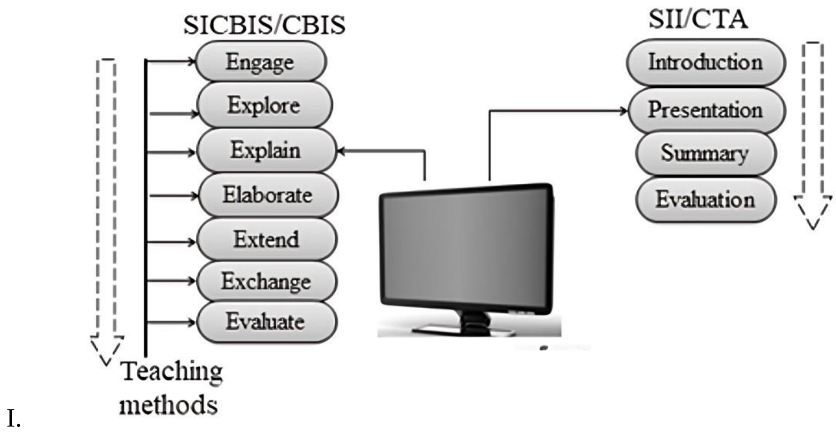

Figure 2. Four instructional strategies (Source: Authors' own elaboration)

Table 2. Few sample contexts used during interventions

Context	Content
Why wood smoke irritates eyes?	Oxides & acids
Why wood ash used for washing, and reliefs for insect stings?	Oxides, bases, &acids
Why do we rinse our hair with conditioner after washing with shampoo? What would happen our hair if it not rinsed with conditioner?	Acids & bases reactions: neutralization
Why Borena people mix megado with tambo while using?	Salts, acids, & bases
How Megado is used for washing purpose? How it gives relief from stomach indigestion?	Acids & bases reactions: neutralization
Why yellow turmeric paper remains yellow in acidic, and changes red-brown in basic solution?	Acids & bases
Why tooth decays? Why is toothpaste used for brushing?	Acids & bases reactions: neutralization

The seven phases of 7E learning model–engage, explore, explain, elaborate, extend, exchange, and evaluate–were incorporated into the development of intervention materials of simulation-integrated context-based instructional strategy and context-based instructional strategy. The content of the intervention material of 7E context-based instructional strategy was similar to the simulation-integrated 7E context-based instructional strategy, with the exception of simulation. At the 'explain' and 'presentation' stages of simulation-integrated 7E context-based instructional strategy and simulation-integrated conventional teaching approach intervention materials, respectively, computer simulations were incorporated (**Figure 2**). All stages of 7E model in the simulation-integrated 7E context-based instructional strategy saw the appropriate application of other participatory teaching methods at the appropriate time. Similarly, with the exception of using the PhET interactive simulations, simulation-integrated conventional teaching approach intervention material was similar to the teaching material of conventional teaching approach, which had four stages: introduction, teacher presentation, summary, and evaluation.

Utilizing software developed especially for chemistry of oxides, acids, bases, and salts, we used "PhET interactive simulations for science and math" (University of Colorado Boulder, 2019). Lastly, we received insightful feedback regarding the content of chemistry of oxides, acids, bases, and salts from secondary school chemistry teachers and university professors in order to validate the materials. According to the curriculum, chemistry of oxides, acids, bases, and salts is the second unit in the chemistry course for grade 10. The four main subtopics of this topic are bases, oxides, acids, and salts. Regular class periods lasted 40 minutes each. Examples of the contexts in which 7E context-based instructional strategy and the simulation-integrated 7E context-based instructional strategy were applied are shown in **Table 2**.

Three chemistry teachers from IG1, IG2, and IG3 received training about the intervention. The students in the groups also received information about the teaching strategies. After that, the implementation of the interventions was started. The researchers watched each group's classroom three times using observation checklists throughout implementation to make sure the interventions went as intended. While we were observing, we had taken some notes. After every observation in the classroom, we provided teachers with feedback to help with implementation. In an effort to address the issues with internal validity, we tried to adhere to the recommendations made by Creswell and Creswell (2018, p. 243). The implementation of each group's instructional strategies is described in depth in the following paragraphs.

