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Factors influencing UAE high school chemistry students' learning of organic qualitative analysis

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Abstract

Chemistry is one of the five science subfields typically covered in secondary schools in the United Arab Emirates (UAE). Chemistry is a branch of science that studies substances' characteristics, components, and structures. Numerous subfields fall under the umbrella of chemistry, including inorganic, organic, analytical, and physical chemistry. One of the topics covered in chemistry classes is the analysis of chemical compounds, which is divided into two types: quantitative analysis and qualitative analysis. While qualitative analysis determines the kind of each element or group present in a given solution sample, quantitative analysis determines the quantity of each element or group present. The research explores responsible factors impacting 12th grade Emirati student's understanding of the organic qualitative analysis in chemistry, acknowledging the critical challenges highlighted within international tests such as PISA and trends in international mathematics and science study results. Deploying qualitative method approach with respondents from an international private school–the research relied on participants' interviews, classroom observations and document analysis to collect the needed data. The research advocated for a shift to practical based teaching methods, providing insights for the educators and policy makers, contributing to global educational excellence.

Keywords: organic qualitative analysis, functional groups, student understanding, UAE, grade 12 students

INTRODUCTION

The United Arab Emirates (UAE) school chemistry curriculum comprises several facets of chemistry, placing emphasis on the significance of understanding concepts at symbolic, microscopic and macroscopic levels. Despite its importance, the students encounter challenges transitioning between these representations. Moreover, the Emirati students, in light of PISA and trends in international mathematics and science study (TIMSS) results have demonstrated low achievements in chemistry. Within UAE curriculum, the focus on organic qualitative analysis (OQA) revolves around the identification of functional groups, yet the students struggle with specific regards. The following research looks forward to the performance of the factors that impact student's learning and performance in chemistry, proposing solutions to improve their performances. It places emphasis on the need for effective instructional strategies that promote conceptual understanding, addressing misconceptions. Furthermore, the following research looks forward to improving the Emirati students' performance within the international examinations and drive appreciation for the chemistry education.

Chemistry in the UAE Schools

Grade 10th students in the UAE have chemistry as an individual subject. In this stage, students must select a science course covering math, chemistry, physics, biology, and geology if they wish to continue with science during high school. Intake of the students and unsatisfactory results of chemistry classes at the high school level represent a problem that disturbs education in the UAE. This is much more serious in secondary school (Ridge et al., 2017). For instance, UAE students' science average score in PISA 2018 is 434 compared to the average score of 489 in OECD countries (Mullis et al.,

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Contribution to the literature

- The study contributes to the limited body of research focusing on chemistry education in the United Arab Emirates, particularly addressing the often-overlooked area of organic qualitative analysis among 12th-grade students.
- Through qualitative methods, including interviews, observations, and document analysis, this article underscores the value of practical-based teaching approaches in enhancing student understanding of complex chemistry concepts.
- This article adds to the existing literature advocating for experiential learning in science education, offering evidence from a non-Western educational setting.

2020). Another example, TIMSS 2019, the average science performance of grade 8 students in UAE is 473, which is less than the median point of scale (Mullis et al., 2020).

Relevant literature show that Emirati students struggle to correctly identify the functional group as well as the correct number and position of multiple bonds in organic molecules (Malkawi et al., 2018). Based on students' feedback, organic chemistry is a difficult subject that places a strong emphasis on memorization and has a great deal of information that needs to be absorbed (Anim-Eduful & Adu-Gyamfi, 2021, 2022, 2023). Therefore, the aim of this study is to identify the factors that influence UAE school students' learning and performance in chemistry, ascertain the extent of the subject's performance, and propose potential solutions that could be implemented to address these issues. Furthermore, the study tries to Enhance UAE students' performance in international examinations like TIMSS and PISA.

Qualitative Analysis of Organic Compounds

According to Al Zarooni (2014), most scientific ideas revolve around the structure of matter, making chemistry an essential subject for any science student. Therefore, chemistry provides a thorough understanding of matter's molecular makeup, making it a vital topic for high school. There are two main approaches to studying chemical compounds in chemistry: quantitative (volumetric) analysis and qualitative analysis. Both aim to provide a better understanding of the structure of the matter.

Matthews (2011) states that quantitative analysis identifies the amount of each element or group in a sample solution, while qualitative analysis determines the types of elements or groups present. The field of qualitative organic analysis focuses on the detection of functional groups, including aliphatic hydrocarbons such as alkanes, alkenes, and alkynes, as well as aromatic compounds like benzene. It also involves identifying carbonyl-containing compounds such as aldehydes, ketones, and alkenones, along with amides, alkanoic acids, alkyl alkenoates, and related organic compounds (Buthelezi et al., 2020, p. 658).

Essential parts of the UAE organic chemistry curriculum in high school, especially in grade 12, identify and characterizing unknown substances' structures instance, alkene and alkyne are unsaturated hydrocarbons that can identify with Br_2 in water. Saturated hydrocarbons have only one single carbon bond and do not change the cold alkaline or acidified tetraoxomanganate (VII) ($KMnO_4$) solution's purple color in any discernible way. Neither Br_2 in tetrachloromethane (Br_2/CCl_4) nor bromine in H2O Br_2/H_2O) reacts with alkanes (Atkins & Beran, 1992; Fieser & Williamson, 1992).

The visible proof of a reaction, in the form of the reddish-brown hue of bromine either fading away or completely disappearing, proves that the unidentified solution includes carbon double or triple bonds (Atkins & Beran, 1992).

Qualitative Analysis of Organic Compounds

Science educators have long emphasized the importance of helping pupils develop a conceptual understanding of scientific concepts and procedures. However, many teachers continue to use traditional, content-heavy techniques that emphasize rote memorization over genuine engagement with the material (Chin, 2004; Adu-Gyamfi et al., 2024). This overemphasis on memorizing frequently leaves students with lingering misconceptions, even after they complete chemistry classes. As Adu-Gyamfi et al. (2024) point out, effective instructional strategies such as analogies, conceptual conflict, and inquiry-based learning–are critical to achieving true conceptual transformation. As a result, chemistry teachers must dedicate time and effort to implementing these research-based methodologies, ensuring that students not only memorize facts but also gain a deeper, more accurate understanding of chemical phenomena.

To help students better understand functional groups in OQA and avoid common misunderstandings, Akkuzu and Uyulgan (2016) suggested using activity-based lessons to reinforce basic chemistry concepts, build on students' existing knowledge, and introduce new material. Results from the study by Asghar et al. (2019) show that students better comprehend common scientific ideas when their teachers employ well-planned instructional activities.

Teachers can better address their students' alternative ideas when they employ suitable inquiry-based activities in chemistry classes. The study conducted by Adu-Gyamfi et al. (2017) revealed several significant findings. One of these is that when chemistry classes are not taught using effective and appropriate methods, students lose interest in the subject, and teachers cannot foster an environment that encourages innovation, creativity, and investigative learning.

Chemistry classes, especially those focusing on OQA, are more engaging and productive when held in well-equipped classrooms with all the required chemicals. To make the ideas more approachable, chemistry professors should examine the process of detecting functional groups of organic compounds before instructing students in OQA using activity-based learning strategies. Regarding chemistry education in the UAE, profile aspects characterize fundamental behaviors in the classroom, on the exam, and in life.

Problem Statement

This research focuses on the pervasive challenges faced by the Emirati students in comprehension and outperforming in chemistry, specifically focusing on the qualitative analysis of the organic compounds. Despite the popularity of chemistry , student failure rates are elevated, resulting in decreased enrolment in chemistry majors, particularly at the 12th grade level. Organic chemistry concepts are sophisticated, influencing students to memorize and gain superficial depth of knowledge. The research focuses on investigating the factors impacting 12th grade students regarding their learning of qualitative organic analysis, pouring insights for educators and policy makers to improve teaching strategies. Furthermore, the research informs the development of the pedagogical approaches for more effective chemistry education contributing to the global pursuit of educational excellence within the national agenda of UAE.

The researcher has not found any previous research in the UAE that has used OQA to identify the variables that influence students' comprehension of the subject in 12th grade. It is believed that the findings of this study can be used as a foundation to improve students' understanding, which in turn may serve as a guide for more effective chemistry lesson delivery. The results of this study also provide a window into the development of new pedagogical approaches and policies that can be implemented in the future to deal with crises that might occur in the educational system (Chen et al., 2020).

Purpose of the Study

This study aims to investigate the challenges that UAE high school students encounter when learning OQA in chemistry. It focuses on the impediments to student comprehension and perceptions of the issue. To gather this data, interviews were conducted with 12th-grade chemistry students, providing insight into their experiences and perspectives. While earlier studies in the UAE have examined various levels of education and fields of chemistry, there remains a conspicuous dearth of research that focuses on OQA at the high school level. As such, this study is the first in-depth examination of the factors influencing grade 12 students' knowledge of OQA in the UAE educational system. As such, this study is the first in-depth examination of the factors influencing grade 12 students' knowledge of OQA in the UAE educational system.

