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Software Project

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Acknowledgment

We would like to express our sincere gratitude to everyone who contributed to the completion of this interactive educational platform project.

First and foremost, we thank our families for their unconditional support, patience, and belief in us. Their sacrifices, encouragement, and constant presence formed the foundation that allowed us to stay focused, motivated, and resilient throughout this journey.

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We also extend our appreciation to our friends and colleagues who supported us, shared ideas, and offered encouragement during challenging moments.

Finally, we are thankful for the opportunity to apply our knowledge and creativity to develop a platform that aims to make science learning more interactive, engaging, and enjoyable for children. We hope that this work contributes, even in a small way, to creating better educational experiences for future generations.

Dedication

This project is for Palestine, and for every child whose curiosity deserves to be protected and nurtured.

For those whose childhood has been overshadowed by war, uncertainty, and loss, and for the young minds that continue to dream, learn, and imagine despite difficult circumstances.

It stands in memory of the martyrs whose lives ended too soon, leaving stories the world may never fully hear. It carries respect for the prisoners who continue to endure behind walls, holding onto hope under the hardest conditions, and for the wounded who live with pain as a permanent reminder of what was taken—and what still remains.

As Palestinian computer engineers, we dedicate this project to them and to every child who believes in a brighter future. Every effort invested in this work is a quiet statement that despite destruction, we continue to learn, to build, and to believe in a future shaped by knowledge, resilience, and purpose.

Abstract:

This project aims to improve children's learning experience by developing an interactive, space-themed educational web application that works on both desktop and mobile devices. Instead of presenting subjects through traditional text-based lessons, the system transforms learning into a visual universe where each subject is represented as a planet and each topic is organised into sections and levels. The main focus of the project is on the Physics and Chemistry planets, where learners can explore scientific concepts through interactive activities, simulations, challenges, and open-ended experimentation.

The platform supports multiple user roles, including child, parent, supervisor, and admin. Children can create accounts and access learning planets, while parents can connect to their child's account using a child-generated code to monitor progress. Supervisors and admins have controlled access through verification, allowing them to create, manage, review, approve, archive, or delete sections and levels. This role-based structure allows the same application to support learning, supervision, content creation, and administrative control within one integrated system.

A major part of the project is the Physics Free Space section, which functions as an open-ended physics sandbox. In this section, learners can place objects, test collisions, change gravity, connect objects using ropes, work with gears and motors, use springs, magnets, fans, ramps, dominos, slingshots, and other interactive tools. Free Space operates in three modes: Kid Play, Supervisor Builder, and Admin Review. This mode-based design allows children to experiment freely, supervisors to build educational scenes, and admins to review prepared levels before approval. The system uses Matter.js for physics simulation, Pixi.js for rendering, custom object registries, scene serialization, preset scenes, attachment systems, goal detection, and theme management to create a realistic and engaging physics environment.

The Chemistry planet is designed as an interactive learning environment that helps students explore chemical concepts through stage-based learning and hands-on experimentation. The system currently includes a set of learning levels focused on different types of chemical reactions, such as exothermic and endothermic reactions, where students learn by completing tasks and observing interactive visual effects and animations. In addition, the planet includes a Chemistry Free Space that allows learners to explore elements and compounds in an open-ended interactive environment. This space is integrated with the PubChem database, enabling access to real scientific data about chemical substances and their properties. The system also uses a cinematic camera system with smooth panning, dynamic zooming, and guided transitions between scenes, enhancing user focus on key interactions and creating a more immersive and engaging learning experience. The platform is built using React, Canvas 2D, and interactive state management, combining visual effects and dynamic camera movements to support exploratory, experience-based learning rather than traditional memorization.

The methodology of this project involved designing a responsive React web application, building a role-based authentication and permission system, creating structured planet and level data, developing interactive physics and chemistry learning environments, implementing progress tracking, and providing management dashboards for parents, supervisors, and admins. The final result is a complete educational platform that combines game-based learning, visual storytelling, scientific simulation, and content management. While many educational websites present lessons in a static format, this project provides a more immersive learning world where children can learn by playing, building, testing, and discovering.

Table of contents

List of Figures

Chapter 1 Introduction

1.1 General Background

Digital learning platforms have become an important part of modern education, especially for children who are growing up in a highly visual and interactive digital environment. Traditional learning methods often depend on reading, memorisation, and static exercises, which may not fully engage young learners or support different learning styles. Children usually learn more effectively when they can see, touch, explore, repeat, and receive immediate feedback. For this reason, interactive educational applications can play an important role in making learning more active, enjoyable, and meaningful.

Science subjects such as physics and chemistry can be challenging for children because many concepts are abstract. Ideas such as force, gravity, motion, collisions, reactions, acids and bases, molecular behaviour, and energy transfer are easier to understand when they are presented visually and experimentally. Instead of only reading about these concepts, learners benefit from simulations, animations, challenges, and virtual experiments that allow them to test ideas and observe results.

This project presents the design and implementation of an interactive space-themed educational web application for children. The application is built as a learning universe, where each subject is represented as a planet. When a child enters the platform, they can explore different planets, open sections, play levels, complete challenges, and track progress. The project mainly focuses on the Physics and Chemistry planets, where learning is delivered through interactive sections, simulations, sandbox activities, and laboratory-style stages.

The platform is designed to work on both desktop and mobile devices, making it accessible for different screen sizes and usage contexts. It also supports multiple user roles, including child, parent, supervisor, and admin. A child can use the platform to learn and play, while a parent can connect to the child's account using a child-generated code to monitor learning progress. Supervisors can create and submit levels, while admins can review, approve, archive, edit, or delete educational content. This makes the project more than a simple learning game; it is a complete educational management platform.

One of the most important parts of the project is the Physics Free Space section. Free Space works as an open-ended physics sandbox where learners can place objects, test motion, build structures, use ropes, gears, springs, motors, fans, magnets, ramps, dominos, slingshots, and other tools. The learner is not forced into one fixed answer. Instead, they can experiment, test, fail, adjust, and try again. This supports discovery-based learning and makes physics feel like a real interactive lab.

The Chemistry planet provides interactive stages focused on different types of chemical reactions, along with a Free Space connected to the PubChem database for exploring real chemical data and properties of elements and compounds in an open-ended environment. This allows learners to access authentic scientific information while engaging with interactive visuals and experiments. The experience is further enhanced by a cinematic camera system with smooth panning, dynamic zooming, and guided scene transitions, improving focus and creating a more immersive and engaging learning environment.

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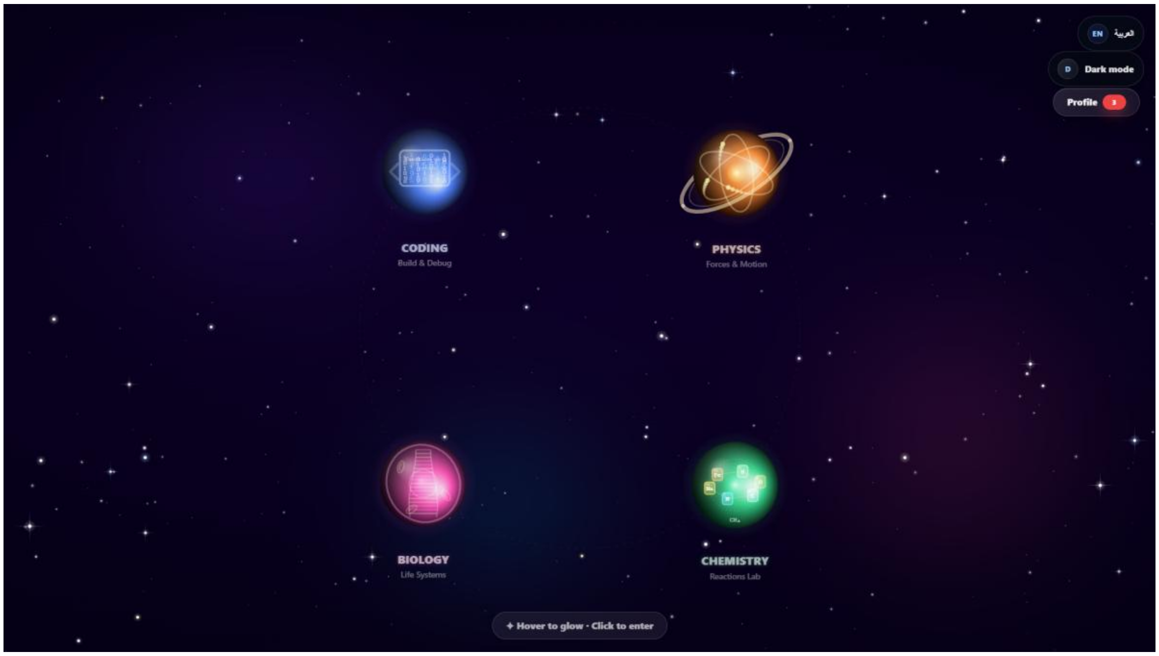


Figure 1.1: Space-themed educational home page showing subject planets.

1.2 Objectives (Purpose and Aims) of the Work

The main purpose of this project is to design and develop an interactive educational web application that helps children learn scientific concepts through play, experimentation, and visual interaction. The system aims to move away from static lesson pages and create a learning environment where children can actively explore subjects through planets, sections, levels, sandbox tools, and game-like challenges.

The main objectives of this work are to:

- Develop a responsive educational web application that works on both desktop and mobile devices.
- Create a space-themed learning environment where subjects are represented as planets and lessons are organised into sections and levels.
- Implement a secure role-based sign-up and login system for children, parents, supervisors, and admins.
- Allow parents to connect to their child's account using a child-generated code so they can monitor learning progress safely.
- Provide verification for supervisor and admin accounts to protect the content management system from unauthorised access.
- Design an interactive Physics planet containing structured learning sections such as Free Space, Forces, Gravity, Laser, Springs, and Gears.

- Develop the Free Space section as an open-ended physics sandbox where children can build experiments, test collisions, change gravity, connect objects, and explore physical behaviour.
- Implement three different Free Space modes: Kid Play, Supervisor Builder, and Admin Review.
- Allow supervisors to create educational scenes and levels using the same physics engine used by the child-facing sandbox.
- Allow admins to review, approve, reject, edit, archive, or delete sections and levels before they appear to children.
- Design an interactive Chemistry planet featuring structured learning stages such as different types of chemical reactions (including exothermic and endothermic reactions), where learners engage through tasks, visual feedback, and animations.
- Provide a Chemistry Free Space connected to the PubChem database, allowing exploration of elements and compounds through real scientific data in an open-ended interactive environment.
- Use a cinematic camera system with smooth panning, dynamic zooming, and guided scene transitions to enhance focus and create a more immersive learning experience across chemistry interactions.
- Support both dark mode and light mode to improve usability and provide a comfortable visual experience in different environments.
- Use modern web technologies such as React, Vite, React Router, Supabase, Matter.js, Pixi.js, Canvas 2D, local storage, and i18next.
- Track student progress through completed, unlocked, and locked levels.
- Support Arabic and English language options to improve accessibility for different users.
- Create an educational experience that is visually engaging, technically interactive, and suitable for children.

Through these objectives, the project aims to demonstrate a complete child-centred learning platform that combines education, game design, physics simulation, chemistry interaction, role-based management, and progress tracking within one integrated system.

1.3 Significance and Importance of the Work

The significance of this project lies in its ability to make science learning more interactive and accessible for children. Many children find science difficult when it is presented only through text, formulas, or static diagrams. This project addresses that problem by transforming scientific topics into visual and playable experiences. By allowing learners to interact directly with objects, experiments, and challenges, the platform helps make abstract ideas easier to understand.

From an educational perspective, the project supports active learning. Children are not only watching or reading content; they are participating in the learning process. In the Physics planet, they can test gravity, build machines, connect gears, launch objects with springs, and create chain reactions. In the Chemistry planet, they can explore reactions, bubbles, acids, bases, states of matter, and molecular views. This type of interaction can improve engagement, curiosity, and memory because the learner experiences the concept instead of only receiving information.

From a technical perspective, the project demonstrates how modern web technologies can be combined to create a rich educational system. React provides the application structure, Supabase supports authentication and profile management, React Router controls navigation, Matter.js handles physics simulation, Pixi.js supports advanced rendering, and i18next enables multilingual support. The combination of these technologies allows the platform to behave like an interactive learning world rather than a normal website.

From a user management perspective, the system is important because it supports different roles with different permissions. Children can learn and play, parents can monitor progress, supervisors can build educational content, and admins can control the quality of published sections and levels. This structure makes the platform more scalable and suitable for real educational use, where content needs to be created, reviewed, and managed safely.

The project is also important because it includes open-ended learning through the Free Space sandbox. Many educational games only allow one correct solution or one fixed path. Free Space gives the learner more freedom by allowing them to build their own experiments and test different outcomes. This encourages creativity, problem-solving, and scientific thinking.

1.4 Scope of the Project

This project focuses on the development of a functional educational web application for children, with role-based access, interactive learning planets, progress tracking, and management features. The main implemented learning areas are the Physics and Chemistry planets, although the platform structure allows additional planets and subjects to be added in the future.

The scope of the project includes:

- User registration and login for child, parent, supervisor, and admin roles.
- Parent-child connection using a code generated from the child's account.
- Admin and supervisor verification through controlled access.
- A space-themed home page where subjects are presented as planets.
- Interactive Physics sections and levels.
- A Free Space physics sandbox with Kid Play, Supervisor Builder, and Admin Review modes.
- Toolbox objects such as balls, blocks, ramps, dominos, gears, motors, springs, ropes, magnets, fans, slingshots, bumpers, axles, wheels, and goal objects.
- Object editing controls for rotation, size, mass, motor power, magnet settings, fan strength, reset, and deletion.
- Preset physics scenes that help learners start experimenting quickly.
- Chemistry sections with interactive lab-style activities and mission-based progress.
- Level progress tracking through locked, unlocked, and completed states.

- Admin and supervisor management routes for adding, editing, archiving, deleting, reviewing, and approving sections and levels.
- Parent dashboard features for monitoring child progress.
- Arabic and English language support.

The project does not aim to cover every school subject in full detail. Instead, it focuses on proving the concept through a strong implementation of Physics and Chemistry learning experiences. The system is also considered a graduation project prototype, meaning that it demonstrates the core design, functionality, and technical approach, while future work may include more subjects, more levels, cloud deployment improvements, stronger analytics, and additional accessibility features.

1.5 Organization of the Report

This report is organised into six main chapters, each covering a specific part of the project.

Chapter 1 introduces the project background, objectives, significance, scope, and overall report structure. It explains why the project was developed and how it addresses the need for interactive, child-centred science learning.

Chapter 2 presents the theoretical background and previous work related to educational games, interactive learning platforms, game-based learning, child-centred design, role-based access, physics simulation, chemistry visualisation, and web-based educational systems.

Chapter 3 describes the methodology used to design and implement the platform. It explains the software tools, system architecture, user roles, authentication workflow, planet and section structure, Physics implementation, Free Space sandbox, Chemistry implementation, progress tracking, dashboards, design constraints, and safety considerations.

Chapter 4 presents the results and analysis of the developed system. It discusses the performance of role-based access, child learning flow, Physics planet, Free Space sandbox, supervisor builder, admin review, Chemistry planet, parent dashboard, desktop and mobile responsiveness, and user interface behaviour.

Chapter 5 discusses the results in relation to the original objectives. It evaluates how well the project solved the problem, identifies the main contributions, explains the implications of the work, and discusses limitations compared with existing educational platforms.

Chapter 6 concludes the report by summarising the main outcomes, key learnings, recommendations for improvement, future work, and final remarks.

Chapter 2 Theoretical Background and Previous Work

2.1 Previous Work Related to Interactive Educational Platforms

Educational technology has developed from simple digital lesson pages into more interactive systems that include games, animations, simulations, progress tracking, and personalised learning paths. Traditional educational websites usually present information through text, images, videos, and quizzes. Although these methods can support learning, they may not fully engage children who learn better through exploration, direct interaction, and visual feedback.

Game-based learning has become an important approach in children's education because it can increase motivation, engagement, and active participation. A 2024 systematic review and meta-analysis on game-based learning in early childhood education found that game-based learning can have positive effects on cognitive, social, emotional, motivation, and engagement outcomes. This supports the idea that well-designed educational games can help children learn by doing rather than only reading or listening.

Gamification has also been widely studied in educational settings. It uses elements such as levels, achievements, progress, challenges, feedback, and rewards to make learning more motivating. However, gamification is most effective when the game elements are connected to real learning goals rather than added only for entertainment. Research on gamification and game-based learning shows that common theoretical foundations include self-determination theory, flow theory, experiential learning theory, and constructivist learning theory.

Many existing educational platforms still have limitations. Some platforms provide fixed lessons with limited interaction, while others use games that are not strongly connected to the learning concept. Some systems allow children to play, but do not provide strong parent monitoring, supervisor content creation, or admin review. Other platforms may include interactive activities, but do not offer an open-ended sandbox where children can freely build, test, fail, and try again.

This project responds to those limitations by combining several features in one platform: role-based access, a space-themed learning world, interactive Physics and Chemistry planets, progress tracking, parent monitoring, supervisor level creation, admin review, and an open-ended Free Space sandbox. The project is not only a learning game. It is a complete educational system that supports children, parents, supervisors, and admins within the same web application.

2.2 Theoretical Background of the Proposed Educational Platform

The proposed platform is based on the idea that children learn more effectively when they actively interact with the learning material. Instead of presenting science as a set of static facts, the system allows learners to explore, test, observe, and repeat actions inside a visual environment. This approach supports active learning, discovery learning, and experiential learning.

In the platform, each subject is represented as a planet. Each planet contains sections, and each section contains levels or learning stages. This structure turns the learning process into a journey. The child is not only moving through pages; they are travelling through a learning universe where each topic becomes a place to explore. This design supports curiosity and gives the platform a stronger sense of identity than a normal lesson website.

The project also uses progression-based learning. Levels can be locked, unlocked, or completed depending on the learner's progress. This gives the child a clear learning path and provides motivation to continue. Progression is important because it allows the learner to understand where they are, what they have completed, and what they can attempt next.

The system also includes different roles with different permissions. A child uses the platform to learn and play. A parent connects to the child's account using a code and monitors progress. A supervisor creates or edits educational content. An admin reviews, approves, archives, or deletes content before it becomes available to learners. This role separation gives the project a learning management structure, not only a game structure.

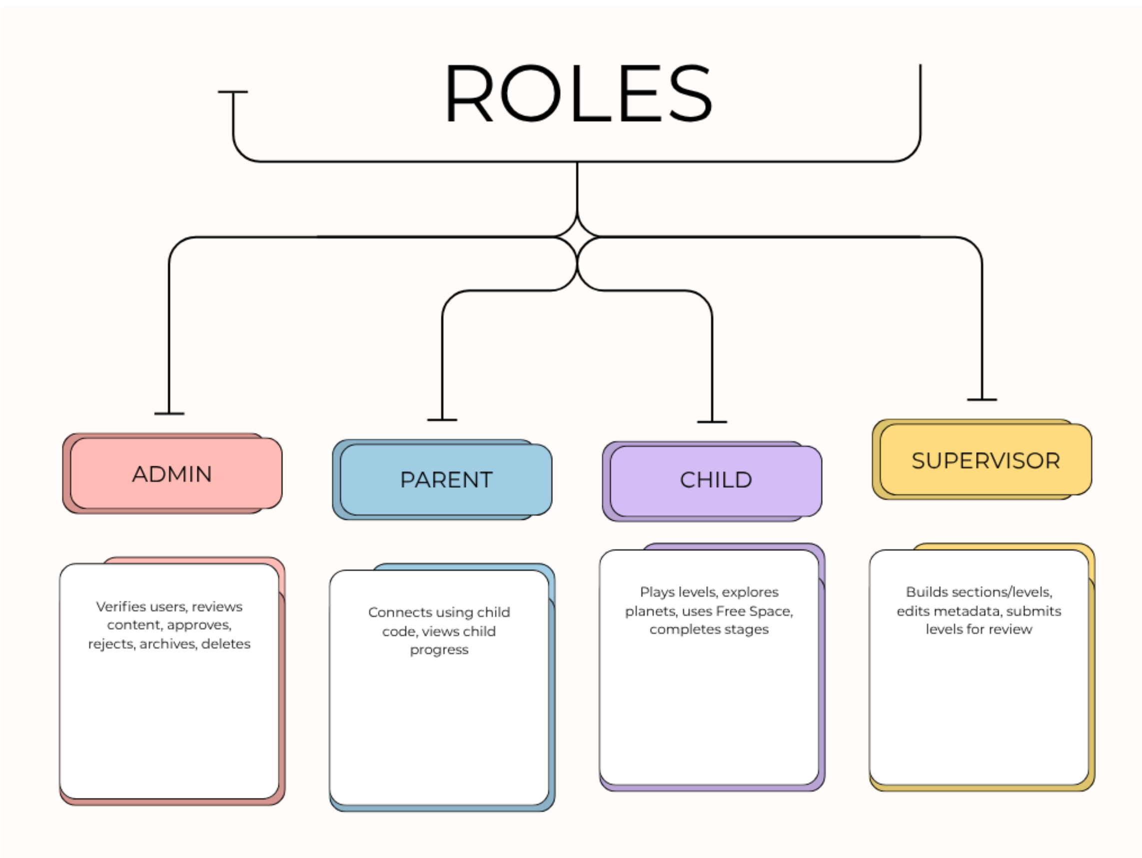


Figure 2.1: Role-based access model for child, parent, supervisor, and admin users.

2.3 Game-Based Learning and Child-Centred Design

Game-based learning is one of the main educational ideas behind this project. In a normal learning system, the child may only read information and answer questions. In this platform, the child interacts with the content directly. For example, in the Physics planet, the learner can move objects, test forces, observe collisions, connect gears, change gravity, and build experiments. In the Chemistry planet, the learner can mix substances, observe bubbles, and test acids and bases

This makes learning more child-centred because the learner controls the experience. The child can explore at their own pace, repeat a stage, try different solutions, and learn from mistakes. Instead of being punished for failure, the learner is encouraged to test again. This is especially important in science learning because experimentation is part of the scientific process.

The platform also uses visual storytelling. The space theme turns subjects into planets and levels into missions. This gives the child a sense of adventure and makes the learning environment more memorable. The project content already describes this concept as a universe where each subject becomes a planet, each lesson becomes a journey, and each level feels like a mission.

Progress tracking is another important part of the child-centred design. The learner can see completed and unlocked levels, while the parent can monitor progress from a connected account. This gives the child motivation and gives the parent visibility without interrupting the child's play experience.

2.4 Role-Based Access and Learning Management

The platform uses a role-based access model to separate learning, monitoring, content creation, and administrative control. This is important because different users should not have the same permissions. A child should not be able to approve levels, a parent should not be able to edit platform content, and a supervisor should not be able to bypass admin review.

The role system includes four main user types:

- **Child:** uses the platform to learn, play levels, explore planets, and complete activities.
- **Parent:** connects to a child account using a child-generated code and views the child's progress.
- **Supervisor:** creates and edits learning content, builds levels, and submits content for admin review.
- **Admin:** manages users, verifies access, reviews levels, approves content, archives content, and deletes inappropriate or outdated material.

This structure is supported by authentication and authorisation concepts. Authentication checks who the user is, while authorisation checks what that user is allowed to access. Supabase Auth supports these concepts by providing authentication and user management tools that can be connected to application profiles and role-based permission logic.

