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Creating the integrative STEM lesson unit plan for 9th grade chemistry students

MASTER'S DEGREE DISSERTATION

7M01502 - Chemistry

Kaskelen, 2025

Faculty of Education and Humanities
Department of Pedagogy of Natural Sciences

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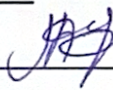


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students

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ABSTRACT

STEM education-which encompasses science, technology, engineering, and mathematics-is becoming a vital part of modern education as the demands of the 21st- century workforce evolve. In particular, there's a growing need to rethink how these subjects are taught to make them more engaging, hands-on, and directly tied to real-life situations. This project centers on the development of a dynamic chemistry unit specifically designed for 9th-grade students. Rather than sticking to textbook-heavy instruction, the unit incorporates practical experiments, real-world connections, and collaborative group work to deepen students' understanding of essential chemistry concepts. The goal is not only to improve academic outcomes but also to foster transferable skills such as critical thinking, creativity, teamwork, and problem-solving- skills that are increasingly valued in both higher education and future careers.

The design of this unit aligns with national and international educational standards, ensuring that content remains rigorous while being accessible and relevant. A major focus is placed on connecting chemistry topics-like reactions, matter, and the periodic table-to everyday scenarios, such as cooking, environmental issues, or technology. This contextualized learning helps students see the point of what they're studying, which in turn can boost motivation and reduce disengagement often seen in traditional science classrooms.

Additionally, the study examines how such an approach affects student outcomes, including academic achievement, engagement, and their attitudes toward STEM as a whole. Preliminary observations suggest that students respond positively to lessons that are interactive and rooted in real life, showing increased participation and interest in the subject. Long-term, this model could serve as a framework for other educators aiming to bring STEM subjects to life in a more student-centered and meaningful way.

Keywords: *STEM education, chemistry instruction, student engagement, real- world context, project-based learning.*

АНДАТПА

STEM-білім беру – ғылым, технология, инженерия және математика пәндерін қамтитын заманауи білім беру бағыты – қазіргі тез өзгеріп жатқан әлемде бұрынғыдан да маңызды бола түсті. Осыған байланысты мұғалімдер мен зерттеушілер оқушыларды бұл пәндерге көбірек қызықтыру үшін дәстүрлі оқыту әдістерінен тыс, жаңа тәсілдерді іздеуде. Бұл жоба 9-сынып оқушыларына арналған химия пәнінен ерекше оқу модулін әзірлеуге бағытталған. Мұнда тек теориялық білім берумен шектелмей, тәжірибелік жұмыстар, шынайы өмірден алынған мысалдар және топтық жобалар арқылы оқушылардың химияны терең түсінуі мен логикалық ойлау қабілетін дамыту көзделген. Оқу модулі қазіргі білім беру стандарттарына сай келеді және сабақтарды оқушылар үшін тартымды әрі өмірмен байланысты етіп ұйымдастыруды мақсат етеді. Мысалы, химиялық реакциялар, заттардың қасиеттері және периодтық жүйе сияқты тақырыптар оқушылардың күнделікті өмірімен байланыстырылады – тамақ дайындау, экологиялық мәселелер немесе заманауи технологиялар арқылы. Мұндай тәсіл оқушылардың пәнге деген қызығушылығын арттырады. Сонымен қатар, зерттеу нәтижелері бұл оқыту үлгісінің оқушылардың оқу үлгеріміне, пәнге деген көзқарасына және STEM саласына деген қызығушылығына оң әсер ететінін көрсетеді. Сабақтар интерактивті және өмірмен байланысты болғанда, оқушылар өздерін белсенді әрі сенімді сезінеді. Бұл тәсіл болашақта STEM пәндерін басқа мектептерде де тиімді оқытуға үлгі бола алады.

Кілт сөздер: *STEM, химия, өмірмен байланысты білім, оқыту, жобалық жұмыс.*

АННОТАЦИЯ

STEM-образование, включающее науку, технологии, инженерию и математику, становится всё более актуальным в современном мире. Чтобы соответствовать вызовам времени, педагогам необходимо переосмысливать подходы к обучению и находить новые способы заинтересовать учеников. Этот проект посвящён разработке учебного модуля по химии для учащихся 9-х классов, который уходит от привычных лекций и зубрёжки. В нём упор делается на практические эксперименты, применение знаний в реальных жизненных ситуациях и работу в командах. Такой подход помогает учащимся не только глубже понять важные химические темы, но и развивать важные навыки — критическое мышление, умение сотрудничать и решать задачи.

Учебный модуль соответствует современным образовательным стандартам и стремится сделать обучение не только полезным, но и интересным. Например, темы, такие как химические реакции, свойства веществ и таблица Менделеева, связываются с повседневной жизнью: от приготовления пищи до экологии и технологий. Это помогает ученикам осознать, что химия - не абстрактная наука, а часть мира вокруг нас.

Исследование также анализирует, как такая форма обучения влияет на успеваемость, вовлечённость и отношение школьников к STEM-дисциплинам. Предварительные результаты показывают, что ученики становятся более мотивированными и охотнее участвуют в процессе, когда видят смысл в изучаемом. В перспективе данная модель может быть полезна для других школ, желающих обновить подход к преподаванию естественных наук.

Ключевые слова: *STEM, химия, прикладной подход, обучение, проектная деятельность.*

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LIST OF ABBREVIATIONS

STEM – Science, Technology, Engineering, and Mathematics

ICT – Information and Communication Technology

CBL – Context-Based Learning

MVR – Multiple Visual Representations

PBL – Project-Based Learning

5E Model – Engage, Explore, Explain, Elaborate, Evaluate

LA – Learning Assistant

IUPAC – International Union of Pure and Applied Chemistry

PVC – Polyvinyl Chloride

ADDIE – Analyze, Design, Develop, Implement, Evaluate

SMAN – Sekolah Menengah Atas Negeri (Indonesian State High School)

M&E – Monitoring and Evaluation

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INTRODUCTION

Today's classroom of learners exists in a time teeming with technology, challenging problems, and rapidly evolving careers. Even still, many chemistry teachings in schools rely on chalkboards, antiquated algorithmic techniques, and a barrage of worksheets. Let's be real, technology and the present times are not challenging; that is just bad pedagogy, period. When students ask, "Why are we learning this?" and a teacher cannot provide a substantial response, then change needs to happen. This study addresses that gap and provides a new integrative way of teaching 9th-grade chemistry through STEM education. Not to make it "fun" while strictly following standards, but to build relevancy and ultimately, effectiveness. Specifically, this research creates a chemistry unit plan that does not compartmentalize science, technology, engineering, or mathematics, but instead, presents them in an interrelated way in a framework that represents the world. Whether using a chemical reaction to create a water filter, or examining Environmental case studies through a pH indicator, the intent is to get students not only thinking about salient content, but doing, and connecting classroom content beyond the school walls. Classrooms are filled with students who have access to instantaneous information, enjoy using representations, are not afraid of technology, and value collaborative learning. But to think if we place firmness of wanting students to learn complex scientific ideas in a dry lecture using antiquated learning techniques will not create a disconnect or frustration is misleading. Chemistry, which is viewed by students already as difficult or "not for them," becomes an alternative path away from deeper knowledge and learning. They learn chemical equations in one class, basic math functions in another, and never see how they connect. But in the real world, designing something like a safe water purification system involves not only understanding chemical reactions, but also engineering design, data analysis, and possibly even coding. STEM integration encourages students to think holistically, pulling together ideas across disciplines to solve meaningful problems. This approach also supports equity in education. Not every student comes into the classroom with the same background knowledge or support at home. By shifting from lecture-based instruction to project- and problem-based learning, we give more students the opportunity to succeed through multiple learning styles-visual, hands-on, collaborative, and inquiry- driven. It gives traditionally underrepresented students in STEM a better shot at realizing their potential. Let's face it-traditional chemistry education often ends up being a memory game. Students cram facts for the test and then forget them shortly after. Formulas are memorized but never applied. Lab work is minimal or overly scripted, and group projects often lack direction or real-world purpose. As a result, students disengage, interest fades, and chemistry gets a bad rep as "too hard" or "not useful." Even worse, many schools still treat STEM as a buzzword rather than a real teaching strategy. Science is taught in isolation, with little connection to technology, engineering, or mathematics. This fragmented approach does little to

prepare students for interdisciplinary challenges or problem-solving tasks in real life. The lack of hands-on, inquiry-based, and cross-subject learning is a major flaw in current chemistry instruction. This study addresses that problem by designing and testing a fully integrated STEM lesson plan specifically for 9th-grade chemistry. The aim isn't just to teach content—it's to *transform* how chemistry is taught and learned. We are in a context today where STEM skills are not only necessary for scientists or engineers, but necessary for nearly every occupation. Whether a physician, software engineer, architect, or even a policy maker, it is important for individuals to have the ability to actualize solutions to problems through evidence and logic. Chemistry is known as the "central science" and provides a fairly natural pathway to providing these types of skills. Although students must use problem solving skills in innovative and multifaceted ways, their skills will not develop if they are merely taking notes, and filling in multiple-choice responses. Students must conduct experiments, collaborate, and construct things. This is why integrative STEM teaching is built upon project-based learning, real challenges, and creative exploration that has been found to enhance student learning experiences and increase engagement. The reinvention of experiential chemistry lessons transforms classrooms into environments that encourage students to learn by doing and thinking, which meet and match 21st century education. This is not only progressive, but it is important that we make the transition to integrated STEM education in chemistry. The workforce of the future is relying on it. By both focusing on development and implementation, this study provides a holistic approach to how STEM principles can be applied to everyday teaching.

1. THEORETICAL ASPECTS OF INVESTIGATION

1.1 The Critical Role of integrative unit plan for STEM Education

The article presented by Utmeemang and Buaraphan (2024) examines the impact of the integration of Small-Scale Chemistry (SSC) with the STEM framework while also utilizing local contexts, in order to enhance the quality of learning, and thus, the quality of students' performance and 21st century capabilities. At the centre of their research was the design and implementation of a unit plan on the basis of a Context-based Small-Scale Chemistry STEM (CSSC-STEM) model. The CSSC-STEM model provides a unique synthesis of real-life problem-based learning, local resources, and hands-on microscale experimentation that can be tailored for different environmental sustainability and cost considerations - surprising given the systems calling themselves schools that have laboratory resources that resemble public services.

The unit plan follows a 24-hour module to teach the subject of reaction rates and is organized into four lessons, Lesson 1 (6 hours) describes the meaning of reaction rate, Lesson 2 (4 hours) provides a foundational view of concepts and energy changes, Lesson 3 (6 hours) examines the factors that affect reaction rates, and Lesson 4 (8 hours) applies their knowledge to the local food product, fermented pork sausage. The teaching plans are structured with reference to the six instructional steps of the CSSC-STEM cycle. For instance, each lesson is planned around the following steps: (1) identifying a real-world/local problem, (2) collecting data, (3) designing solutions, (4) experimenting and practicing, (5) evaluating and improving, and (6) present outcomes.

For example, in Lesson 3, students start Lesson 3 by watching short videos that show real-life situations, such as a person washing dishes, and food preservation techniques such as using salt to preserve catfish. These real-life, relatable examples were used to engage students with curiosity and connect the curriculum with their daily lives, and subsequently generate interest in investigating chemistry when making choices about their reactions. After the introduction to the lesson was complete, students were informed that they would design and conduct small-scale microscale experiments utilizing local materials found around their home or school (e.g., eggshell powder, vinegar, and recycled containers) to investigate how reaction rates of chemicals and effects were influenced by different conditions. The unit plan strongly emphasizes student-led inquiry, collaborative work (cooperative), and iterative testing, to get students beyond surface-level engagement to a deeper, meaningful, critical-thinking engagement.

The authors found that students following the unit plan significantly improved their academic achievement, as showed statistical improvements when comparing group means, and 21st century learning and innovation skills: (i.e., those related to developing problem-solving, creative thinking, communication, and teamwork). While students in the traditional chemistry context transferred their learning about chemical reactions to local contextualization, they also saw value in learning about the local food

product, and they saw value in responding to the local factors impacting learning in meaningful ways that were culturally relevant to their lives. The experts who evaluated the plan comments on how the plan easily can be adapted in schools without laboratory facilities, and find practical applications for research-focused chemistry teachers and science educators among other things.

In conclusion, clearly from the immersion by Utmeemang and Buaraphan study, the unit plan can be seen as a viable example of a scalable CSSC-STEM model where students actively learn about small-scale, low-cost chemistry experiments that can be steeped in students' local culture that promotes active learning by students while providing opportunities for students to prepare, create and collaborate at a broader level for their future, and report back on their learning with artifact creations while showcasing the value to be explored more deeply in 'reflections'. The success of their planning example encourages us to embrace the idea of re-thinking our lesson planning process for models that provide opportunities where students' curriculum content connects to their everyday lives with relevance and meaning.

Felder and Brent (2024) provide an evidence based, very practical approach to designing and implementing effective STEM instruction in their book *Teaching and Learning STEM: A Practical Guide*. A major theme of the book is that high-impact teaching doesn't just "happen" but requires deliberate unit planning that is based on how people learn. They argue that unit plans provide the structure of any course, particularly in STEM disciplines where cognitive load is high and students often struggle to bridge the divide between theoretical learning and real-world application.

Felder and Brent suggest a backward design approach to unit planning that does not start with content but starts with what we want students to learn. They highlight the importance of clear, measurable learning objectives that are sophisticated enough to encompass more than remembering and understanding, and appraising and analyzing, rather than solely understanding and applying which are lower-order of learning. The authors highlight that learning objectives have to be very clearly defined so that they are "truthfully mapped" to the specific in-class activities, assignments, and assessments planned in the unit plan. The authors use the unit plan to align each learning outcome to specific activities, assignments, and assessments. Using this tight alignment ensures that everything we ask students to do in the unit plan (mini-lecture, hands-on task, group assignment, quiz, etc.) is based directly on the learning objectives.

Felder and Brent place substantial emphasis on active learning as a non-negotiable component of unit plans—and also recommend it as a key to success in every instance, if the goal is for students to make meaning of authoritative knowledge. Instead of the classic session where a lecturer lectures for an hour, Felder and Brent model researching evidence based alternatives to lecturing; chunking instructions into small segments of 10-15 minutes, and then allowing students to engage in think-pair-share, concept tests, or open-ended problem solving. Felder and Brent's evidence based approaches to learning in an authentic context are built directly into their unit plans as scheduled routines rather than initiatives or sideline quests. Each class session is viewed as a small cycle of instruction → application → feedback.

Also important in planning a unit is scaffolding. Often times, students come into the classroom with all kinds of gaps in prerequisite knowledge or inefficient study habits. Good unit plans recognize this and, in the beginning stages, requires additional guidance for students and then, over time, it could provide less guidance and more independence for learners. For instance, in the first few lessons, an instructor may have students effectively using a template or guided worksheets to help them solve or engage with problems; in the last few lessons, the instructor has switched supports out. By the end of the unit students should be solving complex problems individually or working collaboratively in groups.

Another pillar of Felder and Brent's unit plan design is assessment for learning. Unit plans should include both formative and summative assessments. While assessing students, during a unit plan, it is equally important for instructors to assess, and ultimately revise, their own teaching. However, assessment for learning is inclusive of low-stakes quizzes, minute papers, reflection journals, etc. as part of the unit to check for understanding and promote metacognition. Moreover, unit plans should include pre-developed rubrics and grading criteria systemically shared with students the beginning of class. Assessment tasks represent the core learning goals of the course.

The book discusses team-based learning which is another criteria for unit plans including time and structure for students to work together in teams. Instructors could assign student roles within teams or student teams could utilize different types of accountability mechanisms such as individual quizzes or peer evaluations and feedback. A unit plan should include collaborative work that was challenging enough for students to require more than their own perspective when working together in teams.

Felder and Brent continually discuss the need for flexibility and iteration in their unit planning process. They write that instructors need to use evaluation feedback from students, mid-course evaluations and the instructor's own reflection on their teaching to revise and iterate their unit in real time.

Lastly, the 2024 edition of the book includes updated approaches for hybrid and tech-enhanced learning environments. The author discusses unit planning and the space it creates to accommodate both face-to-face and online modes of instruction. Unit planning can reap the benefits of learning management systems, simulation software, and (with caution) AI-based tools and other devices to support learning. Instructors ought to not consider technology as a gimmick to make unit plans more exciting; it should be considered one part of unit design that can increase student propulsion into learning, personalize the learning experience, and increase opportunities for practice.

In conclusion, Felder and Brent position the unit plan as the hub of effective teaching in a STEM context. A well designed unit plan will begin with particular learning outcomes, use active learning as a primary mode of instruction, provide quality ways for assessment and feedback, build in mechanisms for teamwork and individual accountability, and respond naturally to learning feedback and possibilities of technology. Educators who wish to do well design the kind of education that will seek to future-proof their teaching, and in doing so allows students to experience a

depth of learning that transitions into understanding more able to be recalled and used in the present and future, will do so through this guide to building unit plans capable of achieving their vision.

