# PUSL3190 Computing Individual Project

## Project Proposal

<u>Chemistry Lab Website for AL Students</u>

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# 01.Problem Statement

Accordingly, mastery in chemistry is very important for students who follow the A/L science stream, as chemistry gives the foundation of nearly all scientific fields related to medicine, engineering, and environmental science. Chemistry at A/L levels, however, has several unique difficulties that seriously hamper the students in acquiring integrated knowledge necessary to be mastered in this extremely challenging subject. These include theoretical and practical problems in inorganic chemistry, organic chemistry, and the use of the periodic table.

Domain Overview
Chemistry as a science deal with the study of matter, its properties, how it interacts, and changes that take place during chemical reactions. The identification of color, flame tests for the identification of metal ions, complexities of organic reactions, and other detailed trends of the periodic table are all to be known at the A/L level. Mastery of these subjects becomes very important for success both in theory examinations and practical laboratory assessments.

Importance of Addressing These Challenges

Several reasons that make addressing these challenges important include:

- Foundational Knowledge - Students need to be well equipped with a sound chemistry platform to enable them to pursue higher studies in the scientific arena. Poor mastery of the basic concepts in chemistry will only lead to improper preparation and may render students unprepared for higher studies.
- Future Opportunities - One's proficiency in A/L Chemistry has real-world consequences in terms of one's scholarships, University Admissions, and career opportunities in Science and Technology fields.
- Cognitive Development - Studying chemistry evokes critical thinking, problem-solving skills, and scientific literacy that are beneficial in making informed decisions in everyday life.

Effects of the Problem

The difficulties that students encounter in A/L chemistry manifest themselves within many detrimental forms:

- Inadequate Understanding - Students largely remain unable to gain a deep understanding of chemical conceptions, which could be a source of misconceptions and superficial understanding.
- Loss of Confidence - Failure to conduct practical activities such as identification of color changes or the execution of flame tests diminishes confidence during assessments and in the laboratory.
- Poor Academic Performance - In effect, these failures equate to lower scores and performances in both theoretical and practical tests, hence hindering total academic achievement.
- High Cognitive Load - Given the huge amount of information that needed to be committed to memory without proper resources and equipment by today's standards, there was a high cognitive load, which is an obstacle to knowledge recall and application processes that students have to undertake during examinations.

Target Group
The main stakeholders who suffer from these challenges are the A/L chemistry students, teachers, and even curriculum developers. Knowing what exactly ails students will help in the development of adequate learning tools and equipment to provide more meaningful education.

 Identified Challenges

1. Inorganic Chemistry - Color Identification - Insufficient laboratory exposure makes students incapable of identifying color changes to specify the chemical change that has occurred.

2. Flame Test - Identification by Flame Color - Insufficient practice results in confusion while identifying flame colors of metal ions, which lowers self-confidence during practical tests.

3. Organic Chemistry - Crams of Reactions and Catalysts - The details of many reactions and catalysts become an overload; applications of knowledge are not possible.

4. Periodic Table - Memorization and Understanding of Trends - Because the amount of information necessary for the understanding of periodic trends is huge, it is cumbersome to predict the properties of an element.

5. Poor Organization of Resources, Lack of Modern Equipment - With unspecialized equipment for several computations in chemistry, there is unorganized retrieval of information which leads to a setback in cognition, especially in situations when there is some time pressure during tests.

This no doubt would address the above challenges in A/L chemistry for better understanding, the improvement of performances, and, eventually, may lay a foundation for future scientific engagements. Indeed, targeted solutions can help students overcome such obstacles and help them establish a sound foundation in chemistry.

# 02. Project Description

## 1.1 Project Objectives and Explanation

1. Identify inorganic compounds by color
2. Use of a flame test simulation module
3. Organic reactions
4. Interactive periodic table
5. Chemistry-specific calculator

Explanations

1. Identify inorganic compounds by color - These objective targets students' ability to identify inorganic compounds by color, which is a frequent problem in practical chemistry. The employment of such verbs as distinguishing and analyzing points to both identification and deeper understanding of color indicators in compounds. An accuracy target set at 85% gives an absolute mark for success, while the timeline set to the end of the first semester brings about accountability and urgency.

2. Flame test simulation module implementation - The development of the flame test simulation module will enhance the student's ability to identify different metal ions by their flame color-one of the most important skills in inorganic chemistry. This objective is essentially practical for a chemistry student since its focus is to bring about identification and differentiation. Accomplishment of at least 90% accuracy, besides being within a timeline of six months, also makes the objective measurable, achievable, relevant in terms of practical chemistry skills, and time bound.

3. Organic reactions - It was designed aimed at enabling students, through a searchable database, to enhance recall and understanding of catalysts and conditions in 75% of syllabus reactions. The verbs recall and understand point to the cognitive focus on memory and comprehension, respectively. Progress will be measured by periodic assessment, and the attainment should be possible within one academic year, hence being relevant and matching students' learning needs.

4. Periodic table - This objective is designed to ensure students master one of the most important areas in chemistry-periodic trends. The application and comparison of properties of elements, therefore, are emphasized in this objective to develop higher-order thinking and foster active analysis. The targeted 80% in practice assessments set at the end of the first term gives a clear framework for measuring progress and reinforcing learning outcomes.

5. Calculator - This objective tends to solve some problems in stoichiometry and equilibrium by building a customized calculator. The calculator will provide the student with doing key calculations without mistakes. This would contribute to making the actual error rate 70% lower than that done by hand. The error decrease is relevant, measurable, and achievable within four months of practice with this calculator to have students confident in their calculation skills.

## 1.2 Project Keywords

- Inorganic Chemistry
- Color Identification
- Flame Test Simulation
- Metal Ion Identification
- Organic Reactions
- Searchable Database
- Catalysts
- Periodic Table
- Periodic Trends
- Higher-Order Thinking
- Chemistry-Specific Calculator
- Stoichiometry
- Equilibrium
- Error Reduction
- Educational Technology
- Learning Outcomes

