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Effectiveness of Blended Teaching on Academic Achievement in Organic Chemistry: A case of Grade-12 Learners from an Underprivileged South African School

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Abstract. In South Africa, particularly in underprivileged high schools, the unavailability of resources means that the use of traditional face-to-face teaching methods that promote passive learning is prevalent. Despite a few of these schools utilising blended teaching methods that can potentially promote active learning, research that evaluates the effectiveness of these methods in promoting academic achievement is limited. Diagnostic reports on National Senior Certificate examinations of South Africa show that Grade-12 learners perform poorly in organic chemistry. Therefore, this study which was conducted during the COVID-19 pandemic, aimed to determine how effective blended teaching methods are in fostering academic achievement compared to traditional face-to-face teaching, focusing on Grade-12 organic chemistry. In this quantitative study, using Vygotsky's socio-cultural and Maslow's hierarchy of needs theories as the theoretical framework, two hundred learners were randomly placed into two equal groups. Group-1 (experimental) was taught all organic chemistry concepts stipulated in the South African national curriculum using a blended teaching method

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while Group-2 (control) was taught the same concepts using traditional face-to-face teaching method. A standardised test (KOOCT) was administered to both groups followed by descriptive and inferential statistical analyses (independent *t*-tests). Findings showed that Group-1 scores (M = 41.74, SD = 19.533) were higher than those for Group-2 (M = 27.18, SD = 13.039), t (198) = 6.234, p = .00 < .05 showing that using blended teaching approach was more effective in promoting academic achievement than traditional face-to-face teaching only. The effect size (Cohen's d=.882) ensures practical significance of the study.

Keywords. blended teaching; traditional face-to-face; academic achievement; organic chemistry; underprivileged school context

1. Introduction

Organic chemistry is a crucial discipline which forms part of most science courses at tertiary education (Abukari et al., 2023) which makes establishing a firm foundation of the discipline at Grade-12 level important. However, this is a daunting task given the numerous organic chemistry challenges that learners encounter, making it imperative that research focusing on organic chemistry be conducted. Most of these challenges are articulated in diagnostic reports of the National Senior Certificate (NSC) examinations that have been highlighting that South African learners (most of whom attend underprivileged schools) struggle with where and when to put hyphens in organic nomenclature, analysing graphs on physical properties of organic compounds and the conditions for organic reactions (Department of Basic Education, 2023). An analysis of these challenges points towards learners' limited proficiency in English which is also the language of instruction and learning in most underprivileged schools of South Africa. For example, some of the learners use incorrect words in definitions such as 'bigger or larger' instead of 'longer' and use terms 'bonds' and 'intermolecular forces' interchangeably (Department of Basic Education, 2022, 2023). Interestingly, the Department of Basic Education has been encouraging teachers to provide Grade-12 learners with more opportunities to practise organic chemistry concepts since 2020. Furthermore, research shows that some of the learners' misconceptions could be traced back to the teaching methods employed (Grove & Bretz, 2012; Salame et al., 2019).

This study sought to determine the efficacy of blended teaching in promoting academic achievement focusing on organic chemistry at one of the underprivileged schools located in the Mpumalanga region of South Africa. This was done by comparing the academic achievement of two groups taught using two different teaching methods: the existing traditional face-to-face teaching method versus blended teaching. In this article, the terms blended teaching and blended learning are used synonymously, referring to what learners do in response to the actions and directives of the teacher (Naaj et al., 2012).

Blended teaching has many potential merits, which include developing ownership of learning (O'Flaherty & Phillips, 2015), flexibility (Bonk & Graham, 2009), promoting enthusiasm among learners (Fisher et al., 2018), and improving self-regulation, self-directedness, and academic achievement (Bond et al., 2020; Nkanyani et al., 2024). However, most underprivileged schools (Quintile-levels 1,

2 and 3 schools) in South Africa still lag in the implementation of blended teaching owing to limited resources, teachers' lack of skills to effectively utilise blended teaching, lack of access to internet services, poor Wi-Fi connectivity, and lack of suitable devices (Fisher et al., 2017; Nkanyani et al., 2024; Ramulumo & Mohapi, 2023). South African public schools are placed into a five-rank order (Quintile system) based on how privileged or disadvantaged they are (Quintile 1–poorest to Quintile 5-least poor).

Most of the abovementioned schools still employ traditional face-to-face teaching methods in which the learners are passively involved in their learning through listening to the teacher teaching (De Beer, 2016; Lehesvuori et al., 2018). Despite a few of these schools utilising blended teaching methods that can potentially promote active learning, studies that specifically determine the efficacy of these teaching methods in fostering academic achievement are scarce (Fisher et al., 2017). Additionally, Fisher et al. (2017) assert that few South African schools have been using blended teaching in mathematics and natural sciences. This shows that most learners (particularly those in Grade-12) studying physical sciences and the sub-disciplines that make it up such as organic chemistry have not been taught using the limited nature of blended teaching methods.

Garrison and Vaughan (2008) defined blended learning as the 'thoughtful' integration of online learning and traditional face-to-face teaching methods in a way that is designed to meet educational goals while catering for learner needs. Other researchers support this definition (see for example Halverson and Graham, 2019; Staker & Horn, 2012; Seery & O'Connor, 2015). This article adopts this definition mainly because it is all-encompassing of what blended teaching entails. In this article, online teaching is understood as an instructional approach that is formally mediated by the teacher and requires the use of web-based technology as well as internet services (Staker & Horn, 2012; Williams et al., 2008). While making a case for blended teaching methods such as flipped classroom, Flynn (2015) indicated that the use of online homework as well as clickers and demonstrations (to make traditional face-to-face more active) to teach university level organic chemistry was not effective on academic achievement as learners were left to attempt more difficult work alone without the help from peers and the teacher. Based on this, it could be argued that combining online work and in-class work thoughtfully by adressing learner needs for interactions could potentially lead to academic achievement.

According to York et al. (2015), academic achievement provides an indication of how much the learners have learnt using grades obtained from standardised assessment tasks. Fisher et al. (2018) support this definition. In this study, a standardised test was used to assess learners' knowledge of organic chemistry. In addition, Back et al. (2016), emphasise the need for improved academic achievement. It is important to highlight that organic chemistry has been perceived as a difficult subject that is associated with poor achievement (Grove & Bretz, 2012; Salame et al., 2019;Tekane et al., 2020).

Given that, according to the annual teaching plan compiled by the South African Department of Basic Education, organic chemistry was scheduled to be taught during the last five weeks of term 1, this study coinicided with the third (dealiest) wave of the COVID-19 pandemic. This made the teaching of the already difficult organic chemistry concepts more dire because of unplanned school closures to decontaminate the classrooms as a way of containing the spread of the disease. This situation was further worsened when the learners and teachers constantly fell sick and the already poor academic achievement of learners in organic chemistry, particularly by learners from underprivileged schools. This made it imperative that blended teaching be implemented to Grade-12 learners and subsequently evaluated considering its limited use in high schools of South Africa.