The parent-child connection code is important because it protects the child's account from being linked to the wrong parent. Instead of allowing any parent to search for any child, the child provides a code, and the parent uses that code to connect. This gives the platform a safer connection flow.

Supervisor and admin verification is also important because these roles can affect educational content. Since supervisors can create levels and admins can approve or remove content, their accounts require stronger control. This prevents unauthorised users from changing what children see inside the app.

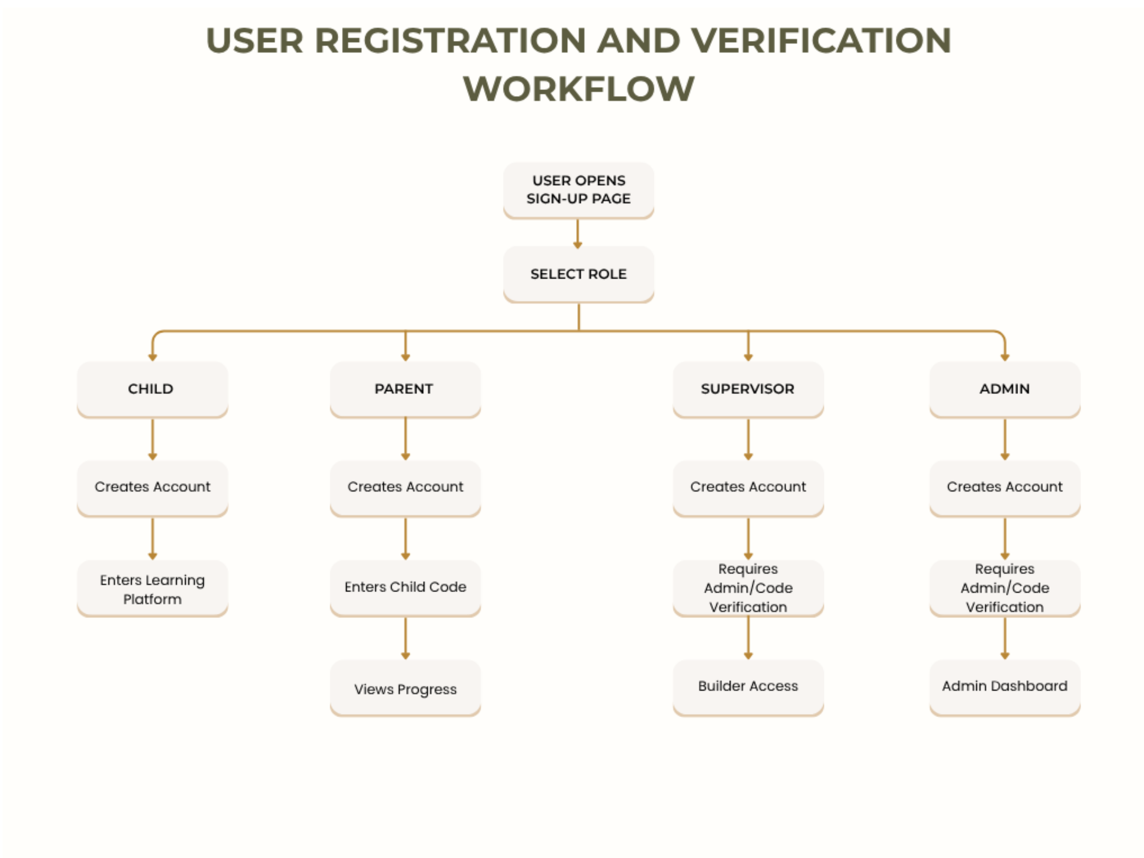


Figure 2.2: User registration and verification workflow.

2.5 Physics Simulation and Visual Learning

Physics is one of the main learning areas in the platform. The Physics planet includes sections such as Free Space, Forces, Gravity, Laser, Springs, and Gears. These sections are designed to make physics practical and visible instead of purely theoretical. The project content shows that the Physics planet contains structured sections and challenge-based levels such as Push and Pull, Friction Fun, Newton 1, Newton 2, and Collisions.

The theoretical foundation of this part is simulation-based learning. In physics, many concepts are easier to understand when learners can see movement and cause-and-effect relationships. For example, a child can understand gravity better by watching a ball fall, understand friction by comparing motion on different surfaces, and understand gears by observing how rotation transfers from one gear to another.

Matter.js is used as the main 2D physics engine in the project. Matter.js supports rigid bodies, collisions, gravity, constraints, friction, restitution, mass, density, sleeping bodies, and events, making it suitable for interactive physics scenes in the browser.

In this project, Matter.js is not used by itself as a complete educational system. Instead, it handles the physical simulation, while the project's custom systems define the educational behaviour. For example, Matter.js can calculate how bodies move and collide, while the custom object registry decides what each object represents, how it is drawn, what settings it has, and how it contributes to the learning goal. This matches the project explanation that custom equations and systems define educational logic while Matter.js handles object behaviour and physical simulation.

2.6 Free Space Sandbox and Discovery Learning

The Free Space section is the strongest example of discovery-based learning in the project. Unlike normal levels that have a fixed challenge, Free Space allows the learner to create experiments freely. The child can place objects, change the scene, press play, observe what happens, pause, edit, and try again. This creates a cycle of experimentation that is similar to a simple virtual physics laboratory.

Free Space supports many interactive objects, including balls, metal balls, blocks, dominos, ramps, balance scales, springs, wheels, powered wheels, axles, gears, motors, ropes, Newton cradles, fans, magnets, slingshots, and bumpers. These objects allow children to build different types of experiments, such as rolling motion, collisions, chain reactions, balance tests, gear systems, spring launches, magnetic interactions, and motor-powered machines.

The section works in three main modes:

- **Kid Play:** the child can explore, build, test, save, restore, use presets, and experiment freely.
- **Supervisor Builder:** the supervisor can build structured educational scenes, add metadata, place goal objects, export JSON, and submit levels for admin review.

- **Admin Review:** the admin can inspect a submitted level in a locked review mode before approving it.

This mode-based structure is important because the same Free Space engine serves different users without giving every user the same permissions. Children receive a playful sandbox, supervisors receive an authoring tool, and admins receive a review environment.

Free Space also uses preset scenes. These are important because a completely empty sandbox can be confusing for beginners. Presets give learners ready-made examples such as ramp starters, domino chains, spring scenes, gear machines, rope swings, and launcher setups. The learner can then modify those scenes and learn by changing an existing system instead of starting from zero.

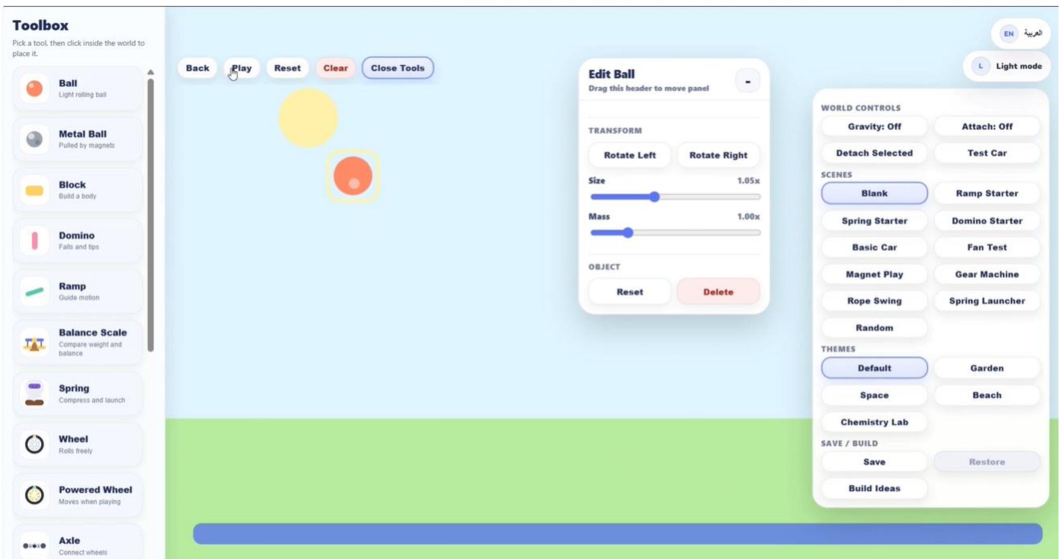


Figure 2.3: Free Space sandbox showing toolbox objects, scene area, and object editing panel.

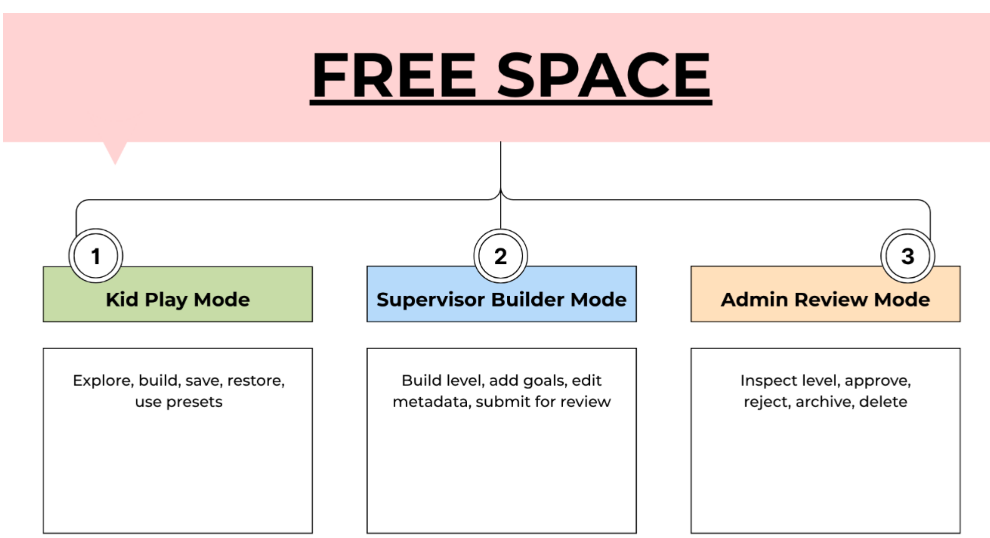


Figure 2.4: Free Space mode structure showing Kid Play, Supervisor Builder, and Admin Review.

2.7 Interactive Chemistry Learning

The Chemistry planet offers an interactive and visually driven learning environment where students explore chemical concepts through structured stages and practical experimentation. Instead of presenting chemistry as abstract theory, the system introduces it through guided learning levels that focus on different reaction types, such as exothermic and endothermic reactions, allowing learners to understand concepts through actions, feedback, and visual simulations.

The platform also includes a Chemistry Free Space that provides an open-ended environment for experimenting with elements and compounds. This space is integrated with the PubChem database to provide access to real scientific information about chemical substances and their properties, helping bridge the gap between simulation and real-world data.

To enhance engagement, the system applies a cinematic camera approach using smooth panning, dynamic zooming, and guided scene transitions, which helps direct attention and improves the overall learning experience. The Chemistry environment is built using React, Canvas 2D, and interactive state management, enabling a responsive and exploratory system that encourages learning through interaction rather than memorization.

Figure 2.5: Chemistry planet laboratory-style activity with animated reaction feedback.

2.8 Web-Based Technologies Used in the Platform

The platform is built as a modern web application. This is important because a web app can run on different devices without requiring the user to install a separate desktop program. The project was designed to work on desktop and mobile screens, which makes responsiveness an important technical requirement.

React is used as the main interface framework. React applications are built from reusable components, which makes it suitable for a platform with many repeated interface elements such as buttons, cards, dashboards, level screens, tool panels, and planet pages.

Vite is used as the development and build tool. Vite supports modern frontend development and creates production bundles that can be served through static hosting or deployment platforms.

Supabase is used for authentication and user profile support. Supabase Auth provides authentication and authorisation tools, while user profile tables can be used to store role-related data such as child, parent, supervisor, and admin profile information.

Pixi.js is used for advanced 2D rendering and interactive visual effects. PixiJS supports WebGL and WebGPU renderers, mouse and multi-touch interaction, text rendering, textures, masking, filters, and interactive graphics, making it suitable for rich browser-based learning scenes.

Matter.js provides the 2D physics simulation layer for gravity, collisions, rigid bodies, constraints, and object behaviour. Three.js provides 3D rendering support for the microscopic chemistry view. i18next provides internationalisation support, allowing the project to support more than one language, including Arabic and English.

Together, these technologies allow the project to combine learning content, user accounts, interactive simulations, responsive interface design, multilingual support, and management dashboards in one system.

2.9 Summary

This chapter presented the theoretical background and previous work related to the proposed educational platform. Existing educational systems show the value of game-based learning, gamification, interactive simulation, and visual feedback, but many systems still separate learning, parent monitoring, content creation, and admin review. This project combines these elements into one integrated platform.

The proposed system is based on active learning, discovery learning, role-based access, simulation-based science education, and child-centred design. The Physics planet uses visual simulation and sandbox experimentation to teach motion, forces, gravity, gears, springs, and collisions. The Chemistry planet uses laboratory-style activities, visual reactions, mission-based stages, and microscopic 3D scenes to make chemistry more understandable for children. The platform's web-based architecture allows it to support desktop and mobile users while remaining scalable and extendable.

Chapter 3 Methodology

3.1 System Development Methodology

This chapter describes the methodology used to design and implement the proposed children's educational web application. The methodology focuses on the software development process, system architecture, user roles, interactive learning design, content management workflow, progress tracking, and safety considerations for child users.

The project was developed using an iterative software development methodology. Instead of building the full platform at once, the system was divided into smaller functional modules. Each module was designed, implemented, tested, improved, and then integrated with the rest of the application. This approach made the project easier to manage because the platform contains several different parts, including authentication, planet navigation, learning sections, physics simulations, chemistry activities, dashboards, and admin management tools.

The development process was divided into the following main stages:

1. **Requirement analysis**

   The first stage involved identifying the required users, features, learning flow, and technical needs of the application. The main users were defined as child, parent, supervisor, and admin. The main learning areas were defined as Physics and Chemistry, with the Free Space section selected as the most important open-ended physics environment.

2. **Interface and user experience design**

   The second stage focused on designing the application as a child-friendly space-themed learning world. Subjects were represented as planets, and levels were designed as interactive missions. The interface was designed to be colourful, visual, simple to understand, and suitable for both desktop and mobile screens.

3. **Authentication and role system development**

   The third stage involved building the sign-up and login flow. The system supports different roles, including child, parent, supervisor, and admin. Each role is directed to the correct part of the platform based on its permissions.

4. **Planet and level structure development**

   The fourth stage involved creating the educational structure of the platform. Each subject was represented as a planet. Each planet contains sections, and each section contains levels or stages. This structure allows the platform to be expanded later by adding more subjects, sections, and learning activities.

5. **Physics planet implementation**

   The fifth stage focused on the Physics planet. This included structured physics levels, Free Space sandbox tools, Matter.js physics simulation, object creation, object editing, preset scenes, goal objects, and supervisor/admin modes.

6. **Chemistry planet implementation**

   The sixth stage focused on the Chemistry planet. This included interactive lab activities, animated reactions, mission-based stages, Canvas 2D rendering, cinematic camera movement, and local progress saving,

7. **Dashboard and management system development**

   The seventh stage involved building the parent, supervisor, and admin routes. Parents can view child progress, supervisors can build and submit levels, and admins can review and manage educational content.

8. **Testing and refinement**

   The final stage involved testing the application on different screens, checking role permissions, testing level progress, reviewing Free Space behaviour, and improving the user interface based on observed issues.

This iterative methodology was suitable for the project because the platform combines educational design, game-like interaction, physics simulation, chemistry visualisation, and user management. Developing the system in modules allowed each part to be tested separately before being connected into one complete platform.

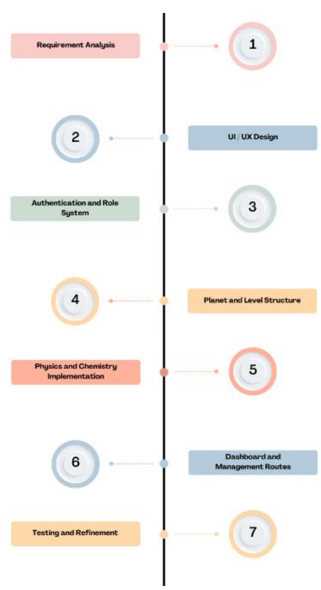


Figure 3.1: Iterative development methodology used for the educational platform.

3.2 Software Tools and Technologies

The project was implemented using modern web development technologies. These tools were selected because they support responsive user interfaces, interactive scenes, physics simulation, 2D visualisation, routing, authentication, and multilingual support.

3.2.1 React

React was used as the main frontend framework for building the application interface. The platform contains many reusable interface parts, such as buttons, cards, dashboards, tool panels, level screens, modals, planets, and progress elements. React components made it easier to divide the interface into smaller parts and reuse them across the project.

React state and hooks were also used to manage user interaction inside many learning activities. For example, Chemistry stages use state to track selected chemicals, reaction progress, stage completion, stars, and unlocked levels.

3.2.2 Vite

Vite was used as the development and build tool for the React application. It provided a fast development environment and allowed the project to be organised as a modern frontend web application. Vite was useful during development because changes could be tested quickly while building the user interface and interactive scenes.

3.2.3 React Router

React Router was used to manage navigation between the main pages of the platform. This includes routes for the login page, sign-up page, universe home page, planet pages, learning sections, levels, parent dashboard, supervisor builder, and admin review screens.

Routing was important because the platform is not a single static page. It contains multiple user flows depending on the selected role. A child is routed to the learning area, a parent is routed to the progress dashboard, a supervisor is routed to the builder tools, and an admin is routed to review and management routes.

3.2.4 Supabase

The Supabase was used to support authentication and user profile management. The authentication system allows users to create accounts and log in securely. Profile data is then used to determine the user's role and direct the user to the correct part of the application.

The system supports the following user roles:

- Child
- Parent
- Supervisor
- Admin

The role data is important because each user type has different permissions. Children access the learning planets, parents monitor progress, supervisors build levels, and admins manage users and approve content.

3.2.5 Matter.js

Matter.js was used as the main physics simulation engine in the Physics planet and Free Space sandbox. It handles physical behaviours such as gravity, collision response, object movement, friction, restitution, constraints, and body interaction.

In this project, Matter.js does not define the educational logic by itself. Instead, the project uses custom systems on top of Matter.js. Matter.js performs the physical simulation, while the custom object systems define what each educational object does, how it appears, how it is edited, and how it contributes to a learning goal.

3.2.6 Pixi.js

Pixi.js was used for rendering advanced 2D interactive scenes and visual effects. It was especially useful in scenes that require smooth rendering, animated objects, glowing effects, and interactive visual feedback.

In the Free Space and Physics areas, Pixi.js helps make the sandbox feel more alive by supporting clear object rendering and visual interaction. It also supports a more polished child-friendly appearance compared with basic static HTML elements.

3.2.7 Canvas 2D

Canvas 2D was used in several Chemistry and Physics activities to draw custom interactive scenes. It was used for animated lab visuals, reaction effects, particles, bubbles, flames, flasks, gears, overlays, and cinematic stage movement.

Canvas 2D was selected for these parts because it gives direct control over drawing and animation. This is useful for educational mini-games where the scene needs to update continuously based on user interaction.

3.2.8 i18next

i18next was used to support multilingual functionality. The platform supports Arabic and English, which improves accessibility for different users. This is important because the project is designed for children, and children learn better when the interface is available in a language they understand.

3.2.9 Framer Motion and Lucide React

Framer Motion was used to support animations and transitions in the user interface. It helped make the platform feel more dynamic and responsive.

Lucide React was used for icons across the interface. Icons helped improve usability by making buttons and actions easier to recognise, especially for children.

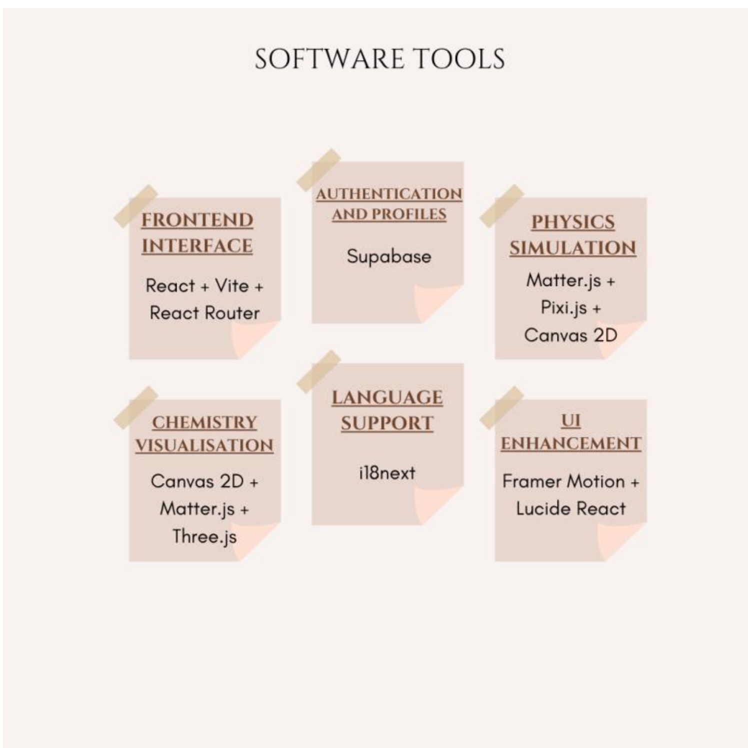


Figure 3.2: Main software tools and technologies used in the platform.

3.3 Project Structure

The project was organised into reusable folders to improve maintainability and make the application easier to extend. The structure separates routing, pages, learning data, engine logic, dashboards, services, and translation files.

The main project structure includes:

- src/app
  This folder contains the main application setup and routing structure.
- src/pages
  This folder contains the main pages of the platform, such as login, sign-up, home, planet pages, and dashboards.
- src/data/planets
  This folder stores subject planet data, learning sections, levels, and stage definitions.
- src/engine
  This folder contains content registration, stage mapping, and logic that connects learning content to the correct interactive components.
- src/routes
  This folder contains dashboard and management routes for parent, supervisor, and admin workflows.
- src/services
  This folder contains authentication services, profile services, progress services, and other shared logic.
- src/locales
  This folder contains translation files for Arabic and English language support.

This structure was chosen to avoid placing all logic into one large file. It allows the project to grow without becoming too difficult to manage. For example, new planets can be added inside the planet data structure, new dashboard routes can be added separately, and new services can be created without affecting the visual interface.

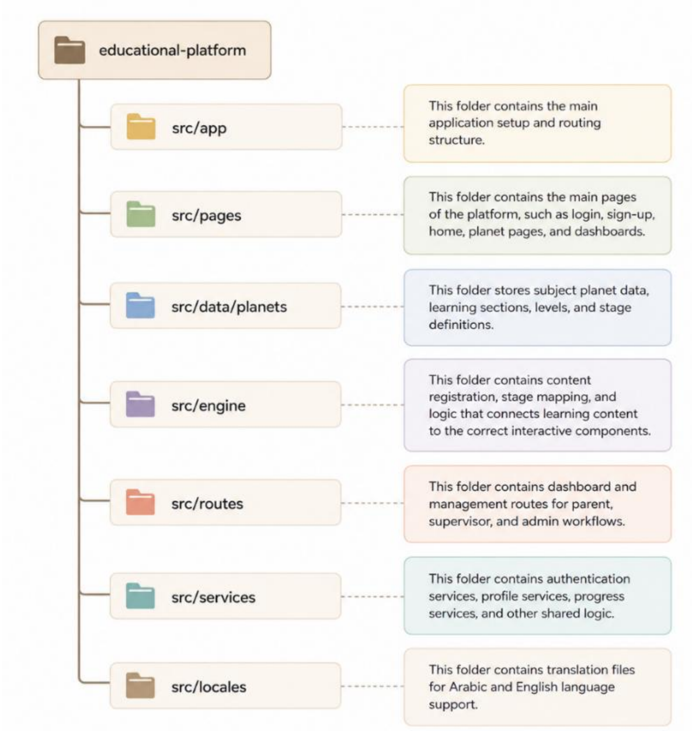


Figure 3.3: Main folder structure of the React educational platform.