## 1.3 Diagram

**Chemistry Learning
Application Architecture**

Request to running script

Stores user data and
learning content

*request handling* →

Application Interface

Updating DB

Database

Central
Processing
Unit

Send request

show data fetching and processing

showing the result display

Users

Request API

API

Updating DB

Fetches data for specific
elements and reactions
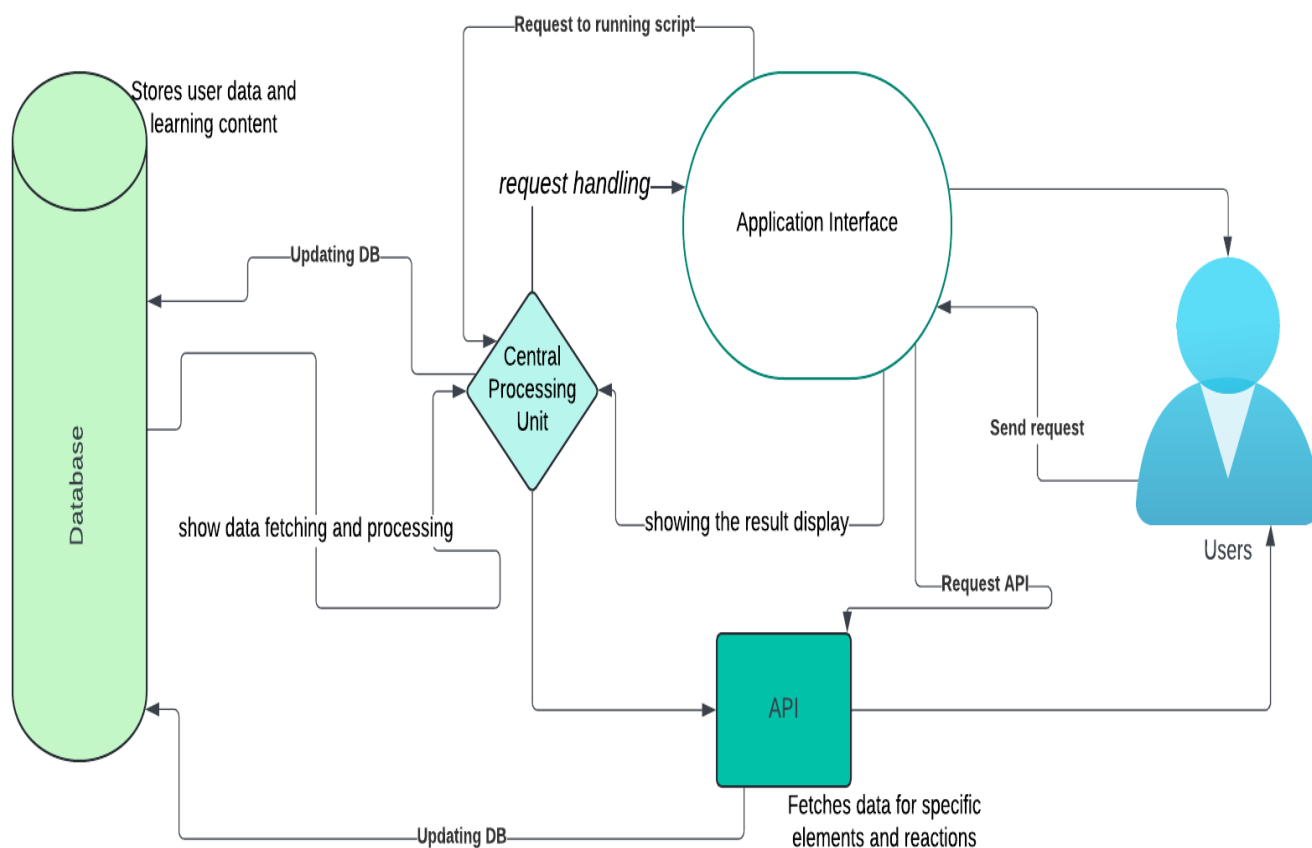
# 03. Literature Review

## 01. Domain Overview

### 1.1 What is Chemistry

Chemistry is the science concerned with composition, structure, properties, and reactions of matter. Chemistry is generally regarded as a fundamental science since it provides the basis upon which many natural phenomena are explained besides being in most instances instrumental in offering solutions to problems in medicine, engineering, and the environment. Chemistry may be broadly categorized into inorganic chemistry, organic chemistry, physical chemistry, analytical chemistry, and biochemistry, while students at the G.C.E. Advanced Level are mainly concerned with inorganic and organic chemistry.

Inorganic Chemistry encompasses characteristics and responses involving inorganic compounds, which contain metals and minerals. Students are supposed to understand color tests, flame tests, and how to predict reactions. Organic Chemistry covers the study of structure, characteristics, and reaction of carbon-containing compounds, hence requiring learners to understand reaction mechanisms and the catalysts' roles too (McMurry, 2017).

### 1.2 Concepts in Chemistry

Concepts that encompass inorganic chemistry are:

- Identification of Elements - Considering tests like the flame test for determination of elements and compounds, requiring a color reference chart. Atkins & de Paula 2018; Ghosh 2020
- Reaction Prediction - Reaction prediction of products from the periodic table and from principles of chemistry. Harris 2016
- Complex Ion Formation - Considering the interaction of ligands and their impact on the formation of metal complexes. Morris & Wilkins 2019
- Acid-Base Reactions - Discuss some basic processes driving the course of chemical reactions. Rochelle 2021.

Organic chemistry concepts include -

- Reaction Mechanisms - The interaction of molecules in chemical reactions (Jones, 2015).
- Catalysis - The facilitation of reactions by means of catalysts with temporary changes (Baker, 2018).
- Functional Group Analysis - Analysis and interconversion between different kinds of organic compounds (Carey & Sundberg, 2007).

## 02. Introduction

Educational technology has now become more imperative in the improvement of student learning outcomes, especially those studying difficult subjects like Chemistry. Besides the present situation of digital tools, it is, therefore, an opportunity to emphasize the prevailing specific challenges among G.C.E. AL Science students, especially in understanding concepts related to elements, compounds, and chemical reactions. The review of related literature provides the significance of educational applications in chemistry, specified coverage and targeted features for the application to be developed, and involvement of technical systems and Learning Management Systems that would support the actual teaching and learning process.

## 2.1 Importance of Educational Applications in Chemistry

The contribution that educational applications make in raising the level of students' interest and comprehension of STEM subjects is well-documented. According to Hwang et al. (2018), technology-enhanced learning environments can remarkably enhance student motivation and engagement in some abstract-thinking subjects such as chemistry. It has also been identified in various research studies that students face numerous problems while trying to visualize higher-level chemical concepts. Applications integrated within technology in chemistry education can therefore render immediate feedback, adapting to individual learning needs, thus improving academic performance.

Key Areas & Target Features in the Proposed Application

Some of the key areas and target features that shall be emphasized in the development of the proposed application, to take up the role of effective support for G.C.E. AL science students, are outlined below:

1. Color Identification for Elements and Compounds - Most students learn better visually and retain more when visual aids are used in explaining concepts or illustrating phenomena. An application feature that may help students identify and describe differences between colors that distinguish various elements and compounds would help in their learning of chemical properties.