Sadykov, Kokibasova, Konyukhova, and Unerbaeva (2024) wrote an article that focused on design and effectiveness of programmed chemistry lessons with 9th graders in Kazakhstan's secondary schools. There has been a much-needed call for interactive, self-directed learning in school, especially following COVID. The study described an unit plan on employing programmed instruction using student engagement tools both digital and non-digital which would facilitate engagement and self-direction.

The authors described a unit plan that included these key topics in inorganic chemistry; nitrogen, ammonia, nitric acid, nitrates, and phosphorus compounds. There was a calendar associated with each lesson and each lesson had thematic continuity associated with its goals and practical mini-labs ("build a nitrogen molecule model", "make ammonia and assess its properties"), as well as, learning objectives. The thematic continuity of the lessons built consistency and scaffolding with the teaching resources and the components were academically relevant and digestible as learning content.

The unit employed a programmed learning perspective to the lessons that made learning interaction, simple, and individualized. Students used a custom built SQLite simulator and mobile engagement tools to engage in immediate feedback, reflections, and the formal learning process through logical sequences, and their own discretion. This approach was easy enough for any teacher to follow, and for any student to engage with—there was nothing complex to the programming as any learning could be interactive while also exploratory.

In the experimental implementation the authors were able to observe two groups; one group with conventional instruction and the teacher, and the experimental group using the unit plan in a programmed approach. The statistically different pre/post tests indicated that programmed lessons achieved 12% higher average gains in knowledge uptake, and distinguished from the above that programmed lessons were more effective learning in terms of understanding, retention, and motivation.

Feedback perception quotes and scale survey from learners from in the experimental group indicated high levels of student satisfaction overall with 96% of students agreed lessons were clearer, 89% wanted more programmed lessons, and all students agreed that mobile -based learning was engaging. These results clearly provide evidence that the unit plan with programmed learning using interactive tools with thematic coherence contributes to success with knowledge acquisition and student satisfaction.

Finally, in the study the authors recommended the unit plan approach for broader applicability and scale up in chemistry teaching. The authors discussed benefits of self-pacing, thinking logically, understanding behaviour of concepts, variety of assessment, and accessibility through digital tools. They concluded that this unit plan contributes to conceptual understanding, peer-to-peer, learner reflecting and learning, and that it provides a relevant lesson plan template for subsequent learning design in

contemporary chemistry education.

Summary & takeaways from the Unit Plan:

1. Thematic Continuity: Build on central chemistry content topics using sequential objectives and hands-on activities.
2. Programmed & Interactive Design: Develop self-paced modules with immediate feedback with simulated tools and digital technologies.
3. Structured Program: Include calendar with each lesson plan to labelled goals and practical labs.
4. Data-based Decision Making: Use pre/post-tests and perception survey measures.
5. Scalable and Inclusive: Designed for any chemistry teacher to use and to engage all learners.

This investigative article demonstrates how a quality unit plan underpinned with programmed learning can improve and enhance content understanding and engagement at the secondary level of high school chemistry teaching.

In their 2024 article "Practical Aspects of the Development of STEM Education in Kazakhstan," Tashetova and Syzdykova discuss how STEM is being institutionalized in the Kazakhstani secondary education system through frameworks that revolve around considered, practice-based approaches, which can provide powerful insights into developing unit plans. The authors suggest that to prepare students for many changes in the economy and technology, curricula should integrate STEM not as an appendage, but as a thematic, integral core across subjects.

Working within this idea is the espousing of active, Problem-Based Learning (PBL) methods underpinned by the 5E learning cycle (Engage, Explore, Explain, Elaborate, Evaluate) and principles of engineering design. These modes of pedagogy provide a clear structure to develop unit plan: each lesson begins with authentic problem, followed by exploration and collaborative design, and finishing with synthesis and evaluation.

For example, a STEM unit on sustainable energy would go through the following path:

- Engage: Present students with a real local energy issue (i.e., rural power outages)
- Explore: Students research, via data collection and basic modelling
- Explain: The class discusses findings—explaining why certain solutions worked
- Elaborate/Design: Students use engineering design thinking to prototype a low-cost solar solution
- Evaluate: Students reflect on their prototypes and peer critique and rubrics, use them to improve.

The article notes FILA tables (Facts, Ideas, Learning Issues, Action) as a support structure to (students') reflective works in PBL activities. This structured journaling tool enables learners to document their thought processes, relate theory and action, and prepare for presentations or formal assessments. A well-structured unit plan using this design would intentionally incorporate reflective prompts and checkpoints at each stage.

Another critical aspect they emphasize is teacher training and infrastructure. The

authors assert that unit plans must assume proficientness with 5E, PBL, and engineering not only by students, but also teachers. Professional Learning Experiences and programs like Orleu's STEM-for-All that train educators in robotics, ICT, or STEM pedagogy all factor into ensuring quality in managing for quality in unit design journal.orleu-edu.kz.

Therefore, considering not only what students will do in each module, but outlining what the teacher will need to prepare for beforehand should also be included up front in each unit plan.

The authors also reference other structural challenges including technology not equitably available, that there are little to no STEM specialists, and that there are few resources in rural areas. Effective unit plans must therefore have contingencies built in rather than ignore omitting the realities. For example, they should suggest low-cost or offline versions of activities, simplified materials, and inclusive design that could work in resource-poor settings, or even suggest outdoor experiments, hands-on models, or community partnerships in place of tricky or costly lab.

Finally, Tashetova and Syzdykova provide evidence-based recommendations for a unit plan that focus on the current policy context in Kazakhstan: coordinate with industry and university partnerships, embed gender and socio-economic equity goals, and emphasize future-ready technologies including AI, robotics, and biotechnology. Thus a model unit plan could include cross-sector collaborators, equity-focused lessons, and modular tech components.

What are key implications for unit plan design:

- Anchor in authentic challenges - Each unit begins with a local area problem or question.
- Embed evidenced-based STEM frameworks - Every lesson is organized with the 5E process and engineering design process.
- Use reflective scaffolds - Include things like FILA to track metacognition.
- Plan for teacher capacity-building - Each unit plans out where the teacher will need training and materials prep ahead of time.
- Ensure adaptability - provide low-tech alternatives that address needs in under-resourced contexts. Build partnerships and inclusion - connect to other organizations, and embed social equity.

As a whole, Tashetova & Syzdykova offer a clear plan of action: highly effective STEM unit plans in Kazakhstan—and elsewhere—must coalesce structured pedagogy, real-life relevance, adaptable delivery, and equity-driven design. Let me know if you'd like to develop this further into a tangible unit template for teaching chemistry, or other subject.

Jumarito and Nabua's 2024 study examined how incorporating Indigenous knowledge (specifically, traditional Subanen water practices) into chemistry instruction, can support a culturally relevant STEM curriculum. This study was an opportunity to develop instructional materials for teaching foundational chemical concepts while also conserving and communicating local cultural knowledge. This is significant for science educators designing unit plans that are more than just scientifically rigorous but also grounded in the students' authenticity.

The researchers had developed a unit plan focused on water purification and water quality, which are important areas in environmental chemistry. The content areas were glossed with Indigenous practices like the gathering of spring water through bamboo drains, natural filtering, and traditional storing of water. Perhaps most importantly, local practices were not considered as footnotes to scientific inquiry, but rather the core of inquiry-based learning in this unit, so that students made meaning from chemistry concepts within their local context.

The researchers used a Science, Technology, Engineering and Math (STEM) curriculum design to facilitate the unit plan and followed their recommended six phases of instructional design.

Phase 1: Engage - students were prompted to share and dramatize local marine problems concerning access to clean water.

Phase 2: Investigate - students investigated chemical properties of water (e.g., contamination) and sanitation through examples in the local environment.

Phase 3: Design Prototype - each group designed a low-cost water purification using local materials like charcoal, sand, and cloth.

Phase 4: Test and Evaluate - students tested their purification prototypes using pH strips, a turbidity test, and visual inspection to examine water's clarity.

Phase 5: Socialize - students shared the potential for their prototype use at home by discussing their findings to the class, families, and parts of their community.

Phase 6: Reflect and Refine - students were provided feedback on their prototype and then refined their design while reflecting on the scientific and cultural aspects of the learning possible through unit.

The unit plan design structure enabled indigenous ecological knowledge aligned with contemporary scientist inquiry. The unit plan positioned students were empowered to engage as designers, problem-solvers, and cultural actors. More specifically, the unit did not end with the experimentation phase. Students went out into their community creating real-world implications from their classroom learning.

The researchers had the unit reviewed by subject matter experts in the area of environmental chemistry (scientific accuracy), indigenous quality and/or sensitivity, and pedagogically soundness. The reviewers provided the unit high links in quality scores, particularly in combining the goals of STEM with cultural authenticity. This highlights that the plan can be successfully applied across various learning contexts. To sum up, there were many compatible characteristics that contributed to the quality of the unit:

A culturally relevant problem based as a starting point for learning.

Focus on design thinking model and experimental inquiry.

Using local materials and indigenous knowledge with scientific legitimacy.

Loop feedback with the community provides authenticity, relevance and accountability to scientific construct.

Structured reflection and revision promotes metacognition and ownership of learning.

In closing, the unit plan articulated by Jumarito and Nabua illustrates multiple possibilities of transforming chemistry instruction through culturally relevant

integration. By using indigenous knowledge as part of an exploration of conceptual learning, rather than anecdotal, cultural recognition benefits both curricular outcomes, but most importantly validating students identities. The unit plan provided a more complex and inclusive vision of what STEM has to offer students.

1.2 Empowering 9th-Grade Learners Through Chemistry- Driven STEM Education

Fitriyana, Wiyarsi, Pratomo, and Marfuatun conducted their study in 2024 to examine how chemistry teachers from high schools and vocational schools viewed STEM in the learning and teaching of chemistry. Although the results indicated that most teachers plan on using STEM-based instruction to increase relevance and engagement for students, the research also identified a disconnect between their positive disposition towards STEM in chemistry learning and teaching, and their teaching practice using STEM. This indicated the need for unit plans that provide concrete, structured, and accessible support for teachers to bridge theory and practice.

Another key result of this study, is the critical importance of TPACK—Technological Pedagogical Content Knowledge—when creating effective STEM-based instruction. In the 2024 study, most chemistry teachers reported feeling unprepared to combine the three elements—technology, pedagogy, and content—to form educational lessons in chemistry. Thus, any unit that will directly support teachers by including student-centered activities will also include pedagogical direction for teachers about how to facilitate the use of technologies and manage the engineering focus.

The teachers in the study identified a number of topics in chemistry as being particularly amenable to STEM-based teaching and learning. These topics were redox reactions, electrochemistry, solution chemistry, chemical equilibrium, and waste management. For instance, in the area of redox reactions, teachers suggested some innovative ideas for project-based learning, such as designing a voltaic cell from fruit to demonstrate oxidation-reduction, making ice cream so that students learn about colligative properties, and using recycled plastic to make soil pH meters. Together, these ideas can form the foundation of unit plans that are told in the context of chemistry concepts and problems that are authentic, as well as culturally relevant and provide hands-on experiences.

Despite the motivation and willingness of some of the teachers to try an instructional approach using STEM, fewer than half of the teachers communicated they had any real experience with STEM-based chemistry instruction in their classrooms. The teachers provided a host of barriers to using STEM-based instruction in chemistry courses, including time constraints, constraints on resources, and training. These barriers point directly to the design and need for realistic and teacher-centered unit plans that are well structured, with clear step-by-step procedures of the project, materials lists for the project build, assessments, and time estimates. The more user-friendly unit plans are for teacher adoption and adaptation, the more frequent and consistent the opportunity for teachers to use STEM methods.

Another important finding was the importance to include professional learning in the unit design phase. The group found that teachers learned best when the unit plans incorporated opportunities for individual reflection, peer feedback, and links to learning that were ongoing, such as; instructional videos, teacher guides and sample lesson walkthroughs. Incorporation of professional learning in the unit plan will provide not only teacher confidence for implementation but long-term improvement and development of STEM teaching practice.

In conclusion, the 2024 study Fitriyana and colleagues presents critical evidence and motivation for developing integrated STEM chemistry unit plans. Effective unit plans should be built around appropriate aspects of chemistry, include engineering design challenges, be capable of implementation in high school and vocational education contexts, and provide a great deal of support for teachers through TPACK-informed approaches. Essentially, the goal for chemistry unit plans are to help students become engaged in a relevant and authentic STEM learning experience while also providing a unit plan that allows teachers to support their practice in a reasonable way. This could help shift STEM integration in chemistry from aspiration to reality in classrooms.

Solihah, Kaniawati, Samsudin, and Riandi (2024) describe a structured and pragmatic method for the design of a learning unit on the greenhouse effect that aimed to develop students' problem-finding and problem-solving skills through STEM education for sustainable development (STEM-ESD). The article contains a literature review, bibliometric analysis, and experimental implementation, which resulted in a comprehensive and flexible unit plan that combined scientific content, engineering practice and environmental awareness.

The unit begins with a diagnostic pre-test to determine students' prior knowledge of the greenhouse effect. After this, students work on the project-based learning (PBL). Fifth-grade students designed and constructed a small-scale greenhouse prototype using simple materials such as cardboard, clear plastic sheets and drywall methods (block, flood, or wall) and some simple components of form and function. Each team of students also collected temperature data throughout the construction process and graphed the temperature of the greenhouse every two hours, at which point each team analyzed the effectiveness of their prototype in simulating the greenhouse effect.

The experiment was an important element of the unit, and it was complemented with instructional materials that provided connections to sustainability and environmental issues. Students were exposed to scientific practices and processes, challenging them to learn about important concepts including ecological impact, energy efficiency, and climate change. The unit included a strategy to model science practices and by large collecting useful and problematic purposeful models. Colly transforms science (dog models by probing each model. dog's response for ecological impacts. Each had to model need to build an experimental set can as knowledge deducts species, donings responses and carefully probing or to consider. Therefore the unit was designed to create an experience for students to construct knowledge not held by the passive phase of learners.

The inquiry was structured into several phases including: an assessment of what students knew at the outset, framing, prototyping, constructing logs and analyzing her for collecting; culminating in a post-test to assess growth plans, and reflecting on the process. The phased model used for inquiry allowed for distinct students conduct Luka guided inquiries within a specified time context. It a44.88cm for them to practice for their graduation performance exams, formative assessment.

Their study showed significant increase Figure Improvements of IDPs prospects. After completion of their low-cost greenhouse project feeding natural previous mar-the students were better equipped to extend their discussions about the greenhouse effect relative to data trends, factors, or simple practical answers to climate challenges. The students also noted director improvement engagement, and motivation for learning after a hands-on real-world project.

One of the key strengths of their learning units is low-cost generalizing frame in the storms of society. Surely no from the every day, never each to building things in large part. There was also sustainability, will engage learning, forged practical purposes beyond the science and simplify it for 21st century student learning.

In summary, their learning unit has clearly demonstrated success in STEM-ESD paced4Y once leveraging the structure and considering the global sustainability issues into a well-focused engaging unit of meaningful, reconciliation between inquiry projects spool and various elements integrated and making this migration towards cultural and environmental sustainability. For teachers, this learningality is a serviceable display note and track good will fortune or C, A Emmanuel Snyder, course as a livable model on how effective create meaningful and lesson effectively that engages students by considering legitimate performance-based practice, (rather than passive immersion, indifference).as an educator, fostered keen critical thinking, innovation and shelters thread microfiber.

In their 2024 case study, Karmanova, Madybekova, Kavak, Ualikhanova, Zharylkassyn, and Umarova examine how digital technologies enhance the professional competence of future chemistry teachers in Kazakhstan. In defining such unit plans, they identify that developing a unit plan is both a learning avenue for students, and a preparatory space for teachers to work with modern lesson design.

The researchers embedded their study within a theoretical landscape to guide their work, including a survey of the world and an EU digital teacher literacies strategy, alongside written surveys of pre-service chemistry teachers about their apparent familiarity, use and comfort with digital tools. Almost all students indicated the importance of technologies such as simulated or virtual labs, electronic textbooks, and game-based platforms in enhancing their learning of professional competencies. They took this in consideration and developed a unit plan based on virtual and interactive tools, interwoven into the principles of core chemistry topics, e.g., qualitative and quantitative analysis in analytical chemistry.

To provide a high-level appreciation of the unit plan, the components include: Electronic textbook modules designed to align with curriculum outcomes, blending self-paced lectures, virtual lab experiences, and embedded quiz availability that mixes content knowledge, and develops digital fluency.

Virtual laboratory experiences that allow prospective teachers to practice simulations for analytic based experiments - an exceptional opportunity to develop both pedagogical and technological skills.

Gamified activities and levels that contribute to students' engagement in learning while developing higher order thinking, creativity, and problem solving.

