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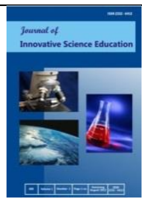

Pre-Service Teachers' Conceptual Understanding and Retention When Taught Osmosis Using Group Discussions

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Abstract

Group Discussion (GD) as a collaborative teaching strategy focuses on the teachers and learners to solve problems through multiple engagements. The purpose of the study was to determine the effect of GD on pre-service teachers' conceptual understanding and retention compared to the Traditional Approach (TA) in teaching osmosis. A quasi-experimental design with pre-and post-tests and a case study design were used for the study. Ninety-four pre-service teachers (N=47) for the Experimental Group (EG) taught using GD, and (N=47) for the Control Group (CG) were taught using the Traditional Approach (TA). Results from post-tests show EG performed better than CG, as indicated by Analysis of Covariance (ANCOVA), $p < .05$, suggesting that GD improved conceptual understanding. A Mann-Whitney U-test shows no significant differences in performance between males and females in EG, implying GD favoured both genders. In addition, EG retention was higher than CG when tested after an extended period. Thus, the results show that GD improves pre-service teachers' conceptual understanding and retention. The implication for educators is that the use of GD in teaching biology improves pre-service teachers' conceptual understanding of Osmosis, and these results have far-reaching implications in teacher education.

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INTRODUCTION

Group Discussion (GD) is collaborative teaching where there is a shared focus between the teachers and learners to solve a problem (Yulianti et al., 2022). Put differently, a classroom discussion is "a sustained exchange between and among teachers and their students with the purpose of developing students' capabilities or skills and expanding students' understanding – both shared and individual – of a specific concept or instructional goal" (Witherspoon et al., 2016, p. 6). GD engages learners in multiple ways of thinking to solve challenges (Jordan, 2022). GD is vital for education in the 21st Century to enhance autonomy, collaborative and critical thinking, communication, and technology use (Bremnar, 2021; Almasco, 2023). Teaching science involves learners experiencing the basic and integrated processes of science (Kibirige & Rooyen, 2006). Caplan et al. (2016) contend that research on learner engagement in science is needed to enhance learners' interest, especially through small group discussions (Jemal, 2017), as compared to a lecture where the teacher's central focus is on the delivery of content to learners.

Typically, a teacher will stand before a class to present information for the students to learn. Learners participate by answering questions and copying notes from the chalkboard. While there is an exchange between the teacher and the learners, the teacher has control over what is being taught and determines the pace regardless of slow or gifted learners. In this instance, gifted learners may be hampered if the teacher's pace is slow, and if the pace is too fast, the slow learners are disadvantaged.

GD can minimise poor performance and enhance conceptual understanding and confidence in enacting group discussions in the classrooms (Kademian & Davis, 2018). Pre-service teachers can be affianced in group discussions to hone their subject content knowledge, which they could use during teaching practice and in-service after that. The discussion groups require individuals to ask questions and get answers, which they write down. In the process, group members improve their explanations using the Language of Teaching and Learning (LoTL) as well as science language (Murphy et al., 2022).

There are perceptions that biology is easier than chemistry and physics in STEM subjects (Wong et al., 2022). Despite those perceptions, pre-service teachers have challenges in understanding some biology concepts, such as the Osmosis process, that are at play (Manning & Kay, 2023) and are abstract (Hudha et al., 2023). Consequently, learners easily forget what they learned about the osmosis process (Vujovic et al., 2018). Learner-centred methods are suggested to address such challenges. Firstly, when learners develop hands-on skills, they are likely to improve the nation's economy in the 21st century, and secondly, learner-centred approaches promise critical and creative thinking skills (Sahlberg & Oldroyd, 2010) deeper learning based on Vygotsky and Piaget's theories (Ginnis, 2002). Thirdly, learner-centred teaching is an emancipatory method for learners to work within the group, express their views and accept other learners' views to improve conceptual understanding.