2. Catalyst Information for Organic Chemistry - This should be one section that comprehensively covers a wide variety of catalysts and their roles in organic reactions, which students should be aware of when discussing concepts on the mechanism of reactions. Knowledge of the catalyst explains in a broader way why and how certain reactions may take place.

3. Interactive Periodic Table - Similarly, by showing the properties of elements and their uses in practical life, including real-life applications, the Interactive Periodic Table will further enhance students' understanding of chemical relationships. As Peters & Khanna, 2020 says, this tool will give a visualization to the students about the relationship among the elements and their behavior.

4. Calculator - Adding a calculator that could be used to calculate chemistry-based problems, like molarity and stoichiometry, is very useful for real applications. This feature will help the students in carrying out the experiment and solving problems.

5. Ease of Use -The design of the interface, for good student engagement in interaction, is an important component in the improvement of learning experiences. The ease of access and navigation in design will allow more convenience to learn.

## 3. Technical Systems and LMS Support

Technical systems and LMS support go in tandem to successfully implement educational applications. The Learning Management System provides a systematic environment where educational resources can be managed and distributed effectively. Integrating LMS into an educational application offers several advantages listed herein.

- Integration with LMS - LMS-integrated applications can allow them to have smooth learning experiences, easily access all the resources, and track student progress with much ease. That will be helpful for educators to monitor usage patterns by adapting their teaching strategies in line with them.
- Data analytics - through the LMS can be used to provide actionable insight regarding students' levels of engagement and learning behaviors, informing instructional design and targeted intervention. Making such patterns known to educators at large helps them in singing out at-risk students and their support through interventions.
- Support for Mobile Learning - The increased ubiquity of mobile learning demands accessibility through multiple devices. Wu et al., 2019 add that the mobile responsive design allows easy access to the platform by students anytime and anywhere, which is very helpful for G.C.E. AL students who may have time schedules that are different from one another.

## 04. Need for Such a System

Advanced learning chemistry is demanding because the students must memorize voluminous information, understand complex reactions, and perform cumbersome calculations. The conventional mode of learning relies on textbooks and calculators, but great potential for the enhancement of learning exists through an integrated educational platform.

## 4.1 Why the Need Exists

- Color Identification of Elements - Color observation by the flame test method in inorganic chemistry is considered one of the most crucial methods of identification of metals. Color-reference inclusive system integrated with periodic tables improves learning efficiency (Wang et al., 2018).
- Organic Reactions - Understanding catalysts and reagents in learning primarily involves reading through multiple resources. An integrated system will provide access to types of reactions, catalysts, and their mechanisms for effective learning - Smith 2019; Sullivan 2021.
- Periodic Table Properties - One of the most challenging areas for students to learn and memorize is periodic table trends and properties. A system presenting comprehensive and accessible information for students will promote understanding beyond simple memorization. Support for this includes Brown 2021, Clark 2022.
- Scientific Calculator - Chemistry problems also involve regular calculation over the moles, concentration, and reaction rates of elements and substances. Having an inbuilt calculator would save time when working with these processes without switching between tools. This agrees with Khan et al. (2020) and Patel (2022).

## 4.2 Decisions and Outcomes Reached

- Color Identifier Tool - A color guide mechanism will provide an easy means of metal detection in any substance through simple inorganic chemistry tests. Ghosh (2020).
- Reaction Pathways Tool - This will be able to walk students through different organic conversions, including the catalysts and conditions required. (Johnson, 2017; Davis & Martinez, 2023)
- Interactive Periodic Table - An interactive periodic table with properties such as atomic radius, electronegativity, and common oxidation states will facilitate an understanding of.
- Scientific Calculator - An in-app calculator allows for immediate calculations, therefore making the learning process more interactive without the need for the user to leave the app for such purposes. As indicated by Harris, 2016; Rochel, 2021.

## 05. Existing Systems and Solutions

The current LMS used in educational institutions are void of specific tools that would make learning chemistry more interactive, such as an interactive periodic table or color identifier.

| Application | Features | Benefits | Drawbacks | Technologies Used |
|---|---|---|---|---|
| Moodle | <ul><li>Course management</li><li>Quizzes</li><li>Discussion forums</li></ul> | <ul><li>Flexible learning environment</li><li>Strong community support</li></ul> | <ul><li>Lacks specialized chemistry tools</li><li>Complex navigation</li></ul> | PHP MySQL HTML/CSS JavaScript |
| Blackboard | <ul><li>Content delivery</li><li>Analytics</li><li>Virtual classrooms</li></ul> | <ul><li>Robust performance tracking</li><li>Supports diverse learning styles</li></ul> | <ul><li>Costly</li><li>Not chemistry-specific</li></ul> | Java HTML/CSS JavaScript SQL |

| | | | • Cluttered user experience | |
|---|---|---|---|---|
| Canvas | • User-friendly interface<br>• Real-time collaboration | • Enhances student engagement<br>• Flexible integration | • Lacks interactive chemistry functionalities | Ruby on Rails<br>HTML5<br>JavaScript |
| ChemCollective | • Virtual-lab simulations<br>• Interactive experiments | • Encourages exploratory learning,<br>• Safe practice | • Limited theoretical content<br>• Focused on lab simulations | JavaScript<br>HTML/CSS<br>WebGL |
| Periodic Table Apps | • Interactive periodic tables<br>• Element properties | • Quick access to information<br>• Aids memorization | • No practical identification tools<br>• Limited contextual info | HTML/CSS<br>JavaScript<br>JSON |
| Khan Academy | • Instructional videos<br>• Practice exercises<br>• Progress tracking | • Comprehensive-topic coverage<br>• Self-paced learning | • No interactive features<br>• Limited engagement | JavaScript<br>HTML5<br>PHP |
| Quizlet | • Study games<br>• Quizzes<br>• Collaborative features | • Aids memorization<br>• Allows peer collaboration | • Limited in-depth content<br>• Less effective for complex topics | JavaScript<br>HTML/CSS<br>React |
| ChemDoodle | • Molecular modeling tools<br>• 2D/3D visualization | • Excellent for visualizing structures<br>• Useful for research | • No educational tools for chemical reactions<br>• Limited guidance | HTML5<br>CSS3<br>JavaScript<br>WebGL |

## 06. Technologies and Project Methodologies

### 6.1 Technologies

- Frontend Development - React.js or Angular allows developers to create dynamic features such as color tests, interactive periodic tables, and real-time reaction simulations (Morrison, 2023).
- Backend Development - Node.js or Django will enable server-side logic and database integration, crucial for user interactions and data storage (Singh & Gupta, 2022).
- Database Management - MongoDB or MySQL will efficiently manage the data of elements, reactions, and student profiles (Hernandez, 2022).
- APIs - Chemistry data APIs will offer real-time updates on chemical properties, reactions, and experimental data (Alvarez, 2021).