Research Questions

This study is trying to answer the following questions:

1. Which cognitive, instructional, and contextual factors impact the understanding of OQA among 12th-grade students in the UAE?
2. What are the key obstacles students encounter in comprehending OQA concepts, and which instructional strategies are most effective in addressing these challenges?
3. What types of instructional and academic support contribute to enhancing students' comprehension of OQA?

Significance of the Study

The findings of this research are expected to make a significant contribution to the enhancement of teaching and learning processes related to the subject of OQA in UAE schools. Specifically, the study aims to raise awareness among academic and administrative staff regarding the various pedagogical, curricular, and contextual factors that may influence students' understanding and performance in OQA both positively and negatively. By identifying these factors, the research offers evidence-based insights that can support the development of more effective instructional practices. Educational experts, policymakers, school leaders, curriculum designers, and classroom teachers can draw upon these findings to inform the design and implementation of targeted educational policies, innovative and inclusive teaching strategies, and professional development programs. These initiatives can equip teachers with the necessary tools and methodologies to deliver the OQA content more effectively, ultimately improving student engagement, comprehension, and achievement in the subject. Moreover, the findings may support long-term reforms aimed at aligning OQA instruction with broader national educational goals and the best international practices.

Research Gap

While studies explore OQA curriculum content and teacher perspectives, few investigate student experiences in depth. This gap hinders a holistic understanding of learning OQA. By investigating these questions, this study aims to address the identified gaps in the literature and provide valuable insights into OQA learning within the unique UAE educational context. This knowledge can inform curriculum development, teacher training, and ultimately, improve student learning outcomes in OQA.

LITERATURE REVIEW

Teaching and Learning Chemistry Globally and in the UAE

Due to its connection with other fields of science, such as mathematics and biology, chemistry is regarded as a fundamental science subject (Abarro & Asuncion, 2021). However, chemistry is widely considered to be the most challenging subject in the world (Gafoor & Shilna, 2015). Chemistry is the toughest science subject to understand, and thus, fewer students are interested in it (Cardellini, 2012).

Chemistry is taught as the main subject in tenth grade in the UAE. Thinking mathematically is essential in chemistry learning, particularly given the nature of communal calculations in chemistry courses. Linking with TIMSS exam began in 1995, the main goal of TIMSS is to evaluate the effectiveness of science and mathematics learning for students in grades 4 and 8 across participating countries. TIMSS also provides professionals in education with information and data that help them improve the educational achievements and outcomes of their students (Mullis et al., 2020).

Students in the TIMSS exam for grades 4 and 8 frequently need more core abilities to comprehend chemistry, which causes difficulty while studying organic chemistry and OQA in grade 12. Despite previous exposure to chemistry, these core skills are not fully mastered, limiting students' capacity to explore complex topics. As a result, students face difficulties appreciating the complexities of organic chemistry and qualitative analysis, revealing a gap in their educational preparation that must be filled. According to the 2019 TIMSS results, students in the UAE have shown a steady improvement in their performance since the UAE's first participation in TIMSS in 2011

Regardless of these measures, performance and attainment in chemistry have deteriorated, with below averages noted year after year (Khalaf, 2000). The persistence of low achievement in chemistry has been attributed to various factors, including students' attitudes toward chemistry, their level of motivation, learning resources, interpersonal relationships, collaboration, and class irregularity (Nja et al., 2019). Parental involvement is also essential in shaping educational aspirations and students' attitudes which is seen to have a significant effect on students' academic achievement in many cultures (Castro et al., 2015; Jackson, 2022), parental expectations and aspirations for education of their children, connectivity with their child about school matters, parental influence, and parents' participation in school activities are all examples of parental involvement variables (Jeynes, 2007).

Studying Organic Chemistry

The study of carbon-containing compounds' structures, alignment, characteristics, and reactions is known as organic chemistry. Organic compounds also contain hydrogen, carbon, and numerous other components. Within sciences education, organic chemistry is an obligatory subject as it offers understanding of chemical phenomenon (Healy, 2019). Science researchers admit students face challenges while grasping organic chemistry related theories and models such as organic reactions, synthesis of functional groups, chemical bonding, radical reactions, bond formations between conformational isomerism, carbon electrophiles and so forth (Graulich, 2015). students frequently struggle to understand and visualize microscopic concepts such as atoms, chemical reactions, or molecules (Akaygun & Jones, 2014).

Organic Qualitative Analysis

Chemical analysis is an important part of learning chemistry. It can be broken down into two categories: qualitative analysis and quantitative analysis according to (Matthews, 2011). OQA is a systematic approach for identifying the components present in provided organic mixture or compound. Unlike the quantitative analysis, that focuses on determining the accurate quantities of substances, qualitative analysis revolves around ascertaining different types of functional groups within a sample. Techniques such as chemical tests, chromatography and spectroscopy are commonly practiced within OQA. identification of unknown substances is a key part of characterizing them.

Globally, chemistry students struggle to understand the chemical reactions and underlying concepts involved in qualitative analysis. In grade 12, students in the UAE study OQA as part of their chemistry curriculum. This includes the identification of functional groups specific groupings of atoms within molecules that confer distinct chemical properties. Examples of such functional groups include carboxyl (COO, found in esters), hydroxyl (OH, found in alcohols and aldehydes), amide ($CONH_2$), as well as both aliphatic and aromatic hydrocarbons.

According to Anim-Eduful and Adu-Gyamfi (2021) the identification and characterization of unknown substance structures are crucial components of the organic chemistry curriculum in high school, particularly in grade 12. Scientists, chemistry researchers and chemists utilize this approach to differentiate the functional groups within unknown substances, which also explains regarding the chemical structure of elements.

Factors Influencing Students Learning of OQA

Attitudes towards science

One of the factors that impact students' learning is their attitudes toward learning science. According to Astalini et al. (2020), students' attitudes have a direct link to students' achievement and may affect their performance. Hacieminoglu (2016) argues that students' attitude toward Chemistry is shaped by the way teachers teach it and might help them adopt an optimistic attitude toward science. However, most students in science classes seldom show positive interest in studying science (Ajemba et al., 2021).

(Gender) girls' and boys' attitudes

Seba et al. (2013) found a variation in girls' and boys' attitudes towards chemistry in regard to unease, pleasure, and self- confidence. Boys were more confident, performed well, and enjoyed Physics and chemistry than their female peers. Consequently, male students have more optimistic attitudes toward physics and chemistry than girls, and they are more likely than female students to participate in physics and chemistry activities. As per Jarrah (2020), the most common factors which positively impact the attitudes of students towards chemistry subject were found to be grade level, instructional methodologies and gender.

Language capability

Researchers such as Beka (2016), Alieto (2018), and Macaro (2019) investigated the role of language within the domain of student's academic progress. This issue has been significant within Emirati context as teacher's majority population are foreigners hence, the English language proficient may differ from the UAE based students. That is, the student's level of language skills can significantly impact the student's science development and overall performance (Jarrah, 2020).

Laboratory techniques

Several studies have investigated the relationship between laboratory techniques, student achievement, and attitudes toward chemistry. Practical experiments in the chemistry lab are essential for learning. In good chemistry education, what students learn in theory should be backed up by experiments (Kurbanoglu & Akim, 2010). The goals of lab work include helping students understand scientific concepts, improve their problem-solving skills, learn how science works, and see the links between experiments and scientific theories.

Teacher Professional Development, Training & Development and Teacher Motivation

For several decades, within the educational paradigm, there has been a consistent debate regarding teacher quality being the most critical variable impacting the academic progression of students and achievement (Sancar et al., 2021). It was argued that dynamic shifts within educational landscape, along with the demand for elevated and improved pedagogical standards and high-quality education has escalated the expectations for teacher's competencies and professionalism as well (Budd, 2004). Collinson et al. (2009) also highlights that teachers themselves have also heightened their expectations driven by innovative thinking within knowledge societies. This has led to educational leaders to focus on how teaching quality can be optimized and consequently, the student learning outcomes.

Context and Structure of Chemistry Education in the UAE

Chemistry education in the UAE is evolving, blending traditional lecture-based methods with a growing emphasis on practical applications. Universities prioritize transferable skills alongside core knowledge. This can be contrasted with some Western systems where rote memorization might play a larger role in earlier years. However, some UAE schools are innovating. The American School of Dubai integrates project-based learning to foster critical thinking, similar to approaches used in progressive Western schools

THEORETICAL FRAMEWORK

According to constructivism, students are active learners who construct their meanings based on prior knowledge they have gained through interactions with their environment. According to this theory, interactions, collaboration, observations, and engagements are the fundamental aspects of students' learning (Ziling & Yan, 2018). After this, students will begin to form their concepts about a specific topic and then apply it in real-life situations and other contexts.