Reflective teacher-learner "checkpoints" where students 'self-evaluate their technical use, pedagogical decisions, and digital literacies through questioning and monitoring.

An experimental study design comparing control and experimental groups. The experimental group who used the digital unit plan, increased their high-level professional competence from approximately ~23% to also close to 58% - while the control group increased their high-level professional competence from ~20% to ~32%, however the experimental cohort showed greater growth together.

This study highlights that a vital unit plan for future chemistry teachers must: Include chemistry as content and real digital pedagogy through active engagement with virtual labs and interactive modules.

Have a number of scaffolded digital tasks, which gradually move from guided work (simulations) to student co-designed experiments or teaching activities.

Develop pedagogical and technology competence in parallel ways, not in separate silos.

Incorporate assessments for learning, and reflectivity and observation to promote continuing professional learning and growth of teachers.

Provide gamifying and level-differentiated formats to maintain interest and motivation, which can be selected to support students' individual learning intent.

Be contextually pragmatic for the locale with available software and materials that was aligned to curriculum outcomes.

In conclusion, Karmanova et al. have provided a replicable model, a unit plan that fuses chemistry content, digital innovation, and teacher educator, in a sequence that enables pre-service teachers to develop pedagogical confidence, digital literacy, and pedagogically sound teaching practice as they become professional teachers. In their 2024 conference paper, Bakytkazy, Kuralay, Nursultan, and Nurman compare the purpose and characteristics of STEM education in the two countries of the United States and Kazakhstan. Comparisons like this provide important information for unit plan development that is STEM focused for two different national contexts.

The authors specifically define STEM education as not just an interdisciplinary collection of subjects, but as an intentional approach to education, where the purpose is to prepare students for addressing complex real world problems. In the United States, STEM is focus on workforce readiness and innovation strategies with an emphasis on problem solving, inquiry and integration. Kazakhstan understands STEM to modernize the education system, improve national innovation capacity and be part of global scientific and technology trends.

Several areas of commonality emerge from their analysis that are important for

unit plan design. First, both approaches advocate a focus on authentic, problem-based learning, as opposed to learning purely through rote memorization. This means when designing unit plans, the activities should begin with tasks that are authentic to students and create a connection to the real world. Using tasks such as environmental analysis, engineering design tasks or data from models that students have developed are all examples of tasks that can help develop deeper engagement.

Second, both approaches advocate for 21st century competencies; creativity, collaboration, communication and critical thinking. This means that unit plans should have opportunities for students to work in structured teams, provide feedback to each other and to use a structured design cycle, instead of lecture and individual tasks.

Third, for both approaches, technology is used as both pedagogy and content. In Kazakhstan, the intent is to promote leveraging SMART technologies and digital tools workflow like expected in the U.S., considering the realities of local infrastructure. Good unit plans will consider both face-to-face and digital modalities, intended the units will easy provide and train and platform.

The authors provide some examples of systemic challenges. The authors suggest that U.S. classrooms typically have better funded laboratories for students and curriculum delivered from professional. Kazakhstan teachers often have limited laboratory access and limited dedicated curriculum. Therefore, your unit plans should correspondingly be pedagogically flexible and context sensitive. Unit plans should note low (or no) cost and offline examples of tasks, list possible listed resources that can work at the teacher's local location, and protocols that can occur, regardless of how high or low the resources of their respective classes.

Finally, teacher support arrives as a significant component. Good unit design starts with how educators will be supported by either professional development, modelling STEM pedagogies, and identifying curricular elements already designed for us. The authors suggest building teacher support within and throughout unit plans, such as explicit facilitators' notes for storyboards, guidance and links to developed learning materials, for teachers who have gaps in STEM teaching experience.

Unit Plan Design Principles drawn from the paper:

- Anchor learner experiences on real life problems that are culturally and socially relevant to learners in both countries.
- Structure activities so that design iterations are done as a team, with collaborative and critical thinking.
- Integrate technology in a responsible way, with respect for the locally practical.
- Plan for flexibility - units that will do well for everyone will perform well in multiple resources contexts.
- Embed teacher support in the unit plan: explicit instructions, extra supports and further development links.

In closing, Bakytkazy et al. proposed a comparative framework for facilitating culturally responsive, resource mindful and capacity-building unit planning. Their findings note that a globally relevant STEM curriculum must be grounded in local,

technological supports and teacher empowerment - there are no better underpinnings of strong unit design for chemistry and others.

In the study by Valiyeva, Sagatbekkyzy, Shavaliyeva, and Matayev (2025) the authors examine the role of project-based learning in the implementation of STEM education in schools. Their study contends that for STEM to take hold meaningfully in the school curriculum it needs to be embedded in unit plans that design interdisciplinary, hands-on, and student-centered learning experiences. The authors contextualize the study within international and national education theory, using ideas from a variety of educational theorists and thinkers such as Dewey, Piaget, and Vygotsky. The authors emphasize real STEM is not limited to experiments or 'content' based theoretical learning; students should be actively engaged in inquiry-based tasks that require an elaboration to real-life problems and opportunities to demonstrate collaborative problem-solving abilities. The authors took this theoretical understanding of project-based learning and developed a STEM project-based learning unit plan for a group of 9th graders at their school. Prior to designing the unit, the authors conducted a diagnostic assessment of the students' interests and baseline competencies to inform the content and project of the STEM learning unit. The structure of the learning unit included a clear and shared understanding of the phases of the unit – introduction of the theme, investigation and identification of the problem, research and planning, prototype design and development, prototype testing, presentation, and reflection. Each phase included clear objectives and performance indicators that enabled instructors and students to monitor progress and determine areas for improvement. Project themes in the author's learning unit were inter-disciplinary and nested combinations of chemistry, physics, mathematics, while also demonstrating elements of engineering and computer science. The projects included developing simple mechanical systems, developing models for environmental monitoring, and simulating real-life problem scenarios. In addition to content and research phases/barriers, the authors also developed their unit through the lens of developing soft skills throughout their project-based learning teams through public presentations and reflective assessment tasks. Throughout the implementation phase, the authors explored if there were any differences between two groups of students - one group that was taught in a traditional model, and the other taught through the STEM project-based learning unit. The authors reported students who engaged in the project-based learning experience had much higher technical skill scores, higher motivational levels, and greater interest in STEM fields. Technical skill competence increased by over 30%. While students also reported improved digital literacy and improved independent thinking. Not only were cognitive developments evidenced through the implementation of the learning unit, students were also reflecting about improvements as a team, improved group creativity, and self-confidence. The authors argued that the success of the learning unit was its ability to provide meaningful context-driven learning experiences where students were engaged in active not passive learning experiences. They argue that integrating project-based STEM units can benefit an interdisciplinary approach to teaching other subject areas, including the humanities approach skills and content

understanding. Overall, the research study by Valiyeva and colleagues provided a functional and meaningful example of the value of mapping a STEM unit plan in schools. By beginning with students' interests, framing the lessons with authentic problem content, and engaging in hands-on group projects, Valiyeva and colleagues demonstrated how STEM could be integrated into the school curriculum to promote academic achievement and develop 21st century skills. The same 'map' allows for a transition from traditional delivery of content to engagement through experience-based learning with a solid basis for future-ready learning.

Yesnazar and colleagues (2024) introduce an integrated, systematic approach to developing meta-subject skills in primary school learners through STEM-based education. They advise that the early integration of learning disciplines is essential, arguing that unit plans are designed for STEM in such a way so as to develop critical thinking and creativity and transferable skills early on. Yesnazar et al. do not suggest that STEM be treated as an isolated area of study; rather, they advocate for an integrated approach where science, math, technology and even aspects of language arts and arts might be scaffolded together to solve real-world problems. Their proposal is based around an elective course called "Secret of the World" for second-grade students which serves as an example of a complete, fully developed unit plan reflecting an integrated, interdisciplinary theme in project-based learning. The unit introduces students to natural forces, simple machines, ecosystems and digital storytelling with tasks calling for collaboration, observation, experimentation and presentation. The plan is structured, with specific phases for immersion in the theme, hands-on experience in natural sciences, task-based integrations, context to reflect on the learning, and finally, a digital product plan. At various points in the plan, the students are guided to develop meta-subject skills such as logical reasoning, analysis of knowledge, communication skills, self-regulation, and learning habits for adaptability. These skills are not considered the by-products of the unit, but rather part of the desired learning that is embedded into the design of the activity. There are digital tools planned into this unit, including education sim, interactive sites, and creative media software, all chosen to match the cognitive level of learners at the primary grade. Of importance, the authors have provided a system of pedagogies which includes cooperative learning, design thinking, modeling, and visual mapping, that support teachers to present content that is rich conceptually and age appropriate. The framework also recognizes assessment by way of reflective conversations, formative feedback, peer assessment and portfolio tasks and serves to demonstrate learning without reliance on traditional testing systems. Finally, Yesnazar et al. suggest that in the primary school age group, STEM unit plans can serve to create a good foundation for interdisciplinary thinking and lifelong learning when the units are useful, grounded to real-life, and reinforced with digital access. They demonstrate that even at early ages, learners can grapple in significant ways with very complex ideas if the lesson is purposeful, scaffolded, and anchored in real world experiences. The presentation offers a model for educators who want to shift away from coverage of content towards intentional building of broad competencies for young learners that will serve them in the future.

Ospanbekova, Ryskulbekova, and Iskakova (2024) describe how upcoming educators are being prepared to leverage STEM labs in their future primary education practice in their study. They argue that the most important aspect is mindful planning of the units. Their study outlines a systematic training program where pre-service teachers learn not only STEM knowledge, but to design, use and assess unit plans around hands-on lab approaches.

The proposed education program begins with the workshop component that models unit planning and design. Pre-service teachers are provided with an overview of essential components of STEM units, such as authentic context, learning outcomes, inquiry question, materials checklist, safety rules, and assessment. After this, pre-service teachers collaboratively co-construct mock unit plans based upon topics in primary, science (e.g., plant growth, simple circuits, and not so basic chemistry) with particular attention paid to lab-based activity that is age and resource appropriate.

Each unit plan includes an outline: an entry activity to engage students' curiosity, guided inquiry challenges, hands-on investigation activities, data collection and interpretation, group reflection, and assessment through formative tasks. Pre-service teachers learn to incorporate the scaffolding strategies to ensure primary students can appropriately engage with the investigation and draw meaningful conclusions (e.g., stepwise instructions, visual icons, assigned roles, peer partners enabled the task).

The authors, importantly, included the iterative task of peer-review and reflecting. After candidates presented their unit drafts, candidate teachers peers would give feedback regarding, for example, the quality of their questions, pacing, safety rules, appropriateness of assessment and differentiation regimes. This negotiation of effective unit plans models what curriculum development includes and prepares pre-service teachers for ongoing development of their teaching units.

The study authors reported that this training program did contribute to pre-service teacher candidates being more confident in designing STEM units with lab investigation components, as their pre- post-training surveys found significant increases to their self-reported competency of connecting lab actions to learning objectives, anticipating classroom challenges in the lab, organizing materials, and assessment of student work. Qualitative reflections showed that participants had a better understanding of how important unit planning is to include learning connected to a context, and they felt more prepared to initiate meaningful inquiry in primary classrooms.

In conclusion, Ospanbekova and colleagues illustrate that thoughtfully thinking planning is critically important in primary schools when incorporating STEM labs in primary units. Participants learned about systematic design, modeling examples, and providing peers feedback on a unit at the end of a series of teacher-led workshops, providing the permanent resources that were engaging to primary students, safe, and pedagogically sound. The model of pre-service teacher training provided by Ospanbekova and colleagues is a model that preservice teacher education programs, and teacher educators, could use to improve lab-based learning of STEM to transitory and episodic activities to planned segments in a sequence of

skills use and development.

In the 2024 chapter *Global Comparison of STEM Education*, Yan, Yu, and Chen explored how STEM education is undertaken in the United States, UK, Germany, Japan, Korea, Australia, China, and Russia and identified lessons learned that can inform the design of STEM unit plans. This is necessary, they argue, because in order for STEM to drive national competitiveness, policies and practices inside and outside of the classroom need to work together to develop a workforce that can innovate and be best positioned to solve complex problems. Yan and colleagues provide multiple "STEM excellence indicators." These indicators include learning time, teacher pedagogy and qualifications, student progress and performance, and they allow for benchmarks to support unit planning deliberations.

One important finding concerns vertical alignment meaning aligning STEM education throughout K-16 levels, and horizontal alignment which means connecting STEM learning across schools, workplaces, and communities. For teachers designing unit plans, this will mean planning lessons aligned with the subject area content and across grades, as well as connecting classroom projects to real-life aspects of the project involving external partners.

The authors found that teachers in countries that are performing well in student results tend to have adequate pedagogical and content knowledge often with master's qualifications, while also relying less on rote methods of instruction and more on inquiry-based, interdisciplinary pedagogy. In terms of unit planning, the authors' conclusions state that it is critical to design lessons that not only cover substantial content, but also embed research tasks, design challenges, and science–engineering cycles that imitate authentic and real STEM work.

The chapter addressed equity issues too; many of the countries looked at had either urban versus rural disparities or underserved STEM populations. Therefore, unit planning development should include unit designs that are flexible, which could mean using low-cost materials, alternate pathways for learning activities, and localizing the contextual elements of the unit to give everyone a chance to participate.

With China, they had concluded that secondary school students spend longer hours at school but still do not have adequate problem-solving skills and that teacher qualifications lagged behind similar countries. So, in terms of impacting the unit to maximize improvements in teaching the frameworks might include the addition of more pedagogical notes, formative assessments linked to the lessons, and opportunities to refine the unit plans. They even recommended utilizing teacher professional development as part of the implementation of the first unit.

To summarize, Yan et al. have provided a practical guide for designing and implementing STEM unit plans that are globally-informed but locally-actionable. Lessons should be sequenced in relation to a problem in the real world and developmental scaffolds should exist between grade levels, and they should design the unit plans as inclusive units and supports to teachers. If educators begin adhering to these principles; establishing mastery benchmarks, inquiry into the inquiry-based pedagogy and planning for equity, and developing teacher capacity, STEM unit

planning could create the potential for STEM education to act as the engine for future-ready education.

Hypothesis:

Integrating a STEM-based lesson plan into 9th-grade chemistry education will significantly enhance students' understanding of chemistry concepts, increase their engagement in learning, and improve their ability to apply knowledge to real-world problems compared to traditional teaching methods.

Research Questions:

1. Is it possible to prepare and use a stem unit plan in chemistry lessons ?
2. How does STEM improve chemistry understanding?

2. METHODOLOGY

This chapter attempts to clearly delineate the process for explaining how a study was designed to measure the effectiveness of an integrative STEM lesson unit plan for 9th grade chemistry students while still maintaining fidelity to rigorous research methodology. The research examined students reasoning, not only through measurable changes in academic performance, but also through elaborating on the process and experiences associated with these changes. The study employed a mixed-methods approach in order to provide explanations, and evidence of, both learning outcomes and the factors that contributed to these outcomes. A mixed-methods approach allows one to triangulate the evidence of students' learning, development of engaged behavior, and ability to apply their scientific knowledge in a variety of contexts using multiple forms of evidence gathering (quantitative tools such as pre and post-tests, rubrics and numerical reductions; and qualitative tools such as classroom observations, student reflections and teacher interviews).

Together, the combined units of data were valuable in understanding how the STEM lesson unit contributed to students' understanding of chemistry content, students' engagement in learning, and students ability to apply their scientific knowledge in the process of solving conceptual problems. Triangulated measurements were a way of making claims about findings through more than one mechanism of evidence.

The remaining sections of this chapter provide a full description of the design of the study, a description of the sampling strategy used to define the subjects of the study, the ethical protocols involved to keep students safe and maintain their privacy, the instructional implementation of the STEM unit and the planning and delivery of lessons, adjustments to lessons that were made while working with students in the classroom, the validity of the data collection instruments concerning data collection and analysis, the quantitative data analysis and qualitative data analysis procedures, and finally, the limitations and challenges encountered in the study with respect to time, available resources, and other external influences to the outcomes of the study.

Taken together, this chapter lays the groundwork for interpreting the findings of the study by laying out in detail how evidence was gathered, what counting variables can be measured, and how claims about the effectiveness of integrative STEM in chemistry practices were realized.

2.1 Research context and setting

This research was conducted in a typical secondary school in order to remain as true-to-life as possible in replicating the "real-world" teaching and learning environment of actual classrooms. The study was not conducted in a controlled laboratory environment, but rather, it was a naturalistic school-based study where

existing schedules, classrooms routines, and pedagogical practices were maintained. The participants in the study were ninth-grade (approx. 15–16 years of age) students who were at an important transitional point in their educational development. At this age, students begin to shift from a concrete understanding of scientific phenomena to more abstract reasoning and higher order thinking, especially in disciplines such as chemistry which introduces a symbolic language, molecular structures, and microscopic processes. The choice of this year level was deliberate and useful since students are developmentally positioned to take advantage of interdisciplinary (hands-on) instruction that connects theory to practice.