## 6.2 Methodologies

- Agile Methodology - Agile empowers one to use iteration to collect feedback for progressive improvement of features (Scrum Alliance, 2023).
- Waterfall Methodology - In the waterfall model, requirement gathering, design development and testing are clearly separated into distinct phases (Sommerville, 2019).

This proposed system addresses these challenges that G.C.E. AL chemistry students face, as it encompasses all these tools in one place. The proposed integrated system is with an embedded flame test guide, color reference, scientific calculator, and interactive periodic table, is purposed to further learning and problem-solving abilities. Since this need is grossly unmet by the existing solutions, the importance of this integrated system cannot be overstated.

The project will utilize contemporary technologies-React.js, MongoDB, and Agile project methodology-to develop an integrated educational tool that will benefit students in their exam preparation and practical assessments.

## 04. Research Gap

Chemistry education at the G.C.E. A/L stage is so vital for students to get into science-related higher education streams. Currently, many platforms are offering general tools for learning chemistry, all these are inadequate to meet the specific needs of A/L students. This research gap analysis covers the deficiencies in the existing tools and discusses how those gaps will be overcome by the proposed solution.

1 Overview of Existing Solutions

Several platforms provide tools to support chemistry learning, including the following examples:

- Learning Management Systems - General course management systems like Moodle, Canvas, and Blackboard are available, and unfortunately, they do not offer subject-specific features for chemistry.
- Chemistry Apps - There are apps related to specific functionalities like Periodic Table by Royal Society of Chemistry, ChemCollective, and Organic Chemistry Tutor, but they are very fragmented, providing only one small component of overall chemistry, rather than being an integrated solution.
- Physical Calculators - Students use scientific calculators to solve problems in chemistry, yet they are not integrated with learning platforms.
- Despite these diverse tools, the following research gaps exist, especially pertaining to G.C.E. A/L chemistry students:

2 Observed Gaps in Existing Solutions

I.    Inorganic Chemistry Reactions - Color Identification Not Available

- Current Status - No well-recognized learning platforms or applications provide color identification features against inorganic chemistry reactions, whereby color plays an important role in identifying elements and compounds, such as flame tests or colors of reactions.
- Gap - Students at the A/L must memorize or look up colors of compounds manually in books, which is unnecessarily cumbersome for them.
- Proposed Solution - Color identifier tool on the platform, integrated with elements and compounds to visualize or memorize color outcomes of several reactions.

II.    Fragmented Access to Periodic Table Information

- Current State - Most periodic table applications currently represent atomic mass, electronegativity and group trends in a non-interactive manner yet fail to offer in-depth exploration of element properties that could allow students to experiment or visualize trends dynamically.
- Gap - A/L students need a much fuller development of element behaviors and trends in the periodic table and reactions that the current resources provide only in bits and pieces or in static forms.
- Proposed Solution - Completely interactive periodic table with the element's properties, extended to reaction simulations and visualization of trends, allows students to achieve intuitive conceptions of such difficult ideas.

III.    Inability of Deep Pathways for Organic Chemistry Reactions

- Current Status - Sites like ChemCollective have simulations for organic chemistry reactions; however, no holistic view of the organic pathways exists where students trace the reaction mechanisms and conversions.

- Gap - Organic Chemistry at G.C.E. A/L requires knowledge of highly complex reaction mechanisms. To this date, students are still using textbooks and separate notes to see these reaction mechanisms, which can be confusing and cumbersome.
- Proposed Solution - An Organic Chemistry Reaction Mechanism Tool will offer a visual mapping of the pathways of reactions, including catalysts and reagents used in conversions, thus making it easier for students to learn.

IV.   Lack of Integrated Chemistry-Specific Calculators

- Current State - Students typically refer to standalone scientific calculators for solving problems on stoichiometry, pH calculations, thermodynamic properties, and so on from chemistry. All too often, this produces a disjointed learning experience.
- Gap - Chemistry problems require special calculators for specific equations that need to be solved, such as those related to equilibrium constants and Gibbs free energy. Current platforms lack integrated calculators designed for chemistry calculations.
- Proposed Solution - The platform will embed a Chemistry-Specific Calculator that will automatically compute moles, concentration, and thermodynamics frequently required calculations within the learning environment with ease for students.

V.   Inadequate Platforms Catering to G.C.E. A/L Chemistry Needs

- Current State - Online Chemistry learning platforms currently exist but are only fragmentary, for instance, tutorials, periodic tables, or simulations. Not one of them offers an integrated system to emphasize theoretical learning, as well as its practical implementation, such as lab exercises and color identification.
- Gap - The current G.C.E. A/L syllabus ranges from physical to organic chemistry, and it is high time that it gets one consolidated platform covering all the topics of the subject under one umbrella.
- Solution - An integrated chemistry learning platform, incorporating several tools like periodic table, reaction mechanisms, color identification, scientific calculator, shall deliver G.C.E. A/L-specific content with an all-encompassing educational experience to its students.

VI.   Limited support for practical application and exam preparation

- State as it is Most of the chemistry platforms currently lack materials such as past papers, quizzes, or mock exams meant for various curricula, for instance, the G.C.E. A/L syllabus. The few that offer quizzes, such as Khan Academy, may not be developed in depth to suit A/L exams.
- Gap - More of the practice-based learning that students should take advantage of through syllabus-aligned quizzes, interactive tutorials, and past exam papers will better prepare them for their final examinations.
- Proposed Solution - On the newly proposed platform, there will be the provision for interactive quizzes, past papers, mock tests about G.C.E. A/L Chemistry Syllabus for practice and reinforcement by the students.

This will be the platform for G.C.E. A/L chemistry students that will fill large gaps not adequately covered by current educational tools. Since it will have a specific, pragmatic orientation toward the needs related to color identification, interactive exploration of the periodic table, reaction mechanisms, and embedded chemistry calculators, it will provide a comprehensive and holistic learning environment. This will greatly enhance the ability of students to understand complex concepts and prepare for their final exams, setting a new benchmark in chemistry education for high school students.

## 05. Requirements Analysis

This is followed by the requirements analysis phase, an important phase for determining what functionalities the system needs to provide, how the users will be interacting with it, and how the system should behave. The requirements are then divided into two main types, namely functional and non-functional, to state clearly what the system can perform and how it can perform.