Figure 1 depicts the constructivist approach to education, which holds that students are integral to learning and that new information is generated from real-world experiences. While things develop, everyone takes stock of their history and applies what they've learned. To organize their newly gained knowledge, students construct schemas. This was the guiding principle in the theories of learning put out by Bruner, Piaget (1952), Dewey (1916), Gagne, and Vygotsky (1978).

One must be knowledgeable about constructivist theory to comprehend students' learning process. That

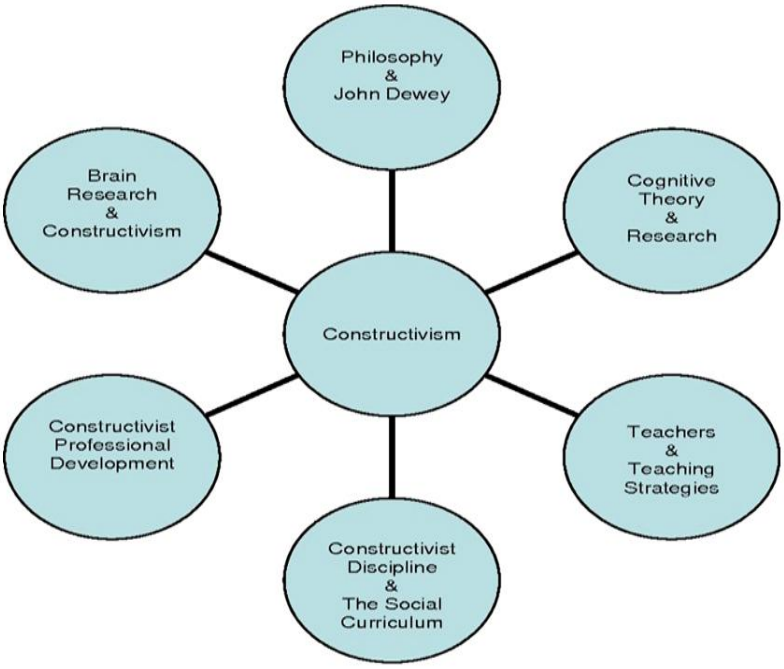


Figure 1. Constructivist learning theory (Kurt, 2021)

students actively build their knowledge is the central premise of constructivism. Students build upon what they already know by drawing on their own experiences. Contrary to what Hoy and Woolfolk-Hoy (1993) said learning is not a passive process of absorbing information but rather an active mental effort.

Cognitive and educational researchers continue to investigate the brain, the seat of learning, which informs and evolves pedagogical theories, such as constructivism. This approach, advanced by scholars such as Dewey (1916), stresses active knowledge acquisition through personal experience and reflection. In the educational setting, constructivist professional development provides instructors with tools such as project-based learning and social-emotional curricula. These strategies reflect cognitive research that emphasizes the social element of learning.

Within constructivism, the teacher's function moves from fact transmitter to facilitator of understanding. Teachers help students generate meaning based on their own experiences and past knowledge. This is especially crucial in today's diverse classrooms, as students bring a wide range of perspectives formed by their culture, background, and life experiences. These distinctions have a substantial impact on how learners comprehend and engage with knowledge. Thus, understanding constructivist pedagogy is critical for all educators.

The concept of building prior knowledge is central to constructivist theory. New material is only valuable if students can relate it to what they already understand. As a result, early educational experiences provide a crucial foundation for lifelong learning. Effective instruction must recognize that students build knowledge by connecting new ideas to existing mental models through debate, inquiry, and discovery.

Participating in class discussions and collaborative projects enhances learning outcomes by encouraging students to articulate, challenge, and refine their ideas in a supportive environment. Contextual learning, which involves memorizing and applying information in meaningful circumstances, helps to develop cognitive connections even more. Constructivism emphasizes that learning is a dynamic process rooted in real-world contexts and shaped by individual experiences.

Recent models in the discipline, such as diSessa's (2018) knowledge-in-pieces (KiP) theory, offer a more detailed understanding of this knowledge production. KiP contends that students learning is based on many small, loosely connected pieces of intuitive knowledge, or "phenomenological primitives," rather than complete mental frameworks. These components are engaged and reshaped in response to context, experience, and instruction. Similarly, Linn et al.'s (2013) knowledge integration framework emphasizes the importance of helping learners connect, distinguish, and reorganize ideas to develop a more cohesive scientific understanding. This concept encourages the creation of learning environments that facilitate the refinement and integration of knowledge over time.

Furthermore, studies on misconceptions in chemistry education, such as those by Taber (2009) and Gilbert and Treagust (2009), demonstrate the persistence of incorrect or inadequate mental models. Misconceptions can develop when students attempt to integrate scientific explanations into current everyday thinking frameworks. Constructivist approaches that elicit and confront misunderstandings through dialogue, model-based reasoning, and inquiry-based learning are crucial in breaking down these barriers to understanding.

This study uses constructivist learning theory to investigate how students learn OQA in chemistry. In this context, students actively construct their understanding through hands-on lab experiences, dialogue, and reflection rather than passively absorbing content. Teachers play a crucial role in facilitating discussions that link OQA observations to a fundamental understanding of functional groups and chemical behavior. The curriculum, too, can be organized on constructivist principles, featuring collaborative activities, opportunities for inquiry, and structured reflection that promote knowledge integration.

This study aims to provide a more nuanced understanding of how knowledge is constructed in secondary chemistry classrooms by examining students' views on OQA, as well as the impact of teacher supervision and curriculum design on their learning processes.

Constructivist philosophy also emphasizes that knowledge cannot simply be "transferred" from a teacher's mind to a student's. Instead, students use classroom knowledge to shape meaning in ways that are personally relevant to them. Examining students' learning from a constructivist perspective may help educators enhance their pedagogical practices for creating student-centered, activity-based learning environments.

Furthermore, combining models like KiP and the knowledge integration framework enables a more in-depth theoretical study of students' cognitive processes, especially in complicated fields like OQA. This study employs qualitative approaches, including interviews and classroom observations, to explore students' perspectives, misconceptions, and conceptual development. These insights can help teachers recognize the cognitive challenges that students face and, as a result, design targeted interventions to facilitate deeper, more lasting learning.

This study uses constructivism, where students actively build knowledge, to understand how they learn OQA in chemistry. Beyond the hands-on lab experiences, teachers play a crucial role by facilitating discussions and encouraging students to connect OQA observations to existing knowledge of functional groups. The curriculum itself can also be designed with a constructivist approach, embedding activities that promote student inquiry and collaboration. By examining student attitudes towards OQA and how the curriculum and teacher guidance influence their learning process, this study can provide a more complete picture of how students construct their understanding of OQA in chemistry. Additionally, the constructivism theory may provide the researcher with a window to understand the experience of students by discovering their perceptions, challenges, and barriers.

RESEARCH METHOD

This study employed an interpretive research paradigm grounded in qualitative methodology to explore the challenges faced by 12th grade students in understanding OQA within an international American curriculum school in Al Ain, UAE. The research was guided by ontological, epistemological, and methodological considerations, aiming to uncover underlying causes of student difficulties rather than generalizing findings. Purposeful sampling was used to select participants from all four grade 12 sections, ensuring a diverse range of perspectives. Data were collected through semi-structured interviews, classroom observations using a custom-designed checklist aligned with next generation science standards (NGSS), and document analysis of student work, lesson plans, and lab-related materials. Thematic analysis, supported by NVivo 12 software, was employed to identify key patterns related to students' conceptual understanding of the material. The UAEU's research ethics policy strictly adhered to ethical protocols, including obtaining informed consent and maintaining confidentiality. The qualitative approach provided in-depth insights into instructional practices, student engagement, and contextual factors influencing learning outcomes in OQA.

Ethical Considerations

It's essential to consider ethical issues at every study step. In this article, we followed the rules and guidelines set by UAEU's policy on ethics. When collecting data, such as through interviews, it is essential to consider ethics. Participants willingly engaged, knowing they can withdraw from the study at any time. Before participating, it was ensured that the complete comprehension of the study's details and obtaining free, unpressured consent is crucial.

Further Ethical Considerations Applicable to Interviews

All the people being interviewed were told what the research was about correctly at the beginning. They were also given a printed copy of the questions they would be asked. The researchers got their verbal agreement to be in the study during the interviews, and they could change their minds any time if they wanted. Also, I informed the interviewee. The information collected during the interviews was kept safe on the researcher's computer with a password. The interviewed people were told their information would be deleted once the research was finished. So, the researcher followed all the rules for collecting data in a live setting.

We also used data from checklist observations and looked at documents related to students and teachers. I spoke to chemistry teachers and lab technicians to understand their challenges when teaching this topic and course. All the information we gathered is kept confidential. Sometimes, the teachers and technicians shared reports about their work, students, or the school.