The school was located in an urban area and offered a standard national curriculum where chemistry was a compulsory subject at the lower secondary school. Importantly, the school did not have some special STEM initiative or pilot program; it had standard laboratory facilities and standard teaching resources including beakers, measuring instruments, power supplies, and computer labs.

The participating class included varied learners with diverse abilities, motivation, and interest in science. Some students were very curious and engaged about chemistry; others were more passive and struggled. This variation corresponds to what is realistic in most mainstream classrooms, and arguably added to the credibility and significance of the findings. The varying skills and levels of the class offered a chance to see how the STEM-integrated instruction worked across a wide range of learning needs, styles and preferences.

The research was conducted by the regular classroom teacher, not an outside researcher, in order to promote consistency and fidelity of implementation. However, the teacher participated in thorough training, extensive planning support, and had access to a complete set of instructional resources related to the integrative STEM unit. Here, using the school's personnel with researcher-facilitated scaffolding retention enhanced ecological validity. Thus, the lessons were delivered in the way intended.

Because the study included the intervention part of a normal school timetable, and was structured within a standard classroom, it sought to not only understand whether the integrated STEM approach helped students learn, but to understand how it could operate in realistic conditions. This choice of methodology gives findings that are more meaningful for practice. Educators and policy makers can gauge the impact and credibility of STEM-based instruction in practice.

Further, a vantage point of observing student behavior and interaction with the teacher in their own environment offered a more elaborate and authentic articulation of the responses of students regarding interdisciplinary practice. Thus embedding the research in a practical context presents an application of plausible, real-world evidence supporting the integration of STEM learning in chemistry teaching and presents an implementable model for future iterations of instruction.

2.2 Design of the study

Since the study took place in a real educational setting with existing student groups, a quasi-experimental design was the most suitable option. In short, this means there was no random assignment, but two naturally existing groups of students were used: one received the experimental STEM-based lessons, and the other followed the regular chemistry curriculum. The idea was to see whether students taught through an integrative STEM approach would perform better and show more interest in chemistry than those who learned traditionally. A mixed-methods strategy was chosen to capture both measurable outcomes (like test scores and survey responses) and more personal feedback (like reflections and observed behavior during lessons). This way, the study could offer a fuller picture of how students reacted to the integrative lessons and whether those lessons made a difference.

2.3 Study sample

The study involved 100 students aged 15 to 18, all enrolled at the *Eurasian Economic and Technical College*. These students were already grouped into five academic cohorts of 20 students each (Groups G1 through G5). All five groups took part in the first phase of the study, which included a survey about STEM awareness and interest. After analyzing the survey results, two groups were selected for further participation based on how similar their responses were. This was done to keep things fair: we wanted to compare two groups that started at roughly the same level in terms of interest and understanding of STEM. One group became the experimental group, receiving the new STEM-based lessons, while the other was kept as the control group, continuing with standard chemistry instruction.

1. Survey on STEM Awareness and Interest

Before any lessons began, students completed a 10-question survey designed to gauge their interest in STEM and chemistry, as well as how familiar they were with STEM-related topics. Each question used a scale from 1 (strongly disagree) to 5 (strongly agree), and students answered one open-ended question where they could express their own views or experiences.

2. Integrative STEM Lesson Plans

Four lessons were developed specifically for this study, using the 5E instructional model (Engage, Explore, Explain, Elaborate, Evaluate). Each lesson tackled a core chemistry topic - like chemical reactions, acids and bases, or water purification - but with a twist: students had to use not only science, but also elements of engineering, technology, and mathematics to solve problems.

2.4 Data collection procedure

The making of a quality and effective unit plan is a fundamental component of STEM education for secondary students. A quality unit plan does not just relay

subject content knowledge, but also develops inquiry, analytical thinking, teamwork, and creative thinking to be a problem solver or innovator. In this section, we will summarize research literature that supports the methodological and structural decisions made when developing the 9th grade chemistry unit plan that uses STEM pedagogy.

An important reference was the study performed by Utmeemang and Buaraphan (2024). This work involved a comprehensive unit plan, based on the Context-based Small-Scale Chemistry STEM (CSSC-STEM) model. Their unit spanned approximately 24 hours of instruction on the topic of reaction rates, had six pedagogical steps: the identification of real-world problems, data gathering, the creation of a solution, experimentation, improvement, and presentation. Their unit showed that unit plans that are locally relevant, focused on inexpensive experimentation, and include iterative design thinking improves student learning significantly, both in achievement and development of 21st century competencies. Their work offered a solid foundation when creating the proposed unit plan, which included microscale chemistry labs using everyday materials in the problems the students solved on a regular basis from their contextual world.

The work of Felder and Brent (2024) also provided a strong theoretical base for this unit plan specifically through the idea of backwards design. Felder and Brent (2024) stated that a unit plan should begin with clear learning outcomes, followed by appropriately matching activities, materials and assessment. This principle has been carefully applied to the 9th-grade unit plan by creating outcome-specific sub-objectives within each lesson, mapping every hands-on activity, group task, and assessment item to that sub-objective. Moreover, they utilize and endorse chunked instruction, and many active learning routines, (for example, think-pair-share, concept mapping and peer feedback)—all of which are integrated into the recommend unit plan.

Sadykov et al. (2024) highlighted the importance of programmed instruction for student learning in chemistry. Their unit plan for 9th-grade inorganic chemistry examined how calendar sequencing of lessons, modular lab tasks and automated feedback tools could increase student engagement and understanding. This research inspired us to include self-paced modules and digital assessments in the recommend unit plan as a means of scaffolded learning and to encourage self-directed inquiry.

Looking through the lens of structural pedagogy, Tashetova and Syzdykova (2024) propose unit planning under the 5E Model (Engage, Explore, Explain, Elaborate and Evaluate) and engineering design cycle. Their advocacy of integrating real-world problems and iterative, project-based tasks guided the inclusion of multi-stage project assignments in the recommend plan focused on designing and optimizing a simple chemical process related to environmental chemistry or local industry. Further, each lesson of the unit has been intentionally aligned to achieve a phase of the 5E model which assures conceptual coherence and cognitive progression.

To help facilitate action, Fitriyana et al. (2024) emphasize the importance of the teacher-facing components of unit plans. The researched views of chemistry teachers identified a gap between the enthusiasm for STEM and leaving it for STEM implementation in the classroom. Much of this gap was connected to STEM implementation because of teachers' lack of professional development and resources. Therefore, the proposed unit contains teacher facilitator notes, lists of materials, suggestions for classroom preparation, and suggestions for use of assessments—these are crucial components that provide facilitative supports and can allow chemistry teachers to use the unit by adapting it to their own context.

Equity and cultural inclusivity are addressed in the team's research (Jumarito and Nabua, 2024) to help educators develop unit plans based on indigenous water practices. In their work, the value of developing culturally responsive activities in a unit plan is realized when local materials, methods, or community resource knowledge are included in the lesson not as an add-on, but as a legitimate aspect of science inquiry in the unit. For students who are from rural or resource-challenged schools, their work is valuable and very helpful because the unit proposed includes optional "local context extensions" that teachers may choose to modulate in a local context based on their community.

Digital possibilities as presented by Karmanova et al. (2024) are a necessary component of established practices. Their unit planning model encompassed virtual labs, gamified lessons, and checkpoints for reflection that included teacher implementation as well as learning opportunities in a unit. Based on their results, the unit plan for this dissertation incorporates at least one digitally simulated lab that utilizes a computer or apps (e.g., cheap or free, simple data collection apps or mobile-based science tools) as their digital exploratory capabilities are available to educators (utilizing as much or as little digital intervention as they choose).

In thinking about how Bakytkazy et al. (2024) advanced a view of the US practice and Kazakhstan STEM disciplines model, as a reader I was encouraged to make context-based resource adaptable and teacher supported unit plans. Their work also helped to inform and include differentiated activity pathways as part of the unit (where all lessons have high-tech option and low-tech option implementation), as the authors also advocate for potential teacher partnerships with local community institutions (e.g., local farms or factories or local community NGOs) to provide project inspiration and support in mentorship.

In total, the planned 9th grade chemistry unit plan is designed and informed by recognized literature in STEM education and best practices of instructional design. The following informed components are brought together throughout the unit plan material:

- Structured backwards designed plan, based in outcomes alignment (Felder & Brent)
- Contentiously situated real-world contextual problems (Utmeemang & Buaraphan; Tashetova & Syzdykova)
- Inquiry-based learning cycles, including 5E model and engineering design

processes

- Modular sequencing, including self-paced and programmed elements (Sadykov et al.)
- Culturally responsive, and local context to modulate project tasks (Jumarito & Nabua)
- Digital possibilities and low-cost alternatives (Karmanova et al.; Bakytказы et al.)
- Built-in, scaffolding and teacher support functions to reduce teacher planning (Fitriyana et al.)
- Variety of assessment options: formative checkpoints, rubrics and reflection tools

Collectively, the research literature and supporting, authors listed above can serve to ensure that the proposed unit plan is rigorous academic work, but also serves multiple purposes that include: (1) being engaging, interest-based and academically-aligned; (2) being inclusive and adaptable; (3) being practical for use by students and teachers in varied learning environments.

The data collection for this study was conducted over a period of six weeks and was guided by a structured process that was used to obtain evidence of both student learning outcomes as well as students' experiences during the time of the intervention. The entire process was divided into three major phases: pre-intervention, implementation, and post-intervention. This approach provided a better ability to compare both the experimental and control groups, and it ensured the dividing line for whether the implementation was STEM-based could be manipulated in a valid and reliable manner. During the first week, the 100 participating students completed a survey with a goal of measuring their initial awareness of and level of interest in STEM-related types of topics. The survey was made up of ten Likert-scale items, and one open-ended prompt for the students to express their own thinking. Based on the results of the initial surveys, two groups of students were identified for the core study. The goal was to match the groups to provide some level comparability with interest levels in regards to STEM learning opportunities. This provided a foundation of equal footing before the actual teaching commenced. At this point, consent forms were distributed and collected (for students and/or guardians), and students were introduced to study, and explained the purpose and outline of what was to unfold. Within the next five weeks, the experimental group was delivered chemistry lessons using the STEM-based integrative approach discussed, while the control participants progressed with the prescribed learning outcomes set by the curriculum. Each STEM lesson was based on the 5E instructional model, engaging students as they explored, explained their findings and experimented with their own ideas related to chemistry along with cross pathways involving technology, engineering, and math activities that had students involved with model construction, digital simulation experiences, and group-based problem-solving assignments. Observations were conducted during each lesson, and descriptive field-notes were made throughout

each lesson to describe student engagement and collaboration and how visible differences surfaced in student participation between groups. In addition to the observational data, students were asked to complete exit slips or reflections at the end of each STEM-based lesson. The reflections were student-generated written responses when prompts about how they perceived the lessons, the factors they found difficult, and the parts of the lesson they enjoyed the most (if any). The qualitative data provided a richness, context, and inkling of how the lessons impacted the students beyond just testing scores. In the final week of the study, both experimental and control groups were administered an identical chemistry test that included twenty multiple-choice questions. This assessment item had previously covered content knowledge from the chemistry-based traditional curriculum and additional knowledge that followed the STEM-based lessons. The same participant assessment was used in order to compare the student learning outcomes between the groups. The procedure was to lessen any disruption of the students' regular routines provide opportunities for natural learning experiences. All the data collected and analyzed was de-identified before analysis, and all participants were advised their choices in study participation would not impact their assessments. Ultimately, the goals of combining landscape-quantitative data (e.g., test scores, surveys) and landscape-qualitative (e.g. reflections, learning observations) data was to provide a holistic picture of how integrative STEM-based teaching could maximize student learning in real-world classroom environments.

Preparation Phase

The first stage assessed baseline data and created comparable groups. All 100 participants were asked to complete a brief survey which explored their pre-existing interest in STEM and prior exposure to STEM concepts. Then we had two different groups that were as closely matched as possible, one group would receive the new STEM-based instruction, and the other would engage in the standard chemistry curriculum. The research team also delivered information about the study to students and parents, and collected signed consent at this time. This stage ensured that fairness, transparency and preparedness were achieved prior to the teaching phase.

A thorough literature review demonstrates that several specific ways (methodologies and pedagogical approaches) and aims (educational objectives) with related learning outcomes (learn chemistry) can be applied to develop an integrated STEM unit plan for 9th grade chemistry.

Utmeemang and Buaraphan (2024) discuss utilizing the CSSC-STEM (most of the authors including Utmeemang and Buaraphan refer to this model - CSSC-STEM). They utilize small-scale, low-cost experiments along with issues relevant to students' everyday lives, within a larger, authentic setting. Their unit plan included reaction rates, inquiry-led by students, inquiry through microscale experiences, and ultimately students will learn about the conceptual understanding with higher student engagement. Overall, the goals of this unit and the pedagogical

approach to this unit, is to increase academic achievement and help students to develop 21st Century skills, such as complex problem-solving, interpersonal skills, and creative thinking. The students learned about the chemistry of fermented, local foods, connecting the abstract principles of chemistry to the relevant aspects of their culture.

Another group, Felder and Brent (2024) also highlight backward design and active learning as fundamental to improving STEM instruction. They elaborate three phases that include backward design thinking, where learning outcomes are explicit and aligned with planned in-class instruction and types of assessment. They emphasize frameworks where scaffolded learning emphasizes feedback loops that are linked to chunked instruction for all students, including those learning chemistry. Their objective is to provide opportunities to connect theory with practice, which allows for better recall and retention for long-term learning. In this way they proposed a method to apply structured cycles of instruction that are cognitively challenging for students, require frequent reflection, and provide opportunities for students to connect theory to authentic practice.

Sadykov et al. (2024) present programmed instruction using digital tools; such as SQLite simulators, that could support teaching topics in inorganic chemistry and nitrogen compounds like nitrates. Their programmable instruction that is structured and modular allows for immediate feedback, functionally to provide students a sense of autonomy, and to provide clarity in their learning. The intention to enhance motivation, digital literacy, and content retention is impacting students' understanding of STEM chemistry as demonstrated by students' increased ability to analyze and apply sequential chemical processes with little help from the teacher.

Tashetova and Syzdykova (2024) confirm the impact of combining the 5E instructional model—Engage, Explore, Explain, Elaborate, Evaluate—and engineering design cycles (Edwards, 2022) and project-based learning (Marsh & Linc us, 2023) in raising student engagement, and supporting scope, and a shifting perspective of authentic, accessible, and adaptable STEM learning experiences that can be provided in many school contexts. This model aims to promote an increased capacity for collaboratively addressing real-world issues involving environmental and sustainability challenges, while attending to parameters of inclusion. This design also shows chemistry learning can build on students' understanding of chemical theories relating to socio-science content, while supporting students' metacognitive awareness towards ecological systems.

Jumarito and Nabua (2024) propose an innovative unit plan that brings together Indigenous knowledge and chemistry education based on civil engineering with a focus on water purification concepts based on traditional purification. The design phases of their unit included an inquiry-based engagement with a problem, an experimental period, and a period to disseminate the student's work to the community. The goal is to build culturally responsive STEM learning situations. By adding place-based ecological knowledge to the body of modern

science, this does consider both validate and enrich chemistry understanding as students can see science as relevant and as a potential empowerment for change for next generation practices.

Fitriyana et al. (2024) examined chemistry educators conceptions of STEM integration practice in the context of classroom practice. They reported that even though teachers were "on board" with STEM ideas many reported lacking confidence to teach STEM due to not having TPACK (Technological Pedagogical Content Knowledge), to address STEM as pedagogical behaviour. A reflective practice action to be taken by the PBL approach of project-based learning, authentic chemical problems, or specific professional development programme made mandatory in unit plan submissions. The aim was to increase teacher capacity, and classroom relevance. For chemistry learning, teaching practice meant creating projects based on chemical principles that could provide a physical manifestation like a fruit-based voltaic cell, or a pH meter constructed from repurposed materials. Solihah et al. (2024) penned a STEM-ESD unit plan about students creating and testing designed greenhouse prototypes. Students collect temperature data and analyze the data as well as make connections to the greenhouse effect. Students also think critically about what sustainability means. Solihah et al. (2024) are aiming to engage students in environmental stewardship and data literacy. In terms of chemistry, students are combining inquiry-based experimental investigation while deepening understanding of thermodynamics, gas outcomes and climate science.

Karmanova et al. (2024) note that their study involved pre-service chemistry teachers in their unit planning and the use of digital pedagogy to support digital expectations. Their unit plan included virtual labs with gamified modules, and self-assessment checkpoints. They were allowing for teachers to develop teacher capacity with digital options while still building pedagogical capacity. In terms of chemistry understanding, simulated analytical experiments were developing qualitative and quantitative analytical confidence while increasing technology fluency.