### 1. Stakeholder Analysis

The following list identifies some of the major stakeholders of this platform:

- G.C.E. A/L Students - The direct users who will use the platform to learn, revise, or prepare for exams.
- Chemistry Teachers - Those teachers who will use this platform to create and provide quizzes, monitor students' progress, and make resources available to them.
- Educational Institutions - Schools or any other educational institute that might make the most of using this platform and integrating it into their curriculum.

### 2. Functional Requirements

### 2.1. User Registration and Profiles

- Need - Users, students and teachers can sign up and create a profile.
- Description - System shall provide a Registration Form that will allow students and teachers to sign up with an email address, password, and option for a school ID. Personal details like name, grade, etc., shall form part of a profile along with the progress tracking and quizzes or past papers attempted.

### 2.2. Interactive Periodic Table

- Need - The platform shall provide an interactive periodic table where elements and their properties can be explored.
- Description - By clicking an element in the table, the user must be able to view certain detailed information like atomic number, electron configuration, and reactivity. A table that allows the user to view periodic trend of electronegativity, ionization energy, and atomic radius.

### 2.3. Color Identification Tool for Inorganic Reactions

- Need - Provide a color identification tool so that the students will be able to identify colors formed during reactions of chemical compounds.
- Description - The system should support searching for compounds and present visualizations of what reaction colors are expected, for example flame test results or colors of precipitates.

### 2.4. Organic Chemistry Reaction Mechanisms

- Requirement - Provide a tool for the visualization of organic chemistry reaction mechanisms.
- Description - Students shall be able to choose organic compounds and be presented with reaction pathways, where reagents, intermediates and products are shown. Step-by-step guides and explanations of the reaction mechanism should be provided.

## 2.5. Built-in Chemistry-Specific Calculator

- Requirement - Incorporate a built-in calculator to automatically run chemical-based calculations.
- Description - The calculator needs to address stoichiometry, molarity, thermodynamic equations, equilibrium constants, and pH calculation. It must be accessible within the learning interface such that users are able to calculate results right within problem sets.

## Use-case Diagram
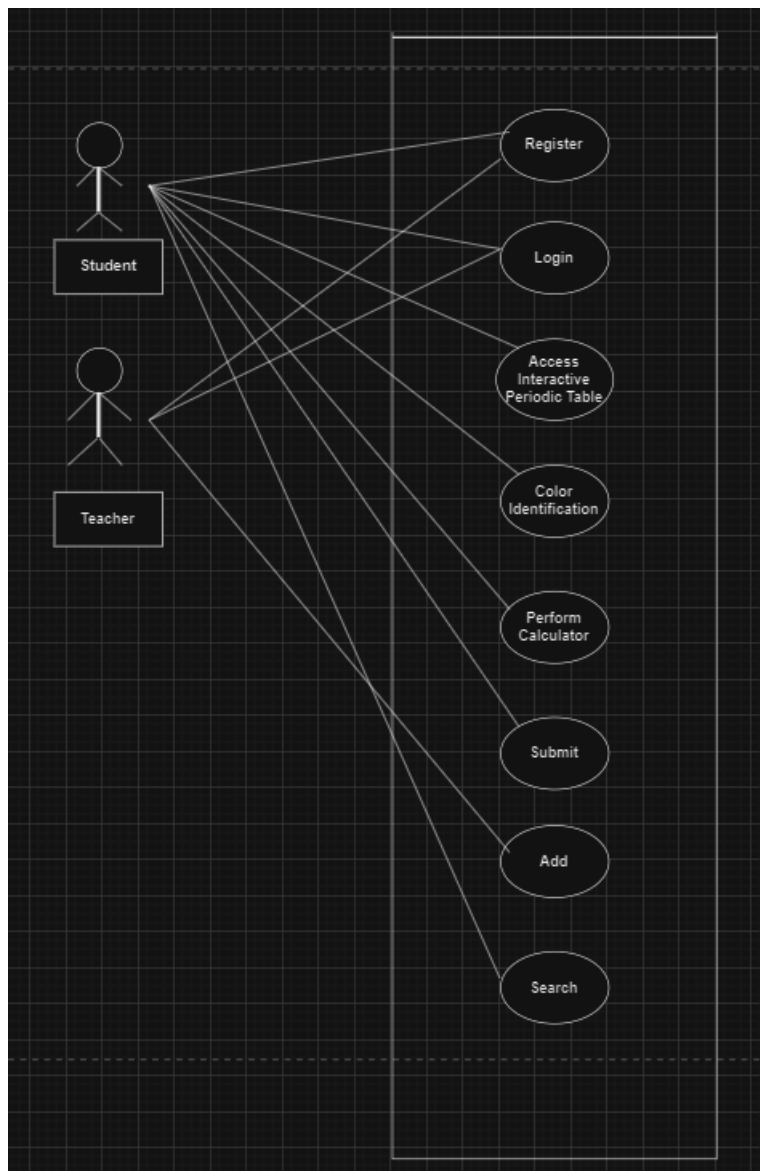


## 3. Non-Functional Requirements

## 3.1. Usability

- Requirement - The platform should have an intuitive and friendly interface to accommodate students who are not aware of advanced technologies.
- Description - It must be simple, responsive, and easy to navigate, with proper labeling of buttons and features.

### 3.2. Performance and Scalability

- Needs - The system would have to endure such heavy loads, at least during the peak season when students are preparing for exams.
- Description - It is envisioned that the high level of traffic would be handled efficiently and fast with minimal loading times. The system would scale up towards higher numbers of users as the platform becomes more popular over time.

### 3.3. Security and Data Privacy

- Need - The platform should provide data security and privacy to its users with special attention to sensitive information about students.
- Description - The platform should encrypt the user data, quiz results, or personal information. It needs to follow data protection regulations and integrate secure authentication such as two-factor authentication.

### 3.4. Accessibility

- Need - The platform should be accessible for students with disabilities.
- Description - The features should follow the guidelines of WCAG screen reader support, keyboard navigation, proper contrast for visually impaired users, etc.

### 3.5. Cross-Browser Compatibility

- Description - This platform should work on multiple devices and browsers.
- Description - The platform should be fully responsive and accessible on desktops, laptops, and tablets. The system should support multiple browsers: Chrome, Firefox, Safari, among others, and it should operate on both Android and iOS systems.

### 4. System Architecture Overview

The system architecture should support:

- Frontend Development - Done using the latest versions of HTML, CSS, and JavaScript with a special focus on responsive design.
- Backend Development - This needs to be driven in the backend by a Node.js or Django framework interfacing with a relational database such as PostgreSQL or MySQL.
- API Integration RESTful APIs for interactive tools including but not limited to periodic table, color identification, calculators, and integrations with external systems where needed.