Conversely, the Programme for International Student Assessment (PISA) shows that the use of learner-centred teaching resulted in low conceptual understanding (Deng & Gopinathan, 2016). The Trends in International Mathematics and Science Study (TIMSS) and the Progress for International Reading and Literacy Study (PIRLS) show mixed results in terms of the relationship between learner-centred teaching approaches and conceptual understanding (Schweisfurth, 2013). The above empirical studies used subjects in science and not specific topics, which might have compounded their findings. Using discussions on energy content with everyday life experiences, Weng et al. (2022) found that learners scored highly in STEM, suggesting that GD can enhance learning. Currently, Learner Centred Pedagogy (LCP) is limited and provisional since empirical and conclusive evidence is not yet established in the literature (Bremner et al., 2022) and learning retention is yet another challenge in learning osmosis. Retention refers to one's ability to maintain new knowledge for future application permanently (Chang et al., 2015) or keeping information in long-term memory (Afoan & Corebima, 2018). It is fundamental to learning in schools and elsewhere because the retained knowledge can be retrieved in different contexts (Saputri & Corebima, 2020). Tenets like paying attention to relevant information are necessary to enhance retention (Gargrish et al., 2022). Hence, retention depends on each learner's use of those tenets (Usman et al., 2021). It is suggested that more time is spent on teaching to enhance learners' retention (Makinde & Yusuf, 2017). This study proposes GD as one of the strategies to enhance retention, and the extent to which GD impacts learners' conceptual understanding and retention remains barely understood. It is a knowledge gap this study addresses using an empirical study to determine pre-service teachers' conceptual understanding and retention when taught Osmosis using GD and TA.

GD are an excellent teaching method when used in conjunction with other methods. Instruction should be varied from day to day to help reach the most students possible. It is a collaborative teaching method where each member offers exploration, explanations and enacting-in discussions (Ajayi & Tanko, 2023). The selection of a suitable educational method for learning is of special importance because, in biology, there are many misconceptions about almost every topic. Osmosis is one of the difficult topics to understand because of its abstract nature and the molecular behaviour of solutes and solvents (Manning & Kay, 2023). One of the strategies to alleviate learning challenges is the use of GD, where learners talk as they perform experiments. Teachers need to provide their students with note-taking skills before starting discussions. Teachers must be good at managing and facilitating discussions. Questioning techniques are effective for this. Two questioning techniques that teachers employ are to increase their waiting time after questions are asked and to ask only one question at a time.

The purpose of the study was to determine the effect of GD on pre-service teachers' conceptual understanding and retention compared to the Traditional Approach (TA) in teaching osmosis. Hence, the following research questions were raised to guide the study:1) To what extent does Group Discussion impact pre-service teachers' conceptual understanding and retention when compared to the Traditional Approach? 2) What is the conceptual understanding and content retention of EG compared to CG? 3) What is the effect of Group Discussion on conceptual understanding and retention between the EG and the CG? 3) What is the effect of Group Discussion on males and females? 4) What are the pre-service teachers' experiences regarding Group Discussion? Three hypotheses were used: 1) Group Discussion significantly impacted learners' conceptual understanding and retention; 2) EG has higher conceptual understanding and content retention than CG; 3) GD increased conceptual understanding and retention in both genders. It is because teaching methods sometimes favour one gender over the other (Eddy et al., 2014; Eddy & Brownell, 2016). This study benefits teachers in improving teaching skills and enhances learners' content retention.

After independence in 1994, South Africa has had three curricula: 1) the Outcomes Based Education (OBE, 2005) to harmonise the then Native and Bantu education curricula, 2) the Revised National Curriculum Statement (RNCS), and 3) the Curriculum Assessment Policy Statement (CAPS) (Russell et al., 2019). These curricula have not improved the learners' performance because Grade 12 matric results show that only 4 out of 100 learners got 60% and above (Naidoo & Sibanda, 2020). The author contends that methods used to teach pre-service teachers need to include GD to enhance pre-service teachers' understanding and retention of content.

METHODS

The study employed quantitative and qualitative approaches (Creswell & Creswell, 2018). The quantitative approach used a quasi-experiment design where two groups were designated: as Experimental Group (EG) and the Control Group (CG). Both groups were pre-tested to determine the level of science content understanding before administering the intervention (Appendix 1). The scores obtained were scaled to 100% for both pre- and post-tests. EG was taught Osmosis through authentic experiments for two weeks using GD, while CG taught for the same period using the TA method, where lectures, 'talk and chalk' dominated. The qualitative approach used a case study design (Creswell & Creswell, 2018) to determine pre-service teachers' experiences regarding GD strategy.

The quantitative study sample comprised 94 third-year Methods of Science course (MBIO 311) pre-service teachers, which were divided into 47 (16 female, 31 male) designated as Experimental Group (EG) and 47 (17 female, 30 male) as Control Group (CG). For the qualitative part, four pre-service teachers (2 males and 2 females) from EG were coded as PT for pre-service teacher, F for females, M for males and numbers 1-4 to represent the teachers' numbers. For example, FPT1 and FPT2 mean female pre-service teachers number one and two; MPT3 and MPT4 mean male pre-service teachers number three and four. All participants volunteered to take part in the study, which was part of the quality teaching and learning under the internal Research Chair granted to the author (Grant Number R792). Researcher-designed pretest was also used for EG and CG post-tests. Two university lecturers and two science teachers evaluated the face and content validity of the test. Their recommendations were considered before the pilot study. For reliability, pre-and post-tests were piloted on 10 in-service teachers of the Methods of Science course (MBIO 311) who were not part of the study. A Cronbach Alpha of 0.85 was obtained, suggesting the instrument was suitable for the study.