3.4 System Architecture

The platform follows a modular web application architecture. The child, parent, supervisor, and admin users interact with the same application, but each user sees a different interface based on their role and permissions.

At a high level, the system contains the following layers:

1. **User Interface Layer**

   This layer includes all visible screens, such as the login page, sign-up page, universe page, planet pages, Free Space canvas, Chemistry labs, parent dashboard, supervisor builder, and admin review page.

2. **Routing Layer**

   This layer controls navigation between pages using React Router. It ensures that users move to the correct page based on their actions and role.

3. **Authentication and Profile Layer**

   This layer uses Supabase authentication and profile data to identify the user and determine their role.

4. **Learning Content Layer**

   This layer stores the planets, sections, levels, stage data, and educational metadata.

5. **Interactive Engine Layer**

   This layer contains the logic for Free Space, Physics stages, Chemistry stages, Matter.js worlds, Pixi.js rendering, Canvas 2D activities, and Three.js scenes.

6. **Progress and Management Layer**

   This layer tracks completed levels, unlocked levels, submitted levels, approved levels, parent-child connections, and admin/supervisor actions.

The system architecture allows the platform to support both learning and management. Children interact mainly with the learning layer and interactive engine layer. Parents interact mainly with the progress layer. Supervisors interact with the builder tools. Admins interact with the review and management layer.

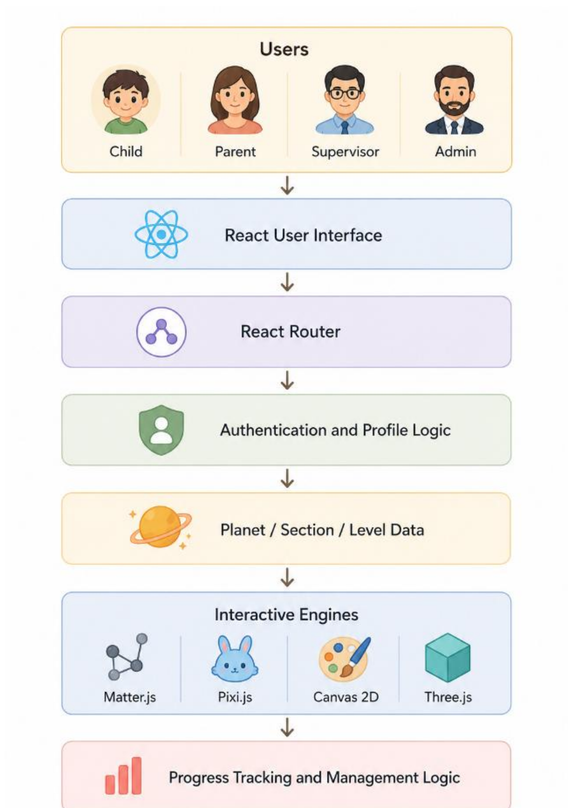


Figure 3.4: Overall architecture of the educational web application.

3.5 User Roles and Verification Workflow

The application was designed around four main user roles: child, parent, supervisor, and admin. Each role has a different purpose and permission level.

Child Role:

The child role is the main learning role. A child can sign up, log in, enter the universe page, select planets, open sections, play levels, use Free Space, complete activities, and progress through the learning path.

The child experience is designed to be visual and simple. The child does not need to manage technical settings or content approval. The interface focuses on exploration, play, and progress.

Parent Role:

The parent role is used to monitor a child's learning progress. A parent account connects to a child account using a code generated by the child. This method helps make sure the parent is connecting to the correct child account.

After connection, the parent can view progress information, such as completed levels, unlocked levels, and learning activity.

Supervisor Role:

The supervisor role is used for educational content creation. A supervisor can access builder tools, create sections or levels, edit level metadata, build Free Space scenes, add goal objects, export level data, and submit levels for review.

Supervisor access must be verified before the user can manage educational content. This is important because supervisors can create material that may eventually be shown to children.

Admin Role:

The admin role has the highest level of control. Admins can review submitted levels, approve or reject content, archive old content, delete unsuitable content, and manage sections or levels. Admin accounts also require verification to protect the platform from unauthorised access.

3.6 Planet, Section, and Level Structure

The educational content is organised using a planet-based structure. Each subject is represented as a planet, and each planet contains sections. Each section contains levels, stages, or activities.

This structure was selected because it supports the space theme and makes learning feel like exploration. Instead of presenting a normal list of lessons, the platform presents a universe where each subject is a destination.

The general hierarchy is:

Figure 3.5: Planet, section, and level hierarchy.

For example, the Physics planet contains sections such as:

- Free Space
- Forces
- Laser
- Springs
- Gears

The Chemistry planet contains sections such as:

- Reactions and Bubbles
- Balloon Reaction Lab

- Alchemist's Attic
- Acids and Bases
- States of Matter
- Elements Basics

Each level can have a different status, such as locked, unlocked, or completed. This allows the platform to guide the child through learning content in a structured way while still keeping the experience playful.

3.7 Physics Planet Implementation

The Physics planet was designed to make physics concepts practical, visual, and interactive. Instead of only presenting formulas or text explanations, the Physics planet allows the learner to observe physical behaviour directly.

The Physics planet includes structured learning sections and open-ended exploration areas. Some sections use fixed stages with specific goals, while Free Space gives the learner more freedom to build and test their own scenes.

The main Physics areas include:

- **Free Space**
  An open-ended physics sandbox where learners can build experiments and test physical behaviour.
- **Forces**
  A section that teaches pushing, pulling, friction, Newton's laws, and collisions.
- **Laser**
  A section that teaches light behaviour through reflection, prisms, lenses, colour mixing, and ray logic.
- **Springs**
  A section that demonstrates compression, launching, bouncing, and energy transfer.
- **Gears**
  A section that teaches rotational motion, opposite gear direction, gear ratios, and machine behaviour.

The Physics planet uses both simulation and visual feedback. Matter.js handles many physical interactions, while custom logic is used for educational rules, level goals, and special object behaviour. This combination allows the Physics planet to feel interactive while still supporting structured learning outcomes.

3.8 Free Space Sandbox Implementation

Free Space is the main open-ended physics studio in the project. It was designed as a sandbox where learners can place objects, test ideas, change the scene, and observe how the world behaves.

Free Space supports three main modes:

3.8.1 Kid Play Mode

Kid Play mode is designed for children. In this mode, the learner can:

- Place objects into the scene.
- Press Play or Pause.
- Reset the scene.
- Clear objects.
- Toggle gravity.
- Use attach mode.
- Detach selected objects.
- Test cars.
- Load preset scenes.
- Open random scenes.
- Change the background theme.
- Save and restore sandbox states.
- Open build ideas for inspiration.

This mode supports free exploration. The learner can experiment without needing to follow one fixed solution.

3.8.2 Supervisor Builder Mode

Supervisor Builder mode is designed for creating educational levels. It includes the normal Free Space toolbox, but also adds goal objects and metadata editing. The supervisor can build a scene, define the learning goal, test the level, export the JSON, and submit the level for admin review.

Supervisor mode is important because it turns Free Space from a child sandbox into a content creation tool.

3.8.3 Admin Review Mode

Admin Review mode is used to inspect levels before they are approved. This mode allows the admin to preview the level and check whether it is suitable for children. The review mode is more controlled than builder mode because the admin is not playing freely; the admin is verifying content quality and safety.

3.8.4 Toolbox Objects

The Free Space toolbox contains many objects, including:

- Ball
- Metal Ball
- Block
- Domino
- Ramp
- Balance Scale
- Spring
- Wheel
- Powered Wheel
- Axle
- Gear
- Motor
- Rope
- Newton Cradle
- Fan
- Magnet
- Slingshot
- Bumper

In Supervisor Builder mode, extra goal objects are available:

- Goal Zone
- Cat Goal
- Food
- Basket
- Star Collectible

These objects allow supervisors to create objective-based levels where the child must complete a mission.

3.8.5 Object Editing Panel

When the user selects an object, an editing panel appears. This panel allows the user to change object-specific settings. Depending on the object type, the panel can include:

- Rotate left
- Rotate right
- Size
- Mass
- Wind strength
- Magnet strength
- Magnet range
- Magnet pole angle
- Attract or repel mode
- Motor power
- Motor max speed
- Clockwise or counter-clockwise direction
- Motor on/off
- Reset selected object
- Delete selected object

This editing panel is important because it gives the learner control over the experiment. The child is not only placing objects; they are adjusting how objects behave.

3.8.6 Preset Scenes

Preset scenes were included to reduce confusion and help learners begin quickly. Instead of always starting from an empty world, the child can load a ready-made scene and modify it.

Preset scenes can demonstrate:

- Ramp motion
- Domino chains
- Gear machines
- Spring launchers
- Rope swings
- Car testing
- Collision setups
- Chain reactions

This supports beginner learning because the child can see a working example first, then change it and observe the result.

3.9 Chemistry Planet Implementation

chemistry as static information, the platform uses interactive missions, animated reactions, visual effects, and stage progression to help children understand scientific concepts through experimentation and exploration.

The Chemistry planet currently includes one main section called **Reactions and Bubbles**. This section contains a series of interactive stages where users perform experiments, observe chemical reactions, and receive immediate visual feedback. Each stage focuses on a specific learning objective and encourages active participation rather than passive reading.

3.9.1 Reactions

Reactions and Bubbles is the main Chemistry section of the platform. It uses mission-based levels to teach basic chemistry concepts through hands-on interaction. Example stages include:

- Toxic Mix Door
- Frozen Escape Lab
- Magic Flower Lab
- Litmus Lab
- Balloon Lift Lab

Each stage has a clear objective, interactive elements, visual feedback, and a completion condition. This structure helps children focus on one concept at a time while progressing through the learning experience.

3.9.2 Visual Feedback

The Reactions and Bubbles section uses visual feedback to make chemical reactions easier to understand. Feedback elements include:

- Bubbles
- Foam
- Smoke
- Colour changes
- Reaction glow effects
- Labels and instructions
- Completion screens
- Animated laboratory objects

These visual effects help learners immediately observe the results of their actions, making abstract chemistry concepts more engaging and easier to understand.

3.9.3 Cinematic Camera System

Some Chemistry stages use a cinematic camera system. This is implemented using Canvas 2D transforms rather than a real 3D camera. The system changes camera scale and position to create zooming and movement effects.

The camera uses values such as:

camScale
camX
camY
setTransform(...)

This makes the beginning of some levels feel like a short animated story instead of a static screen.

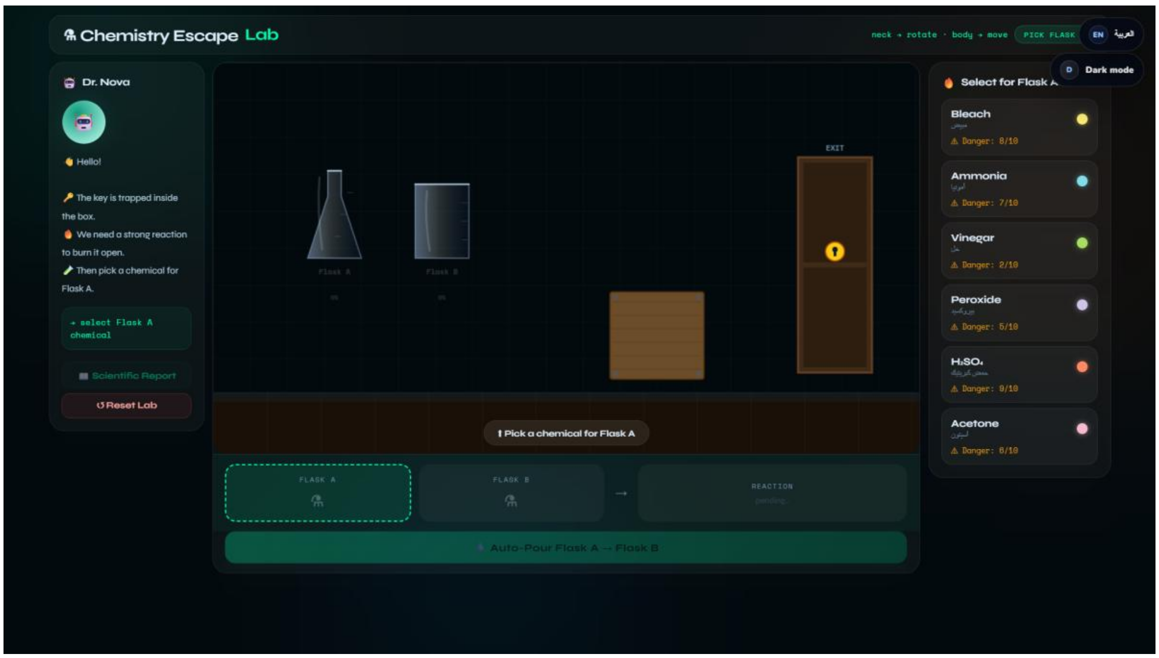


Figure 3.6: Chemistry laboratory-style stage with animated reaction feedback.

3.10 Content Management and Review Workflow

The platform includes content management routes for supervisors and admins. This is one of the main differences between the project and a normal educational game.

The content workflow is:

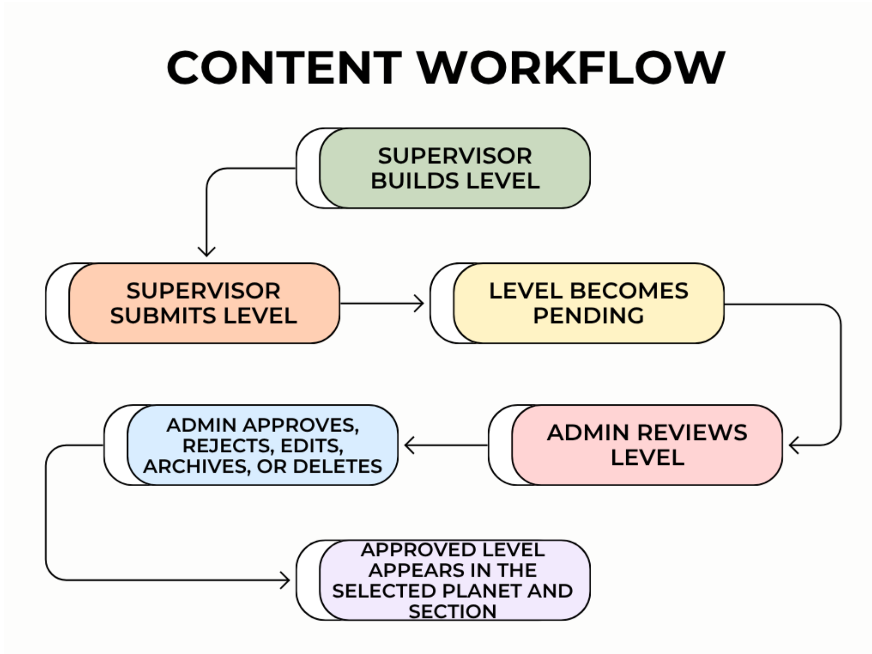


Figure 3.7: Supervisor submission and admin review workflow.

This workflow ensures that children only see approved educational content. It also allows the platform to grow because supervisors can create new content without directly publishing it to children.

The admin can manage:

- Sections
- Levels
- Pending submissions
- Approved content
- Archived content
- Deleted content
- Review decisions

This system improves content quality because there is a review step before publication.

3.11 Progress Tracking and Parent Dashboard

The platform tracks the learner's progress through the educational content. Each level can be locked, unlocked, or completed. This gives the child a sense of achievement and helps guide them through the learning path.

Progress tracking supports:

- Completed levels

- Unlocked levels
- Locked levels
- Stars or stage completion
- Section progress
- Parent monitoring

The parent dashboard uses the child connection system. A child provides a code, and the parent uses that code to connect to the child's account. After connection, the parent can view the child's progress.

This feature is important because it allows parents to support learning without interfering directly with the child's play experience.

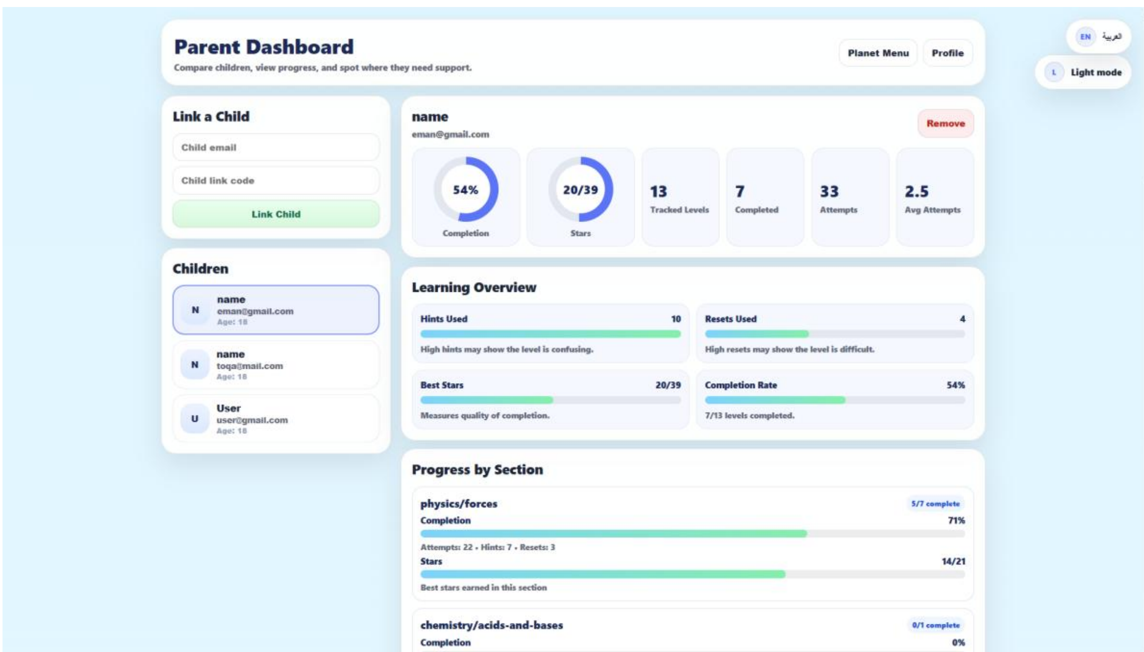


Figure 3.8: Parent dashboard showing child learning progress.

3.12 Responsive Design Methodology

The platform was designed to work on both desktop and mobile devices. This was important because children may use the application on laptops, tablets, or phones.

Responsive design was considered in:

- Login and sign-up pages
- Universe home page
- Planet selection screens
- Section and level pages
- Dashboard layouts

- Free Space scene framing
- Toolbox panels
- Admin and supervisor management screens

The interface was designed to adjust to different screen sizes. On larger screens, more panels and controls can be shown at the same time. On smaller screens, controls need to be arranged more carefully to avoid clutter and keep the learning area usable.

Special attention was required for Free Space because it contains a canvas scene, top action bar, toolbox, object editing panel, and More Tools panel. These elements must be positioned carefully so that the scene remains clear and the child does not feel confused.

3.13 Operational Procedures

The operational procedures describe how the main users interact with the system.

3.13.1 Child Learning Procedure

The child learning procedure is:

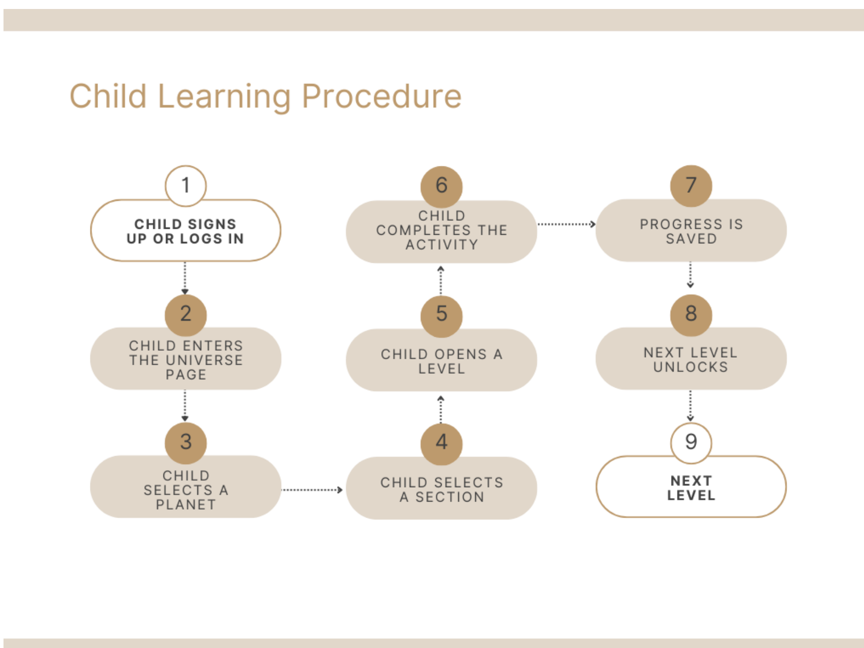


Figure 3.9: Main operational workflows for child.

This procedure supports a simple and guided learning experience.

3.13.2 Parent Monitoring Procedure

The parent monitoring procedure is:

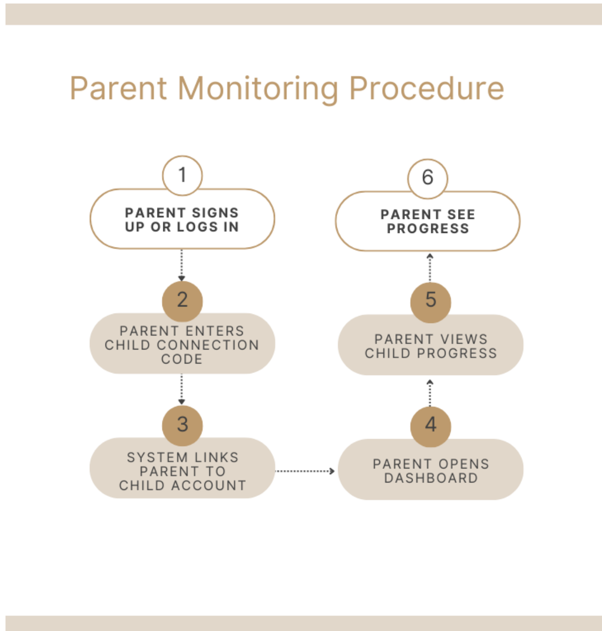


Figure 3.10: Main operational workflows for parent.

This procedure allows parents to monitor learning without needing to share the child's login details.