Moreover, Fisher et al. (2018) made it clear that studies focusing on blended teaching methods or models such as flipped classroom have been mostly conducted at university level. Given that Fazal and Bryant (2019) emphasised that one type of blended teaching may not be equally responsive in all educational settings, it became necessary to conduct a study focusing on organic chemistry in the high school context of South Africa. Furthermore, most of the few privileged South African schools that utilise blended have not determined its effectiveness (Fisher et al., 2017). Given that effective blending is dependent on contextual factors (Dziuban et al., 2018; Fazal & Bryant, 2019), blended teaching adoption and its subsequent evaluation in terms of its efficacy in promoting academic achievement among Grade-12 learners studying organic chemistry at underprivileged high schools of South Africa is under researched.

A study by Nkanyani et al. (2024) aimed at determining how rural blended teaching was progressing and which focused on Grade-11 physical sciences showed that the teachers could not use flipped classroom effectively. Consequently, it could not specifically determine the effectiveness of blended teaching on academic achievement despite being conducted in South Africa's rural schools, most of which can be said to be underprivileged. However, it is important to emphasise that, in South Africa, organic chemistry is only covered in Grade-12 which makes it clear that, despite focusing on Grade-11 physical sciences, the study in question did not focus on organic chemistry. This made it imperative that the current study should specifically evaluate the effectiveness of blended teaching (in underprivileged South African high schools) on academic achievement focusing on organic chemistry. Similarly, a study by Ramulumo and Mohapi (2023) which was also exploratory in nature focused on teachers' perspectives on the potential merits of blended teaching of science and mathematics without specifically determining the efficacy of the teaching method on academic achievement.

Additionally, according to Bond et al. (2020), there is dearth of research on blended learning that focuses on Africa, particularly that which focuses on organic chemistry. This assertion is supported by Brenya (2023) who conducted research that focused on challenges associated with the utilisation of blended teaching methods in a higher education context of developing countries and

which was conducted in Ghana. Research by Abukari et al. (2023) which was also conducted in Ghana was more concerned with cooperative learning in organic chemistry. Despite the few examples from South Africa and other parts of Africa which have been cited, it can be concluded that research on blended teaching in the African context is still limited. Therefore, this study becomes important. The research problem is stated below.

1.1 Problem statement

Despite being difficult, organic chemistry is an important and compulsory topic in the chemistry component of Grade-12 physical sciences curriculum (Department of Basic Education, 2011). There is a need to ensure learners develop a deep conceptual understanding of the topic (Grove & Bretz, 2012; Richards-Babb et al., 2015). Nonetheless, in South Africa, learners persistently achieve poorly in organic chemistry which accounts for a large percentage of marks in the chemistry paper (Department of Basic Education, 2019, 2020, 2021, 2022, 2023). This poor achievement has been linked to the persistent use of traditional face-to-face teaching (De Beer, 2016; Lehesvuori et al., 2018), particularly in underprivileged schools. Given that the vast majority of South African learners attend these underprivileged schools, with the identified problem exarcerbated by the COVID-19 pandemic, it became important that this study be conducted. Furthermore, a gap in research that specifically evaluates the effectiveness of blended teaching methods on academic achievement at high school level and in the context of South African underprivileged schools has been identified. This study has the potential to contribute towards closing this gap and informing policy on the type of blended teaching model combination that should be either used or avoided. This required that the following research question be addressed.

1.2 Research question

Compared to traditional face-to-face teaching, how effective is the use of blended teaching approach in fostering academic achievement in organic chemistry at Grade-12 in a school in South Africa?

The hypotheses that were tested are as follows:

H_0: Compared to learners taught using traditional face-to-face teaching methods, Grade-12 physical sciences learners taught using the blended teaching approach will not score significantly higher in a post-instruction test on achievement in organic chemistry.

H_1: Compared to learners taught using traditional face-to-face teaching methods, Grade-12 physical sciences learners will score significantly higher in a post-instruction test on achievement of organic chemistry.

To develop a clearer understanding of the stated problem and map the way to address the formulated research question, a review of literature was undertaken.

2. Literature review

2.1 The blended learning concept

According to Dziuban et al. (2018), attempts to define the 'blended learning' have been challenging and often result in an array of definitions, thereby making it difficult to determine with certainty what the term entails. This is further complicated by blended learning being cited as context dependent (Dziuban et al., 2018; Fazal & Bryant, 2019). This, makes the evaluation of literature on blended

learning a difficult task. Dziuban et al. (2018) defined blended learning simply by stating that it is a combination of online teaching and face-to-face teaching. Notably, even though this definition is supported by other researchers (see for example Bonk & Graham, 2012; Kuo et al., 2014), it raises questions as to how this combination of the two identified components ought to be achieved.

Considering the above, Armellini and Rodriguez (2021) underscore the need for online teaching and traditional face-to-face teaching components to be linked in such a way that they operate as a single system. The emphasis is on ensuring that the online component informs the traditional face-to-face teaching, and vice versa (Seery & O'Connor, 2015). Furthermore, Vaughan and Garrison (2008) define blended learning as a 'thoughtful' combination of the traditional face-to-face and the online teaching components. Halverson et al. (2019) support this definition. Whichever way the word thoughtful is interpreted, emphasis is placed on the notion that there ought to be reasons that inform how the blend is configured. For example, the blend configuration ought to meet learner needs (Bonk & Graham, 2009). This study adopts the definition proposed by Garrison and Vaughan (2008) which makes it imperative that a situation or needs analysis be conducted first. Such an analysis would inform the blend configuration including ensuring that learner needs are met. It could also be argued that this definition has implications on the choice of blended learning model to be utilised.

2.2 Blended learning models

According to Tomas et al. (2019), the term blended learning model refers to the approach used in configuring the blend. Given that the approach adopted is dependent on several contextual factors, many blended learning models are identifiable in literature. Most researchers identify four models (Picciano et al., 2014; Staker & Horn, 2012). These are 'rotation model' (inclusive of 'laboratory rotation', 'station rotation', 'flipped classroom/flipped learning' and 'individual rotation'), 'self-blend' model, 'enriched-virtual model' and 'flex model' (Dai et al., 2021; Picciano et al., 2014; Staker & Horn, 2012). Contrary to this, Tekane et al. (2020), suggest a four-model list comprising replacement, supplemental, emporium and buffet models.