With the use of the intervention material, IG1 was exposed to the simulation-integrated 7E context-based instructional strategy. Based on this material, the teacher prepared daily lesson plans. The teacher connected prior knowledge to the present by using small group discussions and question and answer sessions to get the students interested in the material. In order to provide answers to the questions posed in the first stage, the teacher provided students with the chance to observe, write about, and analyse results in the second stage. In-class and at-home practical assignments were used to accomplish this.

In the third stage (explain) concepts were then covered by the teacher with the aid of simulations to assist in connecting concepts to contexts. This was carried out after the student presentation. Using questions and/or practical tasks, the teacher allowed students to connect previously taught concepts (stage 1 through stage 3) to extra relevant ideas in the 'elaborate' stage of 7E learning strategy. At this point, it was anticipated that students would get more information, a broader and deeper understanding, and increased engagement (Fatimah & Anggrisia, 2019). The next step was the 'expand' stage. This stage involved putting concepts into analogous situations. At this point, students were told to generate concepts in response to actual events

Table 3. ANCOVA results for postCES scores

Source	Sum of squares	df1	F	Significance	Partial η²
Treatment	226.53	3	3,957.82	.000	.981
PreCES	.011	1	.601	.439	.121
Error	4.274	224			
Total	1,515.751	229			

Table 4. Bonferroni post-hoc comparison for post-engagement scores

(I) Group	(J) Group	Mean difference (I-J)	Standard error	Significance	95% confidence interval	
					Lower bound	Upper bound
IG1	IG_2	0.1	.03	.000	.07	.22
	IG_3	1.4	.03	.000	1.28	1.42
	CG	2.6	.03	.000	2.50	2.65
IG2	IG_3	1.2	.03	.000	1.14	1.28
	CG	2.4	.03	.000	2.36	2.50
IG3	CG	1.2	.03	.000	1.15	1.30

Table 5. Descriptive statistics of postCES dimension scores

Group	n	Mean	Standard deviation	Adjusted mean after ANCOVA
SICBIS	60	3.33	.11	3.32
CBIS	58	3.23	.17	3.21
SICTA	56	2.03	.15	2.01
CTA	55	.77	.12	.76

Note. SICBIS: Simulation-integrated 7E context-based instructional strategy; CBIS: 7E context-based instructional strategy; SICTA: Simulation-integrated conventional teaching approach; & CTA: Conventional teaching approach

from their surroundings. A conducive environment was established during the exchange phase so that students could talk to their peers about new information they had learned. Lastly, at 'evaluate' stage, students had the chance to evaluate their own learning.

IG2 received 7E context-based instructional strategy. The method in this group did not make advantage of the PhET interactive simulation, which was the only distinction between IG1 and IG2. Other than that, everything else was done in a similar manner. IG3 received simulation-integrated conventional teaching approach with the use of its own intervention material. The group's approach to teaching was similar to that of the conventional teaching approach group. The use of simulation was the only exception between these groups (IG3 and CG). The PhET interactive simulations were integrated and used by the teacher during the 'presentation' phase. CG was taught via conventional teaching approach in compliance with the curriculum. The context was either given as an example in the text or at the end of the student textbook in the current conventional curriculum.

RESULTS

Results of Overall PostCES Scores

Using ANOVA, the preCES scores of the four study groups were compared. The groups' mean differences were statistically significant, according to the results (F[3, 225]=8.95, p<.05). PreCES scores demonstrated significant baseline differences based on these findings, and as a result, it was considered a covariate. The total postCES scores for each group were then compared using ANCOVA to see if there were any variations. According to **Table 3**, there was a significant difference in each group's total level of student engagement with chemistry of oxides, acids, bases, and salts chemistry (F[3, 224]=3,957.82, p<.05, partial η^2=.98). According to this finding, some groups participated more than others. Bonferroni comparisons (.008 vs. .05) were then used to find this (**Table 4**).

Descriptive statistics results (**Table 5**) showed that simulation-integrated 7E context-based instructional strategy had the highest adjusted mean scores among the groups, followed by 7E context-based instructional strategy. Similarly, conventional teaching approach and simulation-integrated conventional teaching approach received the lowest mean scores and third place, respectively. Every set of two groups differed from the other considerably (Bonferroni adj < .008). Thus, it is clear from this study that, when compared to 7E context-based instructional strategy, simulation-integrated conventional teaching approach, and conventional teaching approach, the simulation-integrated 7E context-based instructional strategy had the most positive effect on grade 10 students' overall chemistry engagement. These results addressed **RQ1**, **RQ2**, and **RQ3**.