3.13.3 Supervisor Level Creation Procedure

The supervisor procedure is:

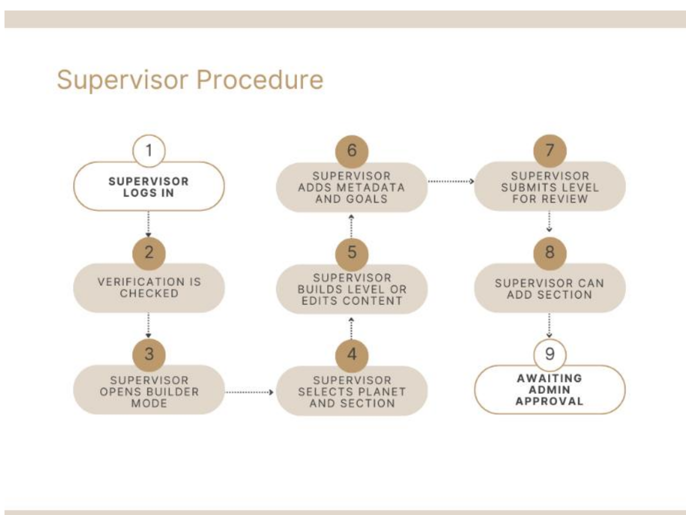


Figure 3.11: Main operational workflows for supervisor.

3.13.4 Admin Review Procedure

The admin procedure is:

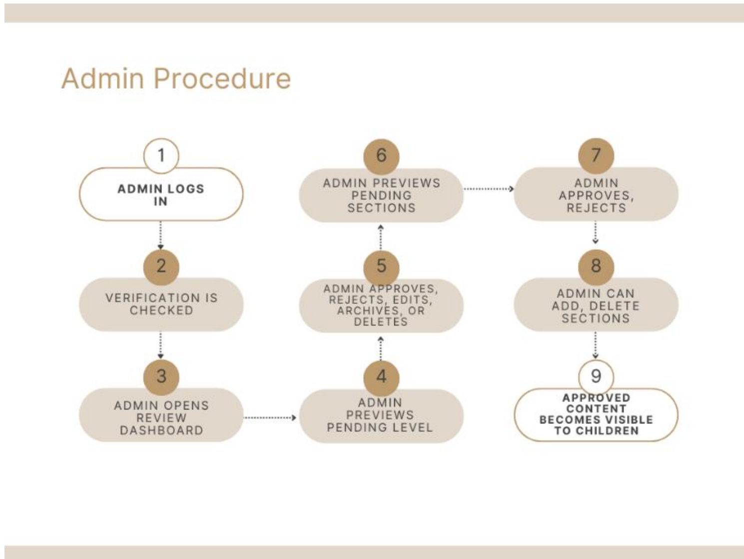


Figure 3.12: Main operational workflows for admin.

3.14 Design Constraints

Several constraints affected the design and implementation of the platform.

3.14.1 Screen Size Constraints

Because the application supports both desktop and mobile, the interface had to be designed carefully. Some screens, especially Free Space, contain many controls. On small screens, these controls can become crowded if they are not arranged properly.

3.14.2 Child-Friendly Interface Constraints

The platform is designed for children, so the interface needed to be simple, visual, and easy to understand. Complex controls had to be hidden or organised under panels such as More Tools to avoid overwhelming the learner.

3.14.3 Performance Constraints

Physics simulation and animated scenes can become performance-heavy, especially when many objects are placed in the Free Space sandbox. The system needed to manage object count, rendering, collision behaviour, and scene reset logic to avoid slow performance.

3.14.4 Content Quality Constraints

Because supervisors can create learning levels, the system needed an admin review process to prevent unsuitable or unfinished content from becoming visible to children. This constraint led to the creation of the pending, review, approval, archive, and delete workflow.

3.14.5 Scientific Accuracy Constraints

Some Physics and Chemistry features are simplified for child learning. For example, some visual effects represent concepts in an educational way rather than using a full scientific simulation. This was necessary because the target users are children, and the main aim is to support understanding through interaction.

3.14.6 Time and Project Scope Constraints

The project focuses mainly on Physics and Chemistry. Other planets may be included visually or structurally, but the main detailed implementation is concentrated on these two subjects. This keeps the project achievable within the graduation project timeframe.

3.15 Safety, Privacy, and Child-Appropriate Design Considerations

Because the platform is designed for children, safety and privacy were important design considerations.

The platform uses role-based access to limit what each user can do. Children cannot access admin or supervisor tools. Parents cannot edit platform content. Supervisors cannot publish content directly without admin review. Admins control approval and content management.

The parent-child connection code helps protect child accounts by preventing random parent accounts from connecting without permission. A parent must receive the child's code before monitoring progress.

The admin review process also supports child safety. Since supervisors can create levels, submitted content should be reviewed before being made visible to children. This helps reduce the risk of inappropriate, confusing, or unfinished content appearing in the learning area.

The interface was also designed to be child-appropriate. The visual style uses planets, animations, friendly colours, simple controls, and clear interaction feedback. Educational content is presented through play and exploration rather than pressure or punishment.

3.16 Summary

This chapter described the methodology used to design and implement the proposed educational platform. The project was developed through an iterative software process that included requirement analysis, interface design, authentication development, planet structure creation, Physics and Chemistry implementation, dashboard development, and testing.

The chapter also explained the main software technologies used in the platform, including React, Vite, React Router, Supabase, Matter.js, Pixi.js, Canvas 2D, Three.js, i18next, Framer Motion, and Lucide React. The system architecture was presented as a modular web application that separates interface, routing, authentication, learning content, interactive engines, progress tracking, and management logic.

The methodology also covered the user roles, verification workflow, planet-section-level hierarchy, Physics planet, Free Space sandbox, Chemistry planet, content management workflow, parent dashboard, responsive design, operational procedures, design constraints, and child-safety considerations. This methodology provides the technical foundation for the results and analysis presented in the next chapter.

Chapter 4 Results and Analysis

4.1 Overview

This chapter presents the results obtained from developing and testing the proposed children's educational web application. The system was evaluated based on its main functional areas, including user authentication, role-based access, planet navigation, interactive learning sections, Free Space sandbox behaviour, Chemistry activities, content management workflow, parent progress monitoring, multilingual support, and responsive interface performance.

The purpose of this chapter is not only to describe what was built, but also to analyse how successfully each part of the system achieved the project objectives. The results show that the platform was able to provide a complete interactive learning experience where children can explore scientific concepts through planets, levels, simulations, missions, and sandbox experimentation.

The system was tested from the perspective of the four main user roles:

- Child
- Parent
- Supervisor
- Admin

Each role was tested separately to confirm that the correct pages, permissions, and features were available. The child role was tested for learning and gameplay, the parent role was tested for progress monitoring, the supervisor role was tested for content creation, and the admin role was tested for reviewing and managing submitted content.

4.2 Authentication and Role-Based Access Results

The authentication system successfully supported separate user flows for children, parents, supervisors, and admins. During testing, each user type was directed to the correct area of the application after login. This confirmed that the role-based access system worked as intended and prevented users from accessing pages outside their permission level.

The child account was able to access the learning universe, select planets, open sections, and play levels. The parent account was able to connect to a child profile using the child-generated code and view the child's learning progress. The supervisor account was able to access builder features after verification, while the admin account was able to access review and management features.

This result is important because the application is not designed for one type of user only. The system must support learning, monitoring, content creation, and administration within the same platform. The successful separation of these roles shows that the platform has a strong foundation for safe educational use.

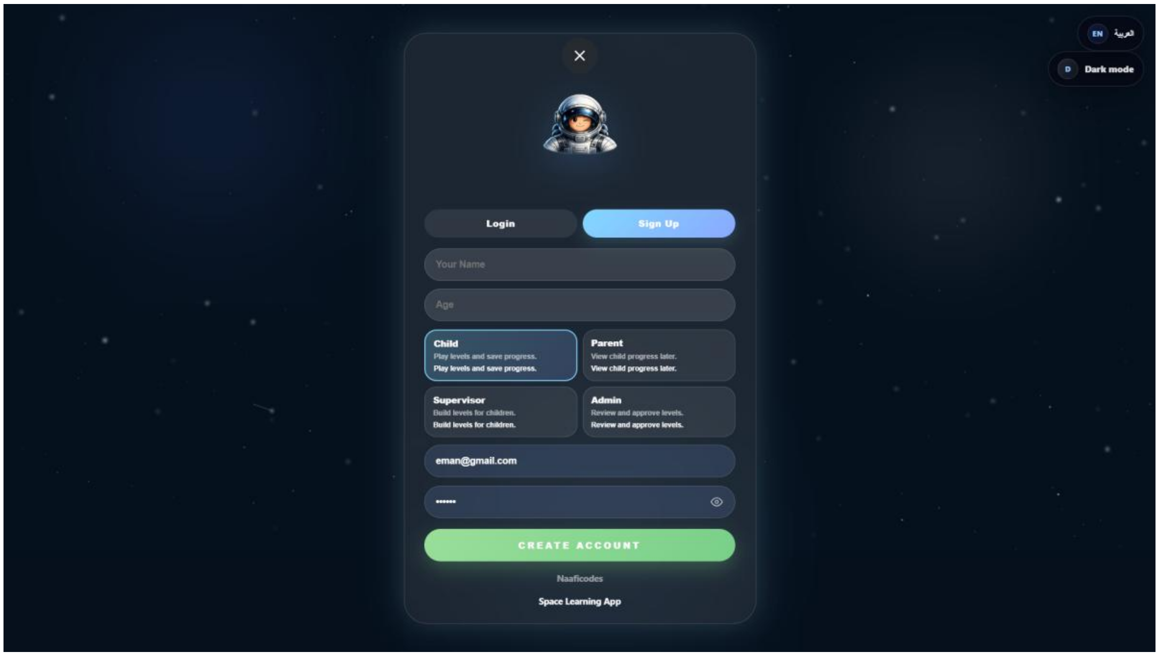


Figure 4.1: Role-based sign-up page showing child, parent, supervisor, and admin options.

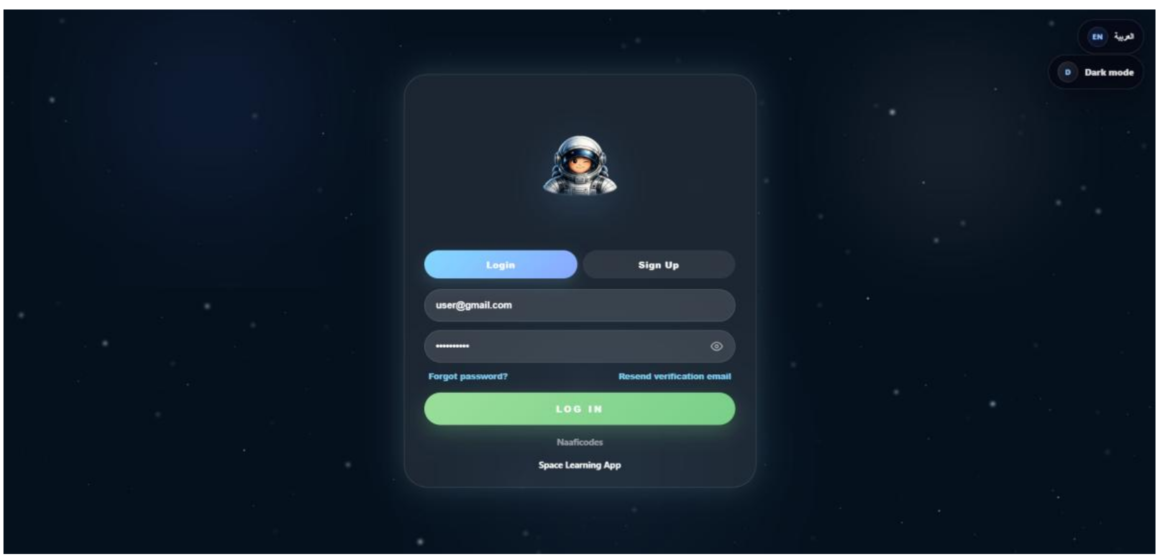


Figure 4.2: Login system directing users to the correct dashboard or learning area.

4.3 Child Learning Experience Results

Child Learning Experience Results

The child learning experience was successfully implemented through the space-themed universe page. After logging in, the child can enter a visual learning environment where subjects are represented as planets. The home page presents the platform as a learning universe rather than a normal list of lessons, which makes the experience more engaging and memorable.

The planet-based design worked effectively because it gave the child a clear and simple way to navigate between subjects. Instead of reading through long menus, the child can visually select a planet and enter the subject area. This supports the project goal of making learning active, visual, and enjoyable.

The child learning flow followed this sequence:

Child logs in
↓
Universe page opens
↓
Child selects a planet
↓
Child selects a section
↓
Child selects a level
↓
Child completes the activity
↓
Progress is saved

Testing showed that the child could move between the universe page, planet pages, sections, and levels without breaking the learning flow. The design also helped organise the learning content clearly because each planet contains related sections, and each section contains related levels.

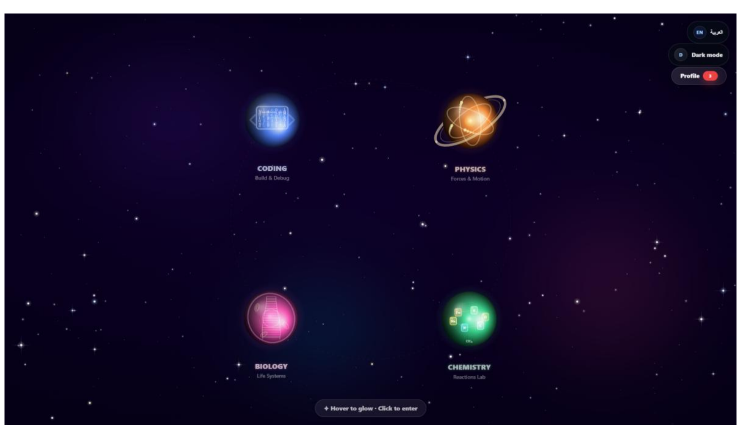


Figure 4.3: Child learning universe showing subject planets.

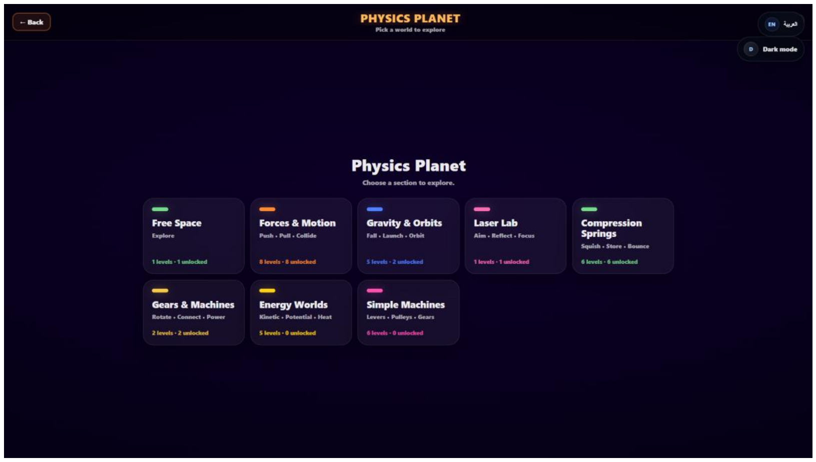


Figure 4.4: Planet page showing learning sections and level progression.

4.4 Physics Planet Results

The Physics planet was successfully developed as one of the main learning areas of the platform. It provides structured learning sections and interactive stages that allow the child to learn physics through visual interaction rather than static reading.

The implemented Physics sections include:

- Free Space
- Forces
- Laser
- Springs
- Gears

The Physics planet achieved its purpose by making abstract concepts more visible. For example, motion, gravity, pushing, pulling, collisions, springs, and gear rotation can be observed directly through interactive scenes. This allows the child to connect the learning concept with what happens on the screen.

The Laser Lab result was especially important because it transformed light behaviour into a visual puzzle. The learner can observe straight beam paths, mirror reflection, prism colour separation, lens focusing, and colour mixing. This makes optics easier to understand because the child can see the result of changing the setup.

The Gears section also produced strong results because it allowed the learner to observe how connected gears rotate in opposite directions and how motion transfers through a gear chain. This supports mechanical learning through direct observation.

Overall, the Physics planet successfully met the project objective of creating practical, visual, and interactive science learning experiences.

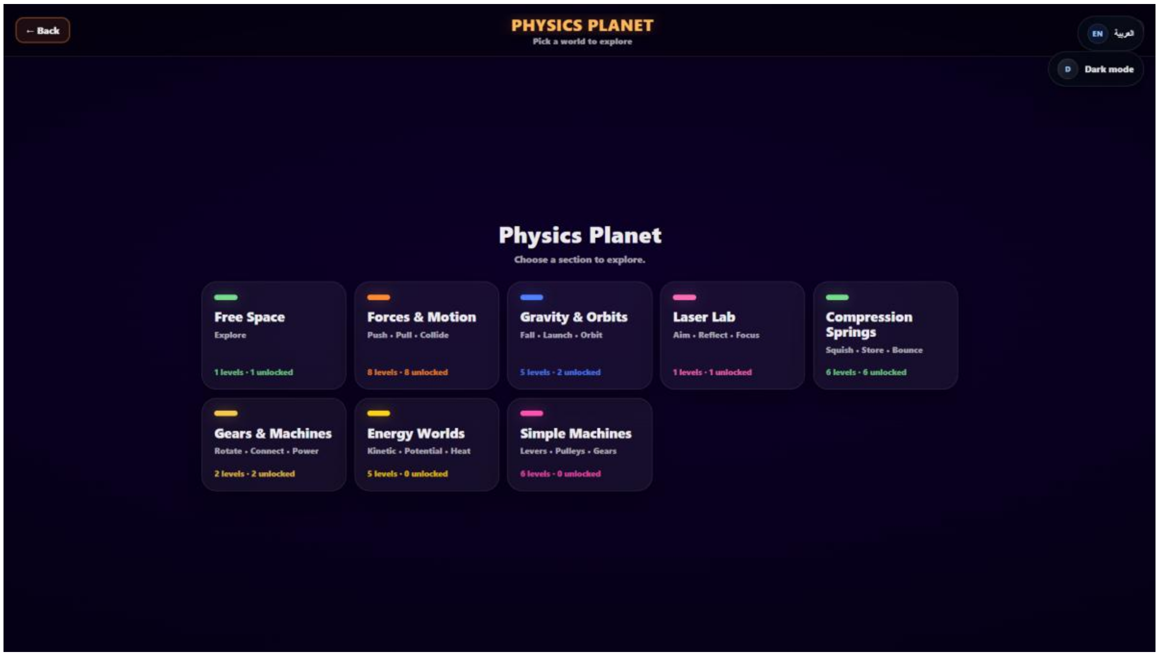


Figure 4.5: Physics planet showing available learning sections.

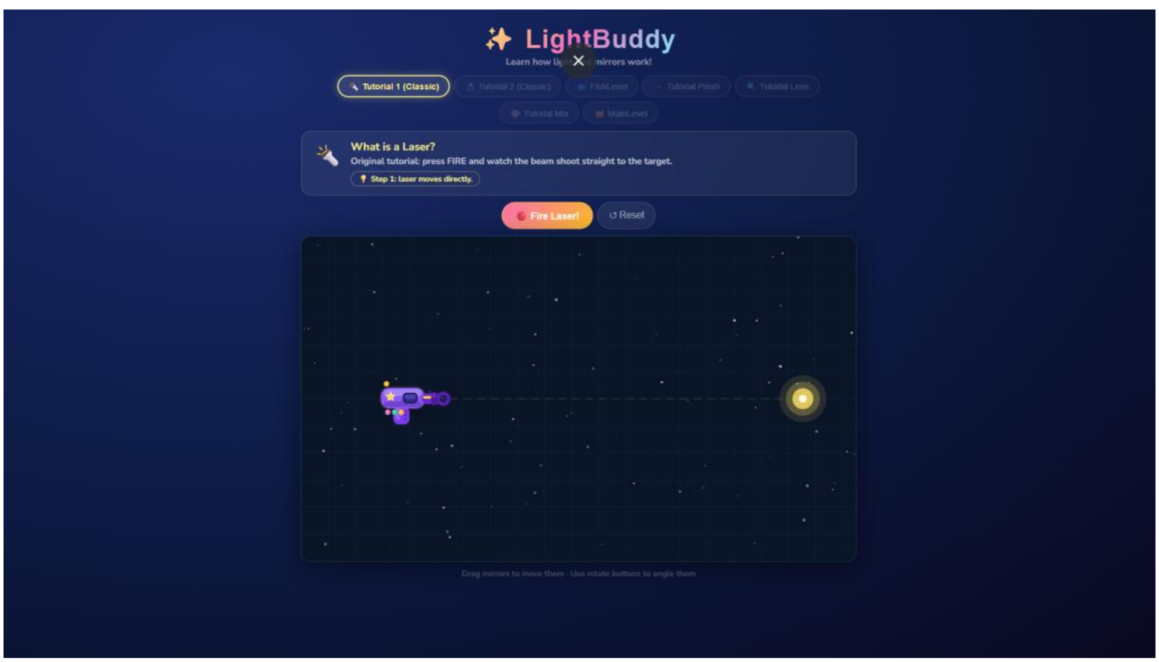


Figure 4.6: Laser Lab stage showing interactive light behaviour.

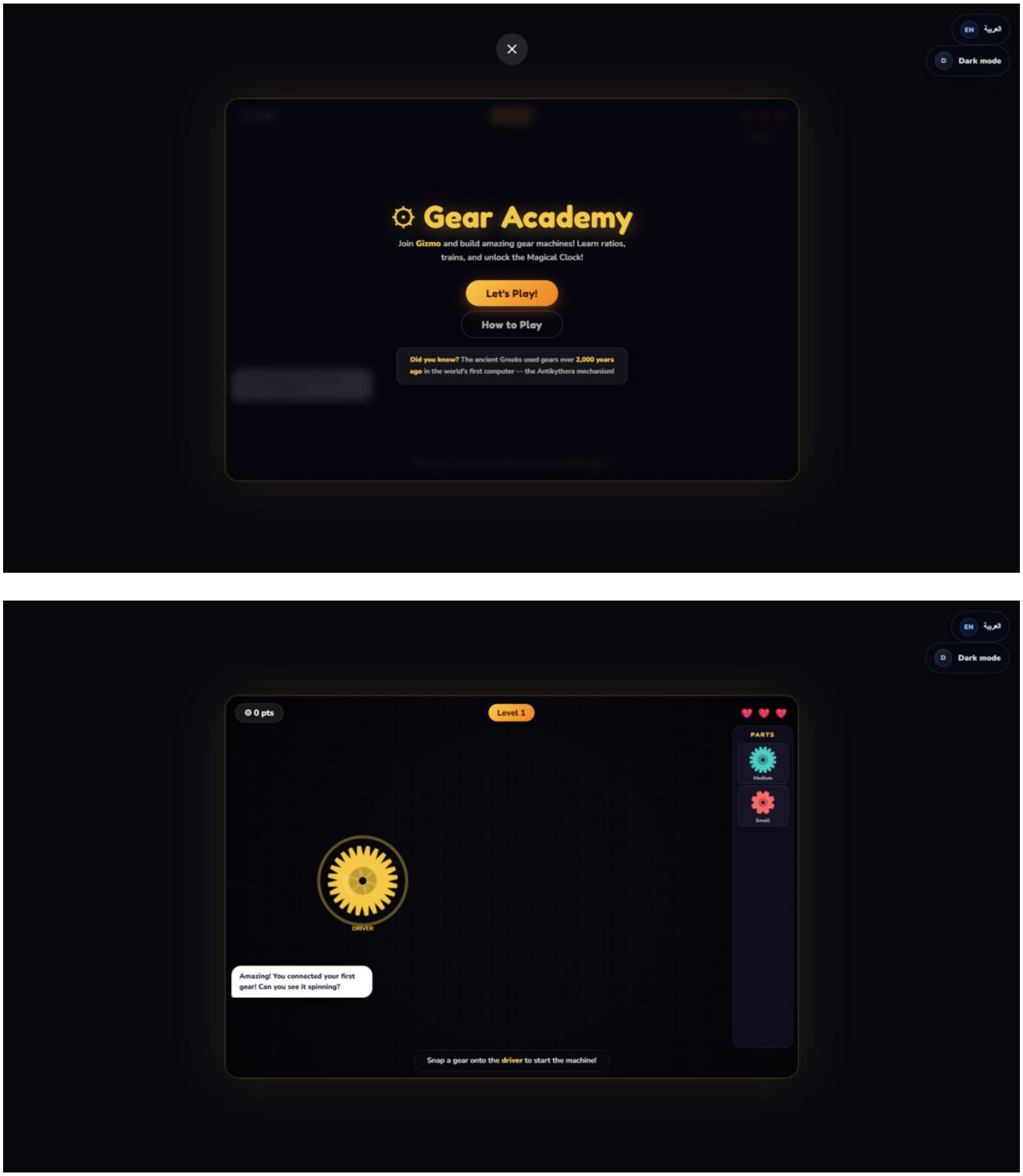


Figure 4.7: Gears learning activity showing rotational motion and connected gears.