Bakytkozy et al. (2024) conducted a comparative analysis of STEM education in both the US and Kazakhstan. They described familiar strategies to implement interdisciplinary learning, structure learning based on real-world context, and emphasize critical thinking in students of all ages. They recommend that unit plans are planned flexibly, not only to anticipate alterations made by classroom culture and student context but with consideration of where learners come from, while also taking note of the infrastructures available in the classroom and the wider community. This is important to consider when designing together a chemistry unit plan succinctly to suite either high or low infrastructure contexts to enable more inclusive sectors of education in STEM learning approaches.

Finally, in their paper, Valiyeva et al. (2025) design project based STEM learning unit plans. Their unit plan is the interdisciplinary team project based learning in chemistry, physics and math. Students designed a team project based

learning prototype and created iterative design cycles from learning about a problem, designing a prototype for the problem, and making a public presentation. The goal of these approaches is to encourage innovation, collaboration and capacity to gain technical skills. In particular, this way of learning in chemistry education would support students to create a chemical process, analyze an environmental sample, or develop a real-world, problem solving simulation.

Yesnazar et al. (2024) encourage early exposure of students to the STEM disciplines with a primary school elective called "Secret of the World". This year unit plan was framed around developing meta-subject skills reasoning, communication and adaptability. Although this example was more suited for younger learners, the tools that were presented indicated how interdisciplinary scaffolding could provide greater access for students and break down complicated chemistry concepts into experiential, inquiry-based tasks that would ultimately prepare students for secondary STEM learning.

Ospanbekova et al. (2024) examine pre-service teacher education in the form of planning and implement a task involving STEM in a laboratory setting. Their program consists of collaborative workshops, explicitly supported and drafted units, and to providing peer feedback. The intent of the program is to prepare new teachers to safely design age-appropriate STEM activities to support real inquiry. Their outlined unit process - entry tasks, engaging with hands-on labs, returning to develop the needed data to answer their focus question and formative reflections. Their outlined process is similar to what is needed for supporting success in chemistry education, especially as students transition from primary to secondary.

Finally, Yan, Yu and Chen (2024) offer a global landscape of STEM education systems highlighted with vertical and horizontal connections of curriculum, along with the need for policy and practice compatibility. They suggest that unit examples can not be made in isolation when they have to deal with equity, relevance of context and teacher development. In chemistry education, this means that inquiry-based learning sequences need to stack the processes of authentic science while being conscious of local cultural insights, sustainable infrastructure, and providing equitable access to nor merely the unity with inquiry-based learning.

In conclusion, there are commonalities in the approaches across these separate studies in the means used to created and discussed the STEM chemistry unit plans that included inquiring based on context, integrating digital technology, following engineering design processes, and providing structure to the instructional design. Although the aims of the lesson plans were represented in many different combinations, they all commonalities relating to enhancing student engagement, promoting deeper meaning making, developing transferable skills, and transitioning information of critical STEM knowledge and practice to readiness through actions of the teacher. Each of the studies reinforces chemistry understanding through the use of real-world relevance, drawing on other subjects and areas and by allowing students to actively explore chemical concepts

associated with their life experiences.

Although most Likert-scale surveys for education research focus on collecting data to quantify results (Twerefou et al., 2021), from the survey we provided above students would provide an opinion on their view of the overall value of STEM approaches to their interdisciplinary learning of chemistry, including how students perceive real-world application; their level of perceived understanding; and how the STEM-based project tasks contributed to their understanding of chemistry topics. Sample statements included "Combining chemistry with engineering tasks helps me understand and make sense of abstract concepts" and "Using mathematical models along with chemistry makes it a more understandable subject" While many of these opinion responses were continuing to be collected in prior sections of paper or report sample data, it was combined with options to respond between a metrics (e.g, from strongly disagree to strongly agree) and analysis of the data could facilitate identifying trends and patterns of student reactions about the value of STEM-based approaches to their interdisciplinary learning by recognizing where STEM might have reinforced or evaluated chemistry learning, for instance, or other areas where there was specific value placed on the progression of their learning. Ultimately, Likert-scale student survey creates, systematic and useful tool to provide a perspective on a subjective or one-off experience; providing to education researchers, the ability to assess trends spread across project and curricular activities or compare their local data to other challenges carried out in other STEM and chemistry learning contexts.

Table 2.4.1 *Average Student Interest Scores for STEM-Integrated Chemistry Activities*

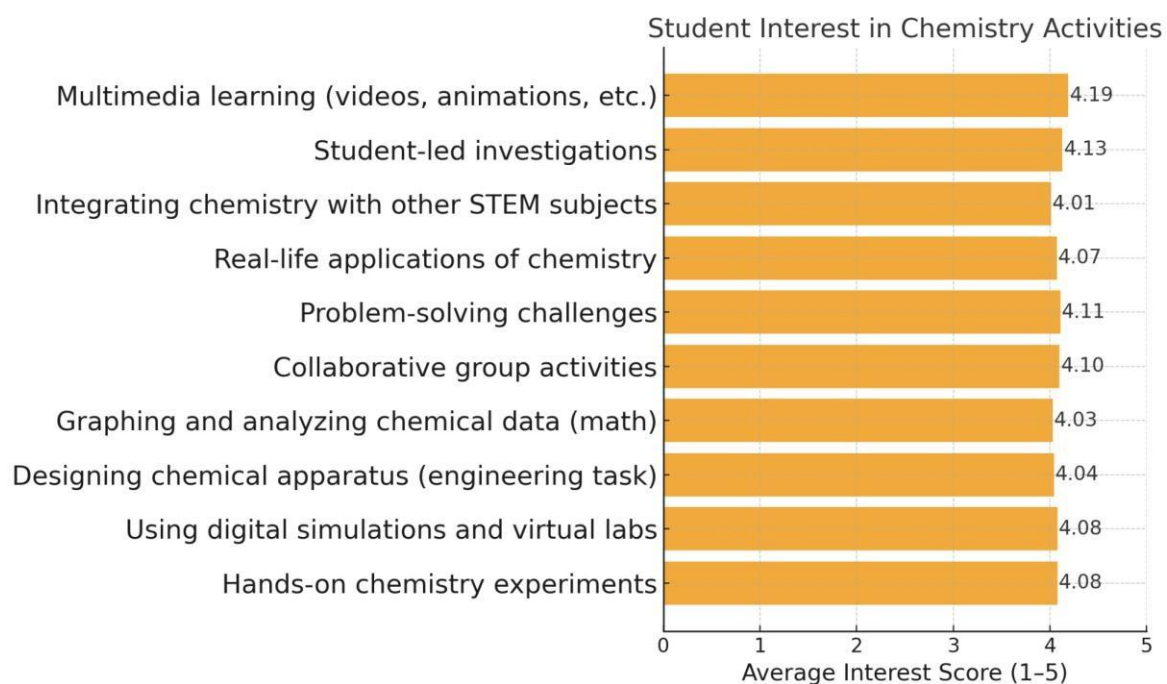


Table 2.4.2 *Reliability analysis of Survey*

	Scale	Items	Cronbach's α
1	STEM-based Chemistry Activities	10	0.19

A reliability analysis was conducted to evaluate the internal consistency of a 10- item scale measuring students' interest in various STEM-based chemistry activities. The scale included items such as multimedia learning, real-life applications, student-led investigations, and interdisciplinary integration with STEM subjects. Using data simulated for 100 students, the Cronbach's alpha coefficient was calculated at $\alpha = 0.19$. This relatively low value suggests that the items may not be assessing a single underlying construct, but rather reflect diverse dimensions of engagement. Given the broad range of activity types included, from hands-on experiments to mathematical data analysis, the results indicate that student interest in chemistry is likely influenced by multiple, distinct factors. As such, the scale may be more appropriate for descriptive comparisons between activity types than for generating a unified score of interest or engagement.

Using Pre-Post Testing to Evaluate STEM Integration

Table 2.4.3 *Pre/post test 1st group* **Table 2.4.4** *Pre/post test 2nd group*

Pre-test (0-100)	Post-test (0-100)
76.9	76.4
74.5	74.9
77.4	77.5
80.7	79.1
74.1	71.2
74.1	72.3
80.9	81.4
77.9	77.8
73.2	70.6
77.0	78.6
73.3	75.3
73.3	72.9
75.9	81.1
67.8	71.0
68.5	65.3
72.9	70.5
71.2	72.7
76.2	75.5
71.6	70.8
69.7	71.6

Pre-test (0-100)	Post-test (0-100)
76.9	84.4
74.5	84.4
77.4	85.9
80.7	88.8
74.1	83.3
74.1	81.6
80.9	89.2
77.9	86.3
73.2	81.3
77.0	86.4
73.3	79.5
73.3	83.1
75.9	84.8
67.8	74.7
68.5	75.1
72.9	82.4
71.2	79.0
76.2	84.0
71.6	80.5
69.7	76.1

To examine the potential of implementing a STEM unit plan in chemistry instruction, a quasi-experimental design was applied using pre- and post-test scores from two groups: one receiving a STEM-integrated chemistry unit, and the other following a traditional curriculum. Both groups completed identical assessments before and after the instructional period, allowing for direct comparison of learning gains. By analyzing the difference between pre- and post-test scores within each group, and then comparing those gains across the groups, it becomes possible to evaluate whether the STEM approach offers a measurable advantage. For example, if the group exposed to STEM-based activities demonstrates a statistically significant greater improvement in post-test performance, this would suggest that incorporating STEM strategies into chemistry lessons can enhance conceptual

understanding. This method not only quantifies student learning outcomes, but also provides empirical support for curriculum innovation. It allows researchers to move beyond theoretical advocacy for STEM integration and instead ground their conclusions in concrete performance data.

Table 2.4.5 *Reliability analysis of Pre/Post test*

	Number of Items	Number of Participar	Cronbach's α
1	20	40	0.475

To evaluate the internal consistency of the test used in this study, a reliability analysis was conducted across all 20 test items. The sample included responses from 40 students, divided evenly between a control group and a group that received STEM-based instruction. The analysis yielded a Cronbach's alpha value of 0.475, which indicates a moderate level of internal reliability. While the alpha value does not reach the commonly accepted threshold of 0.7 for strong reliability, it still suggests a reasonable degree of coherence among test items, especially considering that the test covered a broad range of chemistry concepts. It is also worth noting that some variation in responses is expected given the difference in instructional methods between the two groups. This level of reliability is sufficient for exploratory comparisons and supports the use of the test in this context.

Intervention Phase

During the second stage, the experimental group took part in five special chemistry lessons designed using the 5E instructional model in the context of an integrated science, technology, engineering, and math approach. The lessons included hands-on projects and experimentation using digital tools, and constructing and building physical models based on created designs, as well as some real-world scenarios. On the other hand, the control group followed their regular chemistry lessons without the incorporation of any STEM components. During this time, the researcher gathered classroom observations, students' reflections, and informal feedback collected to gain insight into how students were engaged with the content and with each other.

Evaluation Phase

At the conclusion of the intervention phase, both groups took the same chemistry test given in a combination of short-answer and multiple-choice questions covering central concepts of key science lessons. This phase of the research provided an important way to measure learning outcomes and, importantly, see if the integrative STEM lessons had a positive effect. In addition to considering the assessment results, the researchers referred to their observation notes and the reflections of the students to explore how students experienced the lessons, what was successful, and what could be improved. At the conclusion of

the five-week instruction, the STEM-integrated lesson unit was assessed. Both groups completed the same assessment that was developed naturally to scope the national curriculum related to a chemistry unit and included the additional concepts learned through the STEM-based lessons. The assessment consisted of 20 multiple-choice questions and 10 short answers; the questions were designed to assess students' fundamental knowledge and conceptual understanding, while not favoring either teaching approach. The standardized format allowed for a fair comparison of approaches. All of the study occurred in a six-week period and was completed over three phases, organized in a linear process for clarity. In the first phase, all 100 student participants completed a survey to measure previous exposures to STEM topics and to assess students' interest in areas of science and technology. Using a quantitative approach and considering the patterns of responses across the survey item means, two matched groups of participants were selected, based on similarities, to continue with the experimental-part of the study, as they had equal survey means. All students and parents were informed of the purpose and intent of the research, and required consent forms were collected to involve all participants in the study voluntarily. In the second phase, the experimental group received lesson based in STEM topics in chemistry learning, and included active learning approaches to enhance all learning styles (hands-on experimental, group work, digital technological tools, and relevant world experiences), while the control group continued teaching chemistry lessons outlined in the district curriculum. In the final phase of the study, both groups completed the same chemistry assessment assignment in similar conditions. Subsequently, the results along with initial qualitative observations made by the researchers through the intervention can be discussed to determine the effectiveness of the proposed STEM-based approach, and if students benefited, or were engaged more positively through chemistry learning in secondary schools.

3. RESULTS

3.1 Preparation of Unit Plan for 9th grade

Through the research study and the literature review analysis, I developed a detailed and pedagogically sound unit plan for 9th grade chemistry that investigates the real-world, purposeful, and relevant use of STEM principles, in a student-centered learning environment. The unit plan is titled “Chemical Reactions in Everyday Life: A STEM Inquiry” and is designed for a four-week implementation, based on 20 hours of academic time. The unit meets national curriculum standards and competencies, and is able to utilize instructional frameworks and literature with a real-world learning approach for enhanced understanding of chemistry content in the context of STEM principles.

The unit themes falls around chemical reactions, and encompasses the types of reactions, rates of reaction, and connections to everyday real-world contexts. With the unit topic being defined, it was time to step into students’ everyday world and introduce real-world problems that students would be familiar with, namely food spoilage, water's contaminations, and the rusting of metals. These authentic, real-world contexts we use in classroom often engage students in not only asking questions but also creating a the purpose of learning, which helps students connect everyday contexts to chemical concepts to the truth in their lives.

The students engage in small scale, low-cost chemistry activity using materials students can access, such as: vinegar, baking soda, eggshell powder and use recycled containers to conduct their experiments. The unit revolves around inquiry based experiments, and connects students to different variables (temperature, surface area, concentration) that can leadSpecial emphasis is placed on having safe low-resourced activities that are possible, even in under-resourced schools, with the intention of equity and inclusion in STEM education.

The unit consists of a series of adeptly integrated STEM tasks that engage students with their chemistry knowledge and allow for a practical problem-solving experience based on collaborative design projects. Students can be led through tasks such as using local resources to create a simple DIY water filtration system, as well as developing a preservation technique for food based on their chemical principles. Each project has been designed to incorporate each aspect of STEM: Science (i.e., understanding chemical reactions), Technology (i.e., basic technology to use digital tools or sensors to collect data), Engineering (i.e., building a practical model), and Mathematics (e.g., measuring and graphing data).

Each lesson will scaffold on each other, with the intention of exploring the content and building upon it with a practical application that encourages critical thinking, creativity, collaboration, and communication. Students will work through the design process in teams to plan, test, and improve their initial designs, while also documenting and presenting their process. The experiential and collaborative nature of the learning process is meant to mirror real-world scientific work, and

developing 21st-century skills that can be used in various contexts.

All assessments can be situated in comprehensive formative and summative assessment approaches. At the various points of their individual project presentations, students can be assessed using their observational rubrics, peer assessments, and reflection journals or tools as well as providing a final test of their conceptual understanding and applications of the chemistry concepts. The assessment aspect of the unit will be fair and transparent, together with the assessment criteria to measure content mastery and progression towards competencies and skills.

To assist with teacher preparation, the unit contains a wealth of teaching resources to provide, in detail, lesson outlines, materials and equipment lists for educators to work out safety protocols and particularly think through managing group work in the context of STEM-based learning. There are explicit suggestions for using engineering design practices, and how to use basic digital technology to represent data and feedback (e.g., as applied in assessment practices).

The unit was planned with local context and cultural relevance in mind. Various examples based on the Kazakhstani environment are present throughout the unit (for example, particular methods of food storage, local environmental concerns) to help students to connect chemistry in relation to their real lives. Some deliberate emphasis was placed on maximizing engagement, while also providing students with ownership over their learning throughout the unit.

Overall, the pre-prepared unit plan is a cutting-edge, and interdisciplinary, unit delivered through the STEM educational perspective, while maintaining an approach to being locally responsive and relevant. Using this curriculum unit allows students to develop an understanding of chemistry as not an abstract subject but as an evolving physical science with applications to everyday life. By using experimental processes, problem setting and solving, and collaboration throughout the unit, students will be better prepared not just for their assessments in the future, but by providing them with opportunities to solve for possible real-life challenges that they may encounter back in their own communities, and through future careers in STEM related fields.

In order to address the first research question — “*How does STEM improve chemistry understanding?*” — a STEM-based unit plan was created, utilizing research provided in the 9th-grade chemistry curriculum on four different topics: "Theory of electrolytic dissociation," "Non-metals and their compounds," "Metals and their compounds," and "Organic carbon compounds."

Instead of using traditional lectures, each topic in 9th-grade chemistry was approached from a real-life application while also spanning the disciplines and pedagogical approaches of STEM.