Results of PostCES Dimensions Scores

MANCOVA results

ANOVA was used to determine whether there was a difference in the groups' pre-test results for each dimension after verifying its assumptions. In pre-emotional engagement and pre-cognitive engagement, there were substantial mean differences between the groups; in pre-behavioral engagement, there were none. This implies that whereas students' behavioral engagement levels were comparable at baseline, their emotional and cognitive engagements varied. Consequently, their effects were determined using one-way MANCOVA (**Table 6**). Every assumption was confirmed. On post-test scores, the treatment showed a large effect

Table 6. Results of MANCOVA for combined post-engagement scores

Source	Wilk's lambda	F	Hypothesis df	Error df	Significance	Partial η^2
Treatment	.02	261.63	9.00	533.14	.000	.75
PreCES_E	.98	1.42	3.00	219.00	.240	.02
PreCES_C	.99	.83	3.00	219.00	.480	.01
PreCES_B	.98	1.65	3.00	219.00	.180	.02

Note. PreCES_E: Pre-emotional engagement; preCES_C: Pre-cognitive engagement; & preCES_B: Pre-behavioural engagement

Table 7. Eigenvalues for three canonical discriminant functions

Function	Eigenvalue	% of variance	Cumulative %	Canonical correlation, R
1	57.722	99.941	99.942	.990
2	.050	.111	100.000	.210
3	.000	.000	100.000	.000

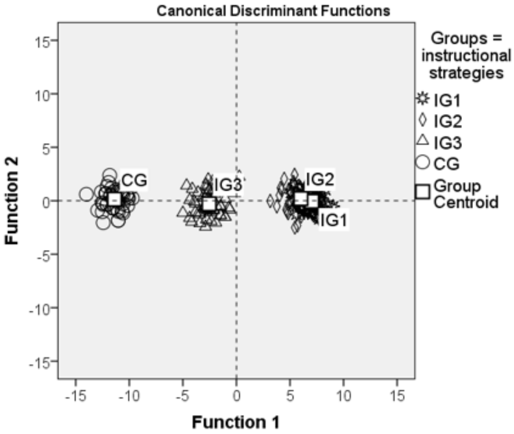

Figure 3. Graphical representation of group centroids (Source: Authors' own elaboration)

Table 8. Standardized canonical & structure matrix coefficients

Dimension	Standardized coefficient (β)			Structure matrix coefficient (r_s)		
	F1	F2	F3	F1	F2	F3
PostCES_E	.55	.83	-.14	.48	.88	-.05
PostCES_C	.75	-.44	-.51	.66	-.53	-.54
PostCES_B	.50	-.23	.84	.48	-.18	.86

Note. PostCES_E: Post-emotional engagement; postCES_C: Post-cognitive engagement; & postCES_B: Post-behavioural engagement

size (partial η^2=.75) (F[9, 533]=261.63, p<.05). This number shows that 75.0% of the variation in the post-test results for the three combined dimensions of student engagement may be attributed to the instructional strategy.

Follow-up DFA results

Follow-up DFA was used to analyse the relative weights of the three engagement dimensions in the composite variable in order to address **RQ3a**. Three main discriminant functions are generated by DFA (**Table 7**). 99.9% of the variation was explained by the first function (R^2=.99), but only 11.0% and 0.0% of the variance were explained by the second and third functions (R^2=.11 and .00, respectively).

A combined-group plot (**Figure 3**) was also analyzed to ascertain which group's means and discriminant function centroid were highest. The two groups (IG3 and CG) were distinguished to the left of the grand centroid by visual inspection of the centroids' positions and signs, whereas IG1 and IG2 were distinguished to the right of the centroid. This showed that when comparing the total scores of the three components of student engagement, the simulation-integrated 7E context-based instructional strategy and 7E context-based instructional strategy outperformed simulation-integrated conventional teaching approach and conventional teaching approach.