Participants

Participants in this study are students enrolled in the 12^{th} grade in one of the international private schools in Al Ain city, UAE. The school hosts approximately 650 students and uses American curriculum. There are four sections for grade 12^{th} students, three sections for male students, and one section for female students. Participating students were selected and consulted to be interviewed from each section. All interviews were held with participating students until the researcher reaches a data saturation level.

The rationale to select grade 12^{th} students in an American curriculum school (UAE) was for their experience with OQA within this specific educational framework. The purpose of interviewing students was to obtain specific information that can be relied upon on the causes or elements that impact students' learning of OQA. During the interviews, it was ensured that the interviewer's perspectives and experiences do not sway the opinions of the students because these conversations were recorded. Furthermore, questions were asked from students to make the interviews more interactive. The opinions of students regarding the process of teaching and learning OQA was used to produce themes.

Participant Interviews

Semi-structured interviews were conducted with **eight grade 12 students** from four different classroom sections (three male sections and one female section). Students were invited to participate through an open call sent via email. The first respondents who expressed interest and consented to participate were selected, following **purposeful sampling** principles aimed at capturing a range of student experiences (Patton, 2015). Gender balance and section representation were also considered to capture diverse perspectives. The interview protocol was developed based on themes emerging from the literature on constructivist learning, misconceptions in chemistry, and the specific challenges of OQA. Questions explored students' perceptions of the topic, conceptual difficulties, classroom experiences, the effectiveness of teaching strategies, and personal or environmental factors affecting their learning.

Each interview lasted approximately 30-40 minutes and was recorded and transcribed for analysis. Thematic data saturation was achieved after eight interviews, when no new themes or insights emerged and responses became repetitive. Notably, one female participant provided unique insights related to student-teacher dynamics, environmental influences, language barriers, and family support, which enriched the dataset and highlighted factors not emphasized by her peers.

Document Analysis

Document analysis provided further contextual insight into instructional planning and student engagement. Materials reviewed included:

(1) teachers' lesson plans, annual plans, and course outlines,

(2) student notebooks and study journals, and

(3) internal documents from lab technicians, such as experiment protocols, safety guidelines, and email communications regarding OQA sessions.

These documents were analyzed to understand how OQA content was structured, taught, and reinforced outside the immediate classroom discourse.

Data Collection

Three qualitative instruments were used: **classroom observations**, **semi-structured interviews**, and **document analysis**. Each method was designed to triangulate findings and ensure a comprehensive understanding of students' conceptual learning experiences.

Classroom observations

Observations were conducted in the classrooms of two chemistry teachers over a period of two weeks during the second academic term, with each teacher being observed three times per week, totaling twelve observation sessions. The focus was on real-time classroom interactions, teaching practices, student engagement, and instructional approaches related to OQA.

An observation checklist was developed based on **NGSS** and research-based criteria for active and inquiry-based science learning. The checklist included two parts:

1. **Section A** collected general demographic and contextual information about the teacher, class, and observed session.
2. **Section B** evaluated teaching strategies, student participation, and lesson outcomes with reference to the intended learning objectives.

This checklist served both as a guide for consistent observation and as a tool for aligning observed practices with constructivist pedagogy.

Data Analysis

All data gathered from participants' interviews, observations, and document analysis were analyzed using several qualitative methods: content analysis, narrative analysis, discourse analysis, and conversation analysis (Bowen, 2009). Content analysis focused on the substance of what was said, while conversation analysis examined how it was communicated. Narrative and discourse analyses considered both the form and content of the data. To further understand the collected qualitative data, thematic analysis was employed to identify recurring themes and patterns in the responses, allowing for a more structured interpretation of the findings.

Data from all three sources were analyzed using thematic analysis, following Braun and Clarke's (2006) six-phase approach: familiarization, initial coding, theme generation, theme review, theme definition, and reporting. Coding was inductive and data-driven, focusing on recurring patterns in students' learning experiences, misconceptions, and contextual influences.

Themes were interpreted in light of constructivist theory, diSessa's (2018) KiP model, and Linn et al.'s (2020) knowledge integration framework, which provided a lens to understand how students integrate fragmented pieces of knowledge or reconcile conceptual inconsistencies during learning.

Trustworthiness Measures

To ensure the trustworthiness and rigor of the study, criteria from Tisdell et al. (2025) and Korstjens and Moser (2018) were followed:

1. **Credibility:** Prolonged engagement through classroom observations and triangulation of data sources (interviews, observations, documents) increased internal validity. Member checking was conducted by summarizing findings with selected participants to confirm accurate representation of their perspectives.
2. **Transferability:** Thick, detailed descriptions of context, participants, and teaching environments were provided so readers can assess the applicability of findings to similar settings.
3. **Dependability:** A clear audit trail was maintained, documenting the research process, coding decisions, and evolving insights during data analysis.
4. **Confirmability:** Reflexive journaling was used to monitor the researcher's biases and assumptions. Peer debriefing with an external colleague familiar with qualitative methods further ensured analytical neutrality.

Data Analysis Software (NVIVO12)

The study utilized NVIVO12, a powerful data analysis software, to handle the complex qualitative research process. NVIVO12 played a crucial role in documenting the data, comprehensively exploring the information, testing and generating theories, and addressing gaps not covered by quantitative research. This software allowed researchers to delve deeply into students' communication challenges in their qualitative analysis studies, specifically regarding improving their chemistry performance among 12th graders in the UAE. By automating tasks such as sorting, processing, and analyzing data, NVIVO12 streamlined the research process, making it faster and more accurate and enabling more profound insights into the qualitative data collected.

RESULTS

To ensure the reliability and depth of the findings, this qualitative study employed multiple data collection methods, including semi-structured interviews with eight grade 12 students in an American curriculum school in the UAE, lesson observations of two chemistry teachers during OQA instruction, and document analysis of student work and school correspondence. These diverse sources enabled triangulation, thereby enhancing the credibility of the results by cross-verifying student perspectives with observed teaching practices and documented materials. . The study did not differentiate between male and female students, treating all participants as a single cohort. Through this comprehensive approach, the researcher aimed to identify the key barriers affecting students' understanding of OQA in chemistry while ensuring confidentiality through the use of pseudonyms. The analysis of individual responses led to the identification of overarching themes that reflected common challenges and perceptions shared by all participants.

Interviewer's Knowledge and Credibility

In qualitative research, the knowledge and credibility of the researcher play a crucial role (Patnaik, 2013). This is particularly true when conducting interviews, as the interviewer must possess technical expertise and strong interpersonal skills. In the context of this dissertation, the researcher holds the administration position, and she acts as a head of the department in school setting. She has been working at the same school for over eight years. Furthermore, the researcher boasts more than 13 years of experience in teaching and learning, gained from working in the UAE and the USA. These extensive experiences enhanced the researcher's credibility in the eyes of the interviewees (Patnaik, 2013).

Moreover, the researcher's familiarity with the school, its students, teachers, and staff further strengthened her position. Being a part of and working at the same school, the researcher has developed a deep understanding of the dynamics within the institution. As the head of the department, she regularly conducts observational visits and uses checklists to assess the performance of the two chemistry teachers. This established rapport and familiarity for the researcher to collect data and information. The teachers felt comfortable and are more willing to assist in providing the required documents and information.

Additionally, the researcher's familiarity with the laboratory materials, chemicals, and processes, along with the support of the lab technician, allows her to access the necessary information and even obtain pictures of the lab setup. Being the head of the science department enables her to keep an open line of communication with the teachers. That helped to create a relaxed environment where teachers can openly share their truthful information. Similarly, students felt at ease during the interviews, making the data collection process more effective and reliable. Regarding the first research question, which focused on studying chemistry and practical skills for teaching OQA, emergent themes included resources for teaching and learning, relationship with chemistry teachers, and using modelling in learning OQA. The second research question pertained to laboratory practices and instruction based on practical learning. Emerging themes included going to the lab every week, using modelling in teaching OQA, having materials in the lab, and providing examples for experiments in lab. And the third research question focuses on the support and help that grade 12th have to understand the topic. Finally, the researcher identified themes that were relevant to all three research questions such as understanding organic compounds and explaining concepts related to OQA, difficulties in learning OQA, expectations for learning OQA, the meaning of OQA and the field of OQA as content for the organic chemistry curriculum..

Three major themes emerged from analyzing the data collected through interviews observations, and documents:

1. **Teaching and learning resources:** This theme centers on providing enough resources to teach practical-based OQA training effectively. These include labs, reagents, and equipment that are necessary for the learning processes to go on.
2. **Practical-based instruction:** This theme addresses teachers' methodology for instruction, focusing on the participatory-based scenario to promote students' understanding of chemical concepts. It investigates how teachers' hands-on' approach, such as through practical discussions, makes the students understand the OQA better.
3. **Organic chemistry curriculum content:** This area is dedicated to the analysis of teachers' and students' perceptions of OQA class content within the framework of the official curriculum. This study about the learners' understanding of the link between curriculum design and methods used in OQA lessons is being coached.