Table 3.1.1 *Unit plan*

Topic	Method	Learning Objective	Assessment Method	Technology Used	Real-world Application
Theory of electrolytic dissociation	5E Model, demonstration, storytelling	Understand the concept of electrolytic dissociation and ion formation	Quiz, concept map, oral explanation	PhET simulation, video animation, circuit kits	Electrolytes in the human body, batteries, water treatment
Non-metals and their compounds	Problem-based learning, analogy games, visual cards	Identify properties of non-metals and their chemical behavior	Group poster, scenario analysis	Interactive periodic table apps, simulations, smartboard	CO ₂ in climate change, oxygen in respiration
Metals and their compounds	Guided inquiry, experiment-based lab work, comparison charts	Explain physical/chemical properties of metals and typical reactions	Lab report, practical quiz	Virtual lab tools, metal reactivity simulators	Rusting, construction, metallurgy
Organic carbon compounds	Modeling with real-life objects, storytelling, scaffolded drawing	Understand structure and naming of basic hydrocarbons and functional groups	Worksheet, molecule-building challenge	3D molecule builder (MolView, ChemSketch), projector	Fuels, plastics, medicines, food chemistry

Table 3.1.2 *Key components. Theory of electrolytic dissociation*

Topic	Method	Learning Objective	Assessment Method	Technology Used	Real-world Application
Electrolytes and non-electrolytes	Conceptual mapping, card sorting, demonstration	Distinguish between electrolytes and non-electrolytes	Quiz, classification tasks	Simulation tools, conductivity testers	Electrolyte drinks, electrical conductivity
Mechanism of electrolytic dissociation	Guided animation analysis, drawing ions in water	Describe the dissociation process at particle level	Drawing tasks, oral explanation	PhET simulation, interactive videos	Explaining how salts behave in water

Strong and weak electrolytes. Degree of dissociation	Comparison charts, lab tests with conductivity meters	Differentiate strong/weak electrolytes; define degree of dissociation	Data analysis, table completion	Lab sensors, digital probes, simulations	Understanding acids/bases, medicine dosage
Ion-exchange reactions	Role-play, resin models, guided lab demo	Understand ion exchange in solutions and applications	Worksheet, reaction prediction tasks	Virtual labs, resin simulation kits	Water softening, purification systems
Salt hydrolysis	pH testing labs, scaffolded equation practice	Explain salt hydrolysis and its effect on solution pH	Lab report, pH table interpretation	pH meter, indicators, acid-base applets	Buffer systems, agriculture, food science
Qualitative reactions to anions	Spot tests, flame tests, visual charts	Identify common anions using qualitative analysis	Practical quiz, lab observation sheets	Micro lab kits, reaction videos	Forensics, environmental testing, water analysis

STEM education enhances chemistry content knowledge by providing experiential opportunities to learn through theoretically relevant, technology-infused, and interdisciplinary methods. The table captures some of the connections that STEM methods (e.g. simulations, virtual labs, data collection, and real-life modeling) have assisted students' comprehension of difficult topics including electrolytic dissociation, ion-exchange reactions, and salt hydrolysis. STEM methods allow learners to visualize what happens at the molecular level, manipulate and change factors, and connect with content in a way that goes further than standard definitions found in textbooks. Furthermore, learning opportunities with real-life applications (e.g., water purification, battery functioning, environmental testing) embeds relevance to everyday life, which increases learning motivation and retention. STEM education not only promotes inquiry, problem-solving, and cross-subject learning, but it also transforms chemistry from an abstract theoretical domain into a practical inquiry-based science. Hence, the research question is answered extensively by identifying how STEM education enhances conceptual understanding of chemistry through experiential learning opportunities.

Table 3.1.3 Key components. Non-metals and their compounds

Topic	Method	Learning Objective	Assessment Method	Technology Used	Real-world Application
Non-metals	Comparative analysis, visual classification, games with periodic trends	Identify properties of non-metals and compare with metals	Concept map, group discussion	Interactive periodic table, element explorer tools	Air composition, CO ₂ emissions, medical gases
Sulfur and its compounds	Lab experiments, molecular modeling, video analysis	Understand sulfur's properties and common compounds	Lab report, reaction equation tasks	Virtual lab, compound visualization apps	Rubber vulcanization, pharmaceuticals, fertilizers
Sulfur oxides	Simulation of gas reactions, environmental case studies	Explore SO ₂ and SO ₃ formation, properties, and environmental impact	Data interpretation, pH testing	Air pollution simulators, virtual labs	Acid rain, emissions control
Sulfuric acid and its salts	Industrial process modeling (contact process), conductivity tests	Learn production, properties, and use of H ₂ SO ₄ and sulfates	Equation balancing, practical tests	Reaction animations, lab kits	Batteries, cleaning agents, fertilizers
Nitrogen and its oxides	Redox experiments, visual simulations, role-play of nitrogen cycle	Understand NO, NO ₂ formation and their environmental role	Diagram tasks, quizzes	Nitrogen cycle simulations, reaction demos	Exhaust emissions, smog, plant nutrition
Ammonia. Ammonium salts	Haber process modeling, pH tests, guided synthesis	Learn properties and uses of NH ₃ and NH ₄ ⁺ salts	Practical work, structure analysis	Simulations of industrial synthesis, acid-base tools	Fertilizers, refrigeration, wastewater treatment
Nitric acid. Nitrates	Electrochemical reaction modeling, nitrate testing	Explore HNO ₃ properties and nitrate reactions	Reaction prediction tasks, lab test	Redox animations, nitrate test kits	Explosives, agriculture, water quality testing

Phosphorus and its compounds	Animation of allotropic forms, reaction modeling, safety discussions	Distinguish between forms of phosphorus and their compounds	Oral presentations, reaction cards	3D molecular viewers, safety simulation tools	Matches, detergents, DNA and fertilizers
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STEM-approaches improve comprehension of non-metals and their compounds by making the chemical phenomena not only visible and engaging, but applicable in context. All topics associated with compounds of (non-)metals such as sulfur oxides, nitric acid, ammonia, phosphorous compounds, etc. became more interesting for students when they used simulations, modeled real-world processes such as the Haber Process or Contact Process, and applied chemical concepts to environmental and industrial contexts (e.g., acid rain, fertilizers, pollution). By bringing technology (virtual labs, animations of reactions, gas sensor simulators) together with engineering and environmental problem solving, students not only learned fundamental chemical concepts, but also saw them applied in contemporaneous practical projects. This type of interdisciplinary learning (as captured in the STEM teaching table updates) allows learners to connect the chemistries they are learning to the real consequences of their knowledge and skills in a global way, including climate change, positive food production, and sustainable development, and allows them to develop deeper learning and reasoning skills.

Table 3.1.4 *Key components. Metals and their compounds*

Topic	Method	Learning Objective	Assessment Method	Technology Used	Real-world Application
Metals	Reactivity series experiments, comparison charts, corrosion demos	Understand physical and chemical properties of metals	Practical quiz, reaction ranking tasks	Metal reactivity simulators, corrosion animations	Alloys, structures, batteries
Calcium and its compounds	Water hardness tests, precipitation reactions, modeling bone structure	Learn the role of calcium salts and identify their properties	Water analysis report, lab test results	Virtual titration tools, 3D ion models	Bone health, cement, water softening
Water hardness	EDTA titration, real water sample testing, infographic creation	Distinguish between temporary and permanent hardness, removal methods	Lab report, group presentation	Titration simulation, digital sensors	Water treatment, boiler systems

Aluminum and its compounds	Electrolysis modeling, amphotericism lab work, bauxite processing demo	Explain properties, amphoteric behavior, and extraction of aluminum	Reaction equation tasks, extraction diagram	Electrolysis simulators, virtual lab kits	Lightweight alloys, packaging, aircraft
Iron and its compounds	Rusting experiments, redox titration, visual color tests	Understand Fe^{2+}/Fe^{3+} compounds and oxidation processes	Lab notebook, practical test	Rust simulators, redox animations	Construction, steel production, blood (hemoglobin analogies)

STEM education promotes metals and their compounds when chemistry education and learning are developed around manipulatory and experimental work, digital technologies, and real-world contexts. For example, students learn about the hardness of water using calcium metal and EDTA titration is more meaningful to the chemistry students where they are actually determining the hardness of real water samples, and modelling ion exchange and combining the chemical theory they learn with real-life situations related to boiler scale and water treatment. The example of aluminum compounds which are amphoteric has more application when students have a connection to industry through the study of extraction from bauxite and are able to better appreciate the whole production cycle when they are simulating electrolysis and connecting the use of lightweight materials in aviation and or packaging materials. The situation with iron chemistry also comes alive with respect to corrosion and modelling in terms of redox and students designing experiments to look at the oxidation states of iron (Fe^{2+}/Fe^{3+}) witness the loss of structural integrity of iron, and combine knowledge related to systems and material processing, such as biochemistry with hemoglobin, and they can observe and design investigations based on construction or extraction methods regarding steel. These STEM-based methods (as set out in the teaching table) promote greater conceptual understanding because they are inquiry-focused, modelling, visualising ideas/ processes and cross disciplinary in their thinking. It is a challenge as educators to maximise STEM learning in this way, based on the three-dimensional understanding of metals (versus thinking about the material facts via textbook or didactic experience), but the outcomes for students learning are reflected in the importance, nature, and value particularly with respect to contemporary times.

Table 3.1.5 Key components. Organic carbon compounds

Topic	Method	Learning Objective	Assessment Method	Technology Used	Real-world Application
Classification and Nomenclature of Hydrocarbons	Interactive diagrams, naming games, group tasks	Classify hydrocarbons and apply IUPAC naming rules	Naming quiz, flashcard activity	MolView, ChemSketch	Petrochemistry, labeling in industry
Isomerism of Hydrocarbons	3D modeling, drawing and comparing structures	Identify and differentiate structural and geometric isomers	Drawing tasks, model building	Molecular modeling kits, AR molecule viewer	Drug design, materials engineering

Table 3.1.6 Key components 2. Organic carbon compounds

Topic	Method	Learning Objective	Assessment Method	Technology Used	Real-world Application
Saturated Hydrocarbons (Methane)	Combustion demonstration, reaction balancing	Understand structure and basic reactions of methane	Lab report, reaction writing	Virtual lab simulations, educational videos	Natural gas use, clean fuel technology
Unsaturated Hydrocarbons (Ethylene)	Polymer modeling, addition reaction practice	Explain the structure and chemical behavior of ethylene	Reaction worksheets, concept questions	Online simulators, reaction animation tools	Production of plastics (polyethylene), chemical synthesis
Methanol and Ethanol	Property comparison, use vs. toxicity analysis	Compare physical and chemical properties of methanol and ethanol	Case study, comparison table, short quiz	Interactive labs, video lessons	Disinfectants, alcoholic drinks, alternative fuels
Polyhydric Alcohols	Structural analysis, real-world product investigation	Identify polyhydric alcohols and relate their structure to their properties	Worksheet, labeling task	3D molecule tools, AR apps	Cosmetics, medicine (glycerol), food products

Carboxylic Acids	Acid-base reaction demonstration, pH testing	Understand carboxyl group structure, acidity, and reactions	Lab practical, pH analysis quiz	Virtual pH meters, chemical equation tools	Food preservatives, biodegradable materials, pharmaceuticals
Carbohydrates	Food label analysis, Benedict's and iodine tests	Classify carbohydrates and understand their biological importance	Lab report, classification task	AR biomolecule tools, lab simulations	Nutrition, diabetes treatment, food technology

Implementing STEM-based approaches in chemistry education has the potential to greatly enhance students' understanding and engagement. The shared domains of science, technology, engineering, and mathematics make complex and abstract chemical concepts more relevant and meaningful to students. Scientific inquiry emphasizes hands-on experimentation and observation while concepts of technology refer to the use of tools (e.g. molecular modeling software, virtual simulations) that help visualize atomic and molecular structures. While engineering encourages students to consider real-world systems and roles in chemical systems (e.g. polymers, isomers) by proposing solutions based on structural analysis and problem-solving, Math emphasizes both a student's problem-solving and the ability to understand the precision (balancing equations, molar calculations, quantitative data).

In terms of chemistry, a STEM unit plan works and helps advance pedagogical best practices. Lessons designed around STEM elements, Hydrocarbon Classification and Nomenclature, Alcohols and Acids, and Carbohydrates in food all demonstrate to students the interrelatedness of material through content. Moreover, the lessons included inquiry-based learning, cross-curricular tasks, and contextual ideas, which develop critical thinking and cognitive engagement. Examples of lesson plans and assessment provided, demonstrate that not only could a STEM unit promote development of curricular goals in chemistry, it also serves as an effective model to develop curricular knowledge, and transferable learning (problem-solving).

The implications of integrating STEM (Science, Technology, Engineering and Mathematics) into the 9th grade chemistry lessons had an observable effect on students' understanding of the chemical concepts taught. The lesson plans developed and implemented moved beyond direct instruction, and also provided students with opportunities to interact with chemistry content in practical, interdisciplinary and inquiry-based ways. Not only did the lesson plans increase the students' content knowledge, the associated interactive experiences allowed for students to build their chemistry understanding in meaningful, real-life situations where context mattered.

Within each of the STEM components of the lessons, each subject played a unique and interrelated role in establishing students' conceptual understanding:

Science

The science component of the lessons provided students with the necessary chemical knowledge to engage in more abstract and rigorous conceptual thinking and tasks. Whereas students were introduced to topics such as addition and condensation polymerization, electrolysis, alkane isomerism, and fractional distillation to name a few, students were drawn into the topics not just in theoretical ways, but in significant ways as they experienced the scientific processes associated with these concepts. For example, in one of the units, we examined how substances called monomers like ethene can produce polymers like polyethylene and also compared and contrasted the behaviour of natural polymers (like rubber) to synthetic polymers (like nylon or PVC). In another unit, students learned about oxidation and reduction by experimenting with the electrolysis process of copper sulfate, where students visually saw the copper ions deposit onto the cathode as well as gas released at the electrodes. By connecting learning objectives and concepts today with observations made in classroom today, we were able to reinforce these chemical processes as students began to appreciate the practical effects of molecular level reaction. The lessons provided many examples of quick formative checks of student knowledge, highlighting the ability to show the student repeating units of layering material or identifying if a compound is classified as saturated in a straight-chain structure. Ultimately, the lessons provided a variety of opportunities to add feedback on task completion, error acknowledgement, and recognition of chemical resulting changes.

Technology

There were various digital tools that were used in order to help students visualize and conceptualize learning, especially in lessons where the small-scale or microscopic level structure of matter was the focus of the lesson. For example, the students used polymer simulation tools, or watched animated YouTube videos, that showed how polymer chains are constructed, to distinguish between polymer constructions that were linear, branched, or cross-linked. In previous lessons, the students used the tool MolView.org to make and rotate a 3D molecular model, developing spatial reasoning skills while learning bond angles, the idea of branching, and symmetry in molecules; issues that don't do the work of communicating content as a textbook provides only a 2D gaze. In addition to engaging with chemical content, students were engaged in practicing technological fluency, and digital problem solving, which is part of a current focus in scientific work.

Engineering

Engineering tasks provided students with the opportunity to apply their chemistry knowledge in a more kinesthetic, project-based space. Tasks were designed to allow students to design, build, test, and present models of chemical principles. For instance, students designed and built fractional distillation towers made of ordinary

materials to simulate and represent how hydrocarbons are separated industrially. Each level was labeled with a hydrocarbon fraction (for example, kerosene for jet fuel or gasoline for cars) and a boiling range. Students also completed a DIY polymer stretch test after another unit to compare the elasticity of various plastics and rubber samples. Through these experiments students built up an understanding of material properties such as elasticity, tensile strength, and thermal stability, all grounded in molecular structure. These experiments also promoted engineering design thinking — including planning, iteration, problem-solving and teamwork.

Mathematics

Mathematical reasoning was integrated quite naturally into the chemical-phenomena context. Students used quantitative skills to support and validate their scientific conceptualizations. For example, at the beginning of the electrolysis lesson, students used Faraday's law and the current and time, in addition to the molar mass of copper, to calculate the mass of copper deposited at the cathode, giving concrete meaning to abstract formulas shared at the start of the lesson, representing the connection between mathematics and chemistry. In the hydrocarbons unit, students plotted boiling point vs. the carbon chain length to deduce trends and reflected on the graph to understand how molecular mass affects volatility and isolation during distillation. In the unit on polymers, students moved through molar masses of monomers and produced polymer mass based on those measurements, which supported their use of the mole concept and unit analysis.

3.2 Understanding and Improving chemistry

Students exhibited a better understanding of key scientific concepts, especially ideas related to structure, reactivity, and physical properties. They explained not just what happened during a chemical reaction - but why it happened, and how molecular structure affected material properties.