4.5 Free Space Sandbox Results

The Free Space sandbox was one of the most successful and technically advanced parts of the project. It worked as an open-ended physics studio where learners could create their own experiments, test physical behaviour, modify objects, and observe the results.

The sandbox successfully supported the main actions required for child exploration:

- Adding objects to the scene
- Playing and pausing the simulation
- Resetting the scene
- Clearing objects
- Changing gravity
- Loading preset scenes
- Saving and restoring scenes
- Changing background themes
- Using build ideas
- Editing selected objects
- Connecting objects using ropes and attachment tools

The toolbox objects were successfully implemented and gave the learner a wide range of experiment possibilities. Objects such as balls, blocks, ramps, dominos, springs, gears, motors, ropes, magnets, fans, slingshots, bumpers, wheels, axles, and balance scales allowed the child to create different types of physics experiments.

The object editing panel also worked as an important learning tool. By changing mass, size, rotation, motor speed, fan strength, magnet range, or magnet mode, the child could observe how different settings changed the behaviour of the scene. This supports experimentation because the learner is not only watching the simulation but controlling the variables inside it.

The preset scenes were useful because they gave learners a starting point. Instead of beginning with an empty world, the child could load an example scene and modify it. This reduced confusion and helped demonstrate what a working physics setup looks like.

The Free Space results show that the section successfully achieved its purpose as a virtual physics laboratory. It allowed the learner to build, test, change, and repeat experiments in a way that supports discovery-based learning.

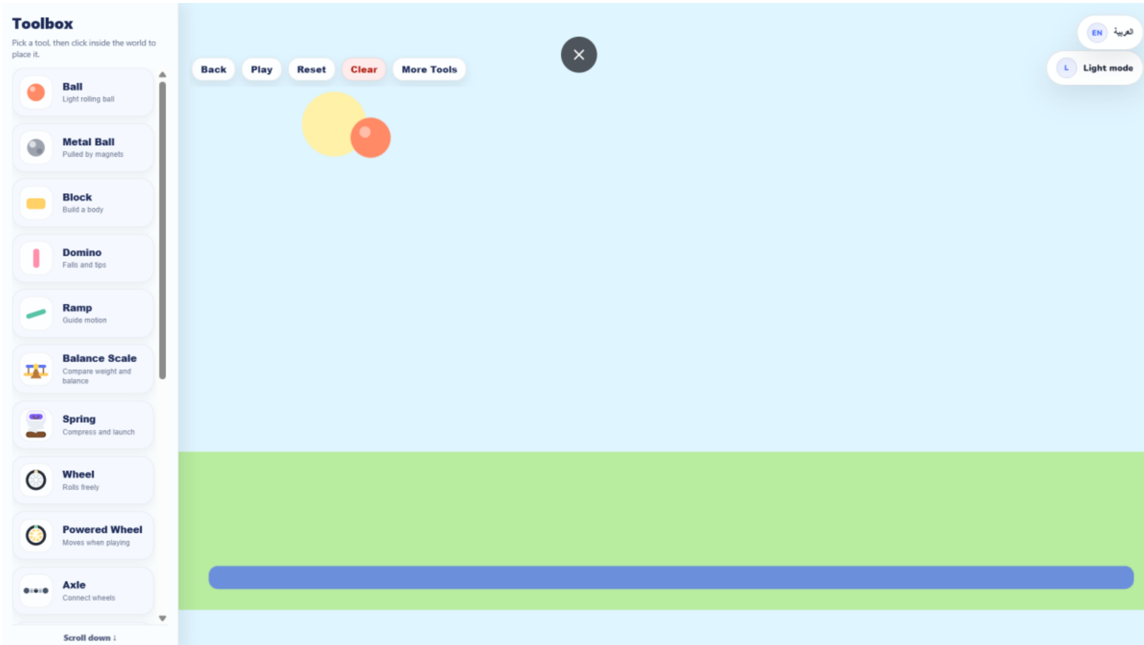


Figure 4.8: Free Space Kid Play mode showing toolbox, scene area, and top controls.

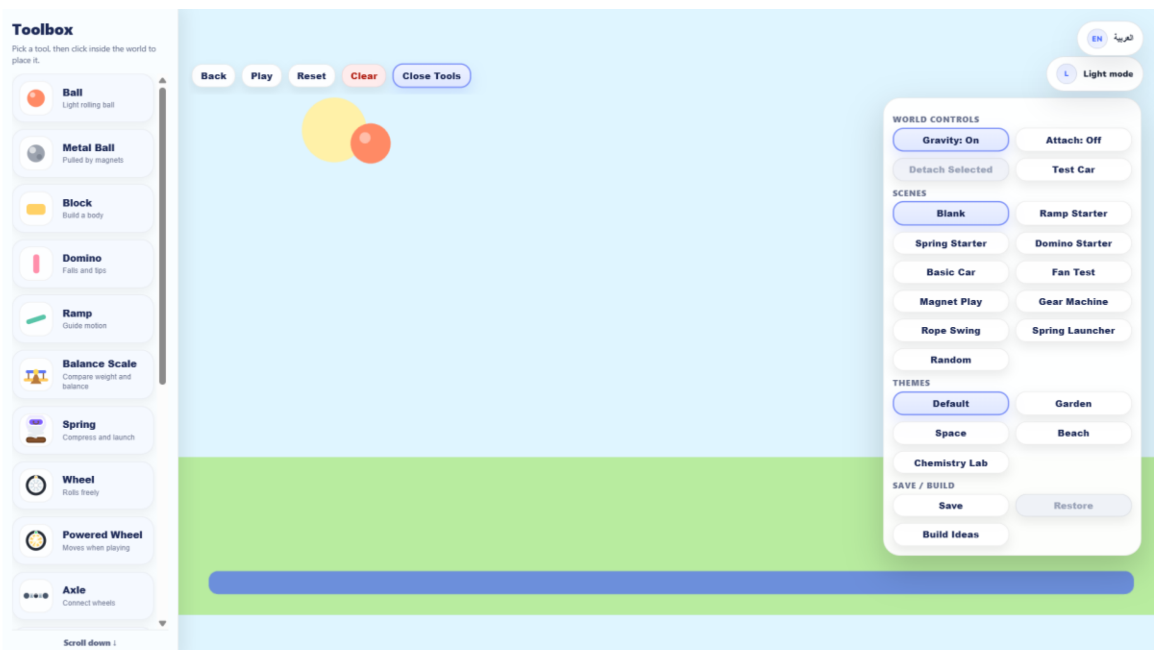


Figure 4.9: More Tools panel showing gravity, attachment, presets, themes, save, and restore controls.

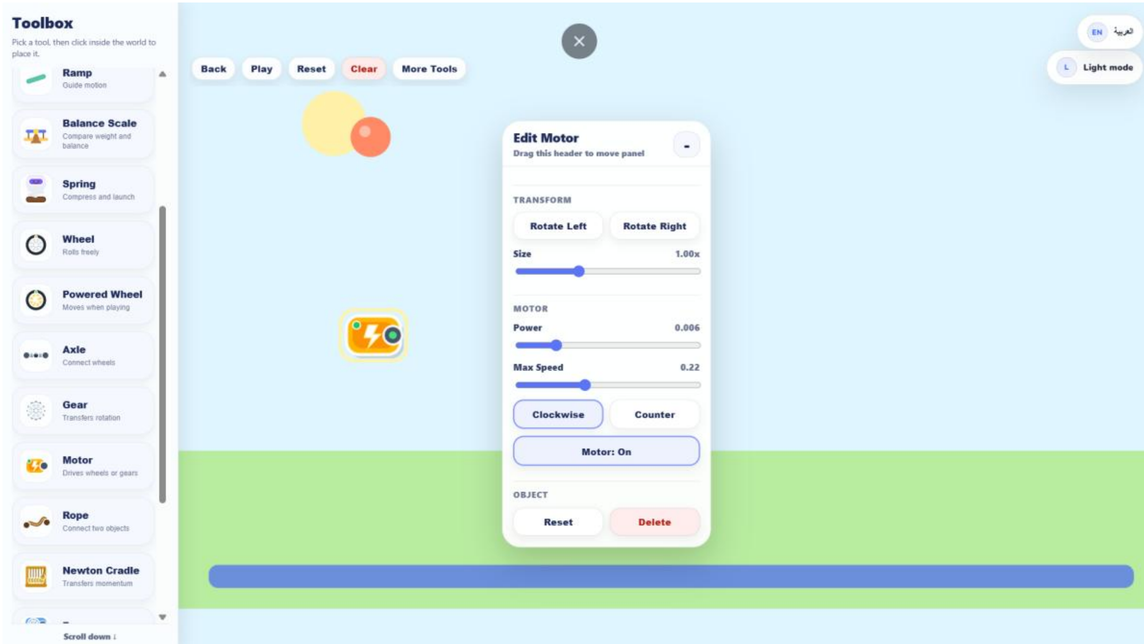


Figure 4.10: Object editing panel used to control object properties in Free Space.

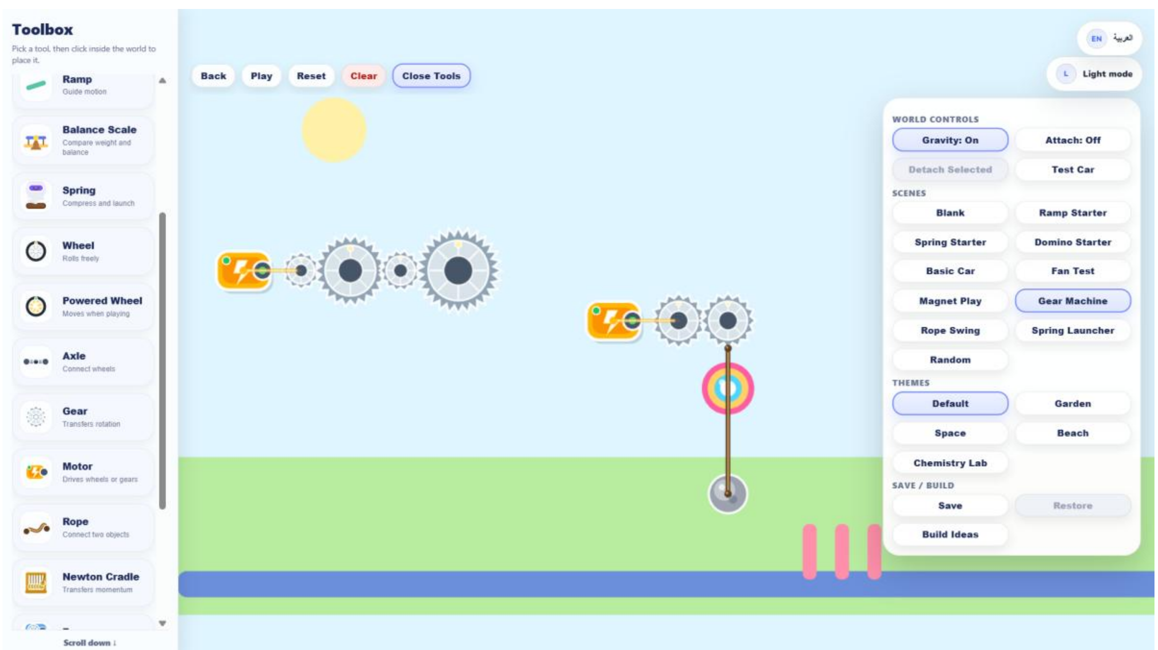


Figure 4.11: Preset physics scene loaded inside the Free Space sandbox.

4.6 Supervisor Builder Results

The Supervisor Builder mode successfully transformed the Free Space system into a level creation tool. Instead of only allowing children to play, the same engine was used by supervisors to create structured educational scenes.

In Supervisor Builder mode, the supervisor was able to:

- Select the target planet and section
- Build a scene using Free Space objects
- Add educational goal objects
- Edit level metadata
- Test the level
- Save or export level data
- Submit the level for admin review

This result is significant because it shows that the platform is scalable. New learning content does not need to be hardcoded every time. A supervisor can create a level using the builder tools and submit it for approval.

The additional goal objects also improved the learning design. Goal Zone, Cat Goal, Food, Basket, and Star Collectible objects allowed the supervisor to create objective-based challenges instead of only open-ended scenes. This makes it possible to create levels where the child must complete a mission, such as moving an object to a target, collecting stars, feeding a character, or solving a small physics puzzle.

The Supervisor Builder mode therefore met the objective of supporting content creation inside the platform.

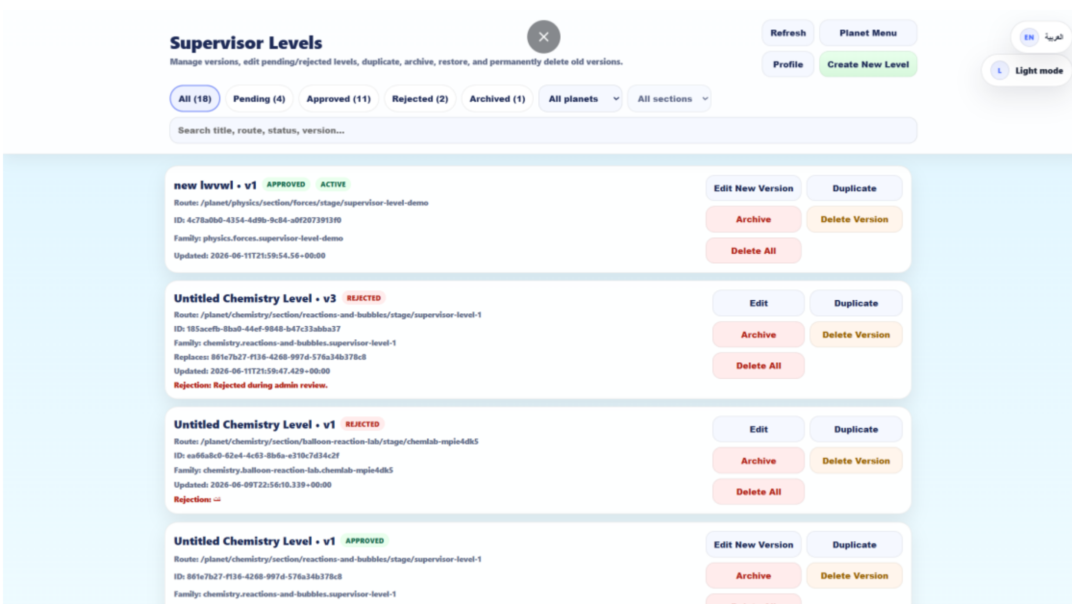


Figure 4.12: Supervisor Builder mode used to create educational levels.

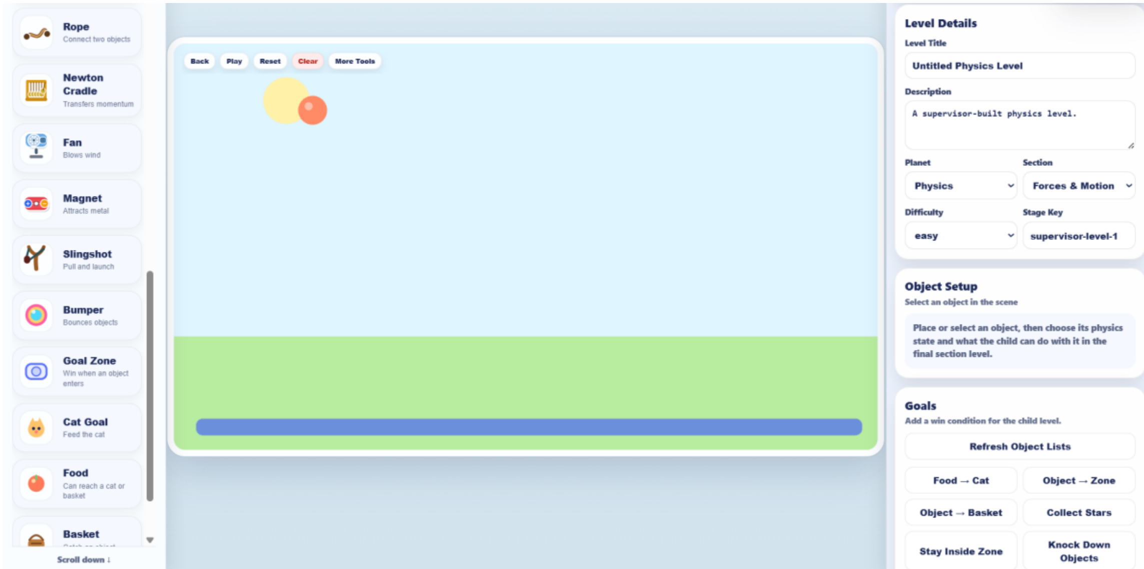


Figure 4.13: Goal objects used to create objective-based learning scenes.

4.7 Admin Review and Content Management Results

The Admin Review system successfully supported controlled content approval. When a supervisor submits a level, the level becomes pending instead of immediately appearing to children. The admin can then review the submitted content before deciding whether it should be approved.

The admin workflow followed this structure:

Supervisor submits level
↓
Level becomes pending
↓
Admin opens review page
↓
Admin previews the level
↓
Admin approves, rejects, edits, archives, or deletes
↓
Approved level appears in the correct planet and section

Testing showed that this workflow helped separate content creation from content publication. This is important for a children's platform because educational content should be reviewed before it becomes available to learners.

The admin management system also supported section and level organisation. Admins could manage content, archive outdated items, delete unsuitable items, and review pending submissions. This makes the project stronger than a simple educational game because it includes real management functionality.

The Admin Review result confirms that the platform supports educational quality control and safer content delivery.

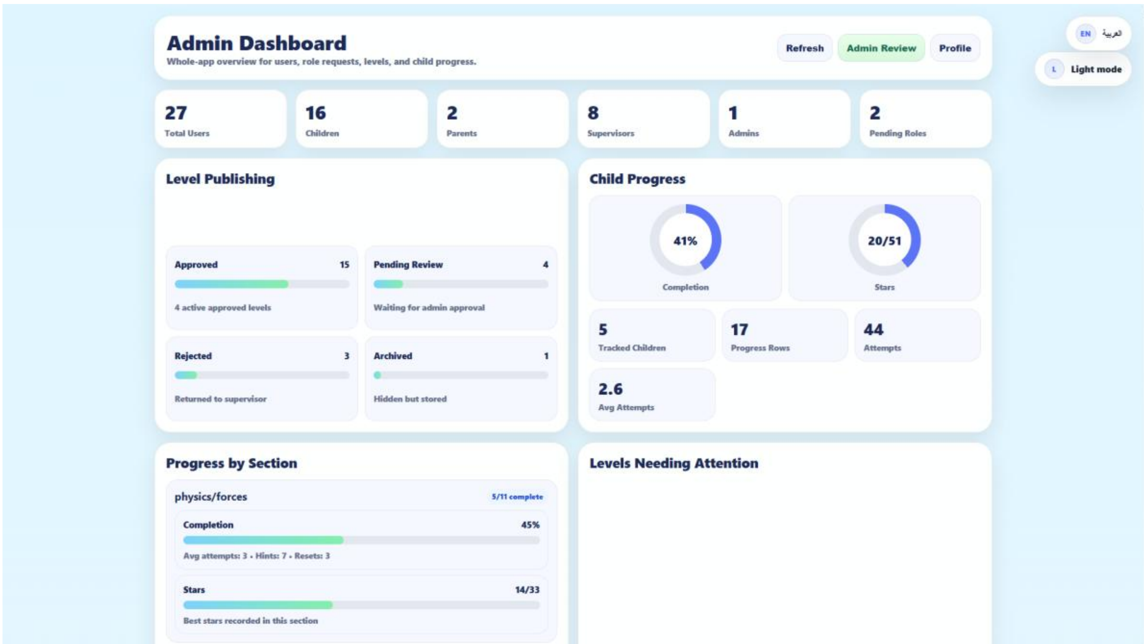


Figure 4.14: Admin Review dashboard showing pending submitted levels.

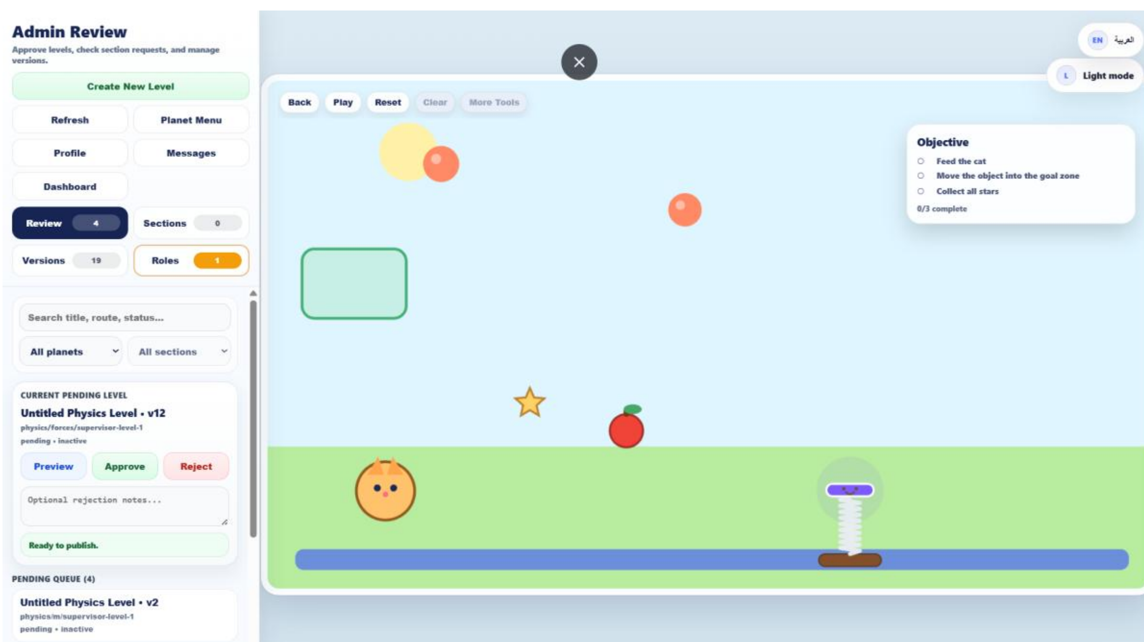


Figure 4.15: Admin preview mode used to inspect a submitted level before approval.

