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INTERACTION EFFECT OF GENDER, ACROSS SCHOOL-TYPE ON UPPER-SECONDARY STUDENTS' DEVELOPMENT OF EXPERIMENTAL REASONING ON ORGANIC QUALITATIVE ANALYSIS

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Abstract. *Chemical tests (qualitative analysis) on functional groups may improve students' understanding of basic concepts about the structure of organic compounds and their reactivity. However, upper-secondary school students have difficulties in learning organic qualitative analysis. This research has studied whether the gender of students and school-type affect development of experimental reasoning on organic qualitative analysis. From three school-types, 50.2% males and 49.8% females were sampled through a multistage sampling procedure and participated in a cross-sectional survey. Data from 263 students were collected with the aid of diagnostic test on knowledge of organic qualitative analysis. A two-way between-groups ANOVA and independent-samples t-test were used to analyse the data. It was found no interaction effect of gender and school-type on students' development of experimental reasoning on organic qualitative analysis.*

Keywords: *gender and school-type, interaction effect, organic qualitative analysis, performance of students*

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Introduction

In learning chemistry, students are expected to have the capacity to deal with chemical concepts and to relate the symbolic representations used at each level of presentation. In doing so, students encounter difficulties in learning if the symbolic language is not well understood by them (Marais & Jordaan, 2000). These difficulties in learning chemistry result into misunderstanding between the material world and theoretical constructs (Kozma et al., 2000; Marais & Jordaan, 2000) as a result of the interplay between macroscopic and sub-microscopic levels (O'Dwyer & Childs, 2017; Sirhan, 2007).

Structural (constitutional) formulas which are used to visualize substances relate mostly to the visual (spatial, imaginary) type of thinking but not "purely abstraction" (Lakhvich, 2021). Symbolic presentation of chemical elements relates to abstraction. But structural formulas being the universal models for organic chemistry are based mostly on visual thinking and contribute to its development. The issue was discussed for many times both in philosophical and psychological/educational contexts (Lakhvich, 2010; 2019). As such, students' misunderstanding in chemical concepts begins to show distinctly when they only operate in the macroscopic world and find it difficult to connect from the macroscopic level to the sub-microscopic level or vice versa (Abd Halim et al., 2013). Thus, there are instances where students need to use mental rotation to operate between the levels of presentation of (organic) chemistry (Stieff, 2007). Hence, one of the commonest questions we ask ourselves as educators and researchers in chemistry is: what problems do students encounter when interpreting chemical representations? (Graulich, 2015).

In Ghana, students in upper-secondary schools learn chemistry in their 3-years stay in school under the following concepts as recommended by the planners of the curriculum (Ministry of Education, 2010). In the first year, students learn introduction to chemistry (such as chemistry as a discipline, measurement of physical quantities, and basic laboratory practices), atomic

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structure (such as particulate nature of matter and periodicity), chemical bonding, conservation of matter and stoichiometry, and states of matter. In the second year, students learn energy and energy changes, inorganic chemistry (such as periodic and transition chemistry), chemical kinetics and equilibrium, acids and bases, redox reactions and electrochemistry, and organic chemistry. Finally, in the third year, students learn industry and environment (such as chemical industry, extraction of metals, extraction of crude oil and petroleum processing, environmental pollution, biotechnology, and cement and its uses), and basic biochemistry (such as fats and oils, proteins, carbohydrates, and synthetic polymers) (Ministry of Education, 2010, pp. iv-v).

Most of these concepts in chemistry are based on structure of the atoms in molecules (Sirhan, 2007), and this structural presentation makes learning of chemistry difficult to most students (Adu-Gyamfi et al., 2017; Childs & Sheehan, 2009; Hanson, 2017; Sirhan, 2007). Thus, students use analytical strategies and heuristics to solve problems in (organic) chemistry (Stieff, 2007). One other area where analytical strategy is required is organic qualitative analysis, and this was why the current research studied the conceptual difficulties of students leading to their experimental reasoning on organic chemistry.

O'Dwyer and Childs (2017) reported that the 276 upper-secondary school and 121 university students from Ireland in a survey have interest in organic chemistry and do enjoy the concepts in it. However, the students consider organic chemistry as difficult to learn and understand. Even in some instances, students perceived some organic concepts as easy, but show weak performance in demonstrating their conceptual understanding. A cross-sectional survey by Adu-Gyamfi et al. (2017) using quantitative and qualitative data from 245 upper-secondary chemistry students in Kumasi Metropolis of Ghana found some students' conceptual difficulties in naming organic compounds through IUPAC nomenclature. The performance of first year university students on organic chemistry, therefore, explains the underlying conceptualization gains from upper-secondary chemistry. The first-year university students are expected to search answers to questions such as: what type of reaction a particular molecule is expected to undergo? (Hassan et al., 2004). To achieve this, students need to use the process-oriented view to analyse an organic reaction (Ferguson & Bodner, 2008).

Concepts in chemistry are purely conceptual (Sirhan, 2007) and when students memorized steps and patterns in (organic) reactions (Bhattacharyya & Bodner 2005), they were unable to demonstrate the why and how of those reactions (Tang et al., 2010). That is, students end up demonstrating their conceptual difficulties resulting in weak performance on (organic) chemistry. Childs and Sheehan (2009) explained that pupils and students in schools and colleges find some chemistry concepts difficult to learn and to perform creditably well in them, inclusive here, are IUPAC naming of organic compounds (Adu-Gyamfi et al., 2017), stereochemistry (Stieff, 2007), and organic reactions and mechanisms (Bhattacharyya & Bodner 2005; Tang et al., 2010). With respect to organic reactions, the difficulties students encounter in learning are evident as lack of skills in analysing the various steps in a reaction, translating reactions to forms that predict the final products, and justifying the steps taken in the reactions. These steps are termed as cognitive steps (Tang et al., 2010).