To find out which dimension contributed most to the combined/overall engagement, the results of the structural matrix coefficients and the standardized canonical discriminant function of the scores are studied. **Table 8** demonstrates that each of the three post-emotional engagement (β=.55, r_s=.48), post-cognitive engagement (β=.75, r_s=.66), and post-behavioral engagement (β=.50, r_s=.47) scores were loaded onto the first function in a highly positive and varied manner. This suggested that each dimension is affected differently by the instruction. With these results, **RQ3a** research question has been addressed.

Follow-up ANCOVA results of three dimensions of engagement

Following the pre-test effects being controlled for, the results of the follow-up ANCOVA (**Table 9**) were analysed to see if there was a statistically significant mean difference between the groups for each engagement dimension. Post-emotional engagement (F[3, 221]=937.52, p<.05, partial η^2=.94), post-cognitive engagement (F[3, 221]=1875.71, p<.05, partial η^2=.96), and post-behavioral

Table 9. Tests of between-subjects effects for postCES dimensions

Source	Dimension	df1	F	Sig.	Partial η^2	Power
Treatment	PostCES_E	3	937.52	.000	.939	1.00
	PostCES_C	3	1,875.71	.000	.961	1.00
	PostCES_B	3	966.39	.000	.928	1.00

Note. PostCES_E: Post-emotional engagement; postCES_C: Post-cognitive engagement; & postCES_B: Post-behavioural engagement

Table 10. Descriptive statistics for postCES dimension scores

Group	PostCES_E		PostCES_C		PostCES_B	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
IG1	3.317	.2557	3.317	.1766	3.383	.2230
IG2	3.237	.3050	3.153	.2300	3.224	.3648
IG3	1.886	.3600	2.040	.2239	2.022	.3108
CG	.741	.2804	.792	.1735	.750	.2546
Total	2.326	1.0997	2.355	1.0273	2.376	1.0950

Note. PostCES_E: Post-emotional engagement; postCES_C: Post-cognitive engagement; & postCES_B: Post-behavioural engagement

Table 11. Bonferroni comparisons

Dimension	(I) Group	(J) Group	Mean difference (I-J)	Standard error	Significance	95% confidence interval	
						Lower bound	Upper bound
Emotional engagement	IG1	IG2	.079	.057	.984	-.072	.230
		IG3	1.431	.057	.000	1.281	1.582
		CG	2.576	.059	.000	2.420	2.732
Cognitive engagement	IG1	IG2	.162	.038	.000	.062	.262
		IG3	1.281	.038	.000	1.181	1.381
		CG	2.528	.039	.000	2.424	2.631
Behavioral engagement	IG1	IG2	.169	.054	.013	.024	.314
		IG3	1.373	.054	.000	1.228	1.518
		CG	2.655	.056	.000	2.505	2.804

engagement (F[3, 221]=966.39, $p<.05$, partial η^2=.93) all demonstrated statistically significant effects on the level of each dimension, according to the evidence in **Table 9**. These indicated that, by limiting the influence of variables, the instructional strategy had positively impacted all of the dimensions. With these findings, **RQ3b** was resolved.

Then, in order to respond to **RQ3c**, the descriptive statistics (**Table 10**) and the Bonferroni pairwise comparison of the scores (**Table 11**) were examined. This study's findings showed that there was no statistically significant mean difference in the emotional engagement of IG1 and IG2 in chemistry (p=.98). However, there are other pairwise comparisons that show statistically significant differences. The most effective method for promoting grade 10 students' emotional, cognitive, and behavioral engagement was the integration of computer simulation within 7E context-based instructional strategy, as opposed to 7E context-based instructional strategy, simulation-integrated conventional teaching approach, and CTA (Adjusted for Bonferroni, $p<.008$).

Qualitative Results

In order to bolster the conclusions drawn from the quantitative data, the qualitative data were analyzed. With these findings, **RQ4** was addressed. Participants responded on how they thought simulation-integrated 7E context-based instructional strategy had increased their level of engagement in learning chemistry of oxides, acids, bases, and salts. They frequently backed up their positions with the following justifications: the application of chemical concepts to everyday life; the use of computer simulations; actual experimental activities; and social interactions. They claimed that simulation-integrated 7E context-based instructional strategy increased their degree of interest in what they were learning. The outcomes based on these characteristics will be given in the subsequent paragraphs.