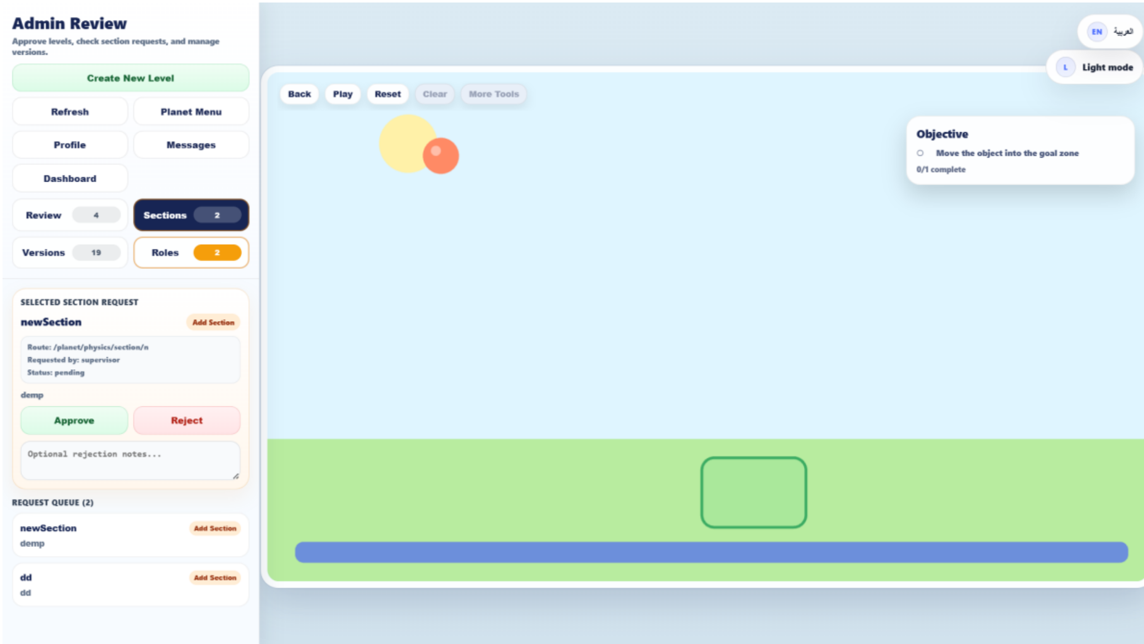


Figure 4.16: Admin section approval actions for submitted learning sections.

4.8 Chemistry Planet Results

The Chemistry planet was successfully implemented as an interactive laboratory-style learning area. It allowed children to explore chemistry through missions, animated feedback, and visual experiments.

The implemented Chemistry sections include:

- Reactions and Bubbles
- Balloon Reaction Lab
- Alchemist’s Attic
- Acids and Bases
- States of Matter
- Elements Basics

The Chemistry planet achieved its purpose by making chemical concepts more visual and interactive. Instead of presenting chemistry only as text, the system allows the learner to complete tasks, observe reactions, and receive immediate visual feedback.

The Reactions and Bubbles section was one of the strongest results. It used mission-based stages where each stage focused on one chemical idea. Examples include choosing chemical pairs, creating a cooling mixture, balancing acid and base drops, testing mystery vials with litmus paper, and creating carbon dioxide to lift a balloon.

The Chemistry activities used visual feedback such as bubbles, smoke, colour changes, foam, labels, glow effects, completion screens, and animated lab objects. These effects made the activities easier to understand because the child could immediately see the result of their action.

The cinematic camera system also improved the learning experience. By using zoom and movement effects, some stages felt like animated story scenes rather than static pages. This increased engagement and made the Chemistry planet feel more polished.

4.9 Progress Tracking Results

The progress tracking system successfully supported locked, unlocked, and completed level states. This helped create a structured learning path for children while still keeping the experience game-like.

The system was able to:

- Track completed levels
- Unlock new levels after progress
- Show locked levels that are not yet available
- Save progress across learning sessions
- Support parent monitoring through connected accounts

This result is important because progress tracking gives the child motivation to continue. It also gives structure to the learning journey so the child does not feel lost inside the platform.

The parent dashboard benefited from this progress system because it allowed parents to view the child's learning status. This supports the project objective of connecting children and parents in a controlled way.

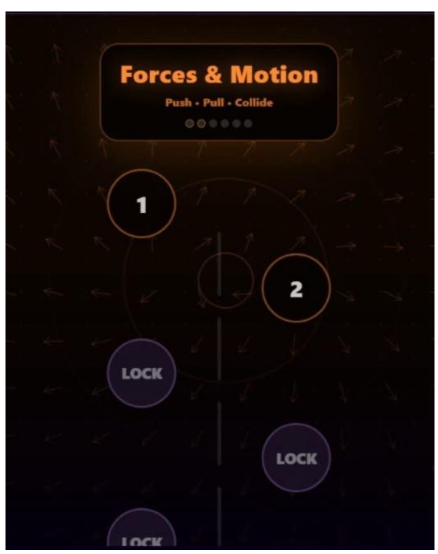


Figure 4.17: Level progress system showing locked, unlocked, and completed stages.

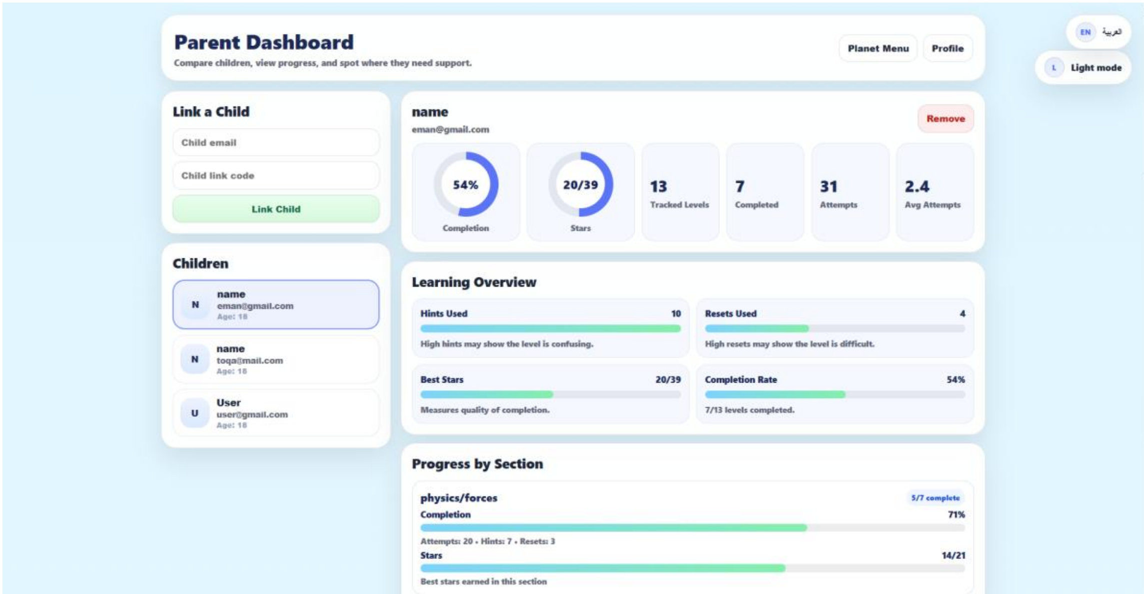


Figure 4.18: Parent dashboard displaying child progress.

4.10 Multilingual Support Results

The multilingual system successfully supported Arabic and English language options. This improved accessibility because children and parents can use the platform in the language they understand more comfortably.

The translation system was applied to interface text, buttons, labels, and learning navigation areas. This was important because the platform is designed for children, and children may struggle if the interface language is difficult for them.

The result shows that the application is not limited to one language group. It can be extended in the future to support additional languages by adding more translation files.

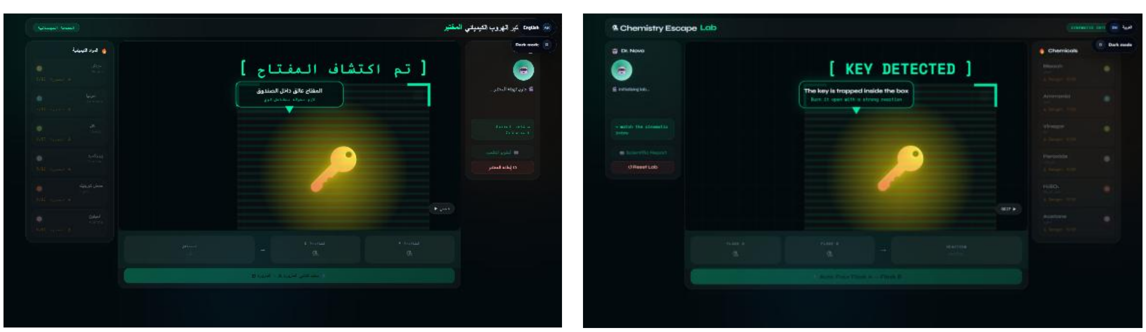


Figure 4.19: English and Arabic interface support in the educational platform.

4.11 Responsive Design Results

The application was tested on desktop and mobile screen sizes. The results showed that the main learning pages, authentication pages, dashboards, and planet navigation screens could adapt to different screen widths.

Desktop screens provided more space for wider layouts, larger scene areas, and dashboard panels. Mobile screens required more careful organisation because the interface needed to remain clear and usable on smaller displays.

The Free Space section was the most challenging part of responsive design because it contains several interface elements at the same time, including:

- Top action bar
- Left toolbox
- Main physics scene
- More Tools panel
- Object editing panel
- Goal tools in Supervisor mode
- Admin review controls

Testing showed that framing and panel organisation were important to prevent confusion. When the scene area is clearly framed, the child can understand where the physics world begins and ends. This improves usability, especially when the level is opened from a supervisor-created scene.

The responsive design result confirms that the platform can support both desktop and mobile use, although Free Space requires the most careful layout control due to its complexity.

4.12 User Interface and Interaction Feedback

The overall user interface successfully supported the visual identity of the platform. The space theme, animated planets, glowing effects, interactive buttons, mission screens, and child-friendly visuals helped make the application feel like a learning world rather than a normal website.

The interface results were strongest in the following areas:

- Space-themed universe page
- Visual planet selection
- Physics Free Space sandbox
- Chemistry lab scenes
- Progress-based level cards
- Interactive toolboxes
- Admin and supervisor workflows
- Parent dashboard

The interface also supported immediate feedback. When children interact with objects, press buttons, complete stages, or trigger reactions, the system responds visually. This is important because immediate feedback helps children understand the connection between action and result.

The user interface result confirms that the project achieved one of its main design goals: making the platform visually engaging, interactive, and memorable for children.

4.13 System Stability and Performance Results

The system was tested by moving through the major user flows and interacting with different learning areas. The main routes loaded correctly, and users were able to move between login, planet pages, sections, levels, dashboards, builder pages, and admin review screens.

The Free Space sandbox required the most performance attention because it includes physics simulation, object rendering, collisions, constraints, and interactive tools. The system worked effectively when scenes were kept within a reasonable object count. However, very large scenes with many active objects may reduce performance, especially on lower-powered mobile devices.

The Chemistry activities performed effectively because most stages were separated into individual scenes. This helped reduce complexity because the browser only needed to run the current activity instead of loading all chemistry content at once.

The system structure also helped stability because the project was divided into reusable parts such as pages, routes, services, planet data, engine logic, and locale files. This organisation made it easier to manage the project and reduce errors during development.

Overall, the platform demonstrated stable performance for the expected graduation project use case. Future improvements could include further optimisation for very large sandbox scenes, stronger mobile layout handling, and more advanced loading strategies.

4.14 Summary

This chapter presented the results and analysis of the developed educational web application. The system successfully implemented the main planned features, including role-based access, child learning flow, planet navigation, Physics sections, Free Space sandbox, Supervisor Builder mode, Admin Review mode, Chemistry activities, progress tracking, parent dashboard, multilingual support, and responsive design.

The results show that the project achieved its main purpose of creating a child-friendly educational platform that combines learning, interaction, simulation, visual storytelling, and management tools. The Physics planet successfully supported simulation-based learning, while the Chemistry planet successfully supported laboratory-style learning. The Free Space sandbox was one of the strongest outcomes because it allowed children to build and test their own experiments while also supporting supervisor level creation and admin review.

The next chapter discusses these results in relation to the original project objectives, identifies the main contributions of the work, explains the limitations, and compares the platform with existing educational approaches.

Chapter 5 Discussion

5.1 Evaluation of Problem Resolution

The main problem addressed in this project was the lack of an engaging, child-friendly, and interactive educational platform that combines learning, experimentation, progress tracking, parent monitoring, and content management in one system. Many traditional educational websites present learning content as static pages, videos, or quizzes. While these methods can support basic learning, they do not always give children enough opportunity to explore, test ideas, and learn through direct interaction.

Based on the developed system and testing results, this problem was successfully addressed. The platform transformed learning into a space-themed experience where children can explore planets, enter sections, complete levels, and interact with science concepts through visual activities. This helped make the platform feel like a learning world rather than a normal educational website.

The role-based access system also helped resolve an important management problem. The application is not limited to children only. It supports parents, supervisors, and admins, which allows the system to manage learning from different perspectives. Children can learn and play, parents can monitor progress, supervisors can create levels, and admins can review content before it becomes available. This creates a safer and more organised educational environment.

The Physics planet successfully addressed the challenge of making physics more practical and understandable. Through sections such as Free Space, Forces, Gravity, Laser, Springs, and Gears, learners can observe movement, collisions, gravity, rotation, light behaviour, spring motion, and mechanical interaction visually. This reduces reliance on memorisation and helps children understand physics through cause and effect.

The Chemistry planet also addressed the difficulty of teaching abstract chemical concepts. By using laboratory-style activities, reactions, bubbles, acids and bases, states of matter, and microscopic views, the system made chemistry more visual and interactive. Children can see reactions and complete missions instead of only reading explanations.

The Free Space sandbox was one of the strongest solutions in the project. It gave children an open-ended environment where they could build, test, change, and repeat experiments. This directly supports discovery-based learning because the child is not forced into one fixed answer. Instead, the learner can explore different outcomes and understand physics through experimentation.

Overall, the project achieved its main purpose by creating an educational platform that is interactive, visual, role-based, and suitable for children.

5.2 Contribution of the Work

This project contributes a complete educational web application that combines several systems into one platform. Its contribution is not limited to one feature, but comes from the integration of learning design, simulation, user management, and content control.

The main contributions of the project are:

- A space-themed learning platform where subjects are represented as planets.
- A role-based sign-up and login system for child, parent, supervisor, and admin users.
- A parent-child connection method using a child-generated code.
- A Physics planet with interactive learning sections and simulation-based activities.
- A Chemistry planet with laboratory-style missions and animated learning stages.
- A Free Space physics sandbox that supports open-ended experimentation.
- Three Free Space modes: Kid Play, Supervisor Builder, and Admin Review.
- A supervisor content creation workflow for building and submitting levels.
- An admin review workflow for approving, rejecting, archiving, editing, and deleting content.
- Progress tracking through locked, unlocked, and completed levels.
- Desktop and mobile support.
- Arabic and English language support.
- Use of modern technologies such as React, Vite, React Router, Supabase, Matter.js, Pixi.js, Three.js, Canvas 2D, local storage, i18next, Framer Motion, and Lucide React.

The most important contribution is the way the same platform serves multiple purposes. For children, it is a learning game. For parents, it is a progress monitoring tool. For supervisors, it is a level-building system. For admins, it is a content management and review system. This makes the project stronger than a basic learning application.

Another important contribution is the Free Space system. It works as both a child sandbox and an educational level builder. This means the project does not only provide fixed levels; it also provides tools for creating future learning content. This improves scalability because more scenes and levels can be added later without redesigning the whole platform.

5.3 Interpretation and Implications of Results

The results show that interactive learning can make science concepts more understandable for children. When children interact with objects, observe reactions, test gravity, connect gears, or change object settings, they are more likely to understand the relationship between action and result. This is especially useful in Physics and Chemistry because many concepts are difficult to understand through text alone.

The successful implementation of the Physics planet suggests that simulation-based learning is suitable for teaching motion, forces, collisions, gears, springs, light, and gravity. The use of

Matter.js allowed objects to behave physically, while custom systems controlled the educational logic. This combination made the Physics planet both interactive and structured.

The Chemistry results show that laboratory-style interaction can make chemical concepts more accessible. Visual effects such as bubbles, colour changes, smoke, foam, reaction glow, and molecular views help children understand ideas that are normally invisible or abstract. The use of mission-based stages also keeps learning focused because each stage teaches one main concept.

The Free Space sandbox has an important educational implication because it encourages creativity and experimentation. In many learning systems, children only answer questions or complete fixed tasks. In Free Space, they can create their own setups and test their own ideas. This supports problem-solving, curiosity, and scientific thinking.

The parent dashboard result also has practical value. It allows parents to follow the child's learning progress without needing to directly control the child's experience. This supports independent learning while still giving parents visibility.

The admin and supervisor workflow has another important implication. It allows the platform to grow while keeping content controlled. Supervisors can create new educational levels, but admins can review the content before children see it. This is important for quality assurance, safety, and long-term platform management.

5.4 Strengths of the Platform

The project has several major strengths.

The first strength is the visual identity of the platform. The space theme gives the application a clear and memorable design. Representing subjects as planets makes the learning structure easier for children to understand and makes the platform feel more exciting.

The second strength is interactivity. The platform does not rely only on reading or watching. It allows children to click, drag, build, test, observe, and repeat. This is important because children often learn better when they are actively involved.

The third strength is the Free Space sandbox. This section gives the learner freedom to experiment and supports different types of physics learning. The wide range of toolbox objects allows children to explore many concepts in one environment.

The fourth strength is the role-based system. The platform separates child, parent, supervisor, and admin permissions clearly. This makes the system safer and more suitable for real educational use.

The fifth strength is content scalability. Because supervisors can create levels and admins can review them, the platform can grow over time. New content does not need to be fully hardcoded into the application every time.

The sixth strength is the use of multiple technologies together. React, Supabase, Matter.js, Pixi.js, Three.js, Canvas 2D, and i18next were combined to create a platform that includes authentication, simulation, visual rendering, multilingual support, and learning management.

5.5 Limitations of the Work

Although the project achieved its main objectives, several limitations remain.

The first limitation is that the project mainly focuses on Physics and Chemistry. Other planets may exist in the platform structure, but they are not developed with the same depth. Future versions should expand the learning content across more subjects.

The second limitation is that some scientific simulations are simplified. For example, some Chemistry effects are visual approximations rather than full scientific models, and some Physics behaviours are designed for child learning rather than advanced scientific accuracy. This is acceptable for the target age group, but it should be clearly understood as an educational simplification.

The third limitation is performance in complex sandbox scenes. Free Space can become heavy if the user places too many active objects, constraints, ropes, gears, motors, magnets, and moving bodies at the same time. This may affect performance on low-powered mobile devices.

The fourth limitation is mobile layout complexity. Although the platform supports mobile screens, some advanced tools such as Free Space, Supervisor Builder, and Admin Review are more comfortable on desktop because they include many panels and controls.

The fifth limitation is the need for more formal user testing. The project was tested functionally, but future work should include structured testing with children, parents, and teachers to measure usability, engagement, and learning effectiveness.

The sixth limitation is that the parent dashboard and progress tracking could be expanded further. The current system supports progress monitoring, but future versions could include more detailed analytics, time spent, strengths, weaknesses, recommended practice, and downloadable reports.

The seventh limitation is that supervisor-created content still depends on the quality of the person building the level. Even with admin review, more guidance, templates, and validation rules would improve content consistency.

5.6 Comparison with Existing Educational Approaches

Compared with traditional educational websites, this platform provides a more interactive and visual learning experience. A normal educational website may present lessons, videos, and quizzes, while this project allows children to enter a space-themed learning world, interact with simulations, complete missions, and experiment freely.

Compared with simple educational games, this project provides stronger structure and management. Many educational games focus only on the child experience. This platform also includes parent monitoring, supervisor content creation, and admin review. This makes it more suitable as a complete educational system.

Compared with fixed quiz-based learning platforms, this project provides more exploration. The Free Space sandbox allows children to build their own experiments rather than only selecting answers. This supports creativity and scientific thinking.

Compared with advanced simulation tools, this project is more child-friendly. Some professional simulation tools may be scientifically powerful but too complex for children. This platform simplifies the interface and uses playful visuals to make learning more accessible.

The platform therefore sits between a learning management system, an educational game, and a science simulation tool. It combines parts of all three approaches:

Approach	Main focus	Limitation	How this project improves it
Traditional educational website	Lessons, text, videos, quizzes	Often static and less engaging	Adds planets, missions, simulations, and interaction
Educational game	Fun and motivation	May lack management and progress depth	Adds roles, parent dashboard, and admin review
Learning management system	Organisation and tracking	Often not child-friendly or interactive	Adds visual learning worlds and sandbox activities
Science simulation tool	Technical simulation	May be too complex for children	Simplifies interaction and uses playful design

Table 5.1: Comparison between the proposed platform and existing educational approaches.

5.7 Summary

This chapter discussed the results of the project and evaluated how successfully the platform addressed the original problem. The discussion showed that the project achieved its main purpose by creating an interactive, child-friendly educational platform with strong support for science learning, role-based access, content management, progress tracking, and visual experimentation.

The project’s main strengths are its space-themed design, Physics and Chemistry interactivity, Free Space sandbox, role-based management, supervisor builder workflow, admin review system, and multilingual support. The main limitations are the current focus on Physics and Chemistry, simplified scientific models, possible performance issues in large sandbox scenes, mobile layout complexity, and the need for more formal user testing.

Overall, the platform provides a strong foundation for an educational system that can be expanded in the future with more subjects, more levels, stronger analytics, better mobile optimisation, and deeper learning assessment.

Chapter 6 Conclusions and Recommendation

6.1 Conclusion

This project successfully designed and implemented an interactive, space-themed educational web application for children. The platform transforms traditional learning into a visual learning universe where subjects are represented as planets, sections are presented as learning areas, and levels are designed as interactive missions or experiments. The main focus of the project was on the Physics and Chemistry planets, where scientific concepts were delivered through simulations, laboratory-style activities, visual feedback, and game-based interaction.

The project achieved its main objective of creating a child-friendly learning platform that works on both desktop and mobile devices. The application allows children to sign up, log in, explore planets, complete levels, and track their progress. It also supports parents, supervisors, and admins through a role-based access system. Parents can connect to their child's account using a child-generated code, supervisors can create and submit educational content, and admins can review, approve, archive, edit, or delete sections and levels.

One of the strongest outcomes of the project was the Physics Free Space section. Free Space was developed as an open-ended physics sandbox where learners can build experiments, test motion, change gravity, connect objects, use gears, ropes, springs, motors, magnets, fans, ramps, dominos, slingshots, and other tools. The section supports three different modes: Kid Play, Supervisor Builder, and Admin Review. This allowed the same engine to support child exploration, supervisor content creation, and admin content approval.