Results of Question 1. What Factors Influence 12th Grade UAE Students' Understanding of OQA?

This question aimed to investigate the factors contributing to challenges teachers and students face in teaching and learning OQA.

This investigation involved observing two chemistry teachers to gain insights into their methods of delivering OQA lessons. Additionally, interviews were conducted with both teachers and students before and after these lessons. In the following paragraphs, I will present the various factors that grade 12th students encounter while learning OQA.

Students' Familiarity with OQA

The interviews and lesson observations revealed a significant challenge teachers and students faced in teaching and learning OQA. One major issue was that not all students were familiar with the term OQA, which is "a method used to determine the number of elements or molecules produced during a reaction". This lack of familiarity was due to a need for more resources. Both teachers and students needed more tools and equipment.

To understand the student's background and familiarity with organic chemistry and OQA, the researcher asked some students about their prior knowledge of OQA. Some of them mentioned that they had been introduced to organic chemistry and OQA and were familiar with these topics. In contrast, others were confused about it and described it as a fascinating *topic.* Here are a few quotes from the interviews.

> Interviewer: Are you familiar with organic chemistry and OQA?
>
> Ahmad: I believe so, but it looks confusing, making me reluctant to learn it. Do you mean hydrocarbons? If yes, then, of course, I am familiar with OQA (class A, student 1).

However, Zaid mentioned that the whole topic of hydrocarbons is complicated to him:

> Zaid: Do you mean our lesson about hydrocarbons? Yes, Miss, it's complicated to understand (class C, student 2).
>
> Majed: No, eeeh, yes, Miss. It does not detect functional groups like alkenes, alkanes, & … alkanols.
>
> Interviewer: Yes, close; we call those hydrocarbons in organic chemistry. Can you explain OQA in your own words?
>
> Majed: Oh, I see. I'm not sure because chemistry isn't my best subject, but I guess it's related to understanding functional groups using lab

experiments. There has been no lab work or practical application, but yes, we have done them. Since I am confused by them, I have not been studying them regularly (class A, student 2).

Rawa**:** Yes, in fact, yes. I know what that is; studying hydrocarbons is a fascinating topic for me. I like learning them, but I have difficulties handling it, but it is enjoyable (class D, student 2).

The same ideas were echoed during my observations of tow chemistry lessons in grade 12th. I noticed that chemistry teachers talked about the OQA topic and tried to reintroduce them to their students several times throughout my visits. However, students still requested some practical and hands-on activities to help them better understand the concept. The teacher responded to his students requests and mentioned that he will take them to the lab to do some chemical activities including the reactions of organic reagents with functional groups:

We will conduct these experiments in a controlled environment so that you can see and feel the interactions between the organic reagents and the functional groups (Mahmoud, a teacher).

Another teacher also mentioned that he would try to conduct practical work in the lab if his students finished the functional group detections. He said during the observation:

Once we finish these functional group detection tests, I will try my best if we can do actual practical work in lab (Tareq, teacher).

Limited Lab Space and Big Class Size

The space of the lab and the large number around 35 of 12th grade students in the schools were identified as factors that contribute to the challenges they face while teaching OQA to students. They complained that the school did not have enough space that is designated solely for chemistry laboratory use. When one of the students asked why they don't go to the lab to do experiments, the teacher replied:

... since we don't have enough space in the lab and our number is large, we can't go to the lab; therefore, we are going to stay in the classroom. Maybe next time, my dear students, we have a lot to cover (teacher Tareq class observation).

When I asked the teacher why he couldn't, he added:

Not only does our school lack laboratory space, but also basic chemicals and reagents are not available in chemistry lab.

The lab technician also mentioned that the concern of limited lab resources and equipment is a problem that limits them from taking their students to the lab. They both mentioned that the only organic material that we have in the laboratory in this entire school is ethanol. Even that ethanol has been there for more than a year. They mentioned:

Most of the remaining compounds are inorganic salts and solutions, to be very honest. Those chemicals are really pricey, and my pay isn't nearly enough to cover their cost for the school. I'm stuck. $K_2Cr_2O_7$, Fehling's and Benedict's solutions, and Tollen's reagent are not available at the moment, thus we cannot do tests for higher functional groups such as alkanols, alkanoic acids, aldehydes, and ketones. On the other hand, we may check for unsaturation and saturation functional groups using reagents like $KMnO_4$ and bromine solution (lab technicians).

Outdated Chemicals and Reagents

Sometimes, while teaching OQA to students, old chemicals and reagents (**Figure 2**) are used. This was

	Name of the material	Expired date	Catalog code
1	Hydro chloric acid	2018	Not available as it is old
2	Nitric acid	2018	SLN2161
3	Sulphuric acid	2018	Not available as it is old
4	Ammonia	2018	Not available as it is old

Figure 2. Chemistry lab expired material report materials that are expired in our chemistry lab (Source: Field study)

found not to provide students with the best OQA experience. One teacher mentioned.

> Even the few chemicals we use for the inorganic practical works are outdated; some have been outdated for four and even five years. As the only chemistry teacher for the three streams, this makes it particularly challenging for me to conduct practical classes (Mahmoud, a teacher).

Additionally, students who were interviewed agreed with their teacher's assessment that their school lacks sufficient chemicals and reagents for teaching OQA, which sometimes limits their understanding of various aspects of OQA. Here is one of the students' responses:

> We are constantly shown examples of chemicals on the whiteboard or some pictures on PowerPoint slides that these reagents are used to detect organic functional groups, and we get confused since we have never seen these reagents before. It can be challenging to learn about all these different functional groups when our teacher asks us to differentiate between primary, secondary, and tertiary alkanols, as well as aldehydes and ketones, on the whiteboard (Saeed B, student 1).

Limited Lab Usage

The limited lab resources make students' understanding of OQA difficult and very superficial. Due to that limitation, teachers find themselves forced to teach the concept theoretically without conducting any hands-on lab activity. Therefore, students learning becomes more superficial and unjoyful. Here is what Amir mentioned during his interview:

> We have never used such reagents before; therefore, it can be difficult to learn something without seeing it. The color changes are something I always have to imagine and remember (Amir C, student 1).

That concern was further clarified during my interview with Omar:

> Interviewer: How do you understand OQA?
>
> Omar: Ms. OQA is abstract.
>
> Interviewer: What do you mean by OQA is abstract?
>
> Omar: It is too complex and complicated. It is also too many and confusing.
>
> Interviewer: Can you explain further?

Figure 3. Using a foam ball and a toothpick to model functional group ketone (Source: Field study)

> Omar: Hmm, Ms., I'm confused by all the functional groups and reagents. It's hard to understand how two or three reagents can be used to detect one functional group. On the other hand, we always see these reagents written on the board for us. I've only seen the ones used to detect alkane, alkene, and alkyne, which is $KMnO_4$, but we don't have Benedicts' and Fehling's reagents, which make learning qualitative analysis tricky. (Omar B, student 2).

Managing the Learning Environment

To overcome the shortage of lab equipment, teachers use pictures in PowerPoint slides and relevant illustrations to assist students in studying OQA. Furthermore, teachers try their best to make the abstract concept more understandable by engaging their students with some simple hands-on classroom activities such as using balls and toothpicks (**Figure 3**).

Another strategy that teachers also use to overcome the shortage of lab materials problem is have pictures of the needed chemical compounds and bring them to the class.

Results of Question 2. What Are the Challenges That 12th Grades Students Face in Conceptualizing OQA and How to Overcome These Challenges?

This question aimed to understand the challenges that 12th grades students encounter when studying the concept of OQA and how these challenges can be overcome. To answer this question, I observed two chemistry teachers in action as they teach OQA lessons to investigate this concept. I also interviewed teachers and students before and after delivering these lessons to gather more information. In the following paragraphs, I will discuss multiple challenges that 12th grade chemistry students face while trying to conceptualize the OQA concept.

Lack of Adequate Teaching and Learning Materials

The lack of sufficient teaching and learning materials often creates a crucial challenge for UAE's 12th grade students to conceptualize OQA. Inadequate availability of up-to-date and extensive resources limits students' ability and performance to conceptualize and grasp the underlying ideas of complex phenomena related to OQA.

Such shortage widens the gap between their theoretical understanding of the concept and its real-life applications. The lack of adequate teaching and learning materials has resulted in the adoption of a range of instructional approaches rather than practical-based methods.

To help students' study OQA, some teachers use the expository process to teach OQA to students. For example, Mahmoud mentioned that:

> I often teach using regular whiteboard illustration, and sometimes, I print out pictures of these organic chemicals like $KMnO_4$ and $K_2Cr_2O_7$ and show them to my students while teaching OQA (Mahmoud, a teacher).