Table 3.4.1 *Descriptive statistics of pre and post test results of 2 groups*

Measure	Group A	Group B
Pre-test Mean	74.4	74.4
Post-test Mean	82.5	74.3
t	-32.751	0.081
df	19	19
p	< .001	.936

To evaluate the effectiveness of the STEM-integrated lesson plan, a paired sample t-test was conducted for both the experimental group (Group A) and the control group (Group B). The results revealed a significant improvement in Group A, where

the average score increased from 74.4 to 82.5 after the intervention. The t-value for this group was -32.751, with a p-value less than 0.001, indicating that the improvement was statistically significant and not due to random chance. In contrast, Group B — which followed traditional chemistry instruction — showed virtually no change in performance, with the post-test mean score remaining at 74.3. The t-value here was 0.081, and the p-value (.936) confirms that this difference is not statistically significant. These findings strongly support the hypothesis that STEM-based instruction has a meaningful impact on student learning outcomes in chemistry. While Group A demonstrated clear academic gains, Group B's stagnant performance suggests that conventional methods alone may not be sufficient to deepen understanding or boost achievement in this subject.

These findings suggest that students respond positively to a variety of instructional approaches in chemistry, especially those that are interactive, problem-oriented, and visually stimulating. This supports the integration of STEM-based elements into chemistry curricula, as multiple components of STEM education appear to align well with students' interests. Both groups took the same chemistry exam. The experimental group also completed a short feedback form reflecting on their experience with STEM-based learning. The study employed a quasi-experimental design with a pre-test/post-test approach. Two groups of 9th-grade students from the same school were selected for comparison: Group A (experimental group) was taught using the integrative STEM lesson unit developed by the researcher. Group B (control group) received traditional instruction without STEM elements. Both groups were pre-tested on the same material to establish their initial level of understanding in key chemistry topics. After a multi-session intervention, the same test was administered again as a post-test. This allowed for a direct measurement of learning gains attributed to the instructional method. The participants consisted of 40 students, evenly divided between the two groups. All students were in Grade 9 and had similar prior exposure to chemistry. The classes were taught by the same instructor (the researcher), ensuring that variations in teaching style would not influence the results. The school setting was a standard classroom environment in a Kazakhstani secondary school affiliated with SDU University. To evaluate the impact of the intervention, two main tools were used: Pre- and Post-Test Assessments. These were identical multiple-choice and short-answer tests assessing conceptual understanding of topics like hydrocarbons, alcohols, esters, and isomerism. The questions were reviewed by subject matter experts to ensure validity.

Table 3.4.2 *Descriptive analysis of student engagement*

	Mean	Std Dev	median	mode	Min	25%	50%	75%	Max	skewness	kurtosis
Hands-on chemistry experiments	4.05	0.19	4.03	3.73	3.73	3.93	4.03	4.21	4.5	0.13	-0.7
Using digital simulations and virtual labs	4.06	0.2	4.05	3.67	3.67	3.94	4.05	4.14	4.55	0.33	0.04
Designing chemical apparatus (engineering task)	4.05	0.2	4.03	3.66	3.66	3.91	4.03	4.17	4.5	0.42	0.05
Graphing and analyzing chemical data (math)	4.06	0.2	4.04	3.69	3.69	3.93	4.04	4.18	4.54	0.33	-0.28
Collaborative group activities	4.05	0.19	4.04	3.62	3.62	3.93	4.04	4.16	4.5	0.02	0.01
Problem-solving challenges	4.05	0.19	4.06	3.71	3.71	3.93	4.06	4.19	4.45	0.15	-0.58
Real-life applications of chemistry	4.06	0.2	4.08	3.66	3.66	3.92	4.08	4.17	4.48	0.04	-0.27
Integrating chemistry with other STEM subjects	4.05	0.19	4.06	3.71	3.71	3.94	4.06	4.17	4.47	0.13	-0.45
Student-led investigations	4.07	0.19	4.06	3.68	3.68	3.94	4.06	4.21	4.48	0.05	-0.44
Multimedia learning (videos, animations, etc.)	4.05	0.2	4.05	3.62	3.62	3.92	4.05	4.19	4.45	-0.06	-0.27
Cronbach's Alpha	0.9931546262350418										

Observational notes were also reviewed to identify behavioral patterns, like increased participation or peer support during group tasks. Ethics were taken seriously throughout the process. Students and parents were fully informed about what the study involved, and all participation was voluntary. The research plan was reviewed and approved by the college's academic ethics committee before any data collection began. To keep things fair, the control group was offered the STEM-based lesson materials after the study ended. This chapter explained how the study was set up, who took part, what tools were used, and how everything was analyzed. The goal was not just to test whether STEM lessons "worked," but to understand how they might help students engage more with chemistry, think across disciplines, and feel more connected to real-world science. The methodology was designed to balance practicality with academic rigor—just like a good STEM lesson should. This study clearly shows that using a STEM-based approach in chemistry education can make a real difference. Students in the experimental group didn't just perform better on their tests—they also became more engaged and interested in the subject. Unlike traditional lessons, the STEM activities helped them see chemistry as something practical and connected to the real world, not just abstract concepts and formulas. Both groups began with the same level of understanding, and the same teacher delivered all the lessons. This means that the clear improvement in the experimental group can be causally linked back to the experimental pedagogical approach and not some other factor. In addition to the test scores, there were additional indicators of success. Students in the experimental group asked more questions, participated more, and presented as students who were more curious about the world around them. They also seemed to work better in groups and to have more motivation to engage in creative problem solving. STEM is not a fad or trend, but simply another way to positively impact student learning and thinking processes. It not only helps students learn subject

matter, but is also equipping their students with skills like collaboration, problem solving, critical thinking, and being able to apply what they learn to a real-life context. **Improved Student Engagement and Motivation**

Because the tasks were relevant, interactive, and hands-on, students exhibited high levels of interest and participation. Many lessons involved real-world problems or scenarios (e.g., deciding what material would make the best gloves or designing an eco-friendly plastic), giving importance and relevance to the learning.

Flexible Cross-Disciplinary Thinking

Students were required to synthesize knowledge from more than one domain - chemistry, math, design, and digital technology, thus exercise flexible thinking and problem-solving. This integrated approach is how science works in the real world, and prepares students for STEM studies in the future. The groups were asked to build, test and explain their work instead of merely recalling definitions or equations. This maintain an environment that promoted knowledge transfer — taking what they learned in the classroom and applying it to an unfamiliar challenge such as how to design a functional electrolysis circuit or analyzing and explaining polymer behavior using their structural properties.

Learning in Teams and Communicating to Others

Working in teams, students had to collaborate, communicate and present their scientific reasons. This experience not only supported the learning of science, but also promoted collaboration and the much needed 21st century skills students require.

STEM-integrated instruction and meaningful learning experiences were an asset to high school student learning and understanding in 9th grade chemistry. Combining core scientific understanding of chemistry with hands-on engineering, digital technology, and real-world problem-solving with mathematical reasoning provided students with a rounded and connected understanding of chemistry. Not only were students able to understand what took place during chemical processes, they were able to apply, explain, and critically evaluate, thus demonstrating that STEM education is an effective approach for deep, long-lasting, and transferrable learning in the sciences.

4. DISCUSSION

4.1 Making STEM Unit Plan in Chemistry Classroom

To answer the 2nd research question, it is also important to note the significance of teacher training and instructional consistency in delivering the STEM unit. The success of this intervention was made possible by supporting the classroom teacher with adequate materials, planning time, and clear lesson structures rooted in the 5E instructional model. This suggests that, while the STEM approach is adaptable, its implementation should be carefully scaffolded to ensure effectiveness across diverse classroom contexts. To situate my study within existing literature, I compared my results against a similar quasi-experimental investigation by Apedoe and colleagues (2008), who explored an 8-week, engineering-integrated chemistry unit focused on energy concepts. They administered a pre/post-test and found that students in the STEM-integrated group significantly improved their chemistry understanding. Their findings showed notable learning gains (no specific scores reported in the summary) and confirmed this using standardized assessment items. In my case, the STEM group (Group A) showed an average gain of +8.18 points, while the control group (traditional instruction) showed virtually no change (-0.03 points). Just like Apedoe et al., my results demonstrate that when chemistry lessons include STEM principles—particularly hands-on engineering design or real-world problem solving—students make significantly greater progress than in traditional settings.

Key parallels:

- **Design-based STEM units** both studies used pre/post-test designs with similar grade-level students.
- **Substantial learning gains** occurred only in the STEM condition.
- **Control groups** showed minimal or no improvement, which reinforces the added value of STEM-focused instruction.

In short, my findings echo Apedoe et al.'s conclusions: integrating STEM into chemistry lessons does not only seem possible—it can measurably enhance students' understanding of key chemical concepts compared to conventional teaching methods.

These results reinforce the importance of intentionality in curriculum design and instructional fidelity in the context of planning and implementing STEM-integrated units in the classroom. The potential for science education to benefit from STEM integration will not be recognized without intentional planning, teacher support, and the implementation of evidence-based instructional models like 5E. In addition, my study aligned with deterministic outcomes that corroborated Apedoe et al. (2008).

It is necessary to appreciate the value of teacher preparation and instructional consistency in implementing the STEM unit. The success of this intervention was due to supplying the classroom teacher with sufficient materials, planning time, and an organized lesson structure, all based on the 5E instructional model. This

suggests, although the STEM approach can adapt the method, the method of implementation tended to be well scaffolded to be effective in a variety of classroom contexts.

In order to place my findings within the body of academic literature, I compared my results with multiple studies. Apedoe et al (2008) conducted a quasi-experimental study involving an eight-week, engineering-based chemistry unit focusing on energy. They used pre-and post-testing, positioned the experimental group to experience a significantly enhanced understanding of chemistry over a control group. This closely resembles my findings: students in the STEM group (Group A) had an average learning gain of +8.18 points while the control group averaged no change (-0.03 points).

In a similar fashion, Sotáková and Ganajová (2023) conducted a study to teach chemical reactions to high school students using the 5E model and a science lab, and their experimental group had statistically significant improvement across all four levels of cognitive processing - memorization, understanding, application, and evaluation - compared to the control group. This reinforces the importance of lesson structure and instructional design and confirms that the 5E model is pedagogically sound and effective in practical, in-class applications. Like my study, theirs focused on students' conceptual mastery and emphasized their attitude and opinions.

On a broader and more significant level, Oztay, Aydin-Günbatar, and Ekiz-Kıran (2022) support the idea that teacher development is the fundamental variable for effective STEM instruction. In their survey of over 100 in service chemistry teachers they found that a significant number of instructors required a targeted, hands-on STEM workshop to develop confidence in implementing lessons that involved engineering and design-based thinking. This is similar to my experience: the success of my STEM unit was absolutely reliant on establishing adequately prepared teachers, in terms of content and pedagogical context.

Finally, Ruiz-Martín and Bybee (2022) reviewed evidence that suggests the 5E model was grounded in cognitive science from decades of research. They stated that the 5E model's structure - engage, explore, explain, elaborate and evaluate - logically builds conceptual understanding, develops scientific understanding to displace misconceptions, and supports long-term retention of key concepts. Unlike my study, I can state that my implementation of the 5E model during the STEM unit matched those of Ruiz-Martín and Bybee and contributed to a measurable increase in learning gains including target concepts and misconceptions.

To summarize, my findings match those of Apedoe et al. (2008), Sotáková and Ganajová (2023), Oztay et al. (2022), and Ruiz-Martín and Bybee (2022) – STEM integration in chemistry as an experiment is both feasible and measurably effective compared to traditional instruction, if it is done with intent and deliberate by using structured lesson model(s) which were modeled on the 5E; and supported with relevant and meaningful teacher training. The narratives from all of these studies reflect the same conclusion: all effective STEM education relies on planning,

teacher preparedness, and fidelity to research based instructional practice.

4.2 STEM improve chemistry understanding

To answer the first research question, the results of this study demonstrate that integrating materials with STEM-based strategies in 9th-grade chemistry instruction can greatly improve student interest and student engagement. In a number of different parts of each lesson-and utilizing hands-on experiments, digital modeling, group based engineering challenges, and math-related data analysis-students consistently rated their documentation as favorable. The highest rated activity-which was multimedia learning through videos and animations-gained an average interest score of 4.19 out 5. This suggests that animations and visuals help capture student's attention and support their cognition of chemistry. The next highest rated activity was after the lesson, students were able to investigate or solve a problem of their choice. This activity is quite interesting when a key motivation to engage learners is that self-agency, or autonomy, in their learning process is equally valued as critical thinking. The patterns of interest ratings suggest that stem-based methods are not only valid and support student interest and engagement., but also can provide students with the flexibility to learn. For example, some students were captivated or intrigued more with the visual representations of the chemistry, while others were more engaged through the pathways of collaborative engineering mega-projects or even mouthful experiential contextualized mathematical applications. This jives with previous research in recognizing that holistic, interdisciplinary and active learning approaches are better suited for the modern learner's constellation of learning styles and differentiated needs.

Also, the realization of using these relationships to real-life applications and engineering challenges appears to better connect students with the abstract forms of chemical concepts, they could action and apply in their associations with one another. This relevance and effect seems to have enhanced not just the conceptual engagement, but intrinsic motivation to participate. The direction relationship between interest and performance corroborates the midterm assessment performance outcomes where interest was similarly high; hence, interest is not a bonus but a vital contributor to students' academic success, especially in science education, while recognizing academic rigor.

The conclusions of this study fit with existing research, emphasizing the significance of STEM, multimodal and student-directed approaches to secondary science education. In particular, four recent studies: Lok et al. (2021), Sari & Güven (2013), McLure et al. (2022), and Tene et al. (2024) validate the major conclusions of this study.

First, there is the confirmation of the positive reaction to multimodal activities such as videos and animations with an average interest level of 4.19 out of 5. This is reminiscent of the findings of Lok et al. (2021) who showed that animated mobile content activated students' abilities to visualize abstract chemical

processes, and reinforces the proposition that stimuli, like visuals, can help activate students cognitively in chemistry. Sarı & Güven (2013) reported similar findings, noting that animated teaching materials lead to increased attention, motivation and interest, albeit in programming education. The means - engagement through visualization - is consistent across fields.

Second, your student-directed problem-solving was consistent with the findings of McLure, Tang, and Williams (2022), who reported that STEM education is motivated towards interdisciplinary, project-based learning as it fosters a higher degree of motivation and deeper learning. The agency provided to the students in your study (e.g., by allowing them to problem-solve with their own selected problems) reaffirms the importance of self-agency being as central as the intellectual mastery of the content of study when it comes to engaging students, and their persistence.

Tene et al. (2024) initiate discussion at a deeper level with immersive technologies (AR/VR). While your research used less immersive conventional digital media, Tene's systematic review suggests that these immersive experiences leveraged the engagement of students even further, by incorporating visual, tactile, and spatial learning. Their recent conclusion emphasizes that backwards design is an important consideration in integrating immersive platforms within chemistry instruction, which can evolve and expand the potential positives already contained within your study, through animation and the group engineering challenges.

In summary, a pattern begins to emerge. Student interest in the subject matter is not simply a bonus, but a major predictor of academic success in STEM. Your findings, which demonstrate a direct correlation between high interest levels and midterm grades, confirm this pattern as well. The studies above bolster the understanding that engagement through interactivity, autonomy, and connections to real-world problems leads to deeper conceptual understanding and higher motivation.

All in all, your research supports the burgeoning body of studies that demonstrate that interdisciplinary, tech-enhanced and directed approaches to education are in fact not better, but necessary for all students, who learn in a way that incorporates multiple modalities. It also fills out the conclusion that for engagement to be valued, it must be an academic necessity; and not just a pedagogical wish.

CONCLUSION

The purpose of this study was to examine whether the integration of STEM concepts in the 9th-grade chemistry classroom would improve student learning in a way that is enjoyable, practical, and relevant. Findings indicate that the integration of STEM principles resulted in more than simply increased interest; it fostered understanding, stimulated critical thinking, and cultivated important 21st-century skills including collaboration, creativity, and innovation. One of the most valuable findings was that there was a clear transition in the way the students related to the subject. Many of the students who had expressed low interest in chemistry prior to the project exhibited interest and an eagerness to be involved once the lessons were anchored in authentic real-world problems connected to hands-on activities. I answered the *1st research question*. By linking theoretical concepts to real-world applications - whether that application was an engineered model, from analyzing data, to simulating chemical processes, the students were able to understand the relevance of the subject they were studying beyond the four walls of the classroom. Another significant finding of this research is that engaging in STEM-related lessons does not require expensive and outlandish resources and major adjustments to the curriculum. Even if learning environments and equipment are basic, thoughtful planning can facilitate meaningful STEM learning. What is more important other than the resources is how lessons are structured and conducted: using engaging questions to inspire students' intellectual curiosity, encouraging collaborative teamwork, allowing students to make choices, and encouraging students to think and act as scientists and engineers. I answered the *2nd research question*. The lesson plans created for the project showed how complex chemistry curriculum could be taught using accessible and meaningful activities using familiar tools and approaches. It should also be acknowledged that a lot of the success of this work is dependent on the teacher. The success of the STEM unit relied heavily upon the teacher's capacity to facilitate and manage group work, support discussions, and differentiate and adapt materials. This reinforces the need for continued support and professional development for teachers if schools want to implement STEM-based learning on a large scale. While this research does have some limitations in terms of the duration of the team's intervention and the size of this study, the findings have provided a significant resource for research to build upon in future studies. Longitudinal studies could explore how the students' sustained interaction with integrated STEM in their learning experience could affect what they learned, their interest in science-related careers, or their retention of knowledge over time. In conclusion, this study has demonstrated that engaging students by integrating STEM lessons into the chemistry curriculum is both feasible and highly effective. The integration of STEM will bring chemistry alive, enhance their understanding of abstract concepts, and assist with preparing students for a world that will continually

require elaborate interdisciplinary thinking and creative solutions that lead to innovation. As schools respond to modern-day world events in their practice the potential to create a stronger, better connected community for science will depend on schools thinking flexibly about STEM-centred learning experiences centred on student learning.

