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A comparative study of the Jigsaw and Chalk-and-Talk Methods on grade 12 learners' achievements in reaction rates in South Africa

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Abstract

The study compared the Jigsaw Method and the Chalk-and-Talk methods of learners' achievements in grade 12 reaction rates. A quasi-experimental design was used, with two classes of 44 learners, one class of 21 as the experimental group and another with 23 as the control group. Data were collected using Achievements Test for pre-test and post-tests and analysed using percentages, Means, Standard Deviations, t-tests and Analysis of Covariance. The post-test results from EG using Jigsaw Method and the control group using the Chalk-and-Talk show significant differences. Analysis of Covariance shows significant effects between experimental and control groups post-test using pre-test covariate. The experimental group outperformed the control group, and the former had no significant differences in gender achievements, suggesting Jigsaw Method favours both genders. The experimental group learners had minimal misconceptions compared to the control group. Thus, the Jigsaw Method enabled experimental group learners to overcome difficulties and misconceptions.

Keywords: : Cooperative learning, conceptual understanding, learners' achievements

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1.1 Introduction

Teachers predominantly use chalk-and-talk (CT) (Costouros, 2020), and they are challenged to apply cooperative methods to deepen learners' achievements (Jayapraba, 2013, Kibirige & Lehong, 2016). There are different cooperative strategies used in teaching. The think pair share (Lestari & Syafryadin, 2022), where learners consider and brainstorm about a question. Reciprocal teaching (Lo et al. (2014) where learners ask questions to each other and read texts. During the cooperative method, learners respond to questions or do a task as a team, but they are awarded according to their performance during examinations.

The Jigsaw Method allows learners to construct knowledge, which agrees with the social constructivism theory of learning (Vygotsky, 1978). Last, the Jigsaw Method (JM) includes home-group, expert-group and teaching groups (Dhull & Verma, 2019; Ismoilovna & Mukhamatova, 2022). Contrasting the CT method, cooperative methods improve learners' academic achievements (Yatimah et al., 2019; Tabiolo & Rogayan, 2019). The JM cooperative method corresponds with the recommendations of the South African Curriculum Assessment Policy Statement (CAPS). CAPS encourages cooperative learning. Hence, JM enhances learners' achievements more than CT (Department of Basic Education, 2011).

The study's theoretical contributions are to social cohesion theories in four aspects. First, learners' interlocutors are the key to increasing learners' achievements. Second, the learner group's role helps to master content before joining the teaching group. Third, the commitments of teachers and learners regarding reflection on the content improve their confidence to learn (Berlyana & Purwaningsih, 2019). Fourth, JM's use extends beyond the classroom because learners gain higher-order thinking skills that could apply to their local communities and future careers.

.2 Theoretical framework

Vygotsky (1978) developed learning constructivist theories based on prior and current knowledge (Alghamdi & Deraney, 2018). Vygotsky (1978) showed that people learn in association with other people. Constructivist theory espouses cooperative learning (KOÇ et al., 2010) and links well to Resnick's theory, claiming that group learning encourages conceptual change (Resnick, 2017). JM in this study builds on the social constructivist theory as it endorses active learning.

1.3. Related Research

According to Marcus (2009) and Dollard & Mahoney (2012), Elliot Aronson in Texas proposed JM to enhance learners' achievements. JM focuses on individual and group learning (Maftei & Pespecu, 2012). Learners engage in three groups: 1) home, 2) expert and 3) teaching. Learners in the entire class reflect on the content (Awidi & Paynter, 2019).

All earners engaged in the three groups reflect on their learning process (Mengduo & Xiaoling, 2010). JM increases learners' self-efficacy and achievements (Kardaleska, 2014; Berlyana & Purwaningsih, 2019). JM eradicates rivalry among learners and enhances cooperative learning (Dollard & Mahoney, 2012). No wonder learners learn better when engaged (Awidi & Paynter, 2019). Active engagement in talking, listening, writing, manipulating, interacting, reading, discussing, and exploring new techniques (Yuhananik, 2018)**.** The JM is integrated into many sub-topics using a unit study as an active learning technique. Learners are divided into smaller sub-units or groups to learn from and with one another (Awidi & Paynter, 2019), and various contents are learnt in an integrated manner.