It is worthy of note that organic reactions and mechanisms are recognized by functional groups. One area of organic chemistry of greater interest in upper-secondary school science is organic qualitative analysis. An area where the presence of the functional group of an organic molecule is detected (Anim-Eduful & Adu-Gyamfi, 2021), because most of organic reactions occur at the functional group site of the organic molecule (Tang et al., 2010). However, there are instances when students of organic chemistry are confused with competing ideas (Ferguson & Bodner, 2008). For instance, dealing with how to identify a functional group through laboratory analysis is quite confusing to students and that they need experience and practice to develop the concept of functionality. And to be good at organic reactions, students need to identify and use functional groups confidently (Hassan et al., 2004). Those experience and practice are offered to students through organic qualitative analysis.

There are a number of factors accounting for students' learning difficulties on organic chemistry. According to O'Dwyer and Childs (2017), the learning difficulties on organic chemistry are intrinsic in nature (for example, cognitive ability, information processing model, attitudes to learning, and misconception) and extrinsic in nature (for example, multi-dimensional nature of chemistry, complex language, laboratory work, and nature of chemistry curriculum). These are not only common to theory aspects, but the practical aspects as well. Upper-secondary school curriculum is structured to help students overcome these learning difficulties through analytical procedures (that is, organic qualitative analysis).

For Ghanaian students learning chemistry as elective, the upper-secondary school curriculum, outlines concepts under which organic qualitative analysis can be studied and practiced under chemistry of carbon compounds.

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These concepts are reactions of symmetrical and unsymmetrical alkenes with bromine, halogen halides, water, and (cold dilute); preparation of ethyne from calcium carbide and water, halogenation of terminal and non-terminal alkynes, combustion of alkynes (oxy-ethyne flame), and test for terminal alkynes; test for benzene and alkene using cold dilute, or in the dark; preparation of alkanols from alkenes and haloalkanes, and determination of the products of oxidation of primary, secondary, and tertiary alcohols using (acidified solution). The rest are laboratory preparation of carboxylic acids, reactions of carboxylic acids with active metals (and), , and , , and alkanol/ and basic and acidic hydrolysis of alkyl alkanoates (Ministry of Education, 2010, pp. 46-51).

Notwithstanding these chemical tests that are recommended by Ministry of Education (2010), Ghanaian upper-secondary chemistry students seem to have conceptual difficulties on organic qualitative analysis. Because the chief examiner's reports (WAEC, 2001; 2003; 2004; 2005; 2012; 2014; 2015; 2016; 2017; 2018) showed that students find it difficult to respond to standardized test items on organic qualitative analysis in both practical and theory components of the examinations.

An explanation for interest in social dimensions of cognition is that social and cultural factors greatly influence cognition in the perspective that thought, learning, and knowledge acquisition are not only influenced by social factors, but also are social phenomena. From this perspective, cognition is a collaborative process (Palincsar, 1998). Hence, factors, such as instructional laboratory lessons, students' prior knowledge, teacher content knowledge, and time constraint contribute to students' success in conceptualizing organic chemistry-related concepts (Mahajan & Singh, 2005). Notwithstanding, Horowitz et al. (2013) expressed concerns of working with students of high degree of diversity, such as ethnicity, income level, English as a second or third language, and family academic qualification. Consequently, there was the need to examine whether the gender of students and school-type affect students' development of experimental reasoning on organic qualitative analysis and if does not, to identify which among the three school-types (well-endowed, endowed, and less-endowed schools) was a contributing factor affecting students' experimental reasoning on organic chemistry. The research was guided by the hypothesis:

H_{01}: There is no statistically significant difference between the development of experimental reasoning of male and female students, across three school-types on organic qualitative analysis

As mentioned earlier, a number of factors influence the performance and interest of students on organic chemistry (Hanson, 2017; Horowitz et al., 2013) and the effects of school-type on students' performance on organic chemistry is as important as any other factor (Gafoor & Shilna, 2014). For instance, Adu-Gyamfi et al. (2013) investigated the performance of 148 students from well-endowed schools and 97 students from less-endowed schools in Kumasi Metropolis, Ghana on IUPAC nomenclature of organic compound. At the end of the investigation, it was reported there was no statistically significant difference in the performance of the students from the two school-types. Upon exposing students from both rural and urban schools to learning chemistry through task-based learning, students from rural schools perform better than students from the urban school (Musengimana et al., 2022).

According to Rojas-Oviedo et al. (2018), it is always worth the effort to consider the issue of gender to help improve the performance of students on organic chemistry. Because Gafoor and Shilna (2014) reviewed that gender bias continues to be a problem in science-related subjects and their classrooms (Aini et al., 2019), and organic chemistry is no exception to that. Even in some countries females are doing well in science compared to males, and other countries, males are doing well compared to females (Askin & Oz, 2020). To be honest, researchers have not so far reached a consensus on how gender and test-format affect measures of students' academic performance in science-related subjects and courses. The performance of female undergraduate students was higher than male students on organic chemistry. However, Turner and Lindsay (2003) found that male college students achieved well in the explanations of organic chemistry, and that notwithstanding the instructional approach employed helped male students slightly outperform their female colleagues on organic nomenclature in chemistry, but there is no interaction effect of instructional approach and gender on students' conceptual understanding of organic nomenclature (Worokwu, 2018).

Moreover, in a research study on a gender fair efficacy of concept mapping test, the scores from the multiple-choice items on organic chemistry favour female students compared to male students (Gafoor & Shilna, 2014). However, though there are misconceptions among students on organic chemistry (Omwirhiren & Ubanwa, 2016), and this playing a greater role in students' learning of the concept (Sibomana et al., 2021), there is no significant difference between the performance of male and female students on organic chemistry (Omwirhiren & Ubanwa, 2016). The issue of whether there exists difference in gender in the literature is associated with the scores on science-related subjects or courses, whereas the interaction effects of other factors are being silent on (Askin & Oz, 2020).

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Research Methodology

Research Design

The research design for this current research was a cross-sectional survey. That is, the research used quantitative approaches to collect data on students' development of experimental reasoning on organic qualitative analysis in one of the 16 regions of Ghana where there were a lot of the renowned upper-secondary schools. As it was a cross-sectional survey, the researchers spent a day in each school collecting data. The quantitative approaches provided the research with quantitative data that were examined to ascertain any differences in the development of experimental reasoning of male and female students in less-endowed, endowed, and well-endowed schools on organic qualitative analysis.