On the other hand, Armellini and Rodriguez (2021) put forward the notion of active blended learning (ABL) as another blended learning model that emphasises ensuring that learners are actively involved in their learning through incorporating gamification, cooperative learning, video watching followed by quizzes, and flipped learning. In addition, according to Armellini and Rodriguez (2021), the key focus of ABL is construction of knowledge, reflecting on the subject matter, developing critical thinking, learning that is self-directed, and the achievement of learning outcomes. Interestingly, they appear to imply that flipped learning is a component of ABL which means that it cannot be identified as a blended learning model.

Nevertheless, this study recognises flipped classroom/learning as a blended learning model which seeks to 'invert' (O'Flaherty & Phillips, 2015) the traditional class in such a way that what is usually taught during the lesson moves to the online platform and is done individually. According to Fisher et al. (2018), online

work focuses on lower-level objectives that learners are required to achieve before attending face-to-face lessons, which motivates the learners to attempt the pre-class work. Higher order thinking questions are then attempted during the face-to-face lessons with the help of other learners and the teacher, as indicated in the definition of flipped learning provided by The Flipped Learning Network (FLN) (2014)

According to the definition, the envisaged role of the teacher is that of a facilitator of learning. Flipped learning is presented as an approach to pedagogy that seeks to promote learner-to-learner interactions and with content. Furthermore, moving some of the content to the online learning platform reduces the cognitive load (Seery & O'Connor, 2015) by ensuring that learners are not exposed to an excessive amount of information within a short space of time, as is likely to happen when traditional face-to-face is used alone. According to Seery and O'Connor (2015), cognitive load is related to mental capacity to handle and process new information in the working memory. When learners are bombarded with a lot of information at once with limited time to process it, the efficiency of the working memory may be compromised resulting in ineffective learning. This is likely the case during the use of traditional face-to-face teaching methods alone. However, when effective flipping of the classroom is achieved, learners are exposed to the new knowledge online as part of the pre-class work, which affords them time to process the information before the face-to-face component where more in-depth concepts are taught (Seery & O'Connor, 2015). Furthermore, O'Flaherty and Phillips (2015) add that teachers are better positioned to provide more effective instruction when they become aware of the learners' misconceptions before the face-to-face component commences. Based on this, flipped learning has the potential of promoting academic achievement even in organic chemistry which is perceived as a difficult topic as noted by Salame et al. (2019).

Based on the discussions undertaken above, it is evident that researchers do not agree on how to categorise blended learning models, nor do they agree on how many there are and the actual types. There appear to be overlaps on what some of the blended learning models entail with flipped classroom being presented as a component of a blended learning model by some researchers. Nevertheless, this study recognises flipped learning as a blended learning model simply because many researchers agree with this (see for example Fisher et al., 2018; Seery & O'Connor, 2015). However, there appear to be merits associated with combining ABL and flipped learning. For this reason, the present study used a fusion of ABL and flipped learning with a view to addressing some of the problems associated with organic chemistry.

2.3 Organic chemistry challenges

Researchers have identified organic chemistry as a discipline that is associated with problems such as being perceived as difficult, associated with poor performance by learners in addition to high dropout rate as well as concepts that most learners struggle to comprehend (Grove & Bretz, 2012; Mullins, 2008; Richards-Babb et al., 2015; Salame et al., 2019). Based on this, an in-depth

understanding of organic chemistry challenges cannot be overemphasised as this would pave the way to the design of a more responsive blend.

According to Salame et al. (2019), the nature of organic chemistry is characterised by abstract concepts in addition to them being disjointed, leading to learners struggling to understand the concepts, and teacher needs such as the ability track learners' competencies in real time. Organic chemistry research shows that the discipline is characterised by a great deal of new terminology which has the potential of impeding understanding (Mullins, 2008; Salame et al., 2019). This problem is, as Salame et al. (2019) assert, further exacerbated by the generally limited language proficiency.

Related to the nature of organic chemistry is the idea that it requires learners to adopt a three-dimensional approach to thinking in which connections are forged among the 'symbolic', 'microscopic', and 'macroscopic' dimensions, as suggested by Tekane et al. (2020). Salame et al. (2019) agree with this evaluation of organic chemistry and add that teachers do not emphasise the microscopic and macroscopic dimensions resulting in a lack of conceptual understanding.

Furthermore, learners come to class with preconceived information that could be riddled with misconceptions (Salame et al., 2019; Vygotsky & Cole, 1978). In this respect, Vygotsky's socio-cultural theory appears to be confirmed. Moreover, it has been noted previously that blended teaching has the potential to address policy-related problems that have led to time constraints, particularly as far as in-class time is concerned. The challenges alluded to make a case for the use of blended teaching.

According to Tekane et al. (2020), organic chemistry requires ways of solving problems which rely on higher order thinking instead of following step-by-step procedures that depend on memorisation. However, Brown et al. (2016), bemoan that teachers were encouraging learners to memorise organic chemistry reactions and engage in rote teaching. Salame et al. (2019) are of the idea that memorisation is promoted by cognitive overload which occurs when the working memory space is exhausted. Such pedagogical practices that force learners to memorise result in poor grades and low confidence levels (Brown et al., 2016). Poor teacher development appears to be a play here. However, some researchers are not entirely against memorisation of concepts even though they underscore the need for conceptual understanding (see for example Mullins, 2008; Salame et al., 2019). The importance of memorisation is acknowledged but there is a need to go further and promote conceptual understanding. Seery (2015) adds that cognitive overload is precipitated by time constraints, a problem that could be mitigated using blended teaching.

Discussions undertaken here show that research does not agree on the best approaches to addressing organic chemistry challenges. However, it could be concluded that developing a conceptual understanding appears to offer a glimmer of hope. Additionally, Salame et al. (2019) suggest that teaching methods that promote active learning and based on constructivist theories ought to be

implemented. This argues for the utilisation of ABL and flipped classroom to enhance active learning. It appears that organic chemistry challenges are mostly caused by ineffective teaching methods, hence the need to determine the effectiveness of blended teaching on academic achievement.

2.4 Blended teaching versus academic achievement

Several studies found that blended teaching has a positive influence on academic achievement (see for example (Fisher et al., 2018; Flynn, 2015; Halverson & Graham, 2019; O'Flaherty & Phillips, 2015; Seery & O'Connor, 2015; Yaghmour, 2016). Conversely, in some studies the efficacy of blended teaching on academic achievement could not be determined (see for example Fazal & Bryant, 2019; Williams et al., 2008).

Research by Flynn (2015) found that blended teaching was effective at promoting academic achievement in organic chemistry at university level; however, the difference in study levels with the current study raises questions as to whether the same results can be replicated. Similarly, Yaghmour (2016) determined the effectiveness of blended teaching focusing on third grade learners studying mathematics. A comparison of the academic achievement of the two classes involved was used to draw conclusions on the effectiveness of blended teaching in mathematics. The rigorous validation processes, conducted in addition to the reliability test (Cronbach's alpha test), ensured the trustworthiness of the results. Most importantly, Yaghmour (2016) showed that blended teaching was more effective than traditional face-to-face teaching.