Group learning and individual enactments improve the learner's accountability (Oshima et al., 2018). There is a sturdy link between learners' cooperative learning and developing higher-order thinking skills (Lestari & Syafryadin, 2022). However, integrating JM raises concerns regarding time to complete home, expert and teaching groups during a single lesson (Williams, 2004). Despite these fears, there are vivacious advantages of using cooperative learning for individual and group learners. Therefore, it is paramount for teachers to organise topics and manage classroom participation for individual learners and group learning regardless of their learning styles (De Wever & Strijbos, 2021; Peña-Ayala, 2021).

In traditional classrooms, teachers do most of the talking while learners remain passive. Teachers do the talking, and learners listen. Later, the teacher writes notes for learners to copy and read for the eminent examination. Teachers in South Africa continue to use CT, like what their lecturers used to teach them (Tewari & Ilesanmi, 2020). They claim that this method helps the teachers to cover the pacesetter or schemes of work (Hendripides & Hikmah, 2018), and they continue CT strategies. Unfortunately, such a teaching method does not encourage concept understanding and leads to low learner academic achievements (Maftei & Popescus, 2012). For instance, in Physical Sciences final examinations, the Matric pass rate ranged from the lowest achievement of 62% in 2016 to 75.5% in 2019. Other years' pass rates were 65.10%; 74.20%; 65.80% for 2017, 2018 and 2020, respectively.

There is a paucity of empirical studies on methods to improve learners' conceptual understanding and increase science pass rates in the country. It is a knowledge gap, which this study sought to narrow using JM.

1.4. Purpose of the study

In active learning, learners are interlocutors with peers regarding materials' observations, explaining their views, and writing the consensus reached (Awidi & Paynter, 2019; Uzer & Uzer, 2021). Several active learning methods have been proposed to improve learner achievement. Using JM in the classroom enhances learners' motivation, produces positive attitudes, develops interpersonal skills, and enhances learners' achievements. Therefore, the effect of the JM and CT on Grade twelve achievements regarding reaction rates were compared using a quasi-experimental design.

The research question for this study was: what effect does using Jigsaw have on grade 12 learners' performance compared to the CT method?

The study tested two hypotheses to guide the study.

1) There are differences in achievements between learners taught Reaction rates using JM and learners taught using TC.
2) There are differences in achievement between boys and girls taught reaction rates using JM.

2. Method and Materials

2.1 Model of the research

The researchers adopted a quantitative approach and a quasi-experimental design using EG and CG to establish the effect of CT and JM on learners' academic achievements. EG taught using JM included group interlocutors, experiments, writing reports, and tests. CG was taught using CT with activities like whole-class discussions, demonstrations, and writing notes and tests, and there were no experiments.

Two secondary schools randomly selected as one and two in the Maleboho Central Circuit, Limpopo, participated in the study. One class from each school was randomly assigned to class X as EG and class Y as CG. The second author taught the EG and CG when implementing the interventions, and

EG was taught using JM, while CG was taught using CT. The researchers cooperated with school physical science teachers to administer the tests.

2.2. Participants

The sample included 42 learners of two classes from two schools randomly assigned to EG for class X with 21 learners (12 boys and nine girls) and CG for class Y with 23 learners (13 boys and 10 girls). Learners' geographical backgrounds were similar, and their ages ranged between 17 and 18.

