

COMPARING FLIPPED AND TRADITIONAL CLASSROOMS FOR GENDER EQUITY IN CHEMISTRY ACHIEVEMENT: A SOUTH AFRICAN CONTEXT

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Abstract

Despite reforms, gender gaps in science, especially chemistry, persist in under-resourced South African schools, with geography, socio-economic status, and teaching practices further disadvantaging female students. Despite the promise of flipped classroom (FC) pedagogy to improve achievement, concerns remain that these innovative methods might widen gaps, as research on FC in these schools, disaggregated by gender, is scarce. The study compared FC with traditional face-to-face (F2F) instruction to assess whether FC improves equity and narrows achievement gaps among Grade 12 organic chemistry students. Participants were randomly divided into two equal groups: Group 1 (52 females, 48 males; FC) and Group 2 (48 girls, 52 boys; F2F). Each group was taught all organic chemistry concepts by one male and one female teacher over seven weeks in Term 1, 2021, before writing a validated organic chemistry test to assess their achievement. No pretest was given since students were learning organic chemistry for the first time. Data were analysed using descriptive statistics and a two-way ANOVA (independent variables: gender [male, female]; instruction [FC, traditional F2F]; dependent variable: test score). All skewness values for test scores fell within the normal range (-1 to +1). Levene's test showed homogeneity of all variances ($p > .05$). Tests of between-subjects effects showed gender had an insignificant impact on test scores, $F(1, 196) = 1.07$, $p > .05$, $\eta^2 = 0.005$, with males' mean ($M = 34.90$, $SD = 19.32$) slightly higher than females' ($M = 33.08$, $SD = 17.34$). A significant main effect of the instruction method was observed, with Group 1 outperforming Group 2. However, the interaction between instruction and gender was not statistically significant, $F(1, 196) = .001$, $p > .05$, $\eta^2 = 0.000$. Group 1 females had higher estimated marginal means ($EMM = 40.54$, $SE = 2.31$) than Group 2 ($EMM = 25.00$, $SE = 2.409$), and the difference was statistically significant ($p < .05$). Similarly, for males, Group 1 ($EMM = 43.04$, $SE = 2.409$) was significantly higher than Group 2 ($EMM = 27.39$, $SE = 2.314$) ($p < .001$). The EMMs for males' and females' test scores in Groups 1 and 2 were similar, with p -values $> .05$, indicating FC does not worsen gender disparities and can improve or maintain equity in chemistry achievement. Findings support extending the FC approach across various contexts to prevent the widening of the gender gap in chemistry while enhancing achievement in under-resourced South African schools.

Keywords: *Flipped classroom, gender equity, chemistry achievement.*

1. Introduction

The equal participation of women in science education has been a topic of debate in many countries, including South Africa, prompting policy reforms to close the gender gap. Despite this, female graduates are still being outnumbered by their male counterparts in science-related degrees, with as little as 28.5% of women obtaining degrees in this field (Paradza, 2025). Several reasons have been proposed to explain why many female students tend to avoid science-related subjects and courses. These include socially constructed gender stereotypes, a lack of gender-sensitive teaching strategies, early pregnancies and marriages, and resource shortages (Idahosa & Mkhize, 2021). Additionally, EL-Deghaidy et al. (2025) observed that women face challenges in both science education and careers due to a lack of mentors and gendered stereotypes that question their abilities, leading to reduced motivation and higher dropout rates. Notably, Oladejo et al. (2023) found that high dropout rates are associated with ongoing underachievement in chemistry and demonstrated that technology-supported teaching methods, such as computer simulations, can help reduce the gender gap in chemistry achievement. It remains to be seen if the same effect can be achieved through a flipped classroom (FC), where students are introduced to new concepts online, followed by in-depth problem-solving activities during face-to-face (F2F) sessions (Flynn, 2015). Contrary to Oladejo et al. (2023)'s assertions, Fernandez et al. (2023) observed that female students prefer recording roles over operating equipment during chemistry practical work, reflecting gender stereotypes. Based on

this, the gender gap in chemistry may stem more from students' beliefs than from systemic barriers, making science less accessible for females. Furthermore, using questionnaires or interviews to assess satisfaction might not fully capture the true situation, as female students could be content with these roles (Fernandez et al., 2023), which may affect their academic progress. Therefore, the present study evaluated academic achievement in chemistry education using test scores rather than self-report questionnaires and compared traditional and FC classrooms.