Data were collected over four weeks where one week was for acclimatisation to the dynamics and dictates of discussions, two weeks for teaching two separate groups, and one week was to engage CG in GD to be at par with EG in GD dynamics. Initially, EG and the CG were pre-tested to determine their levels of science understanding and, for two weeks were taught similar topics regarding Osmosis. EG was taught using GD with five to 6 pre-service teachers per group. According to Corrégé and Michinov (2021), these numbers per group were sufficient for effective discussions. Six tenets of LCP (Bremner, 2022) were used: 1) active participation, where active learning was through hands-on learning in groups; 2) adapting to needs was based on learners' prior experiences; 3) autonomy was evident when learners used GD in deliberating on issues as a lifelong learning skill; 4) relevant skills were exhibited in the content used for developing 21st Century skills; 5) power-sharing was achieved through decision-making and accepting peer opinions; and 6) formative assessment was the affordance of learners to self and peer assessment of the interlocutors. In addition, for all discussion tasks, pre-service teachers were asked questions based on Mehan's (1979) model: Initiate, Response, and Evaluate (IRE). Pre-service teachers were provided with three of the following: solutions of unknown concentrations, potatoes, beakers, and a knife. They had to decide which and how solutions should be used for an experiment and which one was for control. Pre-service teachers used GD in three situations: 1) pre-experiment, 2) during the experiment, and 3) post-experiment. In pre-experiment, they had to discuss how to determine the concentrations of the solutions. During the experiment, they had to agree if they used thin rod-like potatoes or cup-shaped potatoes. They resolved to have three beakers for each solution, and in each beaker, they placed 2 similar rods of potatoes, making a total of 18 pieces of potatoes. In the post-experiment, group members had to discuss and agree on how to report the findings to the rest of the class using graphs or tables.

In the case of the CG, the lecturer used TA and gave notes on different solutions: hypertonic, isotonic, and hypotonic and explained what would happen to a piece of potato in each of these solutions. He demonstrated how to cut rod-like potato pieces and demonstrated how to measure their length with a ruler. After that, groups of learners followed the lecturer's demonstration. In the authentic experiments, learners were to show what happens to the potatoes in three types of solutions. CG pre-service teachers measured the size of the potatoes once in each solution of the three beakers to confirm the changes they expected according to the notes the lecturer gave them. So, they used three pieces of potatoes, one in each solution, and there were no replicas. Learners filled in the structured laboratory report. Qualitative data were collected from four pre-service teachers using interviews to explain their experiences regarding GD and how it impacted their conceptual understanding of osmosis. At the end of two weeks of teaching, EG and CG were post-tested using the same questions as those in the pre-test, but their order was shuffled to minimise recognition. After 12 weeks, at the end of the semester, learners were tested on similar concepts to determine their retention levels. One week was used to engage CG in GD to catch up with the EG and for ethical issues.

A t-test was used to measure the difference in learners' pre-and post-test conceptual understanding for both EG and CG. In addition, means and standard deviations were calculated for EG and CG scores. A Mann-Whitney U-test was used to test for any differences in conceptual understanding between males and females in EG. Analysis of covariance (ANCOVA) (Leppink, 2018) was used to determine the differences due to the treatment. The pre-test scores were used as a covariate to control for initial group differences, minimise the error and eliminate systemic bias (Dimitrov & Rumril, 2003). The effect size was calculated using Cohen's d (Cohen, 1988). All statistics were computed using the Statistical Package of Social Sciences (SPSS) Version 22. The responses to qualitative interviews for EG regarding the use of GD in learning Osmosis were thematically analysed (Braun & Clarke, 2006).

RESULTS AND DISCUSSION

The post-test results show that EG scored higher than EG and there were no gender differences among pre-service teachers in the EG.

The summary of pre-and post-post for EG and CG results are stated below (Table 1).

Table 1: Pre- and post-post for Experimental and Control Groups.