Sample and Sampling Procedures

The research was conducted in the Central Region of Ghana. The region is currently the fourth most populous region in Ghana. The total population of this region was estimated as 2,859,821. The region was endowed with three universities, five nursing and midwifery training colleges, three colleges of education, and 76 upper-secondary schools. These institutions were all government own. The region was purposively selected as it had all the characteristics observed in the Ghanaian upper-secondary schools and attracted students from all other regions of Ghana.

Not all the 76 upper-secondary schools in the Central Region were targeted for this research. This was because 55 schools were those where students learnt chemistry as one of the elective subjects. A multistage sampling procedure was used to select 263 third year students for this research. That is, the 55 schools were stratified into six grade A (well-endowed) schools, 18 grade B (endowed) schools, and 31 grade C (less-endowed) schools. From each school-type, two were simple randomly selected for this research. This gave six schools. This was done to have reasonable numbers of male and female students from all categories of school because there were large numbers of male and female students in the single-sex schools compared to the co-educational schools. Of the six schools, the two well-endowed schools were single-sex (that is, a male single-sex and a female single-sex) and the other four schools were co-educational institutions. In each of the single-sex schools, 50 students were simple randomly selected. That gave equal numbers of male and female students from the single-sex schools. In the four co-educational institutions, students were stratified into male and female students and where there were lesser number of female students (say less than 50), they were all conveniently selected because two of the co-educational schools had lesser numbers of females. Thus, 163 students consisting of 82 males and 81 females were selected from the co-educational institutions. Of the 263 students, there were 50.2% males and 49.8% females, and they were distributed across the three school-types as 38.0% from well-endowed schools, 24.0% from the endowed schools, and 38.0% from the less-endowed schools. Also, among the 263 students, 1.1% were aged 15 years, 35.4% were aged between 15 to 17 years, and 63.5% were aged 18 years and above.

Data Collection Instrument

Knowledge of Organic Qualitative Analysis Test (KOQAT) was the research instrument used to collect the quantitative data on students' development of experimental reasoning on organic qualitative analysis in the upper-secondary school. The Section A of KOQAT sought for the biodata: sex, school-type, and age making up four items. The Section B comprised multiple-choice and essay-type items. At first, there were 13 multiple-choice items being two-tier and students upon selection of one of the four options, needed to provide reason for their selection. Also, there were two essay-type items with 15 sub-items. Here students were to identify and analyse the particular functional group with the organic reagents used in the reaction (Appendix A). Each item on KOQAT scored 2 marks. That is, 2 scores for correct option and reasoning (as a full scientific understanding), 1 score for either correct option or reasoning (as a partial scientific understanding), and zero score for no or wrong response (as a no scientific understanding) with the scheme used by Anim-Eduful and Adu-Gyamfi (2021).

The items on KOQAT were constructed by the researchers using the chemistry curriculum (Ministry of Education, 2010), WAEC test items, and other literature as a guide. To further ensure face validity of KOQAT, the items were given to two upper-secondary school chemistry teachers who were WAEC assistant examiners to critique and make suggestion to improve the quality of KOQAT. Thereafter, KOQAT was pilot-tested with 30 upper-secondary school

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students outside the research zone, but of similar characteristics to the students who participated in the main research. The items on KOQAT were subjected to item analysis after the pilot test. This led to the deletion of seven items and another, modified. After deletion of those items on KOQAT, there were nine multiple-choice items and 13 sub-items on the two essay-type items distributed across synthesis and reactions of alkanes, alkenes, alkynes, benzene, alkanols, carboxylic acids, alkyl alkanoates, aldehydes, and ketones (Appendix A). As each item scored 2 marks, the total score from KOQAT was 44. That is, 18 scores from the multiple-choice items and 26 scores from the essay-type items. The calculated value for KR 21 reliability coefficient was 0.7, indicating KOQAT was reliable.

Data Collection Procedures

The researchers collected the data in six schools in person using KOQAT. The intent was to eliminate any form of biases or assistance from other students and teachers in responding to the items. In each school we had a discussion with the teachers teaching the third-year students to be sure of the readiness of students to participate in the research. The selected students were briefed on the purpose of the research and that their performance though would not influence any gains in continuous assessment, but we needed them to put up their best. It was confirmed that students covered all the topics normally following the curriculum, and any school where students had not covered a lot on organic chemistry was dropped and another simple randomly selected to replace. This only happened in one of the less-endowed schools, where the teacher had just begun teaching the organic aspects of the curriculum. The researchers used six working days to collect the data from the six selected schools using KOQAT. That is, the researchers spent one day in each school.

Data Processing and Analysis

After data collection, the students' responses were scored according to Anim-Eduful and Adu-Gyamfi (2021) scheme of scoring a test on functional group detection. Means, standard deviations, two-way between-groups ANOVA, and independent-samples t-test were used to analyse the data on students' development of experimental reasoning on organic qualitative analysis by gender, across three school-types. To be sure the right statistics for comparing the mean scores was selected, the results of the Kolmogorov-Smirnov statistics were considered. A significant value of *.000* (being less than $p = .05$) was obtained of the Kolmogorov-Smirnov statistics. This was an indication that though the sample size of 263 students was large, but the students' scores on organic qualitative analysis were not normally distributed. However, a two-way between-groups ANOVA was used to examine differences in means between two independent variables (gender; male and female students and school-type; well-endowed, endowed, and less-endowed schools) on students' experimental reasoning on organic qualitative analysis because the two-way between-groups ANOVA had no corresponding non-parametric statistics that could have helped to examine any interaction effect of gender and school-type on students' development of experimental reasoning on organic qualitative analysis. From the Levene's test of the two-way between-groups ANOVA, a significant result of *.000* (being less than p at *.05*) was obtained. This meant that the variance of the students' scores on organic qualitative analysis across the groups (sex and school-type) was not equal. Hence, the significance level for evaluating the results of this statistics was set at $p = .01$. In addition, the independent-samples t-test was used to examine any gender differences in the split data on students' development of experimental reasoning on organic qualitative analysis in each school-type.