Furthermore, Mahmoud sometimes makes use of several available animations and virtual lab tools to support his student's understanding of OQA:

> Also, sometimes … Since we do not possess the necessary chemicals or reagents to identify these functional groups, I mostly instruct my students on this subject through the use of organic models, videos (animations), and virtual labs (Mahmoud, a teacher).

When asked why he did not follow his lesson plan, Mahmoud argues there is no need to have a lesson plan in hand while teaching. When asked to elaborate on that, he mentioned:

> Why do I need a lesson plan? I change the plans several times based on the available organic chemicals and reagents that we have in the lab. So, sometimes I use plan b and c as I expect my students to understand the topic, so I do my best using the models and animations better than using nothing (Mahmoud, a teacher).

Issues in Instructional Methods Usage in the Classroom

One of the primary factors contributing to students' struggles with learning OQA is the instructional teaching methods used in the classroom. After conducting lesson observations and interviews with grade 12th students, it became evident that the two teachers needed to be more concerned about the effectiveness of their current instructional approaches. They firmly believed that a practical-based teaching process, incorporating hands-on activities and laboratory interactions with chemicals, reagents, and equipment, would be the most suitable method for effectively teaching the concepts of OQA.

Challenges of Applying Practical Lessons to Facilitate Understanding

Limited availability to well-equipped laboratories and updated apparatus limits practical lessons' ideal and effective integration. Despite having exceptional knowledge and experience in the field of organic chemistry, the absence of adequate resources restricts their teaching and knowledge-delivering capabilities.

One of the teachers mentioned:

> Students must take an active role in using the reagents and chemicals while in the lab. As a result, the subject of qualitative analysis becomes more accessible. In my opinion, they should be able to grasp it with the support of ongoing practical instruction. In my classes on OQA, I make sure my students get the material by using practical examples. Reagents are not all of which we have. That's why I don't follow the lesson plan or course breakdown (our plan for the term and daily lesson plan). Also, most of the laboratory materials were unavailable in the investigation sheet, so I tried my best to explain this activity with limited regents. I use multi-based teaching methods and many teaching techniques like the lecture method and participatory approach to teaching group work (Tariq, a teacher for class A).

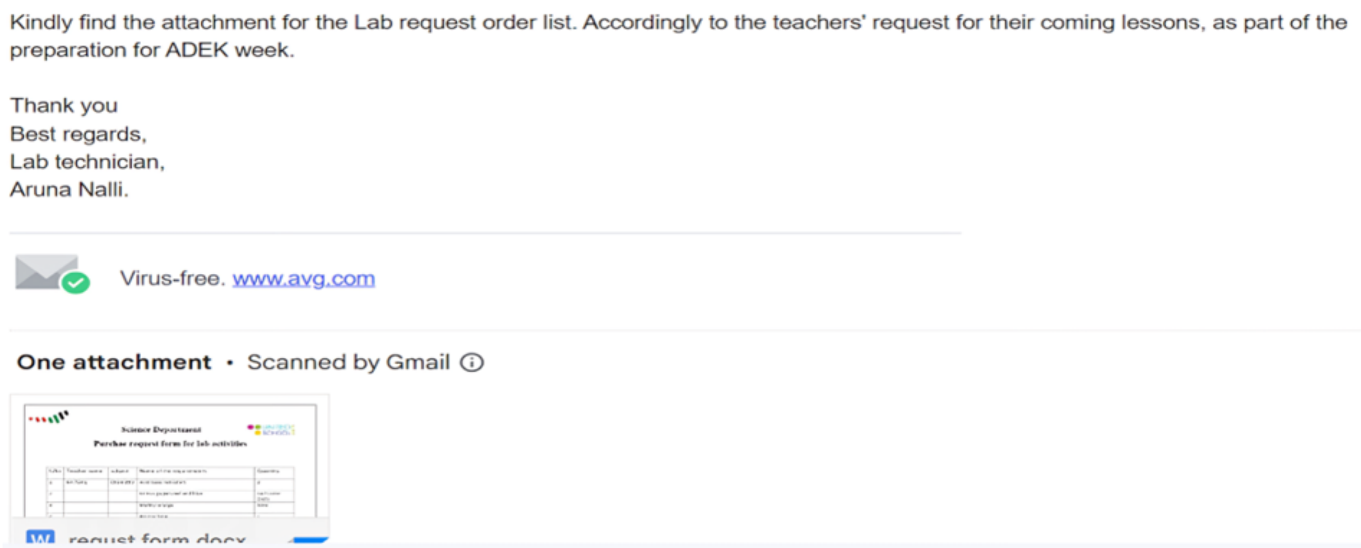
School Financial Issues

Some UAE private high schools' financial issues highly impact educational quality as they cannot organize sufficient budgets for integrating up-to-date learning materials. The schools' financial problems make it impossible for them to arrange new reagents and chemicals to carry out practical activities. Here are a few quotes from teacher Tariq:

> Interviewer: Okay, sir. If you could go back in time, what would you change?
>
> Tariq: Practical work. In my opinion, hands-on experience is more beneficial than classroom instruction of abstract concepts. I promise to prepare these reagents in advance of our next class meeting.

When teacher Tariq asked the lab technician to write down these reagents to bring them next time, the lab technician looked at me and smiled. The lab technician responded to me during his interview:

> Ms. whenever I try my best and send emails (**Figure 4**), there is no answer–nothing in my hand. The school doesn't want to pay any money, and I can show you emails if you want (lab technician).



Kindly find the attachment for the Lab request order list. Accordingly to the teachers' request for their coming lessons, as part of the preparation for ADEK week.

Thank you
Best regards,
Lab technician,
Aruna Nalli.

Virus-free. www.avg.com

One attachment • Scanned by Gmail

Figure 4. Purchase request email for chemistry lab (Source: Field study)

Teaching Language Challenges

The interview highlighted teacher language challenges as crucial in understanding and conceptualizing the knowledge by the 12th grade chemistry students in acknowledging the OQA. Students found difficulty in understanding instructional material during lectures and practical activities as well and wanted a language-rich learning environment to cope with their challenges with the English language My interactions with students before some lesson observations are:

> Interviewer: What would you expect if you were learning OQA today?
>
> Majed: I want our teacher to help me understand even if he needs to translate some words and concepts (the student is weak in English); I wish we all had the chance to do experiments. There was no shortage of material, and I wanted the class to be dull and consisted solely of explanations. (Ms. I'm telling you something secret, you know sometimes I feel lost, especially when the teacher talks in English, so I start drawing better than nothing). Additionally, he should use models and animations to aid comprehension; seeing things helps more than hearing about them (class A, student 2).

Unmotivated Teacher

The interview helped me acknowledge that the teachers seem unmotivated for several reasons. Due to the unavailability of reagents and chemicals and small laboratory spaces, it becomes frustrating for the teachers to carry out practical activities and make students learn the concepts in a better way. However, teachers try to do their best by explicitly explaining the theoretical concepts and using available materials, such as pictures and illustrations, to make students' learning effective. Following that lesson, I conversed with Tariq in my office and invited him to join me for a cup of coffee at my office. I asked him "if his lesson went as expected?" He surprised me when he said,

> At the start, I was not very hopeful because I was unable to carry out practical experiments, but I explained it well to my students. As the topic was complex, I tried to provide several examples of compounds to enhance students' understanding. Furthermore, to provide more understanding, I review their previous knowledge and then give compounds examples such as esters, ethanol, and other functional groups based on their earlier knowledge.

This is what a class D student had to say when questioned after the lesson:

> Because he thoroughly discussed those functional groups, and I grasped what he was teaching, the class was effective. However, I would better understand if we had completed hands-on activities. Therefore, I will independently observe and complete that task (class D, student 1).

Results of Question 3. What Sort of Support Do 12th Grade Students Need to Better Understand OQA?

This research question aimed to discover what kind of help 12th grade students require to improve their understanding of OQA. To answer this question, I focused on delving into the viewpoints of both teachers and students regarding OQA content in the context of the official curriculum. I aimed to comprehend their perspectives on how well the curriculum matches the content and teaching techniques applied in OQA lessons. The following paragraphs present students' perspectives on the support they need to better understand OQA.

Reconsidering the Nature of the Chemistry Textbook

The curriculum's content, chemistry curriculum's nature, and time subject is expected to be taught were other factors noted by the two chemistry teachers and grade 12 students that explain their difficulties conceptualizing OQA in connection to teaching & learning. OQA's substance was extensive and abstract. Here is an excerpt from teacher Tariq:

> In all my teaching experience, this topic has been always found difficult by students because of its nature year after year, I have tried to explain it effectively, but due to small lab areas and the unavailability of chemical compounds and reagents, it has become very difficult for me. I use models, animations, and videos. But still, it is not easy. (Tareq, a teacher)

Tariq believes that to teach OQA effectively, teachers need more support. He suggests organizing workshops specifically for teaching tough topics like OQA. These workshops should show successful teaching methods, including hands-on activities. Teachers also need access to good labs, teaching materials, and model kits.