Test	Group	N	M	SD	t	P	d
Pretest	EG	47	7,30	5,65	.26	.30	5.93
	CG	47	8,66	6,70			
Post-test	EG	47	44,11	19,98	-11,69	.00	6.20
	CG	47	8,72	6,32			

Table 1 indicates no differences in EG pre-test (T-test: t(92) = -11,69; p = .00) and a Cohen d = 6.20. At the beginning of the study, EG and CG were pre-tested, and their content knowledge did not differ, suggesting that the two groups had a similar conceptual understanding regarding osmosis. However, EG post-test results were statistically different from the pre-test, whereas no differences were observed in CG (p<.05) (Table 1), implying that GD used had a positive impact on conceptual understanding in the EG compared to CG taught using TA.

ANCOVA was used to determine the effect of the intervention with pre-test as a covariate (Table 2).

Table 3. ANCOVA report on the post-tests EG where CG pre-tests was the covariate.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared (η)
Corrected Model	12365.53[a]	1	6182.76	17.61	.00	.28
Intercept	108695.51	1	108695.51	309.63	.00	.77
PREPOSTC	2.93	1	2.93	0.018	.94	.00
Group	12253.84	1	12253.84	34.91	.00	.28
Error	31945.45	92	351.05			
Total	334632.00	94				
Corrected Total	44310.98	93				

R Squared = .28 (Adjusted R Squared = .26)

Analysis of co-variance (ANCOVA) shows that the difference was indeed due to treatment F(2.92) = 34.91, p< .00, η = .28 and the pre- test scores were used as a covariate to reduce the error variance and eliminate bias (Dimitrov & Rumril, 2003). Results show that GD has a significantly positive effect on learners' conceptual understanding of Osmosis ANCOVA (p<0.05) (Table 2).

In the CG, TA resulted in poor pre-service teachers' conceptual understanding of Osmosis (Table 2). These results concur with Kose et al. (2006), who found that learners taught using the discussion method performed better than those taught using TA. These results are not surprising because pre-service teachers from CG were not active when compared to EG. These findings agree with Teshager et al. (2021), who contend that context-based teaching that includes active learning produced better learning outcomes than TA. Also, the authentic practical work missed in CG denied learners thrilling and discovery moments, and as such, they could not retain much because they did not own the content through notes taking. These results agree with Cullinane et al. (2023), who contend that learning without authentic work does not improve conceptual understanding. The outcome of this is that learners do not see a need to look for alternative answers to the challenges as it is in the life of a scientist.

A Mann Whitney U-test to distinguish conceptual understanding in EG is shown (Table 3)

Table 3. A Mann Whitney U-test with male and female medians.

Test Statistics[a]

Mann-Whitney U	**210.00**	**Male**	**Female**
Wilcoxon W	346.00		
Z	-.85		
Asymp. Sig. (2-tailed)	.39		
a. Grouping Variable: POST EG males and females			
Median		73.00	61.50

In Table 3, a Mann-Whitney test shows U = [210.00] [-0.85], p = .39. After the intervention, males and females improved in their conceptual understanding but no significant differences in performance between them. Males' performance was higher (Mdn = 73.00) than females' (Mdn = 61.50), U= 210.00, p = .39, but these differences were not significantly different (Mann Whitney U-test, p = .39). Thus, these results suggest the two genders performed equally well in EG taught using GD. The results suggest that the differences were due to the treatment and not any other variables. Therefore, we accept hypothesis 1, that GD impacts learners' conceptual understanding and retention. Also, the benefit of using GD in science classes is gender neutral. It means GD does not segregate gender because the performance of males and females in EG did not differ significantly (Table 3). So, we accept hypothesis 3, stating that GD equally increases the conceptual understanding and retention of males and females in EG. These results concur with Kazeni and Onwu (2013), who found that GD produced better learning outcomes than TA. It is no wonder Bussey and Bandura (1999) show that both genders succeed in science, provided the contexts are similar.

The qualitative findings show that pre-service teachers enjoyed the lesson using GD. Three themes were identified from qualitative responses: 1) searching for information, 2) recalling and critical thinking, and 3) reflecting on failures and successes. The verbatim statements depicting pre-service teachers' sentiments regarding GD are stated below.

Theme 1: Searching for information.

Pre-service teachers expressed that searching for information was useful.

"I checked for academic papers regarding the content on osmosis, how to determine concentrations and the use various laboratory equipment. We debated on some of the materials and how to address any shortcomings" [MPT3].

Another teacher added:

"After the experiment, my peers and I reflected on the process from searching for information to how to report the results. We came to a consensus on areas where we had disagreements. We downloaded papers from the Internet to assist us in resolving some of our dilemmas. Lastly, we consulted the lecturer on how to interpret some difficult language and concepts in some articles."

Theme 2: Recalling and critical thinking.

The role of recalling and critical thinking was highlighted.