Research Results

Interaction Effect of Gender and School-Type on Students' Development of Experimental Reasoning on Organic Qualitative Analysis

The hypothesis, first, examined whether there was an interaction effect of gender and school-type on students' development of experimental reasoning on organic qualitative analysis in the upper-secondary school. To be able to achieve this, the 263 students from the three school-types responded to KOQAT. Thereafter a two-way between-groups ANOVA was conducted on students' experimental reasoning. The results are reported in Table 1.

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Table 1
Analysis of Variance of Male and Female Students' Development of Experimental Reasoning on Organic Qualitative Analysis by School-Type

Source	Type III sum of squares	*df*	*Mean squares*	*F*	*p*	*Partial eta square*
Correct model	6226.950	5	1245.390	16.918	.001	.248
Intercept	20402.860	1	30402.860	277.170	.001	.519
School-type	6140.499	2	3070.250	41.709	.001	.245
Gender	.997	1	.997	.014	.907	.000
School-type*gender	85.833	2	42.916	.583	.559*	.005
Error	18918.130	257	73.611			
Total	44600.000	263				
Corrected total	25145.080	262				

*Not significant, $p > .01$

As seen from Table 1, a two-way between-groups ANOVA was conducted to examine the effect of gender and school-type on students' development of experimental reasoning on organic qualitative analysis. Students were, then, divided into three groups according to their school-type (Group 1: well-endowed school; Group 2: endowed school; and Group 3: less-endowed school). The interaction effect between gender and school-type was not statistically significant (F (2, 257) = .583, p = .559) on students' experimental reasoning on organic qualitative analysis. However, there was statistical significance on the main effect for school-type (F(2, 257 = 41.709, p = .000). The effect size was large enough (*partial eta square = .245*) because it explained 24.5% of the variances shared among the three school-types and therefore, the finding had practical significance that was worth noting.

Main Effect of Gender on Students' Development of Experimental Reasoning on Organic Qualitative Analysis

Though the research examined the interaction effect of gender and school-type on students' development of experimental reasoning on organic qualitative analysis, there was the need to look at the main gender effect. The mean scores of male and female students from the two-way between-groups ANOVA are reported in Table 2.

Table 2
Mean Scores of Male and Female Students' Development of Experimental Reasoning on Organic Qualitative Analysis (N = 263)

Gender	*n*	*M*	*SD*	*Max score*
Male	132	8.55	9.987	43
Female	131	8.65	9.639	41

As seen from Table 2, though the means were very low at high standard deviations, but the mean of male students (M = 8.55, SD = 9.987, *Max. score* = 43) seemed equal to that of the mean of female students (M = 8.65, SD = 9.639, *Max. score* = 41) on experimental reasoning on organic qualitative analysis. The high standard deviations were an indication that most of the students within each group were far from the centre of the distribution of the scores on organic qualitative analysis. Notwithstanding there was no statistical significance on the main effect of gender of students (F(1, 257) = .014, p = .907) on their experimental reasoning on organic qualitative analysis.

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Main Effect of School-type on Students' Development of Experimental Reasoning on Organic Qualitative Analysis

To examine the main effects of the three school-types on the development of experimental reasoning of upper-secondary students on organic qualitative analysis, the mean scores of students in relation to school-type were calculated as part of the two-way between-groups ANOVA statistics. The results on the mean scores are reported in Table 3.

Table 3
Mean Scores of Students' Development of Experimental Reasoning on Organic Qualitative Analysis in Relation to School-Type (N = 263)

School-type	*n*	*M*	*SD*	*Max score*
Well-endowed	100	12.63	10.020	36
Endowed	63	11.98	11.579	43
Less-endowed	100	2.44	2.757	20

As seen from Table 3, the students' experimental reasoning in relation to the three school-types was relatively low. That is, the mean scores were lower than one-half (22) of the total score of 44. For instance, for the less-endowed school, the mean score was extremely low ($M = 2.44$, $SD = 2.757$, *Max score* = 20) though the mean score of the well-endowed school ($M = 12.63$, $SD = 10.020$, *Max score* = 36) and the mean score of the endowed school ($M = 11.98$, $SD = 11.579$, *Max score* = 43) were not high either. The high standard deviations for the three schools gave an indication that the individual scores of students of each school were widely spread from the means of the distributions of scores. As the effect of school-type on students' development of experimental reasoning on organic qualitative analysis was modified by gender (Table 1), there was the need to examine whether mean scores of students in the three school-types differed significantly by gender and where the difference lies. To investigate further, there was need to conduct a post-hoc tests to examine the mean scores of pairs of groups in the school-type. The results from the post-hoc are reported in Table 4.

Table 4
Multiple Comparisons of Students' Development of Experimental Reasoning on Organic Qualitative Analysis by Three School-Types

School-type		*Mean difference*	*SD* error	*p*
Well-endowed	Endowed	.65	1.380	.886
	Less-endowed	10.19	1.213	.001*
Endowed	Well-endowed	-.65	1.380	.886
	Less-endowed	9.54	1.380	.001*
Less-endowed	Well -endowed	-10.19	1.213	.001*
	Endowed	-9.54	1.380	.001*

* Significant, $p < .01$

As seen from Table 4, the results suggested that there was a statistical difference in the development of experimental reasoning of students from the three school-types on organic qualitative analysis because the mean score of students from the well-endowed school ($M = 12.63$, $SD = 10.020$, $p < .01$) was statistically significantly different from the mean score of the students from the less-endowed school ($M = 2.44$, $SD = 2.757$), but not that of students from the endowed school ($M = 11.98$, $SD = 11.579$) on organic qualitative analysis. Also, the mean score of students from the endowed school (*Mean* = 11.98, $SD = 11.579$, $p < .01$) was statistically significantly different from the mean score of students from the less-endowed school ($M = 2.44$, $SD = 2.757$) on organic qualitative analysis.