According to a thorough discussion with students, understanding chemistry might be difficult because, when taught in a traditional manner, it is not applicable to real-world situations. Every participant (P1-P6) concurred that simulation-integrated 7E context-based instructional strategy assisted them in learning chemistry of oxides, acids, bases, and salts locally, which led to the beginning of their association between chemical concepts and context.

> My level of engagement in chemistry was quite poor because the concepts were abstract and difficult to visualize when we learned it the traditional way. Chemistry has become very relevant to my life because of simulation-integrated 7E context-based instructional strategy, and I am grateful for that. I believe that I am more involved in chemistry now than I was before.

Students also discussed how their scores on the chemistry topic they learned using this method related to how much they appreciated simulation-integrated 7E context-based instructional strategy. Furthermore, three participants (P1, P2, and P5) expressed their opinions about chemistry and said they felt they had grown up surrounded by chemical surroundings.

> Simulation-integrated 7E context-based instructional strategy helped me understand what chemistry is. Chemistry is something that is present in our homes and is not something that is far or abstract, in my opinion. In reality, chemistry is

> what we can see, smell, and touch. I therefore think that my engagement will be higher than it was in my past chemistry lessons.

The two local compounds' relationship to the chemistry of oxides, acids, bases, and salts concept was additionally addressed by the students. They did not know why the people of Borena liked 'megado' with 'tambo' above normal salt or sugar until the intervention. This investigation found that megado had an alkaline characteristic while tambo had an acidic behavior. When it comes to dissolving tambo (powdered leaves), megado (a white powder) neutralizes them better than common salt and sugar. As a result, students were more engaged to learn chemistry of oxides, acids, bases, and salts. P1, for example, stated:

> Megado is a common chemical in Borena, as far as I know. It has been employed by society for various objectives. However, I had no idea why individuals had been taking tambo with megado previously. All these queries have answers now that you have knowledge of this subject thanks to simulation-integrated 7E context-based instructional strategy. Then, it sharpens my attention and inspires me to participate in more advanced.

Studies show that people's perception of chemistry is appropriate when they describe chemical processes at the macroscopic level (Suits & Sanger, 2013). Nevertheless, submicroscopic representations are usually used to explain these phenomena. Students consequently claimed that there were some benefits to using computer simulations. They felt that their engagement had increased by imitating abstract ideas in relation to actual activities and circumstances. These findings demonstrate how adding simulations to 7E context-based strategy increases students engagement in chemistry. This was particularly clear from P3 and P4.

> In lower classes, I was familiar with the concept of chemistry of oxides, acids, bases, and salts. At the time, chemistry was very theoretical and challenging to comprehend. My engagement was poor as a result. However, I was more active in chemistry of oxides, acids, bases, and salts now. Computer simulations had helped to make abstract notions understandable by allowing macroscopic processes to be comprehended at the particle level.

Every participant thought that using simulations may aid in their comprehension of chemical concepts at the molecular level and help them make the connection between their real-life situations and the underlying submicroscopic and symbolic representations. In this regard, they commended simulation-integrated 7E context-based instructional strategy for offering students a wide range of chemical representations. Their interaction seems to be much improved. One participant also concurred those using computer simulations in conjunction with a context-based 7E instructional strategy can improve students engagement in chemistry. P6 provided the subsequent evidence.

> To maintain my interest in chemistry in the future, I always prefer to learn it via simulation-integrated 7E context-based instructional strategy. Specifically, CBA's integrated simulations aid in my comprehension of the larger picture and context by displaying particle matter, which raises my level of engagement.

Students were also interviewed in-depth to find out what they took away from the simulations and how it connected to their engagement. In the course of the conversation, it became clear that simulation was a very powerful tool for accurately replicating what the naked eye could not see and for thoroughly comprehending difficult ideas, which could increase student engagement in chemistry. In instance, P1, P2, P4, and P5 students expressed:

> When more acid was added to a solution, the pH of the solution changed, and we compared the concentration of HA, H3O+, and A for strong and weak acids. I learned more about the distinctions between strong and weak acids thanks to these simulations. Using simulations, we have also created both a concentrated and diluted solution of orange juice and battery acid. These helped me understand the difference between diluted and concentrated acid solutions with pH changes. These assisted me in increasing my engagement.