2.3 Data collection tools

A researcher designed pre-and post-test lesson Achievements Test (AT) qu estions and the lesson plans. All were checked for validity by two senior university lecturers and two experienced high school science teachers. Thus, four raters assessed the questions, and the Content Validity Index (CVI) was 0.95, implying the items were appropriate for the study. A pilot study with 10 Grade 12 learners from school three, not included in the study but from the same circuit as schools one and two, was used to find out the reliability. The internal consistency of Cronbach's Alpha 0.80 was achieved in the pilot study, suggesting that the instrument was appropriate for the study. Pre-post-tests data were collected from EG and CG. A pre-test was conducted with CG as well as EG erstwhile the intervention. Thereafter, EG and CG were taught using JM and CT for four hours per week for three weeks. After fourteen days, a post-test was conducted with EG and CG.

2.4 Data collection tools process

JM Intervention and CT were the methods of collecting data. The JM was used for learners to learn many themes simultaneously in class. In this study, letters represented home-groups, while numbers were for expert-groups (van Rooyen & de Beer, 2006). W-Z was designated home-groups, while 1-4 were expert-groups. For example, W-1 was learner 1 from home-group W designated to expert-group 1; learners with X-1 were in home X and expert 1 group. Learners from different home groups studied unique themes: W-1 to Z-6 Concentration, W-2 to Z-2 Temperature, W-3 to Z-3 Catalysts, W-4 to Z4, and W-5 to Z-6 Pressure (Table 1). The teaching group could be arranged by taking one member from the expert-group for each theme so that the entire class covers all the themes.

Table 1: Allocation of number of learners in Home-Group, Expert-Group and themes per group.

	HOME-GROUP				**THEME**
EXPERT-GROUP	W-1	X-1	Y-1	Z-1	Concentration
	W-2	X-2	Y-2	Z-2	Temperature
	W-3	X-3	Y-3	Z-3	Catalysts
	W-4	X-4	Y-4	Z-4	Pressure
	W-5	X-5	Y-5	Z-5 Z-6	Surface area

1) Teacher assigned activities in four home-groups.

2) Five expert-groups were formed, where each of the four groups had four learners, while the fifth group had five learners (Table 1). Each learner made presentations to the rest of the members in the expert-group.
3) From expert-groups, a teaching group was formed. One learner from the expert-group could teach others, assisted by home group members.
4) Finally, the teaching group individually or as groups reflect on concepts learned and generate new action plan. Activities are presented here below:

Background information

A rate of a reaction was affected by:

1. Concentrations of solids and gases
2. Temperature
3. Catalysts
4. Pressure
5. Surface area

❖ **Activity 1**

Concentration

Four experiments were conducted at different concentrations, mass, and temperature conditions (Table 2). Identical apparatus was used to measure the gas released in (ml). The equation of the reaction and the results are shown below.

$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

Table 2: Table 2: *A table showing results of an experiment carried out at varying t concentration, mass, and temperature conditions*.

	Experiment			
	1	2	3	4
Acid concentration in (mold m^{-3})	1.0	0.5	1.0	1.0
Calcium carbonate in (g)	15.0	15.0	15.0	25.0
Acid initial temperature in (^{O}C)	30.0	30.0	40.0	40.0

1. Examine 1 and 3 results and write:
a) What the research controlled
b) What the research measured

____

1. Using the collision theory state why experiment four had higher values than experiment three.

____

2. Learners placed the solution of thiosulphate solution over a white paper where a cross was marked. After adding different chemicals, they watched to see how long it took the cross to disappear. They completed the table by writing the concentrations in ascending order for the reaction time for the cross to become invisible.