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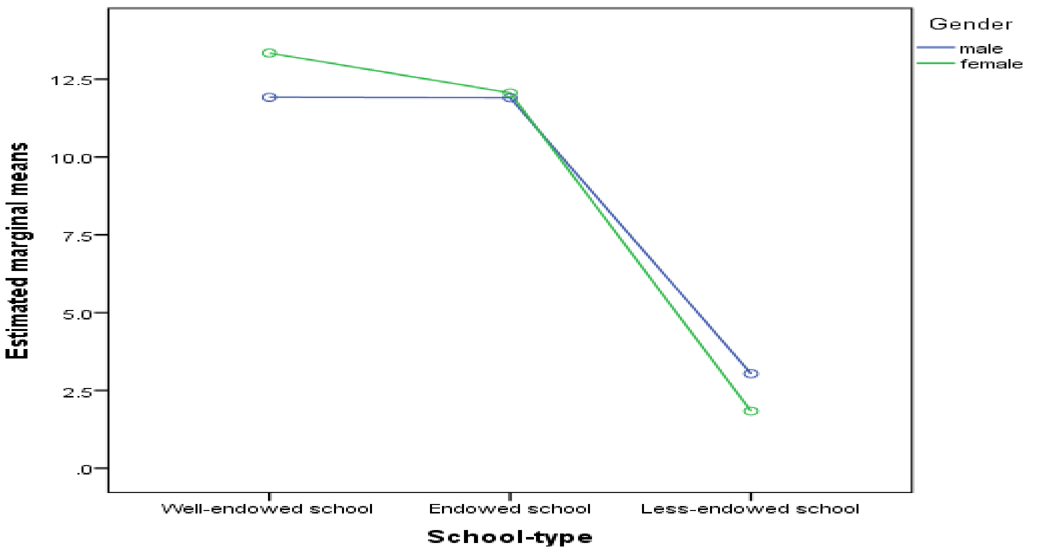
To better examine the effect of gender across the three school-types on students' experimental reasoning on organic qualitative analysis, there was the need to plot the relationship among the two independent variables. The mean scores of male and female students across the three school-types are reported in Table 5.

Table 5
Cell Mean Scores of Students' Development of Experimental Reasoning on Organic Qualitative Analysis by Gender by School-Type (N = 263)

School-type	Gender	*n*	*M*	*SD*
Well-endowed	Male	50	11.92	9.930
	Female	50	13.34	10.159
	Total	100	12.63	10.020
Endowed	Male	32	11.91	12.910
	Female	31	12.06	10.240
	Total	63	11.98	11.579
Less-endowed	Male	50	3.04	3.563
	Female	50	1.84	1.390
	Total	100	2.44	2.757

The plot of the mean scores of students' development of experimental reasoning on organic qualitative analysis by gender by school-type is reported in Figure 1.

Figure 1
Graphical Presentation of Mean Scores of Students' Development of Experimental Reasoning on Organic Qualitative Analysis by Gender by School-type



As seen in Figure 1, there appeared to be differences in the mean scores of male and female students' experimental reasoning on organic qualitative analysis in well-endowed and less-endowed schools, but not the endowed school. However, an independent-sample t-test statistics of the split data confirmed a significant difference amongst male and female students only in the less-endowed school with equal variances not assumed ($p = .007$). This is

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because there was no statistical significance between the mean score of male students from well-endowed school (M = 11.92, SD = 9.930, t(98) = -.707, p = .481) and the mean score of their colleague females (M = 13.34, SD = 10.159) on organic qualitative analysis. Also, there was no statistical significance between the mean score of male students from endowed school (M = 11.91, SD = 12.910, t(61) = -.054, p = .957) and the mean score of their colleague females (M = 12.06, SD = 10.240) on organic qualitative analysis. However, there was statistical significance between the mean score of male students from less-endowed school (M = 3.04, SD = 3.563, t(63.587) = 2.219, p = .030) and the mean score of their colleague females (M = 1.84, SD = 1.390) on organic qualitative analysis. The calculated effect size (*eta square* = .048) showed that only 4.8% of the variance in the scores of the students from the less-endowed school on organic qualitative analysis was shared by their gender.

Discussion

The students show of weakness on the development of experimental reasoning on organic qualitative analysis is a confirmation of reported weaknesses of students in the upper-secondary school by the WAEC chief examiner on chemistry on this concept (WAEC, 2001; 2003; 2004; 2005; 2012; 2014; 2015; 2016; 2017; 2018) and empirical research in Ghana on organic-related chemistry (Adu-Gyamfi et al., 2013; 2017; Hanson, 2017; Sarkodie & Adu-Gyamfi, 2015) and others outside Ghana (Childs & Sheehan, 2009; Graulich, 2015; Turner & Lindsay, 2003). Though all students demonstrate weak development of experimental reasoning on organic qualitative analysis, but it was found that gender and school-type have no interaction effect on students' reasoning on organic qualitative analysis is worthy of note. That is, there is no net effect of gender and school-type on students' development of experimental reasoning skills. Hence, any difference could not be the combined effect of gender and school-type. And that any observed difference could be the result of either gender of students or school-type. This finding could call for a look at the education strategy in Ghana in relation to upper-secondary schools to appreciating the shortfalls in the teaching and learning of organic qualitative analysis, thereafter students will be able to develop and demonstrate their experimental reasoning skills on organic qualitative analysis. As the government of the Republic of Ghana is revising the upper-secondary school curriculum in line with the 2019 education reforms, the developers of the curriculum should focus on selecting the most appropriate education strategies for upper-secondary school chemistry. In addition, this finding is in line with that of Worokwu (2018), where there is no interaction effect of gender and instructional approach on organic nomenclature in chemistry. The issues of gender biases in organic chemistry will continuously be discussed in the literature, but this research has showed that there is no main effect of gender on students' development of experimental reasoning on organic qualitative analysis in chemistry. And if there is any difference it would be seen in a school with less share of the facilities and equipment as well as human resource to facilitate instruction of organic qualitative analysis. Consequently, the difference in students' development of experimental reasoning on organic qualitative analysis is by the main effect of school-type, where students from less-endowed school demonstrate weak experimental reasoning skills compared to students from well-endowed and endowed schools. Teachers teaching chemistry in the upper-secondary schools categorised as less-endowed schools should make good use of STEM Centres (furnished with state-of-the-art materials) in their catchment communities to help facilitate students' learning of organic qualitative analysis.