Tariq thinks technology, like virtual labs, can help, and teachers should be trained to use it well. He suggests a flexible curriculum, continuous assessments, and feedback to allow teachers to explore complex topics like OQA. Collaboration among chemistry teachers and mentoring programs can also be helpful.

Devoting More Time to Teach the Topic

According to the two chemistry teachers, the OQA topic is extensive, but they prefer to teach it during the second term of the academic year. This timing is chosen because many students require a solid understanding of this topic for the international exam. The examination council includes a few questions related to this topic in the exam, making it crucial for students to be well-prepared. The teacher needs to consider presenting the topic of OQA to students before taking their EmSAT[1]. However, some students believe it has a complex structure; therefore, it should be taught right from term 1.

Amir, one of the students, believes that organic chemistry, specifically OQA, should be introduced earlier in the academic year, spanning from term 1 to term 3. He emphasizes the abstract and voluminous nature of the subject, expressing concern about the confusion that arises when learning it later in grade 12. Amir argues that by starting OQA in term 1, students would have ample time to comprehend the topic's complexities, creating a solid foundation for subsequent terms and better preparing them for the international exam. In essence, Amir advocates an early introduction to OQA to facilitate a deeper understanding and alleviate the challenges of learning this intricate subject later in the academic year.

At the same time, another student, Ahmed, agrees with the teachers who prefer teaching OQA in the second term. Ahmed thinks the timing is essential, mainly because OQA is extensive and crucial for the international exam. This matches the teachers' plan to concentrate on OQA nearer the exam time.

When asked about his view, Amir and Ahmed said,

> Amir specifically, I think we should begin learning qualitative analysis in organic chemistry in the first three terms of the course so that everyone is on the same page. They are dense and difficult to grasp, and teacher also waited till the final year, grade 12, to explain why we didn't take Introduction in grade 11. Hence, we had plenty of time to understand this complicated topic, not just in grade 12 and second term, soon enough, he began flooding us with functional group detections. Whenever I begin to study it, I get confused (class C, student 1).

Conceptualize OQA and Other Concepts in Organic Chemistry

Conceptualizing OQA is difficult for students as it requires techniques to locate and characterize organic compounds. Students mentioned that the OQA includes functional group and solubility tests, which require more profound understanding and continued practice. The interviewees from classes D and C agreed with Tareq, the chemistry instructor, that the students had trouble understanding OQA because of the timing and kind of the lesson.

The following are the students' views:

> Rawaa: Studying and comprehending OQA is incredibly complex, sophisticated, and hard.

Rawaa expresses that OQA needs to be more explicit; they feel that OQA is too abstract, complex, and complicated, suggesting that it might be more suitable for university-level learning, especially for those pursuing pure chemistry. Rawaa suggests removing OQA from their syllabus.

Meanwhile, Omar supports Amir's suggestion, which advocates introducing OQA teaching starting from term 1. Much like Amir, Omar acknowledges the potential complexity of OQA and may emphasize the benefits of an early commencement. He could argue that

[1] EmSAT–The Emirates standardized test is a national system of standardized computer-based tests, based on UAE national standards.

initiating the topic early enables students to progressively grasp its intricacies, leading to a more comprehensive understanding when the exam approaches.

> Omar**:** Teachers are scrambling at the last minute to teach this complex subject, particularly the alkenes, alkynes, and alkanes. I won't even grasp it. Ms, please, was it like that during your time? He laughs … (school B, student 2).

The outcomes from student interviews present a nuanced comprehension of varied viewpoints regarding the optimal timing for instructing OQA. The student interviews shed light on different opinions about the best time to teach OQA. For instance, Ahmed and perhaps Rawa, point to the importance of timing, especially in the second term, in order to be well-prepared for the exams. On the other side of the argument, students like Amir and probably Omar strongly recommend the early start of OQA to address the complexities some people have with this kind of system.

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Analysis of Findings

Teaching and learning resources and teaching challenges

Reagents, the laboratory space, and equipment for effective practical based OQA teaching is immensely significant–according to the resource based learning theory, the role of tangible resources is critical in developing relevant knowledge and improving learning outcomes (Duffy & Cunningham, 1996). According to Ratamun and Osman (2018), practical work fosters scientific attitude among chemistry students, contributing to improved problem-solving competencies. Laboratory activities play an integral role in cultivating interest altering attitudes and supplementing effective chemistry teaching. Furthermore, virtual labs are immensely effective compared to physical labs.

The study conducted by Hsiung (2018) revealed that students overall academic performance in chemistry improved due to Moodle e-learning platform where the learners could access the digital resources at any time. When chemistry instructions were integrated with augmented reality, and simulations, the students found digitalized resources highly beneficial–it led to improved ability to answer questions and grasp in-depth knowledge about several chemistry concepts. The outcomes of the research indicated a positive impact on the student's chemistry learning through incorporation of e-resources. Digitalizing chemistry education seems to offer a workable solution for the insufficient materials and chemicals in the laboratory, that participants in this study mentioned.

In such regards, the issues faced by the chemistry instructors, such as the large class sizes, and unavailability of the academic resources, resonate with the previous research on the impact of the materials constraints of practical lessons, limiting the student's ability to understand conceptually which present significant obstacles to students' understanding of OQA (Carey, 2000). Concepts are developed through experiences, which involve the construction of complicated representational structures (Carey, 2000).

As per Lee and Takahashi (2011), lesson plans are integral instruction tools, which dictate and order the teaching sequence. Yet discrepancies often exist between the planned and actual class outcomes. This prompts inquiries on the issue of how teachers adapt to uncertain situations during real-time interactions and incorporate lesson plans adequately. Lesson plans typically lack precise details regarding the actions and choices teachers and students make during the real-time classroom conversations. Hence, it is critical to analyze the teaching practices within a particular variating context of the classroom settings, as highlighted by Cochran-Smith and Zeichner (2009), teacher educational programs should be examined in such a way that it identifies their complexities, connections, and dynamics to the individuals involved and environment. The lack of mandatory academic resources leads to potential barriers towards the conceptualization of OQA by the students. This resonates

The absence of resources significantly limits the student's abilities to comprehend OQA within chemistry.

According to Katsampoxaki-Hodgetts et al. (2015), science laboratory techniques are immensely integral for understanding the scientific concepts are hindered by the challenges related to ineffective teaching strategies and inadequate resources.

The importance of overcoming the challenges discussed is evident in the call for inquiry based or cooperative learning approaches as discussed by Concannon and Brown (2008) to improve student learning and achievement within OQA. The findings of Vermaat et al. (2003) revealed that groups of chemistry students were able to develop animations which led to a strong learning effect. Students were able to give an explanation of why solid salt and distilled water are insulators. However, the salt solution is able to conduct electricity. The students were also able to replicate scientific accepted models. Teplá et al.'s (2022) outcomes revealed that almost 565 science students who utilized 3D models and animations elevated the intrinsic motivation of the students for leaning natural science subjects. The most positive effect was evident in chemistry (g = 0.74). Similarly, Wu et al. (2001) found that through the utilization of computer-based visualization tools, the students became proficient in understanding symbolic and

Practical-based instruction and student perspectives

The practical based instruction places emphasis on the utilization of the participatory driven pedagogical approaches to improve the students learning of the chemical related concepts. This is aligned with Constructivist theories that argue for active engagement and hands on experience in the knowledge attaining process (Piaget, 1973; Vygotsky, 1978). The challenges associated with the limited laboratory space and insufficient materials/resources hinder the adoption of the practical based instruction, influencing the students conceptual understanding.

For instance, Van Brederode et al. (2020) found a significant impact of pre laboratory activity design on the student's conceptual understanding during the inquiry tasks. Chemistry students engaging in conceptual understanding of the pre-laboratory activities also illustrated elevated levels of motivations for in-depth contemplation of the measurement meanings as compared to those students who are involved in conventional or limited pre-laboratory activities. The paper published by Nedungadi et al. (2015) proposed an innovative pedagogical methodology for chemistry practical experiments which facilitated the practical based instruction, utilizing three modes of inquiry-based learning:

(1) open,

(2) guided, and

(3) structured.

For this purpose, online labs proved to be effective as they offered animations, assessments, simulations, tutorials, fostering student centered learning, evidence-based reasoning, scientific thinking, and creative problem solving competencies for knowledge development and improved recall.

The study conducted by Ifepe and Anekwe, (2022) found that due to limited laboratory space, students had poor practical chemistry knowledge related to identification of atoms, molecules and ions, and acid-base titration experiment. Recommendations were made to elevate the exposure of the students to experimental work

The student-based perspectives on the issues of acquiring knowledge regarding OQA with the absence of practical based instruction aligns with the educational theories, placing emphasis on the hands-on experiences within the learning process. Moreover, the desire of the students for visible, and practical lessons corresponds with the constructivist learning theories, suggesting that learners actively build their understanding through direct experiences (Piaget, 1952).