Williams et al. (2008) also conducted a study to determine whether blended teaching was efficacious in fostering academic achievement in inorganic chemistry at university level. Unlike Yaghmour (2016), Williams et al. (2008) used study packs in addition to online learning work and the learners were not required to attend in-class lessons daily. However, the research findings were deemed inconclusive as they could not be subjected to any kind of statistical analysis. One of the teachers also retired and had to be replaced, which posed a threat to internal validity.

An analysis of the two studies above shows that blended teaching was conducted differently. The contextual factors were also vastly different. The results somewhat demonstrate that blended teaching could be effective in fostering academic achievement since improvement in the group taught using blended teaching showed signs of improvement. However, Dziuban et al. (2018) sounded a warning pertaining to inequivalent blends being utilised. Fazal and Bryant (2019) agree with this assessment.

Fazal and Bryant (2019) conducted their research in a high school context. In one test, learners taught using blended teaching scored higher than those that were taught using traditional face-to-face approach while the opposite was true in the second test. Given that both Yaghmour (2016) and Fazal and Bryant (2019) focused on the same subject, mathematics, even though the research sites were different, this emphasised the need to conduct this study.

Based on the above, it becomes clear that research on the effectiveness of blended teaching on academic achievement is inconclusive, which shows that more research is still required. Furthermore, it could be argued that, among other things, contextual factors play a significant role in determining the effectiveness of blended teaching in any discipline. Considering the findings by Yaghmour (2016) compared to those obtained by Fazal and Bryant (2019), it became clear that focusing on the same subject at different study levels (in terms of primary, high school or university) may not necessarily guarantee comparable results.

Given that most research on the effectiveness of blended learning was conducted at university level, there is a need to conduct more research that focuses on primary and high school levels. Additionally, other contextual factors such as the socioeconomic status of some schools may lead to different results. More research which seeks to determine the effectiveness of blended teaching focusing on underprivileged schools is still needed. In South Africa, and indeed many developing nations, such research could be impactful given that such schools cater for the largest number of learners. Given the discussions undertaken above, this study was supported by Vygotsky's socio-cultural theories and Maslow's hierarchy of needs.

2.5 Theoretical framework

Even though Vygotsky's socio-cultural theory focused on children's use of private speeches to direct their thought processes when performing tasks which require the help of adults at times (Vygotsky & Cole, 1978), implications to educational practice can be drawn. In this study, the focus was on creating opportunities for learners to practise, engage in meaningful social interactions and promote shared creation of knowledge while improving academic achievement in organic chemistry, which made the use of Vygotsky's socio-cultural theory a suitable anchor for this study. Furthermore, Maslow's hierarchy of needs complemented Vygotsky's theory by ensuring that learners were motivated. Emphasis can be placed on the need for learner-to-learner and teacher-to-learner interactions to occur, particularly when performing learning tasks. Blended teaching has the potential to create more opportunities for effective social interactions to occur. These opportunities were provided using discussion boards, the 'chat' tool in addition to playing the flashcard game in pairs and, after completing the pre-class work, learners went to the face-to-face lessons with questions and they further engaged in debates and discussions. Closely linked to the social interactions, is Vygotsky's concept of 'Zone of proximal development or 'ZPD'.

The ZPD was conceptualised as representing a region between what the learner can do without any help from a more competent peer or from the teacher (Vygotsky & Cole, 1978). This theory can be used to explain that learners in the same class may have different capabilities, which requires that teaching such as blended teaching methods, which can cater for individual learner needs, are more likely to promote academic achievement. Additionally, by using internal speeches to direct problem solving, learners can perform better in more complicated concepts of organic chemistry. Furthermore, learners, through imitating the teacher or a more competent learner, can proceed beyond their own 'zones of proximal development' thereby promoting academic achievement.

Given the emphasis placed on social interactions, it becomes important to apply Maslow's hierarchy of needs which progress from basic ones to higher level ones (Maslow, 1943). Additionally, basic needs (stage 1) such as being able to access online platforms also play a significant role in ensuring that learners utilise a blended learning system leading to academic achievement. When the stage 1 needs are met stage 2 needs become the source of motivation (Maslow, 1943). This entails creating a 'safe zone' in the classroom where learners are free to contribute to discussions and to ask questions. When applied to blended teaching, rules of engagement need to be established to guarantee learner safety during both face-to-face and online interactions. Equally important is the need to belong (stage 3), which relates to feelings of being loved or accepted by peers (Maslow, 1943). This is an important ingredient in building a sense of community and promoting willingness to share information and help classmates who may be struggling with concepts that more competent learners have mastered. This stage 3 need has implications on shared construction of knowledge and academic achievement Additionally, providing learners with more than one chance to attempt quizzes would also go a long way in motivating the learners so that they increase their chances of experiencing a sense of accomplishment and self-confidence. It must be noted that self-confidence is a stage 4 need (Maslow, 1943). More importantly, the numerous opportunities to attempt the quiz are better implemented when technology-mediated teaching methods such as blended teaching are used. This is because blended teaching can be used to grade assessments in real-time. When stage 4 needs are met, learners may proceed to set self-actualisation (reaching full capacity in terms of success) goals which will drive the motivation (Maslow, 1943). It must be noted that, as learners set goals motivated by higher needs, academic achievement improves. In summary, the review of literature illuminated the various research methods used by other researchers and their shortcomings as well as merits thereof, which was instrumental in influencing the choice of the research method.

3. Method

3.1 Research design

A positivist paradigm which emphasises that the need to obtain knowledge through measurement was used to establish relationships between the two variables (Rosenthal & Rosnow, 2008): blended teaching methods or traditional face-to-face teaching (independent) versus academic achievement (dependent). Numerical data in the form of test scores were collected using a standardised achievement test, referred to as the Knowledge of Organic Chemistry Test (KOOCT). Considering this, quantitative research was utilised. Approaching the study this way was appropriate considering the research question to be addressed.

Given the challenges noted previously, it was decided that the establishment of an online learning platform that was powered by MOODLE was cost-effective since it came with an offline app which allowed learners to complete the pre-class work away from school. Given that the school did not have any online learning platform, the researchers developed it taking into consideration the situation analysis results that showed that learners needed more opportunities to practise, and immediate feedback. As pointed out by Florian and Zimmerman (2015),

MOODLE comes with many benefits, which include supporting a constructivist design in which learners can collaborate, can expand with growing population, analyses data such as from assessments and being able to support institutional, learner and teacher diverse needs. Despite the challenges brought about by COVID-19, the learners persevered as they completed their pre-class work with most of them securing their own data to refresh their apps when they were away from the school. Based on the idea that traditional face-to-face teaching was predominantly being used, a comparison between blended teaching and traditional face-to-face teaching was drawn to address the research question that guides the present study. However, effective sampling had to be done to guarantee validity of the findings.