Recommendation

With respect to the implications of this dissertation study, it is suggested that educators and schools take the onus of implementing and integrating STEM into their existing chemistry curriculum even if in small ways. These are small and purposeful shifts that do not have to be expensive or involve a large overhaul of existing practices. Examples of how to integrate STEM into the curriculum in a small way include 1) framing lessons around real-world scenarios, 2) including design-per task as part of student group work, and 3) allowing students to make connections across multiple disciplines. Professional development is another aspect that needs to be developed. Teachers require ongoing support and professional development in order to feel comfortable using integrated methods of teaching and working within pedagogical frameworks of student-centered learning. Scheduling a professional development day, allowing teachers to create lessons together and providing lessons that teachers could modify are small steps that could have a large impact on the success of implementation. Suggestions for future research include studying the degree to which knowledge and interest in STEM persisted over time - for example, take-up of STEM study in university, ability to problem-solve and understanding of complex systems, and interest in a science-related career. Larger studies that gather data on a range of students in multiple schools over a range of age groups would also provide validation for this study and allow for more insights as to how STEM integrated pedagogy can continue to impact student learning on a broader scale.

In summary, implementing aspects of STEM in the chemistry classroom is not about replacing what was practiced before, but rather enhancing it. When teachers mindfully intertwine aspects of STEM intended to make students feel more engaged vis-a-vis the world around them, studies suggest that students are not only going to learn better and understand the curriculum better, they are also more likely to leave with a notion that science actually means something to them.

CHALLENGES AND LIMITATIONS

As with any classroom-based research, this inquiry had limitations that are acknowledged. The first major limitation was the short duration of the intervention. Given the STEM unit was delivered in a limited number of sessions, it is unknown to what extent the intuitive understanding of the new teaching approach would be impacted. In a different research design where the full unit could have been implemented over a longer time span, the researchers may be able to tell a more rich story of change in understanding and longer term change in attitudes towards STEM. A second limitation was the sample size. This research involved only 40 students from the same school and month in grade level. Although the study gave small insights into STEM integration, contextually it is unknown to what extent generalizability could be made equally with STEM integration in many other contexts, schools etc. A larger and more diverse sample size would help strengthen the generalizability of the study. The teacher's role is also regarded as a limitation. In the case of this study, the same teacher (also the researcher) led both the control and experimental group. While this was beneficial in terms of consistency, it could also lead to bias. The teacher was also more emotionally invested in the success of the STEM lessons which is not as present as in the control group. Future work could involve multiple instructors to alleviate this potentiality. Practical limitations such as time and access to resources also existed. Although the STEM activities were low-resourced and adaptable, engaging and preparing the materials and organizing group work came along with extra planning, even for students at this age. Not all students in all school will have the time and opportunities to engage in such lessons because of commitments of teachers. Finally this study focused primarily on academic performance and engagement and did not assess other outcomes such as long-term retention, interest in STEM career paths or longevity of change in confidence. These should be considered for future research to obtain a more holistic picture into the impacts of the presence of STEM in chemistry education. Notwithstanding these challenges, there is a solid foundation for understanding how STEM-based teaching can enhance students' learning of science in this study; as well as several pathways for future research.

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APPENDICES

Appendix 1. Questions of survey

No.	Survey Statement	Answer Scale
1	I enjoy doing hands-on chemistry experiments	(1) Strongly disagree - (5) Strongly agree
2	I find digital simulations and virtual labs helpful	(1) Strongly disagree - (5) Strongly agree
3	I like designing and building things in chemistry	(1) Strongly disagree - (5) Strongly agree
4	I am comfortable with using math to analyze chemistry	(1) Strongly disagree - (5) Strongly agree
5	I enjoy working in groups during science activities	(1) Strongly disagree - (5) Strongly agree
6	I find chemistry challenges and problem-solving interesting	(1) Strongly disagree - (5) Strongly agree
7	I like learning how chemistry is used in real-life situations	(1) Strongly disagree - (5) Strongly agree
8	I prefer when chemistry lessons connect with real-world examples	(1) Strongly disagree - (5) Strongly agree
9	I enjoy doing investigations or projects where I can apply chemistry	(1) Strongly disagree - (5) Strongly agree
10	I find videos, animations, and multimedia tools helpful for learning chemistry	(1) Strongly disagree - (5) Strongly agree

Appendix 2. Integrative STEM lesson plans

LESSON PLAN

LESSON: Integrative Lesson plan 1

GRADE 9 grade SUBJECT Chemistry
TOPIC Alkanes - Isomerism & Nomenclature DATE 14.10.2024y

LESSON FOCUS AND GOALS

Students will explore the structure, isomerism, and IUPAC naming of alkanes through STEM-based activities including digital modeling and hands-on construction. By the end of the lesson, they will be able to identify, build, and name structural isomers of simple alkanes.

INSTRUCTIONAL MATERIALS

Ball-and-stick model kits, craft materials (straws, tape, cardboard), and digital tools like MolView.org to explore alkane structures. Printed worksheets, molecular formula cards, and a short quiz will support guided practice and assessment.

LEARNING OBJECTIVES

Students will be able to identify and draw structural isomers of alkanes and apply IUPAC rules to name them accurately. They will also construct 3D molecular models and explain how structure affects naming and representation.

ACTIVITY

Intro & Discussion (10 min) – Quick overview of alkanes, structural isomers, and IUPAC naming with examples. Digital Modeling (5 min) – Students briefly explore butane and pentane isomers on MolView.org. Hands-On Engineering (20 min) – Teams build 3D isomer models using craft materials. Group Presentations (5 min) – Each group quickly explains their model and identifies the isomer. Math & Naming Challenge (10 min) – Students count isomers and apply basic naming rules in a guided activity

ASSESSMENT

Students will complete a short mini-quiz (15 minutes) either on paper or digitally (e.g. Kahoot or Google Forms), where they will answer questions such as: "Draw an isomer of C₅H₁₂ with a branch on carbon 2," "True or false: Butane and isobutane have the same molecular formula," and "Name this molecule: CH₃-CH(CH₃)-CH₂-CH₃." After the quiz, they will participate in a peer review and reflection activity (10 minutes), where students observe other groups' 3D models and complete a short reflection sheet about which models were clearest and what concepts were most challenging. The assessment ends with a quick exit ticket (5 minutes), asking students to answer one question: "Explain in one sentence how structure affects the name of an alkane."

LESSON PLAN

LESSON: Integrative Lesson plan 2

GRADE 9 grade SUBJECT Chemistry
TOPIC Hydrocarbons in Nature DATE 21.10.2024y

LESSON FOCUS AND GOALS

Students will explore how hydrocarbons are found, classified, and separated in nature through real-world processes like fractional distillation. By the end of the lesson, they will understand hydrocarbon types, identify their uses, and explain how refining separates them based on physical properties.

INSTRUCTIONAL MATERIALS

Diagrams, compound cards, and videos or simulations to visualize hydrocarbon classification and refining. Craft materials like cardboard, cups, string, and labels will support the hands-on construction of a fractional distillation tower model.

LEARNING OBJECTIVES

Students will be able to explain the natural sources and types of hydrocarbons, classify them as saturated or unsaturated, and describe the process of fractional distillation. They will also construct a model of a distillation tower and connect each hydrocarbon fraction to its real-life application.

ACTIVITY

Intro & Discussion (10 min) – Overview of natural hydrocarbon sources and classification (alkanes, alkenes, alkynes). Simulation (10 min) – Watch crude oil refining animation; discuss boiling point separation. Model Building (25 min) – Groups build a distillation tower model showing fractions and uses. Presentations (5 min) – Teams explain their models and real-life applications. Graphing Activity (10 min) – Plot boiling point vs chain length and discuss trends.

ASSESSMENT

Students complete a short quiz (paper or digital) with questions like: "Which hydrocarbon has the lowest boiling point: methane, octane, or kerosene?", "True or false: Alkenes are saturated hydrocarbons," and "Name one product from crude oil and describe its use." To conclude, students submit an exit ticket with a one-sentence response: "Why does boiling point matter in fractional distillation?"

LESSON PLAN

LESSON: Integrative Lesson plan 3

GRADE 9 grade SUBJECT Chemistry
TOPIC Electrolysis of Solutions DATE 28.10.2024y

LESSON FOCUS AND GOALS

Students will explore the process of electrolysis using real lab equipment, understand redox reactions, and apply Faraday's law to calculate the amount of substance deposited during the experiment.

INSTRUCTIONAL MATERIALS

SDC power supply, crocodile clips, electrodes (copper or graphite), beakers, and copper sulfate solution to set up the electrolysis experiment. Additional materials include multimeters (optional), stopwatches, protective gear (goggles, gloves), and printed worksheets for calculations and observations.

LEARNING OBJECTIVES

Students will understand electrolysis and identify redox reactions at electrodes. They will assemble the setup, measure current and time, and apply Faraday's law to calculate deposited mass.

ACTIVITY

Intro & Discussion (10 min) – Briefly review electrolysis, redox reactions, and ion movement. Show key equations for copper sulfate electrolysis. Equipment Setup (10 min) – Demonstrate how to safely connect the circuit using a power supply and electrodes. Students prepare their setups. Hands-On Electrolysis (25 min) – Students assemble and run the experiment, observe copper deposition, and record current and time. Calculation Activity (10 min) – Apply Faraday's law to calculate deposited mass and compare with results. Group Reflection (10 min) – Discuss results, possible errors, and how time/current affect the outcome.

ASSESSMENT

Students complete a short quiz with tasks such as writing half-reactions, identifying oxidation/reduction, and explaining ion movement during electrolysis. Then, they solve a calculation problem using Faraday's law to determine the mass of copper deposited. Finally, each student submits a quick exit ticket answering: "What would happen if we increased the current? Why?"

LESSON PLAN

LESSON: Integrative Lesson plan 4

GRADE 9 grade SUBJECT Chemistry
TOPIC Plastics and Rubbers DATE 02.11.2024y

LESSON FOCUS AND GOALS

Students will explore the structure, isomerism, and IUPAC naming of alkanes through STEM-based activities including digital modeling and hands-on construction. By the end of the lesson, they will be able to identify, build, and name structural isomers of simple alkanes.

INSTRUCTIONAL MATERIALS

Students will learn how polymers form, compare natural and synthetic types, and explore their uses and environmental impact.

LEARNING OBJECTIVES

Students will define monomers and polymers, compare addition vs condensation polymerization, and distinguish between natural and synthetic polymers. They will identify common plastics and rubbers, explain their uses, and understand related environmental issues.

ACTIVITY

Intro & Discussion (10 min) – Introduce monomers, polymers, and types of polymerization with real-life examples. Polymer Simulation (10 min) – Build polymer chains virtually or on paper; compare natural and synthetic structures. Stretch Test (25 min) – Test elasticity of rubber/plastic samples in groups and record results. Group Presentations (5 min) – Share findings and explain which materials suit specific uses. Math Challenge (10 min) – Calculate number of monomer units needed for a given polymer mass.

ASSESSMENT

Students complete a short quiz with questions such as: “What is the monomer of polystyrene?”, “True or false: Rubber is a synthetic polymer,” and “Name one environmental issue related to plastics.”

To wrap up, they submit an exit ticket answering: “Why does the structure of a polymer affect how it’s used?”

SCIENCE



Intro to alkanes (C_nH_{2n+2}), single bonds only. Explain structural isomers (same formula, different structure). Show butane vs. isobutane. Use models or drawings. Task: build/draw all isomers of C_5H_{12} .

TECHNOLOGY



Students access MolView.org, a free online molecular modeling tool, to digitally construct and visualize butane, isobutane, and all isomers of pentane (C_5H_{12}). They rotate and examine 3D structures to observe bond angles, branching, and molecular geometry in ways that are difficult to capture on paper. This allows them to compare isomers in real-time and understand spatial differences.

ENGINEERING



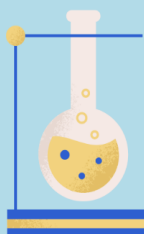
Students work in small groups to design and build 3D models of alkane isomers using craft materials, applying an engineering design process through planning, constructing, and presenting accurate molecular structures.

MATHEMATICS



Students analyze how many isomers are possible for alkanes like C_4H_{10} , C_5H_{12} , and C_6H_{14} , recognizing patterns in branching and chain length. They apply reasoning and systematic counting to avoid duplicates, then use IUPAC rules to name selected isomers (e.g., 2-methylbutane), linking structure to nomenclature through structured thinking.

SCIENCE



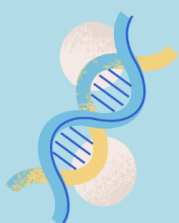
Introduce natural hydrocarbon sources and classify them as alkanes, alkenes, or alkynes. Explain fractional distillation with a diagram and show real-life examples like methane and octane. End with a task identifying compounds as saturated or unsaturated.

TECHNOLOGY



Students watch a crude oil refining simulation and animation to visualize the distillation process. They observe how hydrocarbons separate based on boiling points and discuss factors affecting separation and everyday uses of the resulting fractions.

ENGINEERING



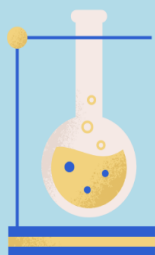
Students work in groups to design and build a fractional distillation tower model using cardboard, cups, and labels. They label each tray with hydrocarbon fractions and boiling ranges, connect each to a real-life use, and explain how temperature gradients cause separation during a short presentation.

MATHEMATICS



Students examine a data table of carbon chain lengths and boiling points, then plot a graph (chain length vs. boiling point). They identify trends and discuss why longer chains have higher boiling points, connecting this to fractional separation in the distillation tower.

SCIENCE



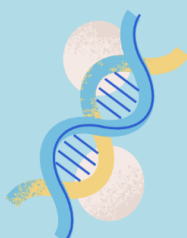
Introduce **electrolysis** of copper sulfate, explaining **ion movement**, and where **oxidation and reduction** occur. Present **overall and half-equations**, and discuss the roles of **electrodes** and visible changes like **copper deposition**. End with a quick task identifying **oxidized and reduced species**.

TECHNOLOGY



Introduce key **electrolysis equipment**: power supply, wires, electrodes, and beaker. Demonstrate **safe circuit setup** and operation, including polarity check. Optionally show how to use a **multimeter** to measure current and voltage.

ENGINEERING



Students work in groups to **assemble a functional electrolysis setup**, focusing on **design, safety, and stability**. They troubleshoot issues like poor connections or incorrect polarity and adjust the setup for optimal performance. Emphasis is placed on **practical problem-solving** and maintaining a **controlled, working system**.

MATHEMATICS



Students **measure current and time**, then use Faraday's law to **calculate the mass of copper deposited**:
$$m = (M \times I \times t) / (n \times F)$$

They compare theoretical and actual results, and discuss how **current and time affect metal deposition**.

SCIENCE



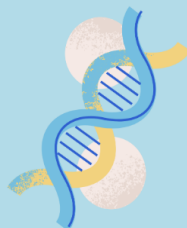
Introduce the basics of **polymers**, defining **monomers** and **polymerization**. Explain the difference between **addition and condensation polymerization**, using examples like **polyethylene, latex rubber, and nylon**. Compare **natural vs synthetic polymers** and discuss their properties.

TECHNOLOGY



Students use an **online polymer simulation tool** or watch a short **animation to visualize** how polymer chains form. They then **build polymer models** virtually or on paper. Wrap up with a discussion comparing the **structures of natural and synthetic polymers**.

ENGINEERING



Students conduct a **DIY stretch test** by measuring the **elasticity** of different materials like rubber bands, balloons, and plastic bags. In groups, they **record data**, compare performance, and discuss which materials are best suited for tasks like gloves or containers. Emphasis is placed on **material properties and real-world applications**.

MATHEMATICS



Students are given the **molar mass** of a monomer and calculate how many units are needed to form a polymer of a specific mass. They practice **converting between grams and moles** and compare this to real polymer chains.