Table 3: A table showing concentrations and the duration for the cross to disappear.

a)

	Concentrations in mol/dm^3	Time in min

b) Write the conclusion---

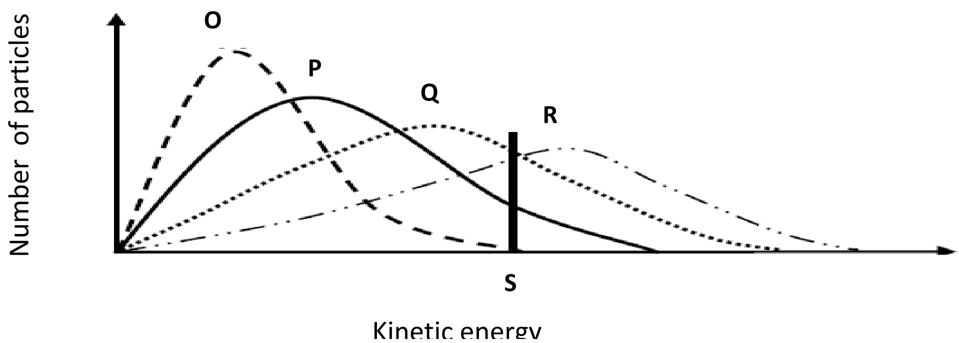
Activity 2

Temperature

High-temperature causes molecules to develop higher kinetic energy, and the kinetic energy increases the frequency of colliding particles. The Maxwell-Boltzmann energy dispersal curves indicate the particle function of their Kinetic Energy (KE) during four varying temperatures. The highest KE required for active collisions is shown by S (Figure 1).

Figure 1

Particles and their kinetic energies under different conditions



The teacher asked the following questions.

1. Write the letter of the curve representing the fewest number of particles. Write down which graph depicts the maximum temperature.
2. Which curve exhibits the maximum reaction rate?

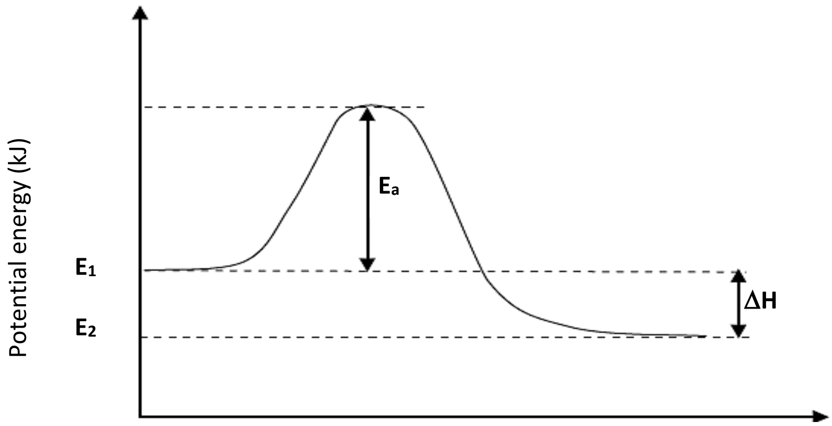
Activity 3

Catalyst

The graph below represents potential energy.

Figure 2

A diagram of a chemical reaction representing different energies



1. Write the energy that will be affected when a catalyst is added.
2. State the effect as an increase, decrease, or no change when a catalyst is added.
3. Will the energy change in question 2) above be positive or negative?
4. Write which state is the reaction above: exothermic or endothermic.

An equilibrium reaction mixture of a gas was reached as shown below.

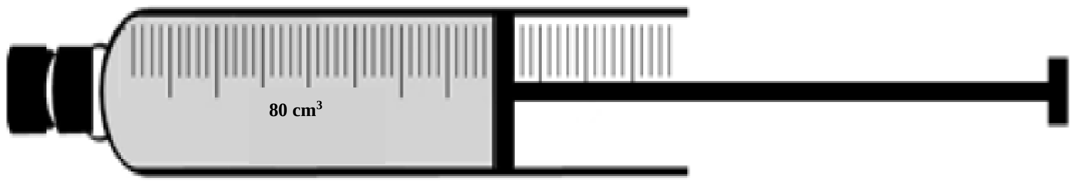
Activity 4

Pressure effect on the reaction rate

The teacher explained and showed learners how to alter the pressure.