3.2 Participants and sampling

Two hundred Grade-12 learners (each group n = 100) from one school participated in this study, which allowed for the statistical analysis. The learners were, therefore, randomly placed into two equivalent groups (experimental and control groups) after voluntarily agreeing to participate (with parental consent) in the study. The random sampling was achieved when learners chose classes to join without interference from the teachers or the researchers. Considering this, participants had equal chances of joining any class. All the learners had passed Grade-11 physical sciences to be allowed to take the subject in Grade-12. Given that organic chemistry is taught in Grade-12 for the first time there was no previous knowledge of the subject matter that could be tested in a pre-test. Both groups had approximately equal numbers of female and male learner participants. These were all of African descent and their ages ranged between seventeen and nineteen years, with the majority of them eighteen years old or above.

One school that was easily accessible (convenience sampling) to the researchers in addition to having many Grade-12 learners (purposive sampling) taking physical sciences was selected. Written permission to conduct research was sought from the regional office and the school. Informed consent and assent forms were signed by the teachers and learners, respectively, prior to voluntary participation in the study. The test results were also not shared with the teachers to ensure confidentiality. Learners who participated were assured that the achievement test was not for marks, which ensured that participants were less anxious. Furthermore, the participants' biographical information was removed and each participant was identified using a number before electronically storing the test scripts in a password protected folder that could only be accessed by the researchers during the data collection stage. The confidentiality and anonymity of participants were also ensured by use of pseudonyms during the writing of the report. The experimental group teacher had gained experience of teaching online lessons during the earlier waves of the COVID-19 pandemic, which ensured a smooth transition to blended teaching. The instrument, KOOCT (available in Appendix 1) as the achievement test used to collect numerical data is described in the following section.

3.3 Research instrument utilised

An achievement test (KOOCT) set by the researchers and the two teacher participants was used. The test was designed to mirror the NSC examinations, which ensured that the objectives were covered in their correct proportions and that all the organic chemistry concepts were in line with the physical sciences curriculum (Department of Basic Education, 2011). The organic chemistry concepts included in the KOOCT were organic chemistry nomenclature, physical properties of organic compounds, organic reactions, basic polymerisation and organic applications. Question items were adapted from past examination papers and modified to make them look like new questions. This test was validated by three chemistry education experts and two teachers from two different high schools before being piloted using fifteen learners from a high school with similar contextual factors.

The test was checked for grade appropriateness (in line with the South African national curriculum) with special focus on the content, clarity of questions and mark allocation. Any items that were deemed unsuitable were replaced by more appropriate ones. Any mark allocation adjustments required were made. Presentation of the one-hour long question paper was also addressed to improve readability which included making some sections bold. The validation of the KOOCT took place during the organic chemistry teaching as part of the data collection procedure.

3.4 Data collection procedure

Following a situation analysis, a blended teaching workshop for the teachers was conducted by one of the researchers to make the teachers aware of what blended teaching entails and how their learners would benefit. Two teachers who had already been engaging in some form of team-teaching, particularly during the extra lessons that were conducted during the mornings, weekends, and holidays, were selected to mitigate against the problem of teacher effect. One teacher was female while the other was male.

A blended teaching cycle like the one proposed by Seery and O'Connor (2015) was adopted in which the online activities and those to be completed during the traditional face-to-face teaching components are clearly spelt out and implemented in a way that ensures continuity between the two phases. For example, the teacher could introduce the video lesson during the online lesson then learners would proceed to watch the video during times best suited for them before attempting the quiz based on the concepts covered. During the in-class time, in-depth questions based on the online work would be discussed followed by more cognitively demanding work. Feedback on the more difficult work completed during the face-to-face component could be posted on the online platform and discussed on the discussion forum. These connections between the two components of blended teaching figured strongly in this study.

Furthermore, Seery and O'Connor (2015) underscored the need to ensure active learning in both components of blended teaching. Considering this, ABL and flipped learning were selected since a fusion of the two would be better suited to address the organic chemistry challenges discussed in the literature review. Both

groups (control group and experimental group) were taught using similar activities except a few that strictly required the use of technology. For example, the same organic chemistry content which was taught using videos was also taught using the traditional face-to-face approach. All the learners from both groups were given the same quizzes and additional notes.

Group-1 learners had to watch the videos before attempting the quiz, a strategy which was designed to foster active learning (Armellini & Rodriguez, 2021). The online work was also designed in such a way that lower-level objectives were addressed while in-class time was used to address misconceptions and explore the organic chemistry content further through discussions and debates. Higher-order thinking questions were also tackled during the in-class time when learners could seek help from peers and the teacher. For example, new terminology in the video lessons was introduced during the face-to-face component to ensure that learners understood the work covered in the video lessons, which also served the purpose of integrating the two components. Similarly, during the face-to-face lessons, learners engaged in discussions on the online work that would have completed. The teacher also split the learners into two groups determined by their performance in the quiz. This entailed teaching again the concepts that each group struggled with before proceeding with the teaching of the more difficult concepts. This way, the online work was integrated into the work that was completed during the face-to-face component of blended teaching.

A discussion forum was established on the online platform in addition to gamification, which was also introduced to assist learners with the understanding of organic chemistry terminology and which was cited as one of the challenges of organic chemistry. Learners played the game individually or in pairs. An organic chemistry quizlet was also embedded to provide learners with extra practice work, in addition to the posting of feedback, and additional notes on the online learning platform. However, due to time constraints which were precipitated by the COVID-19 pandemic, simulations could not be introduced as the data collection period was also extended to seven weeks instead of five. All the organic chemistry topics (organic structures, functional groups, saturated unsaturated structures, isomers, International Union of Pure and Applied Chemistry (IUPAC) naming, organic reactions, physical properties of organic compounds, basic polymerisation and organic applications) were taught as stipulated in the physical sciences curriculum for South Africa followed by the administering of the achievement test, the KOOCT. The test was written under strict examination conditions. Teachers from other departments volunteered to invigilate. The test was graded using the validated memorandum. The consistency of marking and the addition of the marks were checked by two teachers who were seasoned markers of NSC examinations. Following this, the numerical data (test scores) collected were analysed.

3.5 Data analysis

This entailed using descriptive statistical analysis to determine the mean academic achievement of each group and the subsequent comparison of these means using two-sample independent t-tests and the determine the calculation the effect size (Cohen's d) using SPSS and the results are presented below.