The Chemistry planet was also successfully implemented as an interactive laboratory-style environment. It includes sections such as Reactions and Bubbles, Balloon Reaction Lab, Alchemist's Attic, Acids and Bases, States of Matter, and Elements Basics. These sections use mission-based stages, animated reactions, Canvas 2D rendering, cinematic camera transforms, Matter.js interactions, and Three.js microscopic views to make chemical concepts more visual and understandable for children.

Overall, the final system demonstrates that modern web technologies can be used to create a complete educational platform that combines learning, play, simulation, progress tracking, parent monitoring, content creation, and admin review. The project is not only an educational website; it is an interactive learning world designed to make science more engaging, practical, and memorable for children.

6.2 Key Learnings

Several important learnings were gained during the development of this project.

First, interactive learning is more effective when the learner can directly control the experience. By allowing children to click, drag, test, build, and repeat, the platform supports active learning instead of passive reading. This was especially clear in the Physics Free Space section, where learners could change variables and immediately observe the result.

Second, role-based access is essential in an educational platform that includes children and content management. The separation between child, parent, supervisor, and admin users made the system safer and more organised. It ensured that children could only access learning content, parents could only monitor connected child progress, supervisors could create content, and admins could control final approval.

Third, open-ended sandbox learning provides strong educational value. Unlike fixed levels with only one answer, Free Space allows children to experiment freely. This supports creativity, problem-solving, trial and error, and scientific thinking.

Fourth, content review is important when supervisors can create levels. The admin review workflow prevents unapproved content from becoming visible to children. This improves quality control and supports child safety.

Fifth, responsive design is more difficult when the application includes complex interactive scenes. Normal pages such as login, sign-up, dashboards, and planet selection are easier to adapt to mobile screens. However, Free Space contains many controls, including the toolbox, top action bar, canvas scene, editing panel, and More Tools panel. This showed the importance of careful layout planning for interactive educational tools.

Sixth, combining multiple technologies can create a richer learning experience. React, Supabase, Matter.js, Pixi.js, Three.js, Canvas 2D, React Router, and i18next each played a different role in the final system. The project showed that a strong educational platform requires both interface design and technical engine design.

6.3 Recommendations for Performance Improvement

Although the project successfully achieved its main objectives, several improvements are recommended to make the platform stronger and more scalable.

The first recommendation is to further optimise the Free Space sandbox. Since Free Space can contain many active physics objects, constraints, gears, motors, ropes, magnets, and effects, performance may decrease on lower-powered devices. Future improvements should include object limits, better cleanup logic, performance warnings, and optimisation of active physics bodies.

The second recommendation is to improve mobile usability for complex tools. The platform works on desktop and mobile, but advanced areas such as Free Space, Supervisor Builder, and Admin Review are naturally easier to use on larger screens. Future versions should include mobile-specific layouts, collapsible panels, simplified toolbars, and touch-friendly controls.

The third recommendation is to expand the parent dashboard. The current parent connection and progress monitoring system is useful, but future versions could include more detailed analytics. For example, the dashboard could show time spent, favourite subjects, completed sections, difficult levels, recommended practice, and weekly progress summaries.

The sixth recommendation is to increase accessibility features. Future versions could include text-to-speech, larger text options, colour-blind friendly settings, simplified language mode, voice instructions, and keyboard navigation support. These features would make the platform more inclusive for different learners.

The seventh recommendation is to conduct structured user testing with children, parents, and teachers. Functional testing confirms that the system works, but user testing would provide stronger evidence about usability, engagement, and learning effectiveness.

6.4 Future Work and Open Problems

Future work can extend the platform beyond its current prototype stage and turn it into a larger educational system.

One major future improvement is to expand the number of planets. The current project mainly focuses on Physics and Chemistry, while other subjects could be developed further in the future. Possible planets include Biology, Mathematics, Coding, Heritage, Security, and Environmental Science. Each planet could contain its own sections, levels, and interactive learning style.

Another future improvement is to add more structured learning paths. The platform could organise levels by age group, difficulty level, curriculum topic, or skill category. This would make it easier for teachers and parents to guide children through suitable content.

A third future improvement is to add teacher accounts. At the moment, the main roles are child, parent, supervisor, and admin. A teacher role could allow classroom management, assignment creation, group progress tracking, and class-based analytics.

A fourth future improvement is to improve the Free Space level builder. Future versions could include built-in validation, level templates, difficulty tags, testing checklists, and automatic detection of broken or impossible levels.

A fifth future improvement is to add cloud-based content sharing. Approved levels could be stored in a shared library where children can access new missions, supervisors can submit new content, and admins can manage published content more easily.

A sixth future improvement is to add stronger learning assessment. Instead of only tracking completed levels, the platform could evaluate the learner’s attempts, mistakes, time taken, repeated failures, and improvement over time. This would help parents and teachers understand what the child is learning more clearly.

A seventh future improvement is to add artificial intelligence support. AI could be used to suggest personalised levels, generate build ideas, explain physics results, provide hints, detect when a child is stuck, or help supervisors create educational challenges. This should be added carefully to make sure the explanations remain child-friendly and accurate.

An eighth future improvement is to deploy the platform publicly and test it with real users. This would help identify usability issues, device compatibility problems, performance limits, and improvements needed before wider release.

6.5 Final Remarks

This project demonstrates the feasibility of building a complete interactive educational web application using modern web technologies. By combining a space-themed design, role-based access, Physics simulations, Chemistry activities, progress tracking, parent monitoring, supervisor tools, and admin review, the platform provides a strong foundation for a child-centred learning system.

The most important achievement of the project is that it changes learning from a passive activity into an interactive experience. Children are not only reading about science; they are building, testing, observing, solving, and discovering. This makes the platform more engaging and supports a deeper connection between the learner and the subject.

The project also shows that educational systems can be both playful and structured. The child receives a fun learning experience, while parents, supervisors, and admins receive the tools needed to monitor, create, and manage content safely. This balance between creativity and control is one of the strongest aspects of the system.

With further development, more content, stronger analytics, improved mobile optimisation, and real user testing, the platform can grow into a larger educational environment that supports children’s learning across multiple subjects.

Appendices

Appendix A: Technical Deep Dive: Free Space Physics Sandbox

A.1 Overview of the Free Space System

The Free Space section is the open-ended physics sandbox of the educational platform. It was designed to give children a virtual laboratory where they can build experiments, test physical behaviour, observe results, and improve their designs through trial and error.

Unlike fixed lesson stages, Free Space does not force the learner to follow one solution. Instead, it gives the user a toolbox of objects and allows them to create their own physics scenes. This supports discovery-based learning because the child can experiment freely and learn from what happens inside the simulation.

Free Space is also used by different roles in the system. The same engine supports:

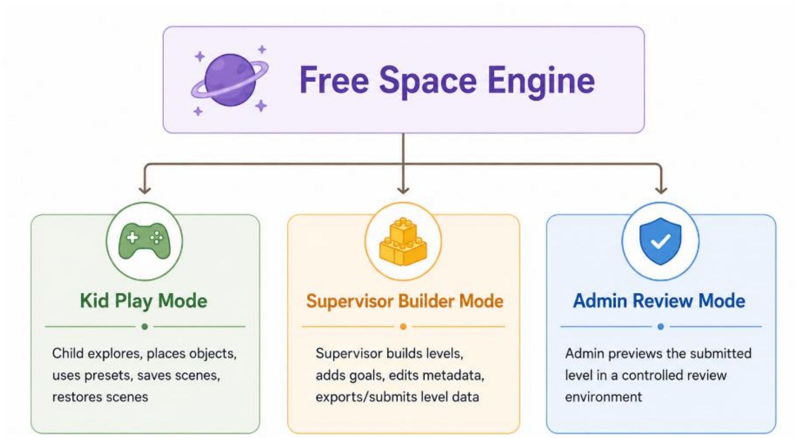
- **Kid Play Mode,** where children explore and experiment.
- **Supervisor Builder Mode,** where supervisors create learning scenes and levels.
- **Admin Review Mode,** where admins inspect submitted levels before approval.

This makes Free Space more than a normal sandbox. It is both a learning tool and a level-authoring system.

A.2 Free Space Mode Architecture

Free Space is controlled through a mode-based architecture. The mode determines which tools, permissions, and controls are available to the user.

The three main modes are:



FigureA.1: Free Space mode architecture showing Kid Play, Supervisor Builder, and Admin Review.

This mode system is important because it allows the project to reuse the same physics engine while changing the available features depending on the user role.

For example, a child can use the sandbox freely, but they cannot approve or publish content. A supervisor can build and submit levels, but the level does not become public until an admin approves it. An admin can inspect levels before they are shown to children.

A.3 Physics Engine Layer

The Free Space system uses **Matter.js** as the main physics engine. Matter.js handles the physical simulation inside the scene, including:

- Gravity
- Object movement
- Collision response
- Friction
- Restitution
- Rigid bodies
- Constraints
- Forces
- Simulation updates

In the project, Matter.js provides the physical behaviour, but it does not define the full educational logic by itself. The platform adds custom systems on top of Matter.js to make the objects meaningful for learning.

For example:

Matter.js handles:
- How objects fall
- How objects collide
- How constraints behave
- How gravity affects bodies

Custom project logic handles:
- What object type is being used
- How the object is drawn
- What controls appear in the edit panel
- How goals are detected
- How levels are saved and restored
- Which tools are available in each mode

This separation makes the system easier to extend. New educational objects can be added without changing the entire physics engine.

A.4 Object Registry System

The Free Space toolbox uses a custom object registry system. Each toolbox object is connected to its creation logic, rendering logic, default parameters, and editable settings.

The object registry allows the system to map a selected tool to the correct object behaviour. For example, when the user selects a ball tool, the system creates a circular Matter.js body. When the user selects a ramp, the system creates an angled static body. When the user selects a magnet, the system creates a special object that can apply attraction or repulsion logic.

The main toolbox objects include:

- Ball
- Metal Ball
- Block
- Domino
- Ramp
- Balance Scale
- Spring
- Wheel
- Powered Wheel
- Axle
- Gear
- Motor
- Rope
- Newton Cradle
- Fan
- Magnet
- Slingshot
- Bumper

In Supervisor Builder mode, additional goal objects are included:

- Goal Zone
- Cat Goal
- Food
- Basket
- Star Collectible

The registry system helps keep the sandbox flexible because new tools can be added by registering a new object type with its parameters and behaviour.

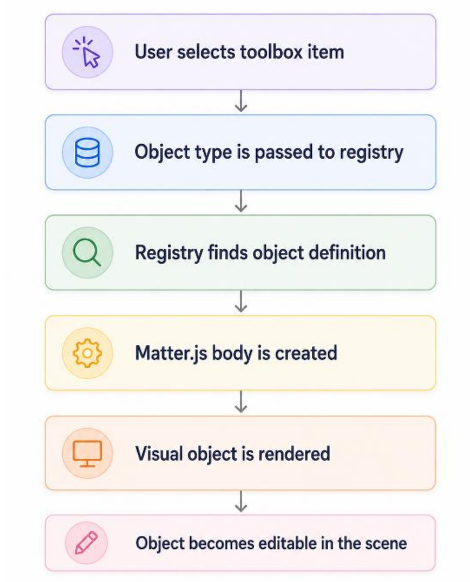


Figure A.2: Toolbox object registry flow.

A.5 Object Creation and Placement

When the user chooses an object from the toolbox, the system places that object into the Free Space scene. Each object has default values such as position, size, mass, rotation, and type-specific parameters.

For example:

- A **ball** is created as a circular body.
- A **block** is created as a rectangular body.
- A **ramp** is created as a rotated static body.
- A **domino** is created as a tall rectangular body.
- A **spring** includes compression and force behaviour.
- A **gear** includes rotational behaviour.
- A **magnet** includes attraction or repulsion settings.
- A **fan** applies directional wind force.
- A **motor** drives connected mechanical parts.

After the object is placed, the user can select it and modify its properties through the object editing panel.

The object placement process follows this general flow:

Select tool
↓
Click or tap scene
↓

Create object with default parameters
↓
Add object to Matter.js world
↓
Add visual representation
↓
Enable selection and editing

A.6 Object Editing Panel

The object editing panel is one of the most important parts of the Free Space system. It allows the user to change the behaviour of objects after placing them in the scene.

The panel appears when an object is selected. It can include general controls and object-specific controls.

General controls include:

- Rotate Left
- Rotate Right
- Change Size
- Change Mass
- Reset Selected Object
- Delete Selected Object

Object-specific controls include:

- **Fan:** wind strength
- **Magnet:** strength, range, pole angle, attract mode, repel mode
- **Motor:** power, max speed, clockwise direction, counter-clockwise direction, motor on/off
- **Spring:** compression and launch behaviour
- **Gear:** rotation and connection behaviour

This panel supports scientific experimentation because the learner can change variables and observe how the simulation responds. For example, increasing the mass of an object can change how it reacts in a collision. Increasing fan strength can push objects further. Changing a magnet from attract to repel can reverse the object interaction.

A.7 Play, Pause, Reset, and Clear Logic

The top action bar controls the main simulation state.

The main controls are:

- **Back:** returns to the previous page.
- **Play / Pause:** starts or pauses the physics simulation.
- **Reset:** reloads the current scene to its initial state.
- **Clear:** removes all placed objects from the world.
- **More Tools:** opens advanced controls.

The Play/Pause system is important because it allows the learner to build first and test later. This helps children understand the difference between scene design and simulation behaviour.

The Reset function is also important because it allows the learner to return to the starting condition after testing. This supports repeated experiments because the child can test the same scene more than once.

The Clear function removes all objects and gives the learner a blank workspace.

General flow:

Build scene while paused
↓
Press Play
↓
Matter.js simulation runs
↓
Observe object behaviour
↓
Press Pause or Reset
↓
Edit scene and test again

A.8 More Tools Panel

The More Tools panel contains advanced scene controls. It keeps the main interface cleaner by hiding secondary tools until the user needs them.

The More Tools panel includes:

- Toggle Gravity On/Off
- Toggle Attach Mode On/Off
- Detach Selected Object
- Run Test Car
- Load Preset Scenes
- Open Random Scene
- Change Background Theme
- Save Current Sandbox State
- Restore Saved State

- Open Build Ideas

This panel improves usability because it prevents the top action bar from becoming overcrowded. It also supports more advanced exploration for users who want extra control over the sandbox.

A.9 Gravity Control System

Gravity is one of the main physics controls in Free Space. The user can turn gravity on or off from the More Tools panel.

When gravity is enabled, objects fall and collide naturally. When gravity is disabled, the learner can test motion in a different way, such as floating objects or force-based movement.

This feature helps children understand that gravity affects how objects move. It also allows supervisors to create levels where gravity is part of the challenge.

The gravity logic follows this simple structure:

Gravity enabled → Objects accelerate downward
Gravity disabled → Objects do not fall naturally → Other forces can still affect movement

A.10 Attachment and Rope System

Free Space includes attachment and rope systems to connect objects together.

The attachment system allows selected objects to be joined in a controlled way. This is useful for building:

- Cars
- Pendulums
- Rope swings
- Connected machines
- Hanging objects
- Multi-object structures

The rope system uses constraints to connect two objects or connect an object to a fixed point. This allows the learner to observe tension, swinging motion, and connected movement.

The attachment process generally follows this flow:

Turn Attach Mode on
↓
Select first object
↓

Select second object
↓
Create constraint between objects
↓
Objects move as connected system

The Detach Selected tool allows the user to remove attachments from the selected object. This is important because it gives learners freedom to modify their design without clearing the whole scene.

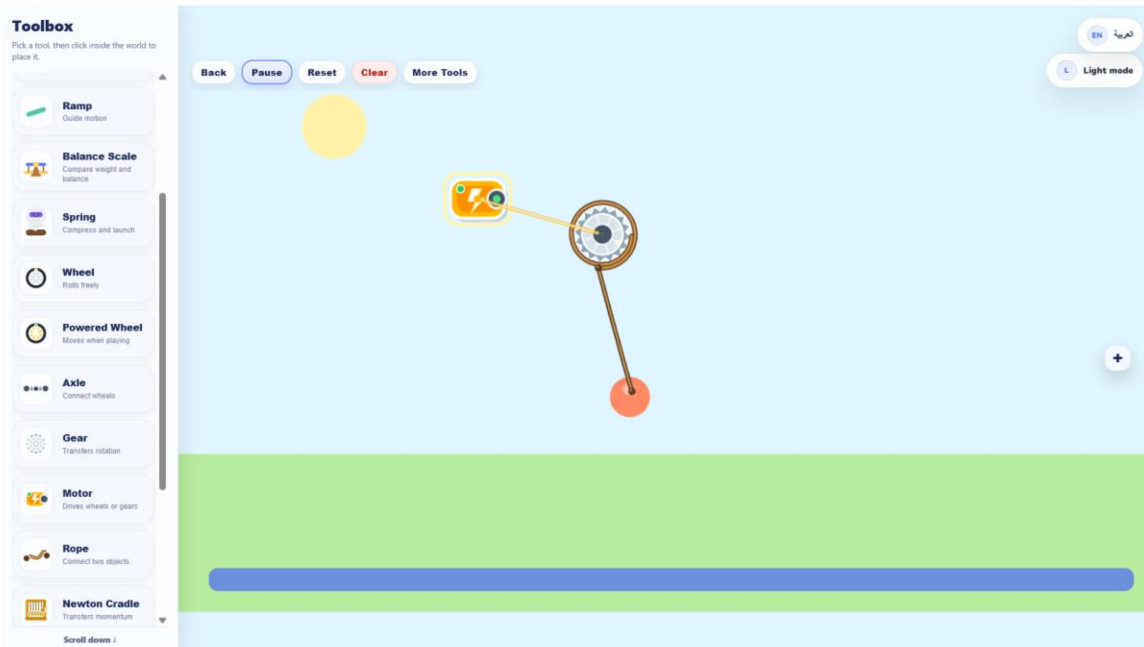


Figure A.5: Rope and attachment system connecting objects inside Free Space.

A.11 Gear and Motor System

The gear and motor system allows learners to explore rotational motion and machine behaviour.

Gears can be placed inside the scene and connected through contact or proximity logic. When gears interact, they demonstrate important mechanical ideas such as opposite rotation and gear ratio.

The basic educational rules are:

Two connected external gears rotate in opposite directions. A smaller gear rotates faster than a larger gear.

A motor can drive connected mechanical parts. The motor object adds powered movement. It can be controlled through the editing panel using settings such as:

- Motor On/Off
- Power
- Maximum speed
- Clockwise direction
- Counter-clockwise direction

This system allows children to build simple machines and observe how motion transfers between parts.

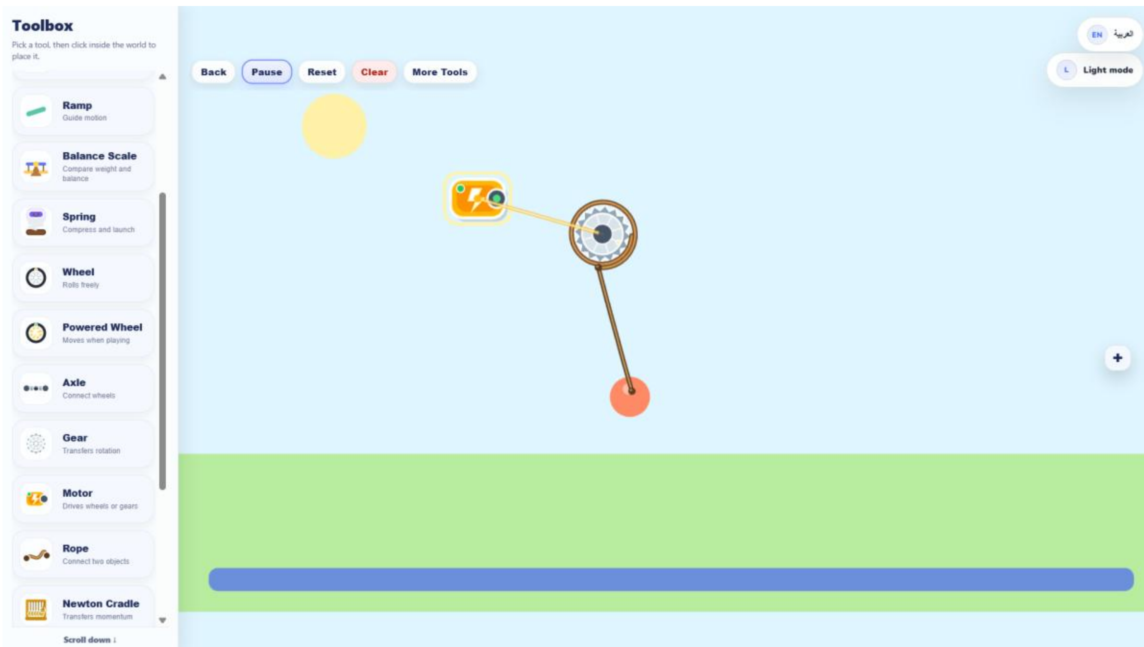


Figure A.6: Gear and motor system demonstrating rotational motion.

A.12 Spring System

The spring system allows learners to explore compression, stored energy, bouncing, and launching behaviour. A spring can compress when an object interacts with it and then release force back into the object.

This helps demonstrate the idea that a compressed spring can store energy and then transfer it into motion.

The simplified learning concept is:

More compression

↓

More stored energy

↓

Stronger launch or bounce

The spring behaviour is designed to feel interactive and understandable for children. It does not need to be a full engineering-grade spring model. Its purpose is to visually demonstrate how compression and release affect movement.

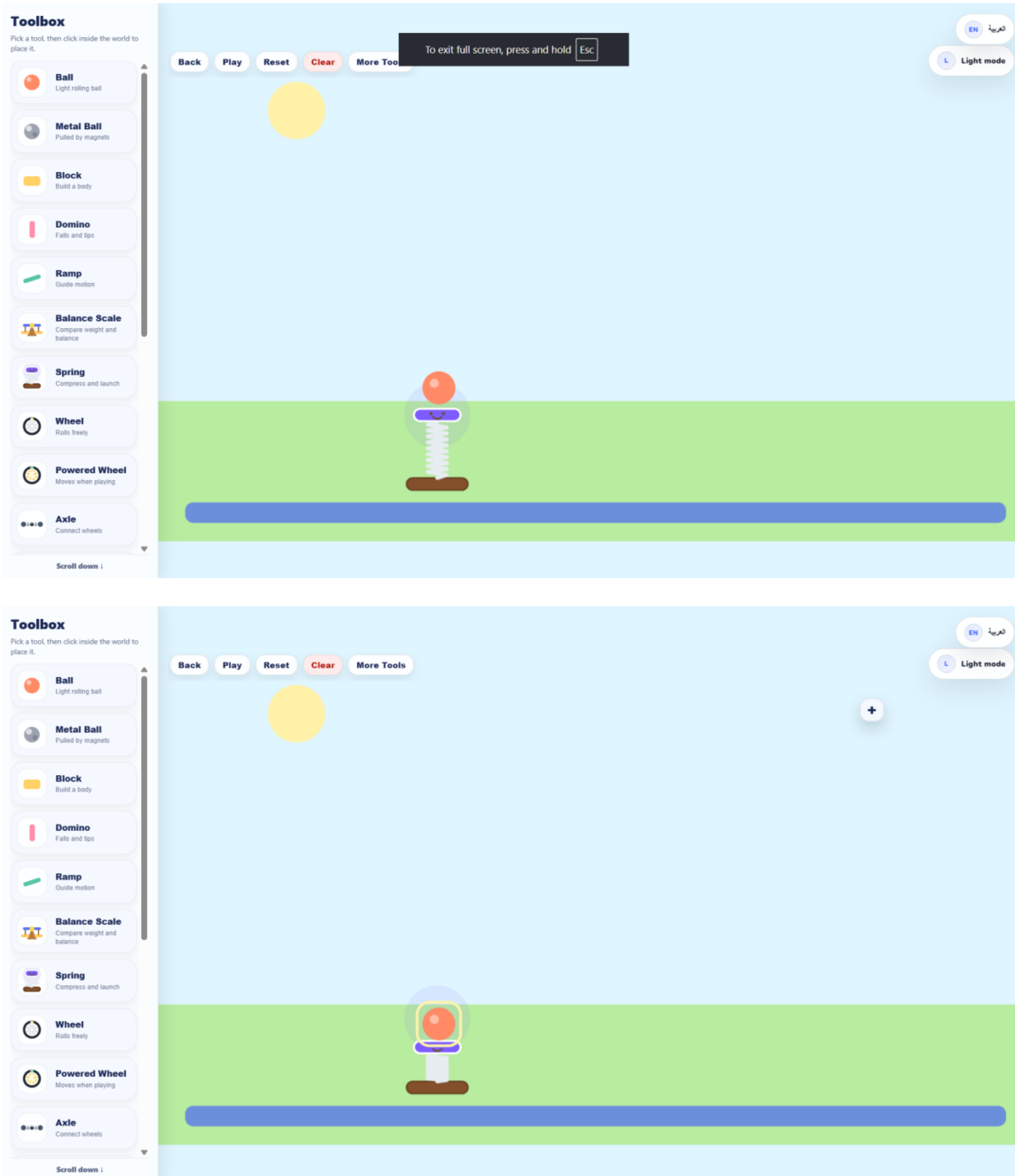


Figure A.7: Spring object demonstrating compression and launch behaviour.