Though there is statistical significance in relation to gender from the less-endowed school, favouring the male students the magnitude of the difference among male and female students is very small. Hence, , no interaction effect of gender, across school-type on organic qualitative analysis. This means that gender is not the main issue when it comes to the development of experimental reasoning of students on organic qualitative analysis, but that of the school-type. The organic qualitative analysis aspects of organic chemistry needing laboratory practical-based teaching and learning, where the student should be at the centre of the instruction to actively interact with materials ((Musengimana et al., 2022) gaining first-hand experience to aiding their experimental reasoning skills because during qualitative analysis in organic chemistry, students are provided with the opportunity to relate the theory to observable experiences, to be able to identify and confirm functional groups (Ministry of Education, 2010). And this opportunity may not be provided for male and female students in a less-endowed, hence their weak development of experimental skills on organic qualitative analysis compared to well-endowed and endowed schools. The government, through the Ministry of Education and Ghana Education Service together with non-governmental organisations should equip less-endowed schools to be at par with the endowed schools for effective instruction of organic qualitative analysis.

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Conclusions and Implications

The research gives insight into issues of gender, school-type, and development of experimental reasoning of students on organic chemistry. The findings are related to upper-secondary school science students who responded to knowledge of organic qualitative analysis test. In its entirety, this research has showed that there is no interaction effect of gender, across three school-types on students' development of experimental reasoning on organic qualitative analysis. This finding of no interaction effect of gender and another three-level factor on students' development of experimental reasoning on organic chemistry is not new. However, this study has added that there is no interaction effect of gender on students' performance, across three school types on organic qualitative analysis. Chemistry educators and researchers may research further to reveal what actually contribute to the difference between male and female students' development of experimental reasoning on organic chemistry. And if gender difference among students on organic chemistry is observed in less-endowed schools, then policy makers should equip all upper-secondary schools with the needed facilities and equipment following the educational standards and curriculum for instructing organic chemistry.

Declaration of Interest

The authors declare no competing interest.

References

Abd Halim, N. D., Ali, M. B., Yahaya, N., & Mohamad Said, M. N. H. (2013). Mental model in learning chemical bonding: A preliminary study. *Procedia – Social and Behavioural Sciences, 97*, 224-228. https://doi.org/10.1016/j.sbspro.2013.10.226

Adu-Gyamfi, K., Ampiah, J. G., & Appiah, J. Y. (2013). Senior high school chemistry students' performance in IUPAC nomenclature of organic compounds. *Cypriot Journal of Educational Sciences*, *8*(4), 472-483. http://archives.un-pub.eu/index.php/cjes/article/view/529/pdf_235

Adu-Gyamfi, K., Ampiah, J. G., & Appiah, J. Y. (2017). Students' difficulties in IUPAC naming of organic compounds. *Journal of Science and Mathematics Education, 6*(2), 77-101.

Aini, R. Q., Rachmatullah, A., & Ha, M. (2019). Indonesian primary school and middle school students' attitudes toward science: Focus on gender and academic level. *Journal of Baltic Science Education, 18*(5), 654-667. https://doi.org/10.33225/jbse/19.18.654

Anim-Eduful, B., & Adu-Gyamfi, K. (2021). Functional groups detection: Do chemistry teachers demonstrate conceptual difficulties in teaching? *Global Journal of Human Social Science-G Linguistics & Education, 21*(7), 47-60. https://doi.org/10.34257/GJHSSGVOL21IS7PG47

Askin, O. E., & Oz, E. (2020). Cross-national comparisons of students' science success based on gender variability: Evidence from TIMSS. *Journal of Baltic Science Education, 19*(2), 186-200. https://doi.org/10.33225/jbse/20.19.186

Bhattacharyya, G., & Bodner, G. M., (2005). "It gets me to the product": How students propose organic mechanisms. *Journal of Chemical Education, 82*(9), 1402-1407. https://doi.org/10.1021/ed082p1402

Childs, P. E., & Sheehan, M. (2009). What's difficult about chemistry? An Irish perspective. *Chemistry Education Research and Practice*, *10*, 204-218.

Ferguson, R., & Bodner, G. M. (2008). Making sense of the arrow-pushing formalism among chemistry majors enrolled in organic chemistry. *Chemistry Education Research and Practice, 9*, 102-113. http://dx.doi.org/10.1039/b806225k

Gafoor, K. A., & Shilna, V. (2014). *Gender fair efficacy of concept mapping tests in identifying students' difficulties in high school organic chemistry.* A paper presented in the Collaborative International Conference on Learning Environment for Excellence in Education (January 24th & 25th), SRM University Tamil Nadu India. https://files.eric.ed.gov/fulltext/ED545404.pdf

Graulich, N. (2015). The tip of the iceberg in organic chemistry classes: How do students deal with the invisible? *Chemistry Education Research and Practice*, *16*(1), 9-21. https://doi.org/10.1039/C4RP00165F

Hanson, R. (2017). Enhancing students' performance in organic chemistry through context-based learning and micro activities – A case study. *European Journal of Research and Reflection in Educational Sciences, 5*(6), 7-20.

Hassan, A. K., Hill, R. A., & Reid, N. (2004). Ideas underpinning success in an introductory course in organic chemistry. *The Royal Society of Chemistry: University Chemistry Education, 8***,** 40-51. https://www.rsc.org/images/p2_reid_tcm18-31146.pdf

Horowitz, G., Rabin, L. A., & Brodale, D. L. (2013). Improving student performance in organic chemistry: Help seeking behaviors and prior chemistry aptitude. *Journal of the Scholarship of Teaching and Learning, 13*(3), 120-133. https://files.eric.ed.gov/fulltext/EJ1017124.pdf

Kozma, R., Chin, E., Russell, J., & Marx, N. (2000). The roles of representations and tools in the chemistry laboratory and their implications for chemistry learning. *The Journal of the Learning Sciences, 9*(2), 105-143. https://doi.org/10.1207/s15327809jls0902_1

Lakhvich, T. (2010). Beautility of chemistry visualization: Whether useful can be aesthetic. *Problems of Education in the 21st Century*, *19*, 46-54. http://oaji.net/articles/2014/457-1399917218.pdf

https://doi.org/10.33225/jbse/22.21.351

Lakhvich, T. (2019). One chemistry-two meanings. Science and education: Comparative analysis of the roles, presentation, and applications. In. V. Lamanauskas (Ed.), *Science and technology education: Current challenges and possible solutions. Proceedings of the 3rd International Baltic Symposium on Science and Technology Education (BalticSTE2019)* (pp. 104-113). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2019.104

Lakhvich, T. (2021). Public science education: Some more roles and contributions. *Journal of Baltic Science Education*, *20*(6), 864-867. https://doi.org/10.33225/jbse/21.20.864

Mahajan, D. S., & Singh, G. S. (2005). University students' performance in organic chemistry at undergraduate level: Perception of instructors from universities in the SADC region. *Education in Chemistry, 14*(1), 25-36. http://khimiya.org/volume14/efficiency.pdf

Marais, P., & Jordaan, F. (2000). Are we taking symbolic language for granted? *Journal of Chemical Education, 77*(10), 1355-1357. https://pubs.acs.org/doi/abs/10.1021/ed077p1355

Ministry of Education. (2010). *Teaching syllabus for chemistry: Senior high school 1- 3*. Author.