FC can free up class time for more challenging work and improving academic achievement (Flynn, 2015). However, in contrast, Mizza et al. (2025) indicated that FC has limitations, including its inability to accommodate student diversity and its overreliance on students' ability to complete online work. Nonetheless, according to Nartey et al. (2023), females dedicate significant time to household chores and caring for the sick and elderly, and some take on low-paid jobs to support their families. This raises questions about the available online work time during the pre-class phase of FC. It suggests females might benefit less from FC than males, since students need online activities to gain from in-class sessions. Consequently, it became essential to compare gender differences in chemistry achievement between students taught using traditional teaching methods common in South African high schools and those taught using FC pedagogy. Furthermore, Rensaa & Fredriksen (2022) emphasise the need for research on gender awareness in FC settings, given the rapid growth in the use of this innovative pedagogy, to offer better guidance on its effective application. More importantly, the effectiveness of FC pedagogies in promoting academic achievement is sensitive to contextual factors (Li & Li, 2022), hence the need to focus on contexts that are often underexplored, such as the under-resourced schools of South Africa.

These schools, which mainly serve Black students, have historically been disadvantaged by the apartheid-era segregated education system that prioritised White students' education (Idahosa & Mkhize, 2021). However, research by Chakawodza et al. (2024a), linked to the present study, demonstrated that FC pedagogy was effective in improving academic achievement in organic chemistry; nonetheless, as with other studies conducted in under-resourced South African schools, the findings were not disaggregated by gender, raising questions about whether gender disparities in academic achievement were addressed. This study compared gender differences in Grade 12 organic chemistry achievement between traditional F2F and FC classes, focusing on a subject often associated with conceptual difficulties worldwide and in South Africa (Chakawodza et al., 2024a; Flynn et al., 2015). To achieve this, research questions RQ1, RQ2, and RQ3 were addressed.

1.1. Research questions and hypothesis statements

1.1.1. Gender effect. RQ1: Do chemistry achievements differ between male and female students, regardless of instructional approach?

H₀: Chemistry achievement does not differ between male and female students, regardless of instructional approach.

H₁: Chemistry achievement differs between FC and traditional F2F classrooms, regardless of teaching method.

1.1.2. Teaching method effect. RQ2: Does chemistry achievement differ between males and females in FC and traditional F2F?

H₀: There is no difference in chemistry achievement between males and females in FC and traditional F2F.

H₁: The chemistry achievement between males and females differs in FC and traditional F2F.

1.1.3. Interaction effect. RQ3: Does the impact of instructional method (flipped vs traditional F2F) on chemistry achievement differ by gender, such that the gender achievement gap either diminishes or remains the same in FC compared to traditional instruction?

H₀: The gender achievement gap in chemistry neither narrows nor widens in FC compared to traditional instruction.

H₁: The gender achievement gap in chemistry either reduces or widens in FC compared to traditional instruction.

1.2. Theoretical framework

This study on chemistry achievement used Bronfenbrenner's ecological systems theory, showing gender disparities through interconnected systems: the microsystem (family), mesosystem (classroom), exosystem (educational policies), macrosystem (societal stereotypes, culture, socio-economic and technological factors), and chronosystem (disruptive events like COVID-19 and life changes like divorce). The systems interact as teachers, parents, students, and policies influence gender perceptions and classroom

dynamics. This framework guided the analysis of the data collected through the methodology described in the next section.