4. Results

The research results were used to address the research question outlined below:
Compared to traditional face-to-face teaching, how effective is the use of blended teaching approach in fostering achievement in organic chemistry at Grade 12 in a school in South Africa?
The research question was addressed using descriptive and inferential (*t*-tests) statistics. To reiterate, the effectiveness of blended teaching was determined by comparing research findings from Group-1 and Group-2. Academic achievement means for the two groups were compared and it became clear that Group-1 (taught using blended teaching methods) results (M = 41.74 and SD =19.533) were higher than those of Group-2 (M = 27.18; SD = 13.039). Furthermore, skewness values of .368 and .278 for Groups 1 and 2, respectively, were within the acceptable range of normality of between -1 and 1, according to Kallner (2017), despite being slightly skewed to the left. Similarly, kurtosis values of .471 and .503 for Groups 1 and 2, respectively, were also within the acceptable range of -3 and 3, according to Kallner (2017). Further analysis of normality data was undertaken.

4.1 Analysis of normality of data on academic achievement

Kolmogorov-Smirnov test and the Z tests were used to test for normality.

4.1.1 Kolmogorov-Smirnov test

The Kolmogorov-Smirnov test was undertaken first mainly because it was more appropriate considering the sample size. A significance level of 5% was used in all the statistical tests conducted in this study. Academic achievement for Group-1, the p-value = .174 > .05 was normally distributed. However, that for Group-2, p-value = .049 < .05 was not normally distributed. Following this, z-scores were determined.

4.1.2 The z-test scores for academic achievement for Groups 1 and 2

The z scores are illustrated in Table 1.

Table 1: Z values of skewness and kurtosis

	$\lvert$Z- value of Skewness$\rvert = \lvert \frac{skewness}{standard\ error\ of\ skewness} \rvert$	$\lvert$Z-value of Kurtosis$\rvert = \lvert \frac{Kurtosis}{standard\ error\ of\ kurtosis} \rvert$
Group 1 y(KOOCT)	1.5270	0.9854
Group 2 y(KOOCT)	1.1535	0.9854

The z-scores of the skewness and kurtosis of academic achievement data for both groups are within ±3.29, as shown in Table 1. Academic achievement for both groups is therefore normally distributed (Ghasemi & Zahediasl, 2012). Similarly, the box plots also showed that there were no significant outliers for both groups. Considering this, no treatment of outliers was deemed necessary. After the analysis of normality, the mean academic achievements for both groups were compared using the T-tests to ensure that more substantive comparisons on the effectiveness of blended teaching on academic achievement could be drawn.

4.2 T-tests comparing means of academic achievement of Groups 1 and 2

The following hypotheses were tested:
H_0: The means of Group 1 and 2 are not equal.
H_1: The means of Group 1 and 2 are equal.

4.2.1 Results and interpretation

The two-sided p-values showed that the Group-1 mean was different from that of Group-2 as illustrated in Table 2 below.

Table 2: T-test comparing means of academic achievement

		Levene's Test for Equality of Variances		*t*-test for Equality of Means			
						Significance	
		F	Sig.	t	df	One-Sided p	Two-Sided p
Academic Achievement	Equal variances assumed	12.821	0.000	6.234	198	.000	.000
	Equal variances not assumed			6.234	177.429	.000	.000

The average academic achievement of the learners taught using the blended teaching method differs significantly from the average academic achievement of the learners taught using the traditional face-to-face method. Additionally, the one-sided p-values showed that Group-1 mean was significantly higher than that of Group-2. Once again, H_0 was rejected.

5. Discussions and conclusions, limitations, and recommendations

5.1 Discussions

As shown in the results above, the mean academic achievement and standard deviation for Group-1, taught using blended teaching methods (M = 41.74% and SD =19.533) were higher than those of Group-2 (M = 27.18%; SD = 13.039). Based on this, the relatively higher mean academic achievement for Group-1 points towards the idea that blended teaching could have been more effective in promoting academic achievement. Furthermore, the standard deviation of Group-1 was also higher than that of Group-2, showing that the dataset for Group-1 consisted of test scores that were more spread out away from the mean while those for Group-2 showed a tendency to group around the mean. When applied to the teaching methods used, this could mean that there was more consistency in Group-2 since the learners used a familiar teaching method which could not improve their levels of motivation. With Group-1 the opposite happened, possibly because the learners were at different stages of Maslow's hierarchy of needs and the way blended teaching was implemented could have appealed to some learners more than others resulting in the manifestation of a wider range of levels of motivation (Maslow, 1943). For example, those who quickly progressed to stages four and five were more likely to excel academically while those who were still in stages 1 and 2 could not attain high levels of academic achievement.

However, there was a need to determine if the two means for the two groups were significantly different. The two-sample independent t-tests results (based on a significance level of .05) in which Group-1 scores t (198) = 6.234, p = .00 < .05 clearly demonstrated that the academic achievement mean for Group-1 was significantly higher than that of Group-2. Hence, the H_0 which was stated in Section 1.2 was rejected. These results are consistent with findings from other research (see for example Flynn, 2015; Fisher et al., 2018; Seery & O'Connor, 2015; Yaghmour, 2016). Given that this study collected primary data, the effect size had to be determined. An effect size (Cohen's d=.882) that could be interpreted as large according to Cohen (1988) was obtained but would not be considered 'very high' according to the revised effect size scale proposed by Sawilowsky (2009).

Cohen (1988) defined effect size as a measure of the extent to which the treatment (in this case blended teaching) has an effect greater than zero in the population to which it was exposed (in this case Grade-12 learners learning organic chemistry at one of the underprivileged schools of South Africa). Based on this, the effect size obtained in this study could be said to highlight the strength of the relationship between blended teaching as the independent variable and academic achievement as the dependent variable, as Alwahaibi et al. (2020) assert. Moreover, it must be acknowledged that the effect size would be expected to be considerably large because the blended teaching utilised was informed by the needs analysis, which made it more effective. Additionally, as indicated by Cohen (1988), the high effect size could have been promoted by the use of a research design in which most of the variables were controlled.

In comparing with similar studies, such as that conducted by Flynn (2015) where the effect size was small, it should be noted that Flynn (2015) utilised an active form of traditional face-to-face teaching which is different from the one being used in the underprivileged schools of South Africa. By doing this, Flynn (2015) introduced a factor that could potentially make the effect size and practical significance of the study less accurate, as indicated by Alwahaibi et al. (2020). Practical significance as determined by the effect size is concerned with the practical application of the research findings in similar contextual factors (Alwahaibi et al., 2020). Based on the effect size obtained, it could be argued that this research can be applied in similar conditions because of several reasons. Some of these would include that, when this study is compared with similar studies, it would be preferable because of the high effective size and that the conditions for Group-2 were not manipulated in any way. This was because Group-2 (as the control group) continued to utilise the same traditional face-to-face teaching method while, for Group-1, a combination of ABL and flipped classroom could have ensured that the blended teaching method used promoted active learning. Nevertheless, the use of active learning is in line with Vygotsky's socio-cultural theory, which becomes evident when learners stop being content with assuming passive roles of recipients of knowledge from the teacher by taking initiatives to ensure that they proceed beyond their ZPDs (Vygotsky & Cole, 1978). This makes it more plausible that blended teaching could have been more effective in promoting academic achievement compared to the traditional face-to-face

teaching method that was used to teach Group-2 participants. These results were explained using Maslow's hierarchy of needs theory and Vygotsky's socio-cultural theory.