A.13 Magnet and Fan Systems

The magnet and fan systems add force-based interaction to the Free Space sandbox.

The magnet can attract or repel metal objects. It includes adjustable settings such as:

- Strength
- Range
- Pole angle
- Attract mode
- Repel mode

This allows learners to test how distance, direction, and force strength affect movement.

The fan applies directional wind force to nearby objects. Its main adjustable setting is wind strength. Increasing the wind strength pushes objects more strongly, while reducing it creates a weaker effect.

These systems are important because they allow learners to observe invisible forces through visible object movement.

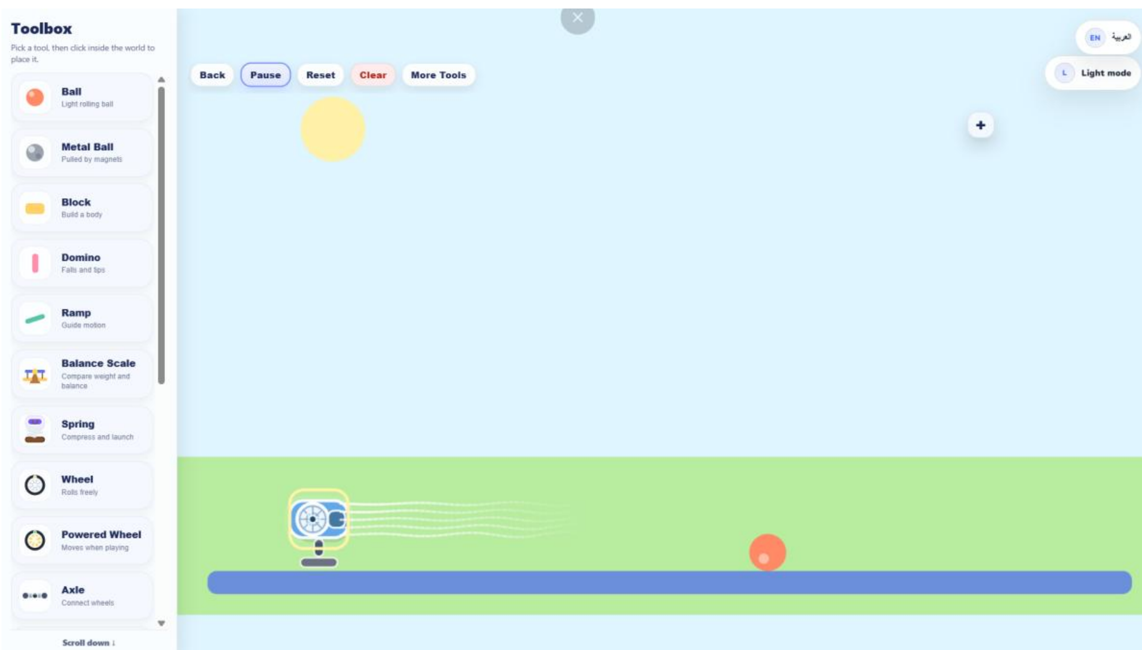


Figure A.8: Magnet or fan system applying force to objects in the sandbox.

A.14 Goal System

The goal system is mainly used in Supervisor Builder mode. It allows supervisors to create objective-based learning levels instead of only open-ended scenes.

Goal objects include:

- Goal Zone
- Cat Goal
- Food
- Basket
- Star Collectible

These objects can be used to create missions such as:

- Move the ball into the goal zone.
- Collect all stars.
- Feed the cat by moving food to the correct place.
- Drop an object into the basket.
- Complete a chain reaction that reaches the target.

The goal system checks whether the required condition has been achieved. When the condition is met, the level can be marked as completed.

General goal flow:

Supervisor places goal object
↓
Supervisor builds challenge scene
↓
Child plays level
↓
Goal detection system checks success condition
↓
Level is completed when goal is achieved

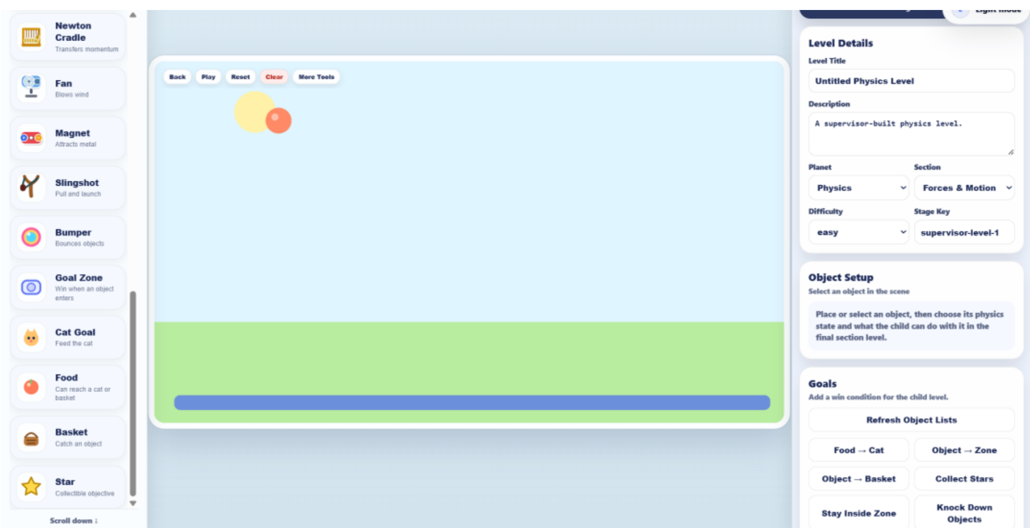


Figure A.9: Goal objects used to create objective-based Free Space levels.

A.15 Serialization and Restore Logic

Serialization is the process of saving the current sandbox scene as structured data. This allows the system to store the objects, positions, rotations, parameters, and scene settings so the level can be restored later.

The system saves information such as:

- Object ID
- Object type
- Position
- Rotation
- Size
- Mass
- Object-specific parameters
- Scene gravity setting
- Background theme
- Preset or level metadata
- Goal objects
- Attachments or constraints, where applicable

Serialization is important for several reasons:

- Children can save and restore sandbox states.
- Supervisors can export level data.
- Admins can review submitted levels.
- Approved levels can be loaded later in the correct planet and section.

The general serialization flow is:

Current scene objects
↓
Extract object data
↓
Convert scene to JSON-like structure
↓
Save or submit scene data
↓
Reload scene later using restore logic

Restore logic performs the reverse process. It reads the saved scene data, recreates the objects, restores their settings, and places them back into the physics world.

A.16 Preset Scene System

Preset scenes are ready-made Free Space examples. They allow learners to open a prepared setup instead of starting from an empty scene.

Preset scenes are important because they:

- Reduce confusion for beginners.
- Show what a working setup looks like.
- Encourage experimentation.
- Allow children to modify existing scenes.
- Help supervisors demonstrate concepts quickly.

Examples of preset scenes include:

- Ramp starter
- Domino chain
- Spring launcher
- Gear machine
- Rope swing
- Car test

Preset scenes support learning because the child can load an example, press play, observe the result, then change the scene and test again.

A.17 Build Ideas System

The Build Ideas button supports creative learning. When the learner does not know what to build, the system shows a random idea card or suggested challenge.

Examples of build ideas include:

- Build a car.
- Create a domino path.
- Build a bridge.
- Design a rolling ramp.
- Create a chain reaction.
- Move a ball into a target.
- Build a gear machine.

This feature keeps the sandbox open-ended but still gives the learner direction. It is especially useful for children who may feel unsure when starting from an empty scene.

A.18 Admin Review and Level Approval Connection

Free Space is connected to the supervisor/admin content workflow.

The process is:

Supervisor creates Free Space level
↓
Supervisor adds metadata and goals
↓
Supervisor submits the level
↓
Level is stored as pending
↓
Admin opens Admin Review mode
↓
Admin previews the level
↓
Admin approves, rejects, archives, edits, or deletes
↓
Approved level appears in the selected planet and section

This connection makes the Free Space system part of the platform's content management structure. It allows new learning levels to be created and reviewed without exposing unapproved content to children.

A.19 Technical Strengths of the Free Space System

The Free Space system has several technical strengths:

- It reuses one engine for three different modes.
- It supports both open-ended play and structured level creation.
- It uses Matter.js for real-time physics behaviour.
- It uses custom object logic for educational control.
- It supports object editing and variable manipulation.
- It includes preset scenes for guided exploration.
- It supports scene saving and restoring.
- It includes goal objects for objective-based learning.
- It connects directly to the admin review workflow.
- It can be expanded with more objects and level types in the future.

These strengths make Free Space one of the most important parts of the project because it combines simulation, creativity, content creation, and learning management.

A.20 Summary

This appendix presented a technical deep dive into the Free Space Physics Sandbox. Free Space was developed as a flexible simulation environment that supports child exploration, supervisor level creation, and admin review. It uses Matter.js for physics simulation, custom object registry logic for toolbox objects, editable object properties, attachment and rope systems, gear and motor logic, spring behaviour, magnets, fans, preset scenes, build ideas, goal detection, serialization, and restore logic.

The Free Space system is a central part of the project because it turns the platform from a normal educational website into an interactive learning environment. It allows children to build and test experiments, supervisors to create learning content, and admins to review that content before publication.

Appendix B: Role-Based Authentication and Verification Flow

B.1 Overview

The application uses a role-based authentication and verification system to control what each user can access after signing up or logging in. This is important because the platform is designed for children, parents, supervisors, and admins, and each role has a different purpose.

The role-based system prevents all users from having the same permissions. A child should only access learning content, a parent should only view connected child progress, a supervisor should build and submit educational content, and an admin should manage, review, approve, archive, or delete content.

The four main roles are:

- Child
- Parent
- Supervisor
- Admin

This structure makes the platform safer, more organised, and more suitable for an educational environment.

B.2 User Role Structure

The system separates users based on their selected role during sign-up.

User signs up
↓
User selects account type
↓
System creates profile
↓

System checks role
↓
User is sent to the correct area

The role structure is shown below:

Child
└── Accesses planets, sections, levels, Free Space, and progress

Parent
└── Connects to child account using child code and views progress

Supervisor
└── Creates sections/levels and submits learning content for review

Admin
└── Reviews, approves, rejects, archives, edits, and deletes content

B.3 Child Account Flow

The child account is the main learning account. A child can sign up, log in, enter the learning universe, select planets, play levels, complete activities, use Free Space, and track progress.

The child flow is:

Child selects Child role
↓
Child creates account
↓
Child logs in
↓
Universe page opens
↓
Child selects planet
↓
Child selects section
↓
Child plays level
↓
Progress is saved

The child role does not have access to supervisor tools, admin dashboards, or content management features. This protects the learning environment and keeps the interface simple for children.

B.4 Parent Account Flow

The parent account is used to monitor a child's progress. A parent cannot automatically view all children in the system. Instead, the parent must connect to a child account using a code provided by the child.

This connection method helps confirm that the parent is linking to the correct child account.

The parent flow is:

Parent selects Parent role
↓
Parent creates account
↓
Parent logs in
↓
Parent enters child connection code
↓
System validates the code
↓
Parent account links to child account
↓
Parent dashboard shows child progress

This method improves privacy because the parent cannot connect to a random child account without the child's code.

The parent dashboard can show information such as:

- Completed levels
- Unlocked levels
- Locked levels
- Subject progress
- Section progress
- General learning activity

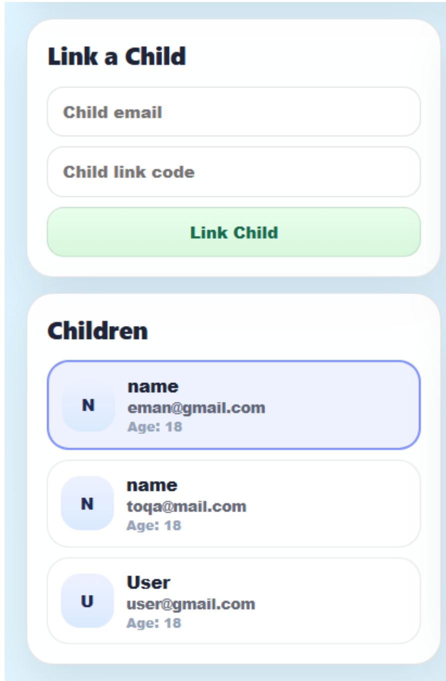


Figure B.1: Parent-child connection using a child-generated code.

B.5 Supervisor Account Flow

The supervisor account is used for educational content creation. Supervisors can create sections, build levels, edit metadata, use the Free Space builder, add goals, export level data, and submit content for admin review.

Because supervisors can create content that may later be shown to children, their accounts require verification. This prevents unauthorised users from accessing content creation tools.

The supervisor flow is:

Supervisor selects Supervisor role
↓
Supervisor creates account
↓
Verification is required
↓
Verification is completed by admin or code
↓
Supervisor gains builder access
↓
Supervisor creates or edits levels
↓
Supervisor submits level for review

Supervisor-created content does not automatically appear for children. It is sent to the admin as pending content first.

B.6 Admin Account Flow

The admin account has the highest permission level in the system. Admins are responsible for managing content and reviewing submitted levels before they become visible to children.

Admin access also requires verification because admins can approve, reject, archive, edit, and delete educational content.

The admin flow is:

Admin selects Admin role
↓
Admin creates account
↓
Verification is required
↓
Admin account is verified
↓
Admin opens management dashboard
↓
Admin reviews pending content
↓
Admin approves, rejects, archives, edits, or deletes content

The admin role is important for maintaining content quality and protecting the learning experience. Since the application is made for children, content should not be published without review.

B.7 Verification Logic

Verification is used for roles that can affect platform content or management. Child and parent accounts can use the normal sign-up flow, while supervisor and admin accounts require additional verification.

The verification process can be completed through:

- Admin approval
- Verification code
- Controlled access check

The purpose of verification is to prevent unauthorised users from becoming supervisors or admins.

The verification logic can be represented as:

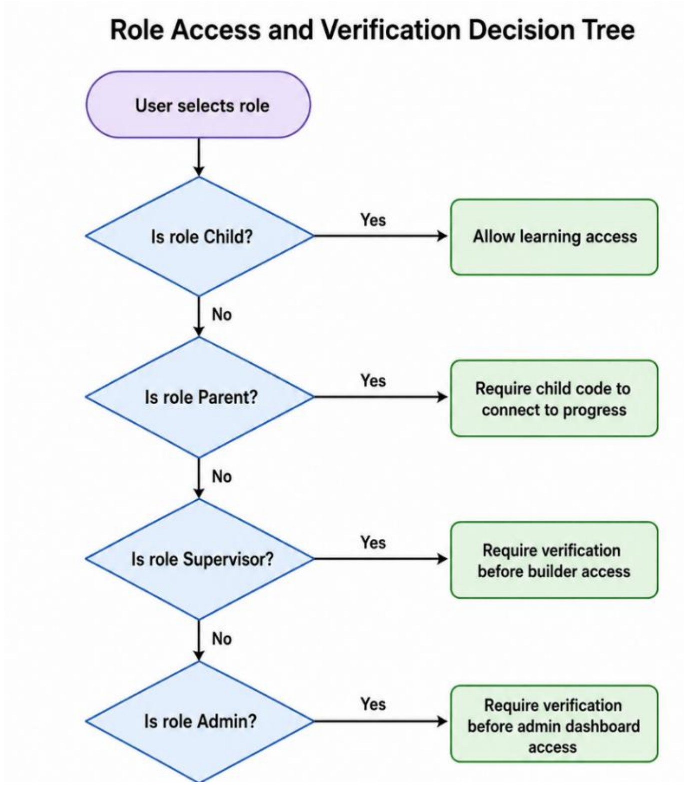


Figure B.2: Verification logic for different user roles.

B.8 Permission Matrix

The following table summarises the permissions of each role.

Table B.1: User role permission matrix

Feature / Permission	**Child**	**Parent**	**Supervisor**	**Admin**
Sign up and log in	Yes	Yes	Yes	Yes
Access learning planets	Yes	No	Optional	Optional
Play levels	Yes	No	Optional	Optional
Use Free Space Kid Play	Yes	No	Optional	Optional
View child progress	Own progress	Connected child only	No	Optional
Connect using child code	No	Yes	No	No

Feature / Permission	Child	Parent	Supervisor	Admin
Create sections	No	No	Yes	Yes
Create levels	No	No	Yes	Yes
Use Supervisor Builder mode	No	No	Yes	Yes
Add goal objects	No	No	Yes	Yes
Submit level for review	No	No	Yes	Yes
Review pending levels	No	No	No	Yes
Approve/reject levels	No	No	No	Yes
Archive/delete content	No	No	No	Yes
Verify supervisor/admin users	No	No	No	Yes

B.9 Parent-Child Connection Security

The parent-child connection system uses a child-generated code. This is safer than allowing parents to search freely for children by name or email.

The connection code system works as follows:

Child account generates or displays code
↓
Child gives code to parent
↓
Parent enters code
↓
System checks if code is valid
↓
Parent is linked to that child account

This system helps protect child privacy because the parent must receive the code from the child account before connecting.

If the code is invalid, the system should reject the connection and ask the parent to check the code again.

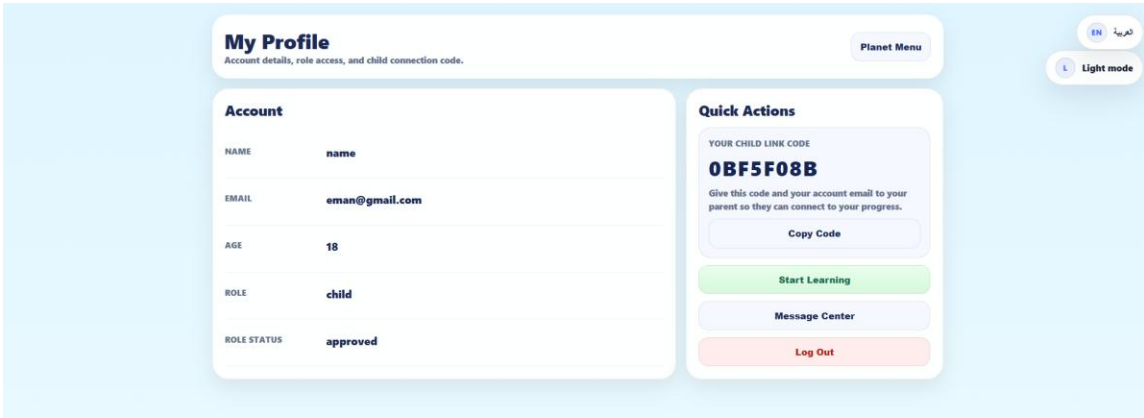


Figure B.3: Child-generated code used for parent account connection.

B.10 Supervisor Submission and Admin Approval Flow

The supervisor and admin workflow controls how new educational content is published.

The workflow is:

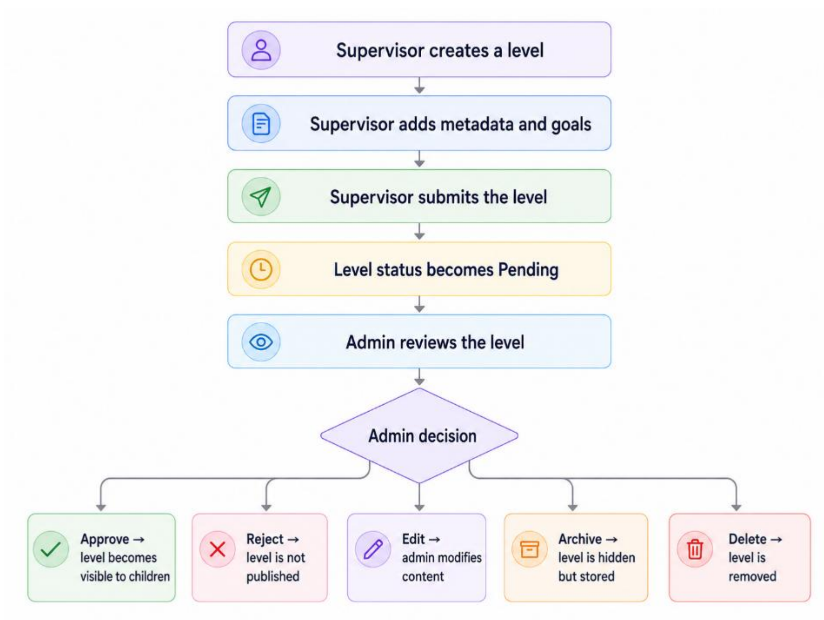


Figure B.4: Supervisor submission and admin approval workflow.

This workflow is important because it prevents unfinished or unsuitable content from appearing in the child learning area.

B.11 Role-Based Route Protection

Route protection ensures that users cannot manually enter restricted pages by typing a URL. For example, a child should not be able to open the admin dashboard route, and a parent should not be able to open the supervisor builder route.

The route protection logic should check:

- Whether the user is logged in
- What role the user has
- Whether the role is verified, if required
- Whether the requested route is allowed for that role

General route protection flow:

User tries to open page
↓
System checks login status
↓
System checks user role
↓
System checks verification status
↓
If allowed → show page
If not allowed → redirect to correct page or access denied screen

This protects the system from unauthorised access and keeps the platform safe for children.

B.12 Summary

This appendix explained the role-based authentication and verification flow used in the educational platform. The system supports four main roles: child, parent, supervisor, and admin. Each role has different permissions depending on its purpose.

The child role supports learning and progress. The parent role supports progress monitoring through a child-generated connection code. The supervisor role supports educational content creation after verification. The admin role supports content review, approval, archiving, editing, deletion, and user verification.

This structure is important because the platform is designed for children and includes content management tools. By separating roles and requiring verification for powerful accounts, the system provides a safer and more organised learning environment.

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