### 5. Future Enhancements

AR/VR Integration - Integrate augmented reality (AR) so students can visualize 3D molecular structures or reactions.
AI-based Personalized Learning - Use AI algorithms so it can suggest personalized learning based on the performance and weaknesses of every student.
Multilingual Support Add support for multiple languages to reach a wider audience.

The requirements analysis provides the major functionality that is needed, and performance criteria required for a fully-fledged chemistry learning environment. Conforming to both the educational requirements of

G.C.E. A/L, and non-functional requirements such as usability, security, and performance requirements, this platform will make the needs of students and teachers more efficient and interactive.

## 6. Summary

| Requirement Categories | Requirement | Properties Required |
|---|---|---|
| Stakeholder Analysis | Students | G.C.E. A/L students use the platform for learning, revision, and exam preparation |
| | Teachers | Chemistry teachers prepare quizzes, tracking student results and exchanging resources |
| | Educational Institutions | Schools or educational institutions implementing the platform within their system |
| Functional Requirements | User Registration and Profiles | It allows students and teachers to enroll and create a profile where they can track their progress |
| | Interactive Periodic Table | Allows users to click elements and view properties such as atomic number, electron configuration, and periodic trends |
| | Color Identification Tool | Provides colors produced by inorganic reaction such as flame test and colors of precipitates |
| | Organic Chemistry Reaction Mechanisms | It visualizes the pathways, reagents, intermediates, and products of reaction in detail |
| | Chemical Calculator | An integrated calculator for stoichiometry, molarity, thermodynamic equations, equilibrium constants, and pH |
| Nonfunctional Requirements | Usability | The interactions provided are of a nature to be intuitive and friendly to make navigation and use easy for the students |
| | Performance and Scalability | Work well under heavy traffic, support minimum loading time, and are scalable to more users as time progresses |
| | Security and Data Protection | Encryption of user data, following data protection laws, so the enabling of secure login options, like two-factor authentication |
| | Accessibility | Presented with WCAG standards in mind, hence screen reader friendly, keyboard navigation supported, and high contrast for readability |
| | Cross-Browser Compatibility | Compatible across multiple devices and browsers, such as Chrome, Firefox, Safari, Android and iOS |
| System Architecture | Frontend | The front-end with an emphasis on responsive design |
| | Backend | Node.js or Django with PostgreSQL or MySQL database |
| | API Integration | RESTful APIs for interactive tools, such as periodic table, color identification, and calculator |
| Future Improvements | Integration of AR/VR | Augmented reality for visualization of 3D molecular structures or sets of reactions |
| | AI-based Adaptive Learning | AI algorithms suggest personalized content to improve student performance |

| | Multilingual support | Support various languages to reach more |
|---|---|---|

## 06.System Design

1. Frontend

- Technologies - HTML, CSS, JavaScript, Three.js/Babylon.js.
- Features - Interactively view 3D molecular views that rotate, zoom, etc., to see compounds and reactions, periodic table, calculators, etc.

2. Backend

- Technologies - PHP or Node.js.
- Features - User authentication, serving 3D models, processing of chemistry data, quiz handling. Provide RESTful APIs for secure data delivery.

3. Database

- Technology - MySQL.
- Data Stored - User profiles, compound details, links for 3D models, quiz questions, calculation history.

4. 3D Visualization

- Technologies - Three.js/Babylon.js with molecular model files (.pdb/.mol).
- Features - The user can rotate the molecule (360-degree view), catalysts are highlighted, and all the steps of the reaction are interactive.

The system design for the study interface of organic chemistry students maintains an interesting platform by introducing involvement with 3-D visualization and interaction tools.

# 07.Data Collection

## 1. Identify the Specific Problems

- Color Identification of Elements and Compounds - Pictorial aids or other resources would provide students with the ability to identify elements and compounds by their specific color.
- Reactions in Organic Chemistry - Different types of catalysts relate to organic reactions, and their individual effects on conversions must be clarified for students.
- Periodic Table and Element Properties - The student's easy access to information about the properties of elements in the periodic table.
- Calculator and Tools - A friendly calculator that can be used to carry out and convert various kinds of chemistry calculations.

## 2. Data Collection Methods

a. Surveys and Questionnaires
- Design surveys for high school science students to ascertain specific needs, difficulties, and preferences of the target group about:
- Color coding of elements and compounds.
- Organic chemistry catalysts and reactions.
- Periodic table and calculator use.

b. Interviews and Focus Groups
- Students and teachers may also be interviewed or conducted in focus groups to provide additional qualitative evidence on areas of difficulty and suggestions for improvement.

c. Research Existing Resources
- Resources and educational platforms should be researched to determine details about the following:
  o Effective color-coding system.
  o Catalyst information and use in organic reactions.
  o Element properties by period.

d. Observations
- Observe classroom settings to notice how students will be interacting with chemistry resources and identify common problematic issues they face.

## 3. Developing Solutions Based on Data Collected
- Interactive Color-Coding Guide - Make a digital resource or a printed document which shows, visually, the colors of all the elements and compounds so that this will be easier for the students to identify.
- Catalyst Database - Make an explicit database listing various organic reactions along with their catalysts and mechanisms of action involved
- Periodic Table Resource - Design an interactive Periodic Table that would enable the user to get detailed properties of every element, atomic mass, state, electronegativity, etc.
- Chemistry Calculator Tool - App for mobiles or web containing a calculator for different chemistry calculations and conversion tools for molar mass, concentration, etc.

## 4. Implementation and Evaluation
- Pilot Testing – Pilot test, before full implementation, the developed resources with a small group of students, and gather feedback.
- Iterative Improvements - Refine, from feedback, the resources in ways that best meet the needs of the students.
- Ongoing Assessment - Continuously assess the effectiveness of provided solutions, adjusting keep up with evolving educational requirements.

## 5. Collaboration with Educators
- Collaborate closely with chemistry teachers and educational institutions to ensure that the resources developed meet curriculum standards and will serve students' needs.

## 6. Surveys and Questionnaires Google Form

A Google Form survey was prepared with the goal of collecting ideas from AL students in school and even from chemistry teachers themselves. The form shall measure difficulties and preferences within a certain specific area of chemistry education, including those to do with color identifications, reaction mechanisms, periodic tables, and calculator requirements.