It could be argued that deeper understanding could have been fostered in Group-1 because of increased levels of learner interactions that were facilitated by the blended teaching methods utilised as implied by Vygotsky's socio-cultural theory (Vygotsky & Cole, 1978). The importance of peer interactions was underscored by Vygotsky's socio-cultural theory in which the learners that were more proficient in a certain topic of organic chemistry, for example, would assist those who are struggling (Vygotsky & Cole, 1978). This help from the peers would ensure that the struggling learners go beyond their ZPDs (Vygotsky & Cole, 1978) and, when this happens, academic achievement is improved. This finding is consistent with existing literature (Flynn, 2015; O'Flaherty & Phillips, 2015). Furthermore, according to Vygotsky and Cole (1978), these interactions have the potential to foster academic achievement. It could also be plausible that, because of this, in-depth learning promoted by blended teaching became possible through an awareness of misconceptions which the learners could learn from in addition to the teacher being able to structure the in-class lessons in ways aimed at addressing these misconceptions. As Vygotsky's socio-cultural theory also points out, learners attend school with preformed ideas which may be riddled with misconceptions (Vygotsky & Cole, 1978). The timely feedback could have helped the Group-1 teacher to detect such misconceptions and address them early. However, for these interactions to occur, the classroom learning environment must be conducive to learning.

Such an environment would be one in which learners feel safe to ask questions, to answer questions and to contribute to discussions without being ridiculed. According to Maslow (1943), such a safe environment is a stage 2 need that must be fulfilled. When these safety needs are met then the learners would set goals to attain feelings of belonging, which again becomes a source of motivation (Maslow, 1943). When the needs to belong are met, the learners then strive to develop self-confidence. The pursuit of each type of need motivates the learners to do more (Maslow, 1943). It could also be argued that self-confidence is attained when learners experience success because of the blended teaching method used, particularly when they improve the marks they obtained after attempting each of the three quizzes. It is important to note that giving learners three attempts is practically impossible when using the face-to-face teaching method alone, which makes it plausible that the academic achievement of Group-1 learners could have improved because of the relatively higher levels of motivation. Moreover, learners who have developed feelings of belonging are motivated when they set self-confidence goals (Maslow, 1943); they attempted more challenging work and completed their pre-class work. This could be attributed to the idea that more learners' interactions are likely to occur when more difficult work is being attempted given that, as Vygotsky asserts, a child would seek the help of an adult when the task becomes too complicated to perform alone or beyond their ZPD (Vygotsky & Cole, 1978).

Based on the above, it becomes more plausible that relatively more Group-1 learners were motivated and strived to complete their work and could construct more knowledge as they had more in-class time, which explains why they became relatively more successful compared to Group-2 learners. However, this is not to say that Group-2 learners lacked motivation completely, it could have been a case of Group-1 being more highly motivated. Additionally, being taught using blended teaching methods for the first time could have introduced Group-1 learners to new ways of learning using technology such as gamification, which could have further increased their levels of motivation while gaining more opportunities to practise. It must be noted that diagnostic reports from the Department of Basic Education have been encouraging teachers to provide more opportunities for learners to practise, but this was more difficult to achieve when the already overloaded teachers had to grade these assessments from overcrowded classes with over sixty learners. The importance of motivation as described by Maslow (1943) cannot be overemphasised given the links that can be forged between motivation and academic achievement.

6. Conclusion

This paper determined the effectiveness of blended teaching on academic achievement focusing on Grade-12 learners studying organic chemistry at one of the underprivileged schools of South Africa. Findings based on both descriptive and inferential (*t*-tests) statistical analyses showed that Group-1 (taught using blended teaching methods) participants scored significantly higher in terms of academic achievement compared to Group-2 (taught using taditional face-to-face teaching methods alone). The effectiveness of blended teaching (which utilised ABL and flipped classroom) on academic achievement could have been largely due to active learning strategies utilised, meaningful and increased interactions (learner-to-learner and teacher-to-learner) that led to deeper learning and shared creation of knowledge. This was in addition to more opportunities to practise that were created and timeous detection and addressing of misconceptions that could have boosted learners' confidence in organic chemistry. Therefore, blended teaching could have motivated the Group-1 learners more, resulting in higher academic achievement, despite having been affected by the COVID-19 pandemic. The study contributes towards closing the gap highlighted which relates to the effectiveness of blended teaching on academic achievement of Grade-12 learners studying organic chemistry at an underprivileged high school of South Africa. The study also contributes to blended teaching in underprivileged high schools of South Africa by providing possible ways of mitigating some of the challenges through the use of smartphones and offline apps. Additionally, this study proposes the use of a fusion of ABL and flipped classroom instead of using only one blended learning model, which could inform policy on blended learning implementation in underprivleged schools of South Africa and other developing countries with similar contextual factors. This study, which was in response to organic chemistry challenges, has implications on how the discipline could be taught more effectively using blended teaching. Despite this, the study had limitations.

7. Limitations

This study was conducted in one country, one regional location, and at a single school. As a result, the research findings are context-bound thereby making generalisation to schools with different contextual factors difficult. Furthermore, the study was conducted during the third wave of the COVID-19 pandemic which could have affected the learners from both groups emotionally and physically when they fell sick, resulting in diminished academic achievement. While steps were taken to minimise teacher effect through combined planning and use of similar activities, the teaching skills cannot be said to be exactly the same. Therefore, teacher effect as a possible limitation is acknowledged.

8. Recommendations

This study was conducted over a total of seven weeks and focused on only one discipline, organic chemistry, which formed a part of the physical sciences syllabus, due to time and budgetary constraints. More longitudinal studies that seek to evaluate the effectiveness of blended teaching on academic achievement in other chemistry topics and subjects focusing on underprivileged schools of South Africa are needed. Furthermore, there is a need to conduct longitudinal studies to find out if the interest will be sustained. The achievement test was also administered once. Therefore, future studies in which tests are administered at various stages of the teaching of organic chemistry concepts are recommended. Furthermore, most of the teachers were not keen to try out blended teaching, which requires that programmes be put in place to develop their skills in the use of technology-mediated teaching methods such as blended teaching. Future studies that utilise mixed-methods research methodology focusing on the effectiveness of blended teaching on academic achievement are also recommended to provide qualitative insights from participants.