Figure 3

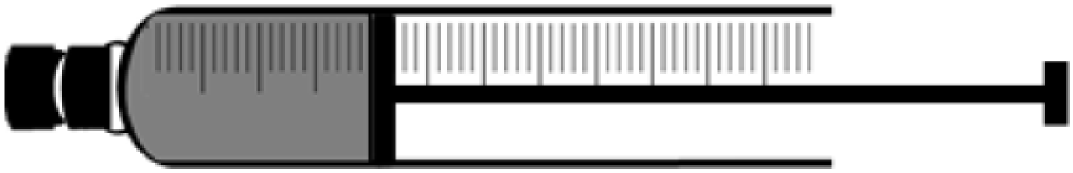
A gas syringe shows an increase and decrease in pressure



In the syringe below, when the pressure increases, the volume decreases, but the temperature remains the same.

Figure 4

A gas syringe shows an increased pressure by decreasing the volume



Explain why altering the pressure affected the amount of the volume of the gas in the syringe.

Activity 5

Surface area

When the surface area is increased, the solid reactants also increase. Learners described the similarities and differences between physical as well as chemical systems and predicted the effect of solids on the equilibrium mixtures.

Example: Study the equation below where calcium carbonate powder and calcium carbonate chips were dissolved.

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

After some time, a gas was released, and the reaction rate was recorded.

Plot graphs and label curve A, calcium carbonate powder and curve B, Calcium carbonate chips.

Use the graph you constructed to fill in the spaces provided.

- ❖ The steepness of the two graphs is different because ---
- ❖ Explain why $CaCO_3$ mass and HCl(*aq*) concentration are similar in the two experiment.

The two reactions slowed down. Write down why the reaction slowed down?

2.5 Analysis of data

The pre-test and post-test data analysis were done by deploying means, standard deviations, t-tests, ANCOVA, and Cohen *d*. A t-test to differentiate between JM and the CT learners' achievements before and after the intervention, and Cohen d for effect size. ANCOVA determined the effect on the learners' achievements because of the intervention**.**

3. Results

The results show that EG using JM outperformed CG using CT. The EG pre-test results (M = 18.50, SD = 7.04) and CG (M = 18.20, SD = 5.52); t(42) = .16, p =.07) show no significant differences between learners' understanding of reaction rates before the intervention. After intervention, EG showed the post-test results (M = 76.88, SD = 12.95), and CG (M = 48.61, SD = 5.59); (t(42) = 9.54, p =.001) were significantly different (Table 4). ANCOVA post-test results show significant effects amongst EG and CG when the pretest is a covariate F(43, 44) = 6.83, p = .012. Also, the results of the pre-test among males (M = 19.67, SD = 6.19) and females (M = 16.89, SD = 8.13); t(19) = .89, p = .207) shows that there were no differences in understanding of reactions rates before the intervention. Similarly, post-test shows no significant differences between male (M = 77.67, SD = 13.14) and females (M = 76.66, SD = 13.50); t(19) =.755, p =.057).

Table 4*:* Pre-post-tests results of EG and CG.

Test	Groups	N	Mean	Std.	T	df	*p*	Cohen *d*
Pre-test	Experimental	21	18.50	7.04	.16	42	.07	.05*
	Control	23	18.20	5.52				
Post- test	Experimental	21	76.86	12.95	9.54	42	.001	2.8
	Control	23	48.61	5.59				

*significant p = 0.05

In Table 4, the pre-test results show no differences for EG (M = 18.50, SD = 7.04) and CG (M = 18.20, SD = 5. 52), T-test: t(42) =.16; *p* = .05) with Cohen *d* = .05. The pre-and post-test results show significant differences score of EG (M = 76.86, SD = 12.95) and CG (M = 48.61, SD = 5.59) (T-test: t(42) = 9.54; *p* = .05), and a Cohen *d* = 2.8. A one-way ANCOVA was determined if the treatment influenced the achievement of the two groups. Table 5 shows the ANCOVA results.