Question topics: The main topics of the questions involved include the following:

01) What features would you like to see on the website?
02) How familiar are you with organic chemistry transformations?
03) What additional resources would help you in learning organic chemistry?
04) How important is it for you to have a section on the colors of inorganic compounds?
05) What features would you like to see in the periodic table section?
06) Would you find a calculator useful for performing chemical calculations?
07) How user-friendly do you find educational websites for chemistry?
08) How likely are you to recommend this website to fellow students once it is launched?
09) Would you like to receive updates about the website launch and features?

# 08. Data Analysis

1. Set Goals - Clearly indicate what you want to be able to say after having analyzed the data. For instance, you may want to find out "What is a typical problem of students in identifying color in chemistry?"

2. Getting the Data Ready –
- Cleaning - Redundant or incorrect information is normally removed or corrected at this stage.
- Data Formatting - Organize and structure data in such a way that it befits the form in which analysis can be done more easily, for example, using spreadsheets or databases.
- Transformation - Data can be transformed to appropriately convert it into a format suitable for analysis. This might involve converting it to categorical or numeric type, depending on the analysis requirement.

3. Analyze Using Techniques - Depending on objectives and based on the nature of the data, adopt appropriate techniques. To that effect, some methods that might apply to your context are listed below:

- Descriptive Statistics - Data description: summarize the main features of data, such as means, medians, modes, frequencies, and standard deviation.
- Inferential Statistics - Predict something about a larger population based on a sample. Techniques usually include t-tests, chi-square tests, and regression analysis.
- Thematic Analysis - In qualitative data, such as responses from interviews or open-ended survey questions, identify themes or patterns in the responses.
- Visual Analysis - The use of visuals-charts, graphs, heat maps-assists in depicting the trend and pattern for this data.

4. Analyze the Data
- Perform the Analysis - The actual analysis using statistical software: Excel, R, SPSS, or Python libraries depending on the techniques applied.
- Interpret Results - Draw a parallel of the results in relation to your goals. See if there is an observable trend, correlation, or anomaly in your results.

5. Draw Conclusions - Summarize the analysis by stating what insight was gained. For instance, one can derive the conclusion that students struggle with some colors in inorganic chemistry and that organic catalysts require further resource allocation.

6. Present Findings - A report or presentation must be produced with an effective delivery of the results. There are relevant visual aids which can be used to effectively communicate complex information.

7. Make Recommendations - Based on the results, suggest practical advice. For example, one could create focused education that deals with the specific issues revealed.

- Analysis Tools
  - Spreadsheet Software - Excel or Google Sheets for simple statistical work and visualizations.
  - Statistical Software - Python - libraries such as Pandas, NumPy, Matplotlib, SPSS, or SAS for advanced statistical analysis.
- Data Visualization Tools -Tableau, Power BI, or Google Data Studio to produce an interactive and engaging visualization of data.
- Best Practices
  - Documentation - Whole records must be maintained of the sources of data, steps of analysis, and assumptions that were used to frame those analyses.
  - Peer Review - Analyze your findings along with their interpretation by a colleague/mentor.
  - Iterative Process - Data analysis is often iterative. Be prepared to revisit your analysis when newer data or insights pop up.

# 09.System Development

1. Planning

- Define Objectives - Predefine the objectives of the system; for instance, resource requirements related to color identification, catalysts involved in organic chemistry, and elemental properties.
- Feasibility Study - Technical, operational, and economic analyses that decide whether the project should be undertaken or not.
- Stakeholder Involvement - Discuss with students, teachers, and education authorities for gathering requirements and their expectations.

2. Requirements Analysis

- Requirements Gathering - Functional and non-functional requirements are to be detailed out through surveys, interviews, and focus groups.
- Use Cases -The use cases must be drawn depicting how the users will interact with the system.
- Prioritize Requirements - Clearly identify the 'order of importance' on what features can be realized to best address the challenges faced by the students.

3. System Design

- Architectural Design - Clearly specify the overall system architecture in terms of client-server model, database, and APIs.
- User Interface Design - Design wireframes or mockups of the user interface, emphasizing aspects of usability and accessibility.
- Data Design - Database schema design along with tables for elements, compounds, catalysts, and user data.

4. Development

- Coding - Implement the system using appropriate languages and technologies; in the case of a web application, it could be implemented with the programming language JavaScript along with React or Angular Frameworks.
- Database Implementation - Design the database on a proper management system, such as MySQL or MongoDB, to securely store data.
- Integration - Integrate different system components to make sure the front-end and back-end interact smoothly

5. Testing

- Unit Testing - Individual components test to be working as required.
- Integration Testing - Various modules should work properly with one another.
- User Acceptance Testing (UAT) - Use end-users in testing so that one can get feedback and ensure that the system meets the needs of a particular audience.

Tools and Technologies

- Project Management Tool - The project management tool will be Trello, Asana, or Jira to handle such tasks, timelines, and collaboration between the team members.
- Development Environments - IDEs: Code development and testing can be enabled via Visual Studio Code, PyCharm, or Eclipse.

- Version Control - Use Git with GitHub or GitLab.
- Prototyping Tools - Figma: For designing UI, creating prototypes, and testing, use Figma, Sketch, or Adobe XD.

Best Practices

- Agile Methodology - Agile development can be applied for iterative development with continuous feedback by the users.
- Documentation - Extensive documentation during the development process for easy maintenance and further development in the future.
- User-Centric Design - The design process should keep the user at the center to ensure the system effectively serves the users' needs.

# 10. Testing

1. Test Planning

- Define Objectives - Identify what you are trying to achieve with testing, such as validation of functionality or performance.
- Develop a Test Strategy - Identify types of testing to be performed, such as unit testing, integration testing, user acceptance testing.
- Create a Test Schedule - Plan the test activity schedule and the resources required.

2. Test Design

- Identify Test Cases - Elaborate test cases from requirements and use cases. Each test case shall be represented by:
    - Test ID - Unique identifier
    - Test Description - What is being tested.
- Preconditions - Setup required prior to test execution.
    - Test Steps - Steps to be taken to conduct the test.
    - Expected Results - What is supposed to occur/test result.
- Prepare Test Data - Identify/create data needed to run tests.

3. Test Execution

- Execute Test Cases - The test cases will be executed in the prepared environment.
- Record Results - Record the actual results and prepare a report on deviations from expected and actual results

4. Defect Reporting

- Defects - Log the defects or issues found during software testing. It should include:
- Log Defect ID - Unique identifier
    - Description - Clear description
    - Severity/Priority - Assessment of the critical nature of the defect
    - Steps to Reproduce - Instructions for reproducing the defect.
- Status - Status of the defect open, in progress, resolved.

5. Test Closure
- Evaluate Test Results - Review of the testing results on defect count and test coverage.
- Prepare Test Summary Report - Prepare a report summarizing the testing activity, results, and outstanding issues.
- Conduct a Retrospective - Reflect on the testing process for improvements that need to be made in the future.