"In doing the experiments, we had to recall what we read and think critically about what was happening and why

in the case of osmosis. We also had to consider chemistry knowledge to kick in to resolve the dilemma we had. For instance, we had to ask the lecturer if the three solutions were volatile. When we established that they were not volatile, we used a Bunsen burner to heat 10 ml of each to retain the solutes" [MPT4].

Furthermore, there was this surprising comment from one teacher.

> "*To our surprise, one solution had no solutes deposited. We used a white copper sulphate test, which established that, indeed, it was water. The remaining two had varying deposits of salt. The one with the highest amount was labelled hypertonic, while the one with low salt deposits was labelled hypotonic.*" (FPT1]

Theme 3: Reflecting on failures and successes.

Pre-service teachers were excited on their findings as stated by these two teachers.

"At first it looked like a nightmare to find out the concentrations of the three solutions, but through our discussion in the group, it was getting better as different ideas were presented and debated. Again, our chemistry knowledge was evoked, you know!" [MPT3].

"One group member proposed replicas. For me I had not heard about replica, but when he explained, I was convinced, and we calculated the averages. To crown it all, the lecturer gave us useful comments on our procedures. This was a soul soothing moment. The lesson was involving and exciting. We learnt a lot about osmosis." [FPT2]

Also, the explanation they arrived at regarding the force that moves water through the semi-permeable membrane. One teacher explained:

"We debated how water could go through but not water molecules. Was it the size of solutes and solvents or the pressure they exert? The solute particles move around and collide with the semi-permeable membrane. We concluded that the solute pushed back by the semi-permeable membrane result in water molecules' movements. Also, osmosis is not a chemical reaction, but a physical reaction." [FPT1]

Like the quantitative results, the qualitative results show that GD had a significant positive impact on the pre-service teachers' understanding of osmosis and their retention. GD is viewed positively by learners because it encourages them to share ideas through interlocutors. Consequently, through GD, pre-service teachers developed interpersonal skills. In question seven, pre-service teachers explained that water molecules moving through a semi-permeable membrane are not diffusion only, but solute particles put pressure on the semi-permeable membrane, causing water to pass through. Also, they were able to explain that it is not a chemical reaction but a physical one. These explanations resonate with the physical model where solute molecules are repulsed from entering the semi-permeable membrane (Debye, 1923).

A similar concept has been echoed that there are two forces Pf (water flux) and Pd (diffusion permeability coefficient). The latter is for water, and the former is for diffusion. Debye (1923) demonstrated that Pf > Pd, suggesting that diffusion cannot take place in the semipermeable membrane. Again, this is supported by White et al. (2022), who contend that water molecules do not diffuse into the frog's skin because the Pf is greater than Pd. Twelve weeks after the intervention, the EG had a clear explanation, which was based on the force generated when a semi-permeable membrane repulses solute molecules, suggesting that GD enhanced retention.

Conversely, the CG stated that there was a link between osmosis and diffusion. Pre-service teachers in the CG explained that the number of water molecules was high and caused osmotic pressure that pushed water through the semi-permeable membrane, which is a misconception (Lodish et al., 2021). The movement of water molecules from its high concentration through a semi-permeable membrane is osmosis is also a misconception. Although osmosis and diffusion are different, pre-service teachers in CG could not provide a clear explanation. They could not imagine solutes hitting the semi-permeable membrane to cause osmosis. CG had misconceptions regarding osmosis. It is no wonder that after 12 weeks, preservice teachers in CG showed low retention of content. Therefore, GD is more effective than TA in enhancing conceptual understanding and retention. This study contributes to the literature regarding GD that enhances conceptual understanding and retention. The use of GD can benefit practising teachers and authors of books, which teachers can use to enhance conceptual understanding and retention. Also, GD benefits pre-service teachers as future science teachers who can debate issues in a bigger forum other than the university training environment.

This study's limitations are a small sample with pre-service teachers registered for Biology Method course from one institution. The effective time was two weeks after acclimatisation, which needed to be more to deal with more GD dynamics in the classroom. Studies using larger samples from different institutions are recommended. Also, the study can explore whether females' and males' preferences differ as far as GD is concerned.

CONCLUSION

This study established that GD is an excellent teaching method for improving learners' conceptual understanding and retention compared to TA. Using interlocutors before, during, and after authentic experiments enhanced EG pre-service teachers' conceptual understanding and resulted in high content retention. Therefore, teachers should allow learners to enact discussions in their groups to enhance understanding and retention. In addition, this study contributes to narrowing the knowledge gap regarding pre-service teachers' conceptual understanding and retention in science using GD and TA. Therefore, it is recommended that teachers should include GD in their teaching methods to improve learner's understanding and retention of science concepts.

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