Table 5: ANCOVA post-test using pre-test covariate.

Tests Between-Subjects					
DV					
Source	Type III SS	*df*	MS	*F*	Sign.
Corrected Model	923.44[a]	2	461.72	3.62	.046
Intercept	23862.87	1	23862.87	186.859	.00
Pre-test EG	46.92	1	46.92	.37	.55
Groups 1 & 2	871.82	1	871.82	6.83	.01
Error	5236.19	41	127.71		
Total	247696.00	44			
Corrected Total	6159.64	43			
a R Squared = .150 Adjusted R Squared = .108					

*DV = depend variable

Table 5 indicates a significant difference in mean scores [F(2,41)=6.83, p=0.01] of pre- and the post-tests, with pre-test covariate.

A Mann Whitney U test pre-post achievements of Males and females in EG is presented below (Table 6).

Table6: Males and females Mann Whitney U-test for pre- and post-test achievements in EG.

Test Statistics[a]				
	Pre-test EG		**Post-test EG**	
	(M & F)	Median for (M & F)	(M & F)	Median for ((M & F)
Mann Whitney U-test	52.50		50.00	
Wilcoxon-W	97.50		128.00	

Z	-0.11		-0.29	
Asymptote. Sign. (2-tailed)	0.92	19.00 : 18.00	0.78	80.00 : 82.00
Exact Sign. [2*(1-tailed Sign.)]	.92[b]		.81[b]	

a. Group Variable: Group

Key: F= Female; M = Male

Table 6 show that a Mann Whitney U-test pre-test of males achievements were higher (Mdn = 19.00) than females (Mdn = 18.00), U = 52.50, p = .92. Although, the achievements of both genders were similar (U-test, p = .92), males' achievements in post-test were lower (Mdn = 82.00) than females' achievements (Mdn = 82.00), U = 50.00, p =.81, (Mann Whitney U-test, p = .81).

4. Discussion

The study investigated the impact of the JM and CT on Grade twelve learners' achievements. Before the intervention, pre-test results show no differences between EG and CG learners' understanding of reaction rates (Table 4). It infers that learners in EG and CG groups had comparable conceptual understanding regarding reaction rate before intervention. After the intervention, facilitating reaction rates using the JM for EG and instructing TC for CG, post-test results significantly differ in learners' achievements (ANCOVA, Table 5). The EG performed better than the CG, suggesting that JM was more effective than TC in improving learners' conceptual understanding of reaction rate concepts. This finding corroborates previous studies by Dollard and Mahoney (2012), who reported that JM produced positive learning outcomes. Unsurprisingly, JM improved achievement because learners in their home group studied to teach their peers in the expert-group. Here, learners think of questions from their home group, and some home group members suggest questions to clarify the concepts. In this way, learners become meticulous, like experts on the subject.

ANCOVA results show significant effects amongst EG and CG post-tests when the pre-test is a covariate (Table 5). The significant difference suggests noteworthy differences in achievement between EG learners using JM and CG learners using CT. Therefore, hypothesis one is accepted which states that there are differences between the two groups. The study findings agree with Ojekwu & Ogunleye (2020), who established that JM learners outperform CT learners. Learners in EG grasped the reaction rate concepts better than CG, especially in predicting the effect of solids on the equilibrium mixture. This observation is not surprising because Tyson et al. (1999) show that learners who identify similarities and differences between physical and chemical systems could predict the effect of solids on the equilibrium mixtures. However, Baken et al. (2020) observed that the efficacy of JM highly depends on the teacher's ability to facilitate the process.