Real experiments are one of the simulation-integrated 7E context-based instructional strategy elements that have improved the concept of chemistry at the macroscopic and contextual levels. Next, the participants were asked to describe how the real experiments affected their engagement in learning. Using locally-made lab kits, in-class demonstrations were an effective way to undertake practical activities in the classroom while also explaining theoretical concepts. According to five participants (P2, P3, P4, P5, and P6),

> "using simulation-integrated 7E context-based instructional strategy, concepts of chemistry were not difficult with the support of practical tasks using real-life materials, The idea also made sense by connecting it to situations from everyday life that are present in our surroundings."

An additional participant (P2) believed that simulation-integrated 7E context-based instructional strategy increased his level of engagement with chemistry of oxides, acids, bases, and salts. This student expressed how much they valued the simultaneous learning of theoretical and practical chemistry concepts in the classroom while they learned concepts utilizing lab kits.

> Learning was usually made easier by the simultaneous presentation of chemistry courses' theoretical and practical applications. If this is how we are going to learn chemistry in the future, I hope that my interest in the subject will grow with time.

According to Suryawati and Osman (2018), social constructivism is predicated on student interaction, discussion, and knowledge exchange. Regarding this principle, SSI showed that students collaborated in groups, exchanging ideas and solving issues in a natural setting. Students have said that their interactions with their peers contributed to generating their knowledge, which increases the likelihood that they will be interested in their learning and successfully fulfill their learning objectives. P5, for example stated that

> "through group discussions, I was able to create shared meaning thanks to simulation-integrated 7E context-based instructional strategy. I had to have discussions with my peers, so it was really interactive. I think that using this teaching method would make me more interested in chemistry."

Our qualitative findings thus indicate that all participants felt that the simulation-integrated 7E context-based instructional strategy had made chemistry concepts tangible, accessible, simple, and authentic to their surroundings, which has boosted their engagement in chemistry of oxides, acids, bases, and salts chemistry. They felt favorably about simulation-integrated 7E context-based instructional strategy, which improved their chemistry engagement. These participants thought that it was amazing to learn chemistry of oxides, acids, bases, and salts using simulation-integrated 7E context-based instructional strategy, and they appreciated it.

DISCUSSION

The impact of simulation-integrated 7E context-based instructional strategy on student engagement in relation to 7E context-based instructional strategy, simulation-integrated conventional teaching approach, and conventional teaching approach is addressed in this section. The results of this study showed that there was a significant difference in the overall engagement scores between the groups exposed to simulation-integrated 7E context-based instructional strategy, 7E context-based instructional strategy, simulation-integrated conventional teaching approach, and conventional teaching approach, favouring the three intervention groups and the simulation-integrated 7E context-based instructional strategy treated group by a significant margin. Although simulation-integrated 7E context-based instructional strategy and 7E context-based instructional strategy have similar effects on emotional engagement, this result is valid for both components (cognitive and behavioral engagements).

Regarding this, the findings'' practical implications has demonstrated that an instructional strategy has a 98.0% effect on students' overall engagement with chemistry of oxides, acids, bases, and salts. This large effect size indicates that there is a strong correlation between student engagement levels and instructional strategies. With simulation-integrated 7E context-based instructional strategy, the relationship was particularly robust. In terms of student engagement with chemistry, simulation-integrated 7E context-based instructional strategy significantly beats the other three instructional strategies, as demonstrated by the results of the Bonferroni comparison. Students in simulation-integrated conventional teaching approach and conventional teaching approach groups had the third and fourth levels of overall engagement, respectively, while students receiving 7E context-based instructional strategy have the second highest degree of engagement. These findings are further supported by the findings from the qualitative data.

The body of research on context-based learning supports our findings, demonstrating that CBA can raise students' levels of learning engagement. For example, students who get context-based instruction exhibit higher levels of engagement than students who receive conventional instruction, according to a study by Geerdink-Klink et al. (2019). They contend that students are better able to participate in chemistry and complete their assignments on time and effectively when they use a context-based learning approach.

This could be because of the ways in which simulation-integrated 7E context-based instructional strategy links abstract concepts to real-world contexts, macroscopic phenomena through in-class and take-home real experiments, submicroscopic representations through simulations, and symbolic representations through chemical formulas and equations. This indicates that the simulation-integrated 7E context-based instructional strategy treated group learns chemistry through different multiple representations and improves their engagement, in contrast to 7E context-based instructional strategy, simulation-integrated conventional teaching approach, and conventional teaching approach. According to Upahi and Ramnarain (2019), multiple representations support students' constructivist learning. As a result, simulation-integrated 7E context-based instructional strategy can offer a supportive learning environment to support students' increased engagement with chemistry of oxides, acids, bases, and salts.