2. Methodology

Ethical approval was obtained from the university's institutional review board, along with informed consent from the participating students (and their parents or guardians) and from the teachers. This was done after obtaining permission from the Mpumalanga Provincial Education Department and the participating school to conduct the study. Given Fernandez et al. (2023)'s highlighting of deep-rooted gender stereotypes, this study had to be quantitative, measuring organic chemistry achievement rather than relying on female students' perceptions. This entailed utilising a combination of sampling strategies.

2.1. Sampling and sample

Purposive sampling was used to select an under-resourced high school with a high enrolment of Grade 12 students to ensure a sample suitable for statistical analysis. The selected school had 300 Grade 12 students studying chemistry (as a component of physical sciences), of whom 200 agreed to participate in the study. The latter were then placed into two equal groups (Group 1: 52 females, 48 males; Group 2: 48 females, 52 males) of Grade 12 students who were randomly assigned to them. Random assignment of students helped eliminate biased selection and ensured group equivalence. Although Group 1 received teaching through FC pedagogy and Group 2 through traditional F2F instruction, both groups were taught organic chemistry by two purposefully selected teachers (one male and one female) during the last seven weeks of Term 1, 2021. Details about the teaching of organic chemistry are covered in the following section.

2.2. Organic chemistry teaching and data collection

Concepts covered included organic molecules, their nomenclature, various organic reactions (substitution, elimination, oxidation, hydrogenation, and polymerisation), physical properties (of organic molecules), isomerism, and intermolecular forces. This was followed by administering a knowledge of organic chemistry test (KOOCT), previously validated by Chakawodza et al. (2024a), to both groups simultaneously, which was used to collect organic chemistry achievement data through test scores. However, a pre-test could not be given because students were learning organic chemistry for the first time. The FC model used is described fully in Chakawodza et al. (2024a). Teaching activities included videos, online quizzes, gamification, discussions (both online and F2F), chats, and practical exercises. Despite efforts to ensure that students in both groups received similar activities, some, such as videos and gamification, could not be utilised in Group 2 due to a lack of technology. To collect gender data, all participants indicated on their answer sheets whether they were male or female. The collected data were analysed using a two-way ANOVA, with Teaching method (FC or Traditional) and Gender (Female or Male) as independent variables and chemistry achievement (Test scores) as the dependent variable, following data preparation.

2.3. Preparation of data for analysis

The data were examined for invalid entries, missing values, and outliers. Skewness was within the normal range (-1 to +1), according to Hair et al. (2022). Levene's test showed homogeneity ($p > .05$). The four groups were independent. Therefore, all assumptions for the two-way ANOVA were met.

3. Results and discussion

Descriptive statistics showed that the males' mean (M) = 34.90, with a standard deviation (SD) of 19.32, was marginally higher than that of females (M = 33.08, SD = 17.34). This suggests a potential gender gap in chemistry achievement in favour of male students. However, a two-sided test showed that the two means are not statistically different.

3.1. RQ1: Gender main effect

Tests of between-subjects effects showed that gender had no significant impact on test scores, $F(1, 196) = 1.07$, $p > .05$, $\eta^2 = 0.005$, as shown in Table 1. Therefore, the null hypothesis was not rejected. These findings do not align with those by Fernández et al. (2023) and Idahosa and Mkhize (2021). However, given Oladejo et al.'s (2023) findings, the current results may be considered expected, despite the authors focusing on electrolysis and electroplating. Applying Bronfenbrenner's ecological theory shows that, although gender stereotypes persist, the interaction between the five environmental systems could have helped reduce the gender gap, especially through ongoing educational reforms.