Learners in EG were given an opportunity and encouraged to express their ideas, unlike in the CG. Using language improved EG learners' ability to explain concepts, which resulted in a better understanding of rates of reactions. KOÇ et al. (2010) encourage learner-centred teaching. For example, learners from EG could explain that according to Le Chatelier's principle, when reactants in a closed system produce heat (exothermic reaction), the products react to reduce the produced heat. Thus, learners from EG could predict any change due to temperature, pressure, concentration, and heat, which altered chemical reactions. Learners explained that the collision theory is where particle collisions depend on concentration, surface area, temperature, and either a catalyst or an inhibitor. According to Mengduo and Xiaoling (2010), involving learners in the expert-groups improves the conceptual understanding of both low and high achievers. High achievers gain a deeper understanding of the subject interlocutors with their peers. Such a teaching style reduces the teachers' role as "experts" and encourages learners to gain confidence in their knowledge as they work in groups (Moate & Cox, 2015).

The groups worked and had cohesion in their enactment, which agrees with Vygotsky (1978) that teamwork is useful. Makgato and Mji (2006) show that teachers' lack of subject knowledge resulted in low achievements. It may be true because CT does not endeavour to achieve deep learning, as learners remain passive (Maftei & Popescus, 2012; Pelley, 2021). The danger of passive learning is that many learners do not master the content, and their knowledge is forgotten, resulting in poor achievement in science.

The pre-test results between males and females show no differences in understanding reaction rates before intervention (Table 6). After the intervention, although all groups increased in scores, there were no differences in male and female achievements (Table 6). It implies that JM did not discriminate against gender, and both boys and girls benefited from the JM. Therefore, Hypothesis two was rejected, stating substantial differences in achievement of boys and girls in EG using the Jigsaw approach. These results parallel the Baena-Morales et al. (2020) study, revealing that learners' success was not based on gender. Each team member played a role in making the team succeed. Hence, the males and females worked together and learned as social entities (Ryzin, 2020). In this way, everyone in a group benefitted, irrespective of gender.

The pre- post-test scores for EG and CG show significant differences, suggesting that learners in CG had misconceptions regarding reaction rates. Learners from CG did not correctly answer most questions in the post-test, and the questions included graph interpretation and equilibrium. Most CG learners had difficulties understanding chemistry concepts (Shadreck & Enunuwe, 2018; Omilani & Elebute, 2020) because learners could not explain the reaction rates at a microscopic chemistry level. In addition, they could not link the microscopic to symbolic reactions. These observations agree with Wardah et al. (2020), who found that learners had difficulties regarding reaction rates at submicroscopic and symbolic levels.

Conversely, learners in EG did not have misconceptions like their CG counterparts, suggesting that JM the use of JM enable learners to overcome those difficulties and misconceptions. After the intervention, the second author taught CG the same topics using JM for ethical issues. Thus, after the whole exercise, all learners who participated in the study learnt 'reaction rates' concepts using JM.

The study was limited to Grade 12 learners and one topic in science. Therefore, it may not represent other topics in schools. Two schools with forty-four learners in one circuit participated in the study. Future research may consider larger samples using different chemistry topics and classes. Again, engaging other circuits, teachers and curriculum advisors is recommended. The experimental duration of four weeks exceeded the usual time for the topic because the teacher needed extra time to prepare JM content. Thus, balancing learners' and teachers' time was an unforeseen challenge. This study shows that JM improved Physical Science learners' academic achievements compared to CT. The method's effectiveness depends on the teacher's aptitude in facilitating the process. It highlights the need for planned teachers' professional development programs in short learning courses to update teachers' pedagogical skills. The results are significant for teachers and curriculum developers to implement learner-centred pedagogies.

5. Conclusion

The study findings show that JM improved learners' achievements. Learners who were taught reaction rates using JM did better than their counterparts taught using CT. The post-test results of both CG and EG (after intervention) showed significant differences in achievements between the two groups. The study also shows that both males and females in EG had similar achievements, suggesting that JM was effective for both genders. It implies JM effectively improved learners' achievements in reaction rates, irrespective of gender.

5. Recommendations

This study used a quantitative approach and was limited to two schools in one region of South Africa. Thus, more studies that include different South African regions using both quantitative and qualitative with different topics are recommended.

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