Direct experiences play an integral role within improving student's learning in scientific concepts through fostering an-in-depth understanding and facilitation of skills development (Sofoklis et al., 2017). As for Shana and Abulibdeh (2020), practical work within science education aligns with the objectives of enhancing the students understanding, problem-solving competencies and appreciation for the nature of science. Sharpe and Abrahams (2019) places emphasis on practical work and offers direct experiences which encourages real life application of theories, and accurate observations.

Organic chemistry curriculum content and conceptualization challenges

This theme looks forward to evaluate and explore how the instructors and students perceive the content of OQA within the curriculum. The curriculum alignment Theory places emphasis on merging the curriculum content with instructional practices (Fullan, 2007)–the discrepancies between the curriculum content and the actual availability of the academic resources creates barriers towards effective alignment of all components, negatively influencing the student's comprehension.

The previous literature by Gabel (1998), and Smith and Scharmann (2008) supports the idea that hands on experiences, proper academic resources, availability of the resources, and mergence with the curriculum objectives positively influence the student's understanding of the concepts related to chemistry subject. Moreover, the research also aligns with the wider literature on the resource constraints within the science education (Bencze et al., 2002; Hodson, 1996).

Researchers such as Moe (2011) and Akkuzu and Uyulgan (2016) places emphasis on well-developed teaching programs and activity-based teachings in order to improve the understanding of chemistry students of scientific theories and promote alternative perceptions. Addressing of these multi-facet attributes contributes to more effective and resourceful chemistry education (Abarro & Asuncion, 2021; Hassan et al., 2017).

According to Fan (2010), foreign background students in university context encounter 'language shocks' stemming from the differences evident in language systems, impressions and attitudes. These shocks variate in stages, and intensity, affecting emotions and learning. Students struggle on a linguistic basis with phenomena absent or/and distinctive in their native languages such as tenses, plural nouns, pronunciation, articles and prepositions. Socio-linguistically, students grapple with different cultural nuances within criticisms, feedback, compliments, greetings, and appellations. These challenges are aligned with the research conducted by James (1980) and

Chesterman (1998), indicating interferences from their first languages. Language discrepancies impact both linguistic and socio-linguistic perspectives of communications, hindering the student's comprehension and integration within the university environment.

Issues in instructional methods usage in the classroom

The concerns within the instructional methodologies utilization within the classrooms underscores the need for effective teaching approaches to facilitate the OQA conceptualization by the students. In line with the constructivist theory, it places emphasis on the active engagement and interaction of the instructional methods (Dewey, 1916). The research sheds light on the current instructional methodologies which lack practical based approaches and contribute to the student's challenges/struggles in the understanding of the OQA.

Previous research such as Weaver et al. (2011) supports the notion of practical based approaches, as they improve the student's understanding different scientific concepts

According to Weaver et al. (2011), the relationship between the instructional methods is evident in the impact of laboratory curriculum on the chemistry students in context to theories and conceptions. It has proved to be most effective, resulting in significant gains for the students as compared to traditional and inquiry-based laboratories

The language challenges faced by students, as expressed in their difficulty in understanding instructional material delivered in English, align with the literature on language-rich learning environments (Cummins, 1981). The students' preference for explanations in their native language reflects the importance of considering language diversity in instructional practices (García, 2009).

The use of visuals, models, and animations suggested by students corresponds with multimedia learning theories, emphasizing the effectiveness of visual aids in enhancing comprehension (Mayer & Moreno, 2003). The incorporation of these elements can address language challenges and facilitate a deeper understanding of complex concepts.

Unmotivated teacher and teacher professional development

The instructors/teachers are facing variating challenges not limited to lack of motivation, frustration and other negative feelings which sheds light on the immediate need for continual professional development. The teachers' efforts to adapt their teaching methods in the face of resource limitations demonstrate resilience, but sustained motivation requires systemic support and recognition (Hargreaves & Fullan, 2013).

The teacher's suggestion for workshops, technology integration, and collaboration among teachers echoes the literature on effective professional development practices (Desimone, 2009). Ongoing training, collaborative initiatives, and mentorship programs can contribute to teacher motivation and effectiveness (Darling-Hammond et al., 2009).

Copriady et al. (2018) explain the significance of continuous training for improving the quality of chemistry education among the teachers, placing emphasis on the development of academic online community; the trainings lead to teachers embracing a mindset that aims to provide valuable experiences, employing effective methodologies like conducting laboratory experiments, to facilitate mastery of chemistry. Furthermore, the progression of school, and caliber of knowledge with experience is imparted to the students depending on Copriady et al. (2018).

According to Chu et al. (2015), teacher's expertise directly impacts the student achievement, and innovative teaching approaches improve instructional quality. Othman (2009) shed light on the positive effects of technology assisted teaching on the student achievement, aligning with the perspective of Rahman and Hasegawa (2011) that training and development of the teachers lead to improvements within competencies, knowledge and student learning. Hence, overall, the training and development of the chemistry teachers positively impact on the academic progress of the students.

Support for 12th grade students

The discussion on the support needed for 12th grade students emphasizes the importance of teacher autonomy and flexibility in adapting to students' needs (Deci et al., 1991). Teachers require support in terms of resources, training, and collaborative opportunities to enhance their instructional practices and better meet students' learning needs. The emphasis on using real-life examples and creating a language-rich learning environment aligns with research on effective pedagogical strategies (Hattie, 2009). Providing ongoing training and establishing support teams within schools can contribute to a positive learning environment (Bryk et al., 2010).

Limitations of the Study

While this study sheds light on student experiences with OQA learning in the UAE, it acknowledges limitations. Firstly, the research focuses on a single international school in Al Ain. This limits the generalizability of findings to the broader UAE educational landscape with its diverse range of schools and curricula. Secondly, the study relies on student self-reported experiences through interviews and observations. While valuable, this approach can introduce bias as students may not always accurately reflect on their learning or challenges. Finally, the chosen qualitative methods, while insightful, don't directly assess students' actual understanding of OQA concepts. This limits the ability to measure the effectiveness of teaching approaches or identify specific knowledge gaps.

According to Zhao (2023), being an experimental sciences subject, chemistry lacks experimental training among middle and high schools commonly. In many developed countries, chemistry labs equipment is replaced by computer simulations, where chemistry students fail to grasp the topic deeply. To address such issues, equipment such as electron microscopes, Raman spectrometers, X-ray diffractometers, and mass spectrometers should be allotted by the Ministry of Education (Zhao, 2023).

Recommendations

A comprehensive approach integrating several vital strategies is needed to effectively address the challenges in teaching OQA. Includes professional development for teachers to enhance their instructional skills, ensuring they are well-equipped to deliver practical-based learning experiences. Adequate resource allocation and providing the necessary materials and equipment to facilitate hands-on learning are also crucial. Language support for students is also essential to improve comprehension, particularly for those learning a second language. The curriculum should be thoughtfully designed to better align with practical learning needs, ensuring that instructional practices support the development of conceptual understanding. Utilizing theoretical frameworks and insights from educational scholars can help guide the development of these strategies and interventions, making them more effective in improving the teaching and learning of OQA in high school chemistry classes. By focusing on these areas–enhancing resource availability, aligning the chemistry curriculum with instructional practices, and improving professional development–educators and policymakers can better understand and address students' specific challenges, ultimately fostering more effective learning environments in chemistry education. Future research may delve deeper into specific interventions and their impact on students' conceptual understanding of OQA. Hence, it can be concluded that addressing the identified challenges in teaching OQA requires a comprehensive and collaborative approach. This includes professional development for teachers, resource allocation, language support for students, and thoughtful curriculum design. Theoretical frameworks and insights from educational scholars can guide the development of interventions and strategies to enhance the teaching and learning of OQA in high school chemistry classes. Rawaa's journey provides valuable insights into the multifaceted nature of students' experiences in the academic realm. By critically examining her case in the context of existing literature, we gain a deeper understanding of the challenges she faces and the broader implications for educational practices. The recommendations proposed by Stojanovska et al. (2020), revolve around ensuring ongoing improvement process within chemistry education; it is critical to improve curricula, enhance working environments, provide needed equipment for experiments, teaching materials and other academic resources. Stojanovska et al. (2020) also proposed financial support should be boosted for maintaining school equipment and facilities. Teaching quality depends upon the availability and access to lab materials and resources, that are critical for students to acquire comprehensive knowledge. Allocation of an annual budget for the teaching resources in natural sciences subjects is imperative along making the labs advance by equipping it with the latest chemistry experimentation equipment. Ineffective fund allocations often leave the schools with absence of sufficient resources to fulfil the basic needs of the 109 students academically wise.

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