Musengimana, J., Kampire, E., & Ntawiha, P. (2022). Effect of task-based learning on students' understanding of chemical reactions among selected Rwandan lower secondary school students. *Journal of Baltic Science Education, 21*(1), 140-155. https://doi.org/10.33225/jbse/22.21.140

O'Dwyer, A., & Childs, P. E. (2017). Who says organic chemistry is difficult? Exploring perspectives and perceptions. *EURASIA Journal of Mathematics Science and Technology Education,13*(2), 3599-3620. https://doi.org/10.12973/eurasia.2017.00748a

Omwirhiren, E. M., & Ubanwa, (2016). An analysis of misconceptions in organic chemistry among selected senior secondary school students in Zaria Local Government Area of Kaduna State, Nigeria. *International Journal of Education and Research, 4*(7), 247-266. https://www.ijern.com/journal/2016/July-2016/20.pdf

Palincsar, A. S. (1998). Social constructivist perspectives on teaching and learning. *Annual Review of Psychology*, *49*(1), 345-375. https://doi.org/10.1146/annurev.psych.49.1.345

Rojas-Oviedo, I., Melendez-Ocampo, A., & Herrera-Garcia, N. (2018). Is chemistry as hard for women as for men? A case study in the bachelor of biological pharmaceutical chemistry at the autonomous Metropolitan University Xochimilco Campus in Mexico, city. *Science Education International, 29*(4), 196-200. https://files.eric.ed.gov/fulltext/EJ1205426.pdf

Sarkodie, P. A., & Adu-Gyamfi, K. (2015). Improving upon students' performance in naming and writing structural formulae of hydrocarbons using the ball-and-stick models. *Chemistry: Bulgarian Journal of Science Education, 24*(2), 203-219. http://khimiya.org/show_issue.php?y=2015&vol=24&issue=2&i_id=54

Sibomana, A., Karegeya, C., & Sentongo, J. (2021). Students' conceptual understanding of organic chemistry and classroom implications in the Rwandan perspectives: A literature review. *African Journal of Education Studies in Mathematics and Sciences, 16*(2), 13-32. file:///C:/Users/HP/Downloads/204184-Article%20Text-510232-1-10-20210224%20(1).pdf

Sirhan, G. (2007). Learning difficulties in chemistry: An overview. *Journal of Turkish Sciences Education, 4*(2), 2-20. https://www.tused.org/index.php/tused/article/view/664/569

Stieff, M. (2007). Mental rotation and diagrammatic reasoning in science. *Learning and Instruction*, *17*, 219-234. https:// doi:10.1016/j.learninstruc.2007.01.012

Tang, A. Y. C., Zain, M, S., & Abdullah, R. (2010). Development and evaluation of a chemistry educational software for learning organic reactions using qualitative reasoning. *International Journal of Education and Information Technologies*, *4*(3), 129-138.

Turner, R. C., & Lindsay, H. A, (2003). Gender differences in cognitive and noncognitive factors related to achievement in organic chemistry. *Journal of Chemical Education, 80*(5), 563-568. https://doi.org/10.1021/ed080p563

West African Examinations Council. [WAEC]. (2001). *Chief examiner's report on West African senior school certificate examination. May/June chemistry practical.* Wisdom Press.

West African Examinations Council. [WAEC]. (2003). *Chief examiner's report on West African senior school certificate examination. May/June chemistry practical.* Wisdom Press.

West African Examinations Council. [WAEC]. (2004). *Chief examiner's report on West African senior school certificate examination. May/June chemistry practical.* Wisdom Press.

West African Examinations Council. [WAEC]. (2005). *Chief examiner's report on West African senior school certificate examination. May/June chemistry practical.* Wisdom Press.

West African Examinations Council. [WAEC]. (2012). *Chief examiner's report on West African senior school certificate examination. May/June chemistry practical.* Wisdom Press.

West African Examinations Council. [WAEC]. (2014). *Chief examiner's report on West African senior school certificate examination. May/June chemistry practical.* Wisdom Press.

West African Examinations Council. [WAEC]. (2015). *Chief examiner's report on West African senior school certificate examination. May/June chemistry practical.* Wisdom Press.

West African Examinations Council. [WAEC]. (2016). *Chief examiner's report on West African senior school certificate examination. May/June chemistry practical.* Wisdom Press.

West African Examinations Council. [WAEC]. (2017). *Chief examiner's report on West African senior school certificate examination. May/June chemistry practical.* Wisdom Press.

West African Examinations Council. [WAEC]. (2018). *Chief examiner's report on West African senior school certificate examination. May/June chemistry practical.* Wisdom Press.

Worokwu, C. (2018). Gender and teaching strategies on chemistry students' achievement in organic compounds nomenclature. *Elixir Educational Technology, 118*, 50569-50574. https://www.elixirpublishers.com/articles/1525508357_ELIXIR2018046176.pdf

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Appendix A

Knowledge of Organic Qualitative Analysis Test

SECTION A

Biodata:

1. School type: Single sex [ ] Mixed School [ ]
2. Category of School: Class A school [ ] Class B school [ ] Class C school [ ]
3. Sex: Male [ ] Female [ ]
4. Age: ………………years

SECTION B

Kindly select one among the alternatives and give reason for the one selected in the spaces provided.