Types of Testing

- Unit Testing -The process of testing individual components or modules normally by developers.
- Integration Testing -Testing interactions between components which have been integrated to ensure that interactions work properly
- System Testing - The whole testing of the system whether the specified requirements are met or not.
- User Acceptance Testing - It is performed by end-users in order to validate whether the system will be able to meet their needs and requirements before going into final deployment.
- Regression Testing - To check existing functionalities by running a test case to make sure new code changes have not introduced any defects.
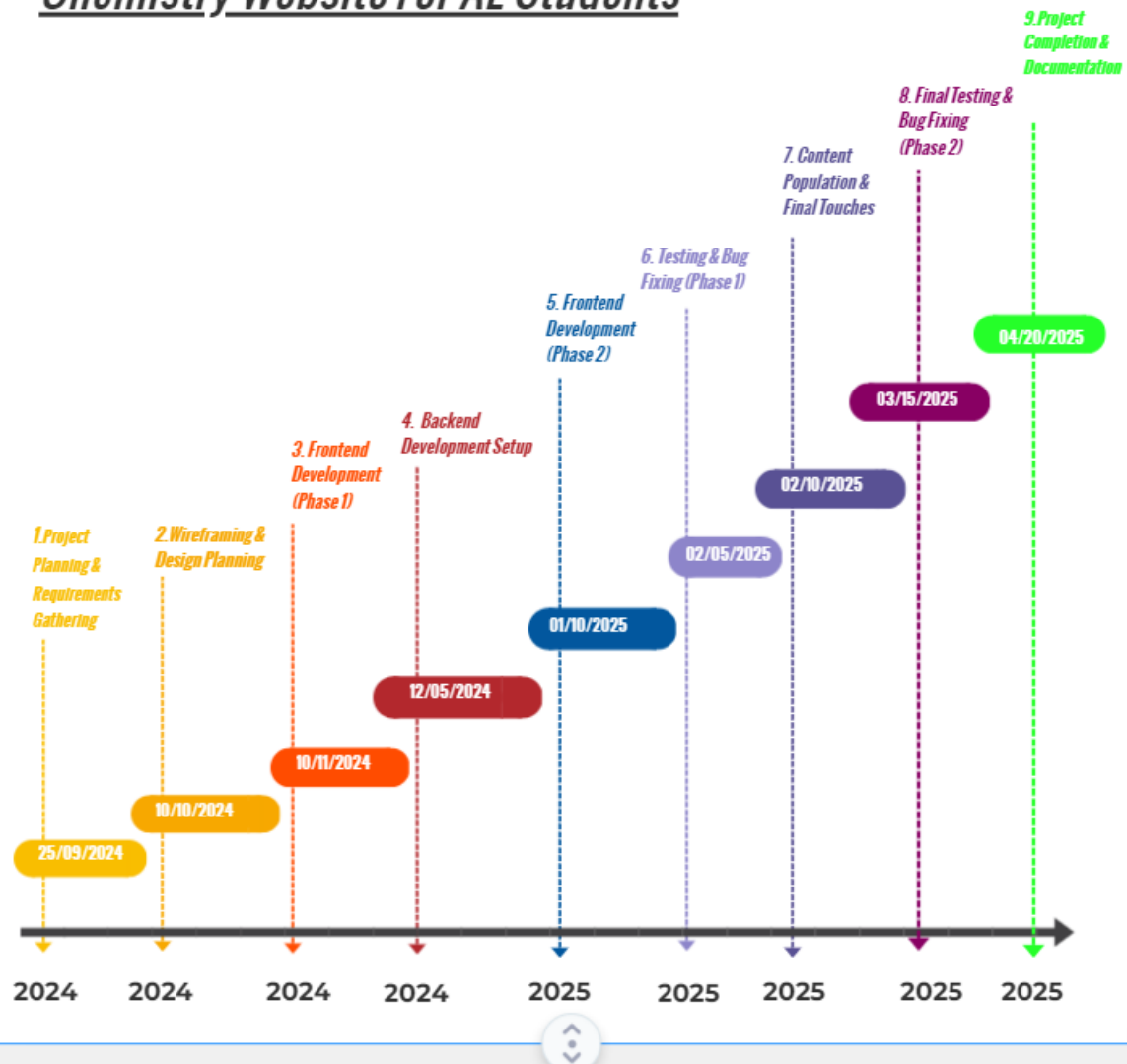
- Performance Testing - Testing the system for responsiveness, stability, and scalability under variant conditions.
- Security Testing - It means finding out vulnerabilities and verifying that the system is guarded against any form of relevant threat.

## 11. Timeline

### Gantt Chart

| ID | Task Name | Start | End | Duration | 2024 | | | 2025 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Q.. | Q3 | Q4 | Q1 | Q2 | Q3 |
| 1 | Project Planning & Requirements Gathering | 2024-09-11 | 2024-09-21 | 11 days | | ■ | | | | |
| 2 | Wireframing & Design Planning | 2024-09-26 | 2024-10-06 | 11 days | | ■ | | | | |
| 3 | Frontend Development (Phase 1) | 2024-10-11 | 2024-11-10 | 31 days | | | ■ | | | |
| 4 | Backend Development Setup | 2024-11-11 | 2024-12-05 | 25 days | | | ■ | | | |
| 5 | Frontend Development (Phase 2) | 2024-12-06 | 2025-01-10 | 36 days | | | ■ | | | |
| 6 | Testing & Bug Fixing (Phase 1) | 2025-01-11 | 2025-02-05 | 26 days | | | | ■ | | |
| 7 | Content Population & Final Touches | 2025-02-06 | 2025-02-25 | 20 days | | | | ■ | | |
| 8 | Final Testing & Bug Fixing (Phase 2) | 2025-02-26 | 2025-03-15 | 18 days | | | | ■ | | |
| 9 | Project Completion & Documentation | 2025-03-16 | 2025-04-20 | 36 days | | | | ■ | | |

**Chemistry Website For AL Students**

1. Project Planning & Requirements Gathering — 25/09/2024
2. Wireframing & Design Planning — 10/10/2024
3. Frontend Development (Phase 1) — 10/11/2024
4. Backend Development Setup — 12/05/2024
5. Frontend Development (Phase 2) — 01/10/2025
6. Testing & Bug Fixing (Phase 1) — 02/05/2025
7. Content Population & Final Touches — 02/10/2025
8. Final Testing & Bug Fixing (Phase 2) — 03/15/2025
9. Project Completion & Documentation — 04/20/2025

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