The present results also align with the findings of Bennett and Lubben (2006), Demircioglu et al. (2005), and King et al. (2007). They found that a useful strategy for raising students' engagement in science in general and chemistry in particular is context-based instruction. This study, therefore, contributes to the body of literature by showing that, in comparison to 7E context-based instructional strategy, simulation-integrated conventional teaching approach, and conventional teaching approach, deploying a simulation-integrated 7E context-based instructional strategy enhances grade 10 students' engagement in chemistry.

Compared to simulation-integrated conventional teaching approach and conventional teaching approach, 7E context-based instructional strategy is the second-most successful strategy for improving student engagement in chemistry of oxides, acids, bases, and salts. Even though simulation-integrated conventional teaching approach was proven to be better than conventional teaching approach, it still lags well behind simulation-integrated 7E context-based instructional strategy and 7E context-based instructional strategy. The results align with earlier studies (Chans & Castro, 2021; Lancaster et al., 2013; Suits & Sanger, 2013), which argued that because computer simulations provide students greater control and flexibility over their learning process, they can enhance their engagement in chemistry more effectively than traditional lectures. Molecular-level chemical processes can be visualized with the use of simulations, which are most effective when paired with actual experimental work. Students learn directly from computer simulations as opposed to through lectures and explanations from teachers (Chans & Castro, 2021).

The results of this study provide support to the social constructivist theory, which holds that improving learning outcomes requires students to ask and respond to questions, engage in class discussions, take ownership of their learning, defend and justify ideas, and summarize concepts (Johnson, 2019). In a similar vein, this study shows that a simulation-integrated 7E context-based instructional strategy can raise chemistry student engagement. Students can take an active role in their learning by being encouraged to engage with each level of 7E learning model. Because simulation-integrated 7E context-based instructional strategy includes all four representations of chemical concepts, it may be seen as a better answer to the issue of diminishing secondary school student engagement than 7E context-based instructional strategy, simulation-integrated conventional teaching approach, and conventional teaching approach.

CONCLUSIONS & IMPLICATIONS

In comparison to other student groups, simulation-integrated 7E context-based instructional strategy treated students demonstrated higher levels of overall, emotional, cognitive, and behavioral engagement in chemistry of oxides, acids, bases, and salts. The opinions of the students gathered through SSIs were added to this. This study outlines the topic-specific instructional strategies (such as 7E learning model) and participatory teaching methods (such as computer simulations, real experiments conducted in-class and at home, small group discussions, student presentations, and question-answers) that are compatible with CBA to enhancing grade 10 students' engagement with chemistry of oxides, acids, bases, and salts. These interactive teaching methods were used using 7E learning phases and were mostly centered on the four levels of concepts. Simulation-integrated 7E context-based instructional strategy might be one of the greatest active instructional strategies for teaching chemistry of oxides, acids, bases, and salts in secondary schools because of its capacity to convey chemical concepts through the four representations. Chemical formulas, computer simulations, real-world experiments, and human elements can all be used to address these various representations.

The study's implication is that students' engagement in the chemistry of oxides, acids, bases, and salts can be increased by using a simulation-integrated 7E context-based instructional strategy backed by relevant topic-specific participatory teaching methods like small group discussions, in-class and take-home real experiments, student presentations, and question-answer sessions. The study implies that adopting a simulation-integrated 7E context-based instructional strategy can boost students' overall and individual levels of engagement in chemistry. Thus, to improve chemistry learning, teachers may consider progressively transitioning from the conventional teaching approach to the utilization of the simulation-integrated 7E CBA over the other strategies.

Limitations

Since it would be difficult to draw a qualitative comparison, students in the other groups (7E context-based instructional strategy, simulation-integrated conventional teaching approach, and conventional teaching approach) were purposefully left out of the interview process. Nonetheless, the following characteristics might be cited as this study's limitations. Teachers were not the source of the research data. In a similar vein, no open-ended questions were used to get rich qualitative data from many students. Future studies in this field must, however, take these limitations into consideration.

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