5. Alkenes and alkynes are organic compounds that usually undergo ……..…… reactions.
   A. addition
   B. condensation
   C. elimination
   D. substitution

Provide the reason for your selected option:
………………………………………………..……………..………………………………….

6. Choose the compound that is miscible with tetrachloromethane ……………………………………………………………………………………………………
   A. $CH_3CH_2CH_3$
   B. CH_3CH_2OH
   C. CH_3OH
   D. HCl

Provide the reason for your selected option:
…………………………………………………………..……………….…………………….

7. Which of the following compounds is sweet scented?
   A. Ethanoic acid
   B. Ethylmethanoate
   C. Methanamide
   D. Sodium methanoate

Provide the reason for your selected option:
…………………………………………………………..……………….…………………….

8. A complete hydrogenation of benzene gives ……………………………………………….
   A. cyclohexane
   B. cyclohexene
   C. hexane
   D. hexene

Provide the reason for your selected option:
………………..…………………………………………..………………..…………………….

9. An alkanol which undergoes complete oxidation reaction to produce an alkanone is likely to be a ………………………………………
   A. primary alkanol
   B. quaternary alkanol
   C. secondary alkanol
   D. tertiary alkanol

Provide the reason for your selected option:
…………………………………………………………..……………….…………………….

10. An organic compound which decolourises both Br_2/CCl_4 and acidified $KMnO_4$ is ……………………………………………………………………………………………………
   A. C_2H_4
   B. C_2H_6
   C. C_3H_8
   D. C_4H_{10}

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Provide the reason for your selected option:
……………………………………………………………………………………………………

11. Which of the following functional groups will liberate hydrogen gas when reacts with sodium metal?
 A. $-CONH_2$
 B. $-CHO$
 C. $-CO-$
 D. $-COOH$

Provide the reason for your selected option:
……………………………………………………………………………………………………

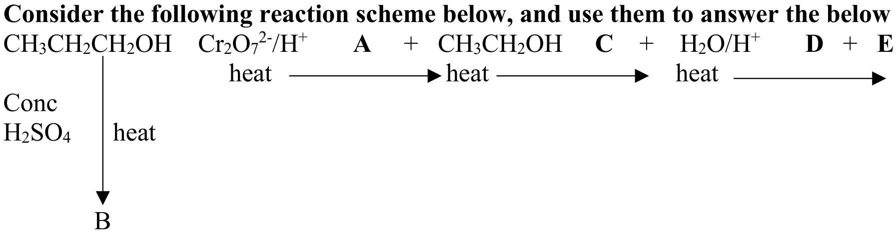
12. The compound that will give brown colour solution with alkaline potassium tetraoxomanganate(VII) is ……………………………………………………………………..
 A. $CH_3CH_2CH_3$
 B. CH_3COCH_3
 C. CH_3CH_2CHO
 D. $CH_3CH = CH_2$

Provide the reason for your selected option:
……………………………………………………………………………………………………

13. The compound to be produced when propanol is completely oxidised in the presence of oxidising agent such as potassium heptaoxodichromate(IV) and heated is …………………………
 A. Propanol
 B. Propanone
 C. propanoic acid
 D. propylpropanoate

Provide the reason for your selected option:
……………………………………………………………………………………………………

Consider the following reaction scheme below, and use them to answer the below questions 14(α) and (β)



14. (α) Write the chemical formula of each of the compounds A, B, C, D, and E.
 A. ……………………………………………………………………………………………
 B. ……………………………………………………………………………………………
 C. ……………………………………………………………………………………………
 D. ……………………………………………………………………………………………

Provide the reason for your answer:
……………………………………………………………………………………………………

(β) Identify the functional groups present in compounds A, B, C, D, and E.
 A. ……………………………………………………………………………………………
 B. ……………………………………………………………………………………………
 C. ……………………………………………………………………………………………
 D. ……………………………………………………………………………………………

Provide the reason for your answer:
……………………………………………………………………………………………………

15. Identify the type of chemical reaction involved in the conversion of $CH_3CH_2CH_2OH$ to:
(α) A
……………………………………………………………………………………………………
(β) B
……………………………………………………………………………………………………
(γ) C
……………………………………………………………………………………………………

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Provide the reason for your answer:

……………………………………………………………………………………………………

Consider the following chemical substances (A to D) and use them to answer questions 16 to 20.

A. $CH_3C{\equiv}CCH_3$
B. CH_3CH_2COOH
C. $CH_3CH_2CH(CH_3)OH$
D. CH_3CONH_2

16. Write your observation when the compound C reacts with acidified potassium heptaoxodichromate(VI) solution.

α. Identify the functional group responsible for this.

……………………………………………………………………………………………..

β. **Provide the reason for your answer**:

………………………………………………………………...

17. Write your observation when the compound **D** is warmed with dilute sodium hydroxide solution.

α. Identify the functional group responsible for this.

……………………………………………………………………………………………..

β. **Provide the reason for your answer**:

………………………………………………………………...

18. Write your observation when the compound **A** reacts with bromine solution.

α. Identify the functional group responsible for this.

……………………………………………………………………………………………..

β. **Provide the reason for your answer**:

………………………………………………………………...

19. Write the observation when compound **C** is treated with sodium hydrogen trioxocarbonate(IV) [$NaHCO_3$].

α. Identify the functional group responsible for this.

……………………………………………………………………………………………..

β. **Provide the reason for your answer**:

………………………………………………………………...

20. Write the observation when compound **B** is treated with hot solution of I_2 in NaOH solution.

α. Identify the functional group responsible for this.

……………………………………………………………………………………………..

β. **Provide the reason for your answer**:

………………………………………………………………...

21. State the reagent that can be used to distinguish between the following pairs of organic compounds in organic qualitative analysis: C_6H_6 and $CH_2{=}CH_2$

α. Reagent:

……………………………………………………………………………………………….……

β. **Provide the reason for your answer**:

………………………………………………………………...

22. State the reagent that can be used to distinguish between the following pairs of organic compounds in organic qualitative analysis: CH_3COCH_3 and CH_3CH_2CHO

α. Reagent:

……………………………………………………………………………………………..

β. **Provide the reason for your answer**:

………………………………………………………………...

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