Table 1. Between-subjects effects.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	12310.833 ^a	3	4 103,61	14,732	0	0,184
Intercept	230 710,42	1	230 710,42	828,235	0	0,809
Gender	298,157	1	298,157	1,07	0,302	0,005
Teaching method	12 145,04	1	12 145,04	43,6	0	0,182
Gender* Teaching method	0,176	1	0,176	0,001	0,98	0
Error	54 597,15	196	278,557			

3.2. RQ2: Teaching method main effect

For Group 1 females, the estimated marginal means (EMM = 40.54, SE = 2.31) were significantly higher than those of Group 2 females (EMM = 25.00, SE = 2.409), as $p < .05$. Similarly, in males, Group 1 (EMM = 43.04, SE = 2.409) was significantly higher than Group 2 (EMM = 27.39, SE = 2.314) ($p < .001$). These results indicate that male students benefited slightly more from FC, although the difference was not significant ($p < .05$), showing that when carefully implemented, the FC pedagogy can address gender diversity. Based on this, the null hypothesis for RQ2 was not rejected. These findings were, on the one hand, inconsistent with Mizza et al. (2025) but, on the other hand, consistent with those of Oladejo et al. (2023). Furthermore, pre-classwork may be influenced by gender stereotypes reinforced by parents when Bronfenbrenner's (1979) ecological systems theory is applied, explaining the marginal differences in EMMs. Furthermore, given that the EMMs for males' and females' test scores in Groups 1 and 2 were similar (p -values $> .05$), a pairwise comparison was conducted.

Table 2. Pairwise Comparisons.

Teaching Method (I) Gender (J) Gender	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^a	
				Lower Bound	Upper Bound
Flipped Classroom	F - M	-2,503	3,341	0,455	
	M - F	2,503	3,341	0,455	
Traditional f2f	F - M	-2,385	3,341	0,476	
	M - F	2,385	3,341	0,476	

This suggests that there were no gender differences in chemistry achievement across traditional and FC classrooms, as shown Table 2. These EMMs were plotted to assess interaction effects.

3.3. RQ 3: Interaction effect

The interaction between instruction and gender was not statistically significant.

Figure 1. Interaction effects.

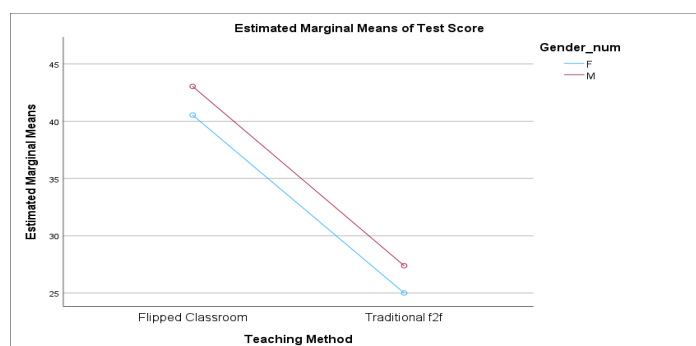


Figure 1 confirms the results: $F(1, 196) = .001$, $p > .05$, $\eta^2 = 0.000$, indicating no interaction effects, and parallel EMM plots showing that both genders benefited equally (with no gender favoured) from both instructional methods. Therefore, the null hypothesis for RQ3 was not rejected.

4. Conclusions, recommendations and limitations

This study compared gender differences in FC and traditional classrooms. For both males and females, there was a statistically significant difference in achievement in organic chemistry between FC

and traditional F2F learning. Therefore, it was concluded that no significant gender gap in academic achievement was observed. Although it does not worsen gender disparities, questions remain about whether FC is the most effective approach for promoting gender equity. Nonetheless, FC could be expanded to include more students without increasing existing gender gaps. However, the ethical considerations of this approach, particularly since FC does little to close the small gender gap, cannot be ignored. Importantly, this study recommends using gender-disaggregated data as the standard for evaluating technology-mediated learning. Nonetheless, due to the brief duration of the intervention, further longitudinal studies are recommended. Additionally, research including diverse genders is advised, as this study treats gender as binary, which may not reflect reality in most schools. Therefore, this portrayal of gender is identified as a limitation of the current study. Nevertheless, the research has implications for chemistry educators and policymakers, as findings support expanding the FC approach across different South African contexts and offer a practical strategy to prevent widening gender gaps in chemistry while improving achievement.

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