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Declaration of interest statement

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Ethics statement

Prior to the commencement of data collection, an ethics clearance certificate was obtained from the University of the Witwatersrand.

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Appendix 1: Knowledge of Organic Chemistry test

Knowledge of Organic Chemistry test (KOOCT)
Time: 1 Hour **Total marks: 50**
This paper consists of two sections-A and B
Instructions to participants:

1. Answer **all** questions in this paper.
2. Answer section A on the first section of your answer sheet in ink.
3. Answer section B on the separate answer sheet provided and write in ink.
4. Take note of the marks allocated to each question which are in brackets (at the extreme right-hand side of each question) as these marks will determine the extent to which you answer each question.
5. Write neatly and legibly.

Section A: Multiple choice questions (14 marks)
Question 1: Each question carries 2 marks. You are provided with four options, A to D from which to choose the correct answer. Write down **only the letter** that corresponds to the answer of your choice. **For example: 1.1 D**. Each question only has **one** answer.

1.1 Which **ONE** of the following compounds is an aldehyde?

A. Pentanal
B. Ethyl propanoate
C. Pentan-2-ol
D. Pentan-2-one

1.2 Nthabiseng, a world renowned scientist investigates a factor which influences the boiling points of alkanes. She determines the boiling points of the first six straight chain alkanes. Which **ONE** of the following is the **INDEPENDENT VARIABLE** in this investigation?

A. Boiling point
B. Functional group
C. Branching
D. Chain length

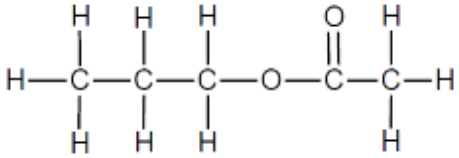
1.3 Which **ONE** of the following compounds is a **SATURATED** organic compound?

A. Ethyne
B. But-2-ene
C. Propene
D. 2-chloropropane

1.4 Which **ONE** of the following is an example of **SUBSTITUTION REACTION**?

A. $CH_2 = CH_2 + HBr \rightarrow CH_3CH_2Br$
B. $CH_2 = CH_2 + H_2O \rightarrow CH_3CH_2OH$
C. $CH_3CH_2OH \rightarrow CH_2 = CH_2 + H_2O$
D. $CH_3CH_2OH + HBr \rightarrow CH_3CH_2Br + H_2O$

1.5 Consider the structural formula of a compound below.



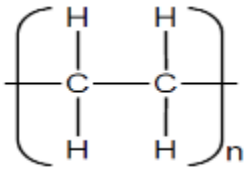
Which **ONE** of the following pairs of reactants can be used to prepare **THE COMPOUND ABOVE** in the laboratory?

A. Propanoic acid and ethanol
B. Propanoic acid and methanol
C. Ethanoic acid and propan-1-ol
D. Methanoic and propan-1-ol

1.6 Which **ONE** of the following organic reactions will take place only when exposed to light?

A. $CH_2CH_2 + H_2 \rightarrow CH_3CH_3$
B. $CH_3CH_3 \rightarrow CH_2CH_2 + H_2$
C. $CH_2CH_2 + C\ell_2 \rightarrow CH_2C\ell CH_2C\ell$
D. $CH_3CH_3 + C\ell_2 \rightarrow CH_3CH_2C\ell + HC\ell$

1.7 Which organic compound is represented below?

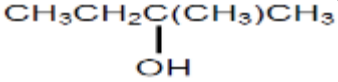


A. PVC
B. Polystyrene
C. Polyethene
D. Nylon 6, 6

Section B
Question 2 (22 marks)
The table below shows the boiling points of three isomers.

	ISOMERS	BOILING POINT (^{0}C)
A	2,2-dimethylpropane	9
B	2-methylbutane	28
C	Pentane	36

USE THE DATA IN THE TABLE ABOVE TO ANSWER QUESTIONS 2.2 TO 2.5.
2.1 Define the term *structural isomer*.
(2)
2.2 What type of isomers are these three compounds in the table above?
(1)
2.3 Explain the **trend in the boiling points** from compound A to compound C.
(3)
2.4 Which **ONE** of the three compounds **(A, B or C)** in the table above has the highest vapour pressure? **Hint:** Refer to the data in the table above to give a reason. (2)
2.5 Using **MOLECULAR FORMULAE** write down **a balanced equation** for the complete combustion of compound B.
(3)
2.6 Consider the formula of an organic compound below.



2.6.1 Is this a **primary, secondary, or tertiary** alcohol?
Give a reason for your answer.
(2)
2.6.2 Write down the IUPAC name of the above compound.
(2)
2.7 Bongi was given four straight chain alcohols, one with a single carbon atom, another with two carbon atoms, third one with three carbon atoms and the last one with four carbon atoms which were produced from four straight chain alkanes.
2.7.1Explain the difference in the boiling points of an alkane and an alcohol, each with three carbon atoms per molecule, by referring to the type of intermolecular forces. (4)
2.7.2 Does the vapour pressure of the alcohols **INCREASE OR DECREASE** with an increase in the number of carbon atoms?
(1)
2.7.3 How will the boiling point of **2-methylpropane** compare to that of its chain isomer?
Is it going to be **HIGHER THAN, LOWER THAN OR EQUAL TO** that of the chain isomer? Give a reason for the answer by referring to the structural differences between the two compounds.
(2)

Question 3 (14 marks)

Thabang and Matshepo are Grade 12A learners at Phumelela secondary school. They used a bromine solution to distinguish between compounds X (pentane) and Y (pent-1-ene) on a Tuesday. They added the bromine solution to a sample of each of the two test different tubes. They observed that one compound decolourises the bromine solution immediately, while the other one only reacts with the bromine solution after the test tube was placed in direct sunlight.

3.1 Write down the:

3.1.1Letter **(X or Y)** of the compound that decolourises the bromine solution immediately. (1)

3.1.2 The type of reaction that takes place in the test tube that contains compound X. (1)

3.1.3 **One** precaution that Thabang and Matshepo must take. (1)

3.2 On a Thursday, Johan and Mary from the same class carried out a reaction between hydrogen bromide and pent-1-ene. Write down the following:

3.2.1 The **IUPAC** name of the **MAJOR PRODUCT** of this reaction. (1)

3.2.2 Whether the **MAJOR PRODUCT** is **PRIMARY, SECONDARY, OR TERTIARY** alkyl halide and why. (2)

3.2.3 A reason for your choice of the **MAJOR** product in 3.2.1 above. (2)

3.2.4 The **condensed structural formula** of the **MINOR** product for the reaction that Johan and Mary did. (1)

3.2.5 A balanced equation for the reaction that Johan and Mary did. (3)

3.2.6 The type of reaction this is. (1)

THE END