FINAL REPORT

European Project Semester | Project ClassVR

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Final Report

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General Information

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Abstract

This project focuses on developing an educational VR lesson for students aged 12-14, centered on the evolution of energy technology. Using ClassVR headsets, the lesson provides an immersive learning experience that aligns with LUMA principles, particularly in engineering and technology. The project includes a fully functional VR prototype, a teacher's handbook, and thorough quality assurance measures. Effective communication, guided by a code of conduct, ensures smooth collaboration. Decisions are made through a structured process, and the project manager oversees progress. The aim is to deliver an engaging, informative, and well-supported educational tool for Finnish classrooms.

Language: English

Key Words: Evolution, Energy, Technology, Virtual-Reality, Education, LUMA

Summary

This project report provides an in-depth study in the development of an educational VR lesson for teaching the evolution of energy technology to students in the age group of 12–14 years. The lesson follows the principles of LUMA and Finnish educational standards, which include interdisciplinary learning and engaging in immersive virtual reality experiences.

Success milestones include the development of a series of VR scenes related to different historical ages in the evolution of energy; this is complemented with hands-on activities for those students who are not 'immersing' themselves in virtual reality. Testing sessions provided some worthwhile feedback in helping focus iterative improvements on the most effective VR experience, parallel activities, and teaching tool support. Neurodiversity was considered in developing the prototype but requires additional substantial research and development to be more globally inclusive.

Challenges included hardware limitations with the ClassVR headsets, motion sickness issues, and underdeveloped text presentation in VR scenes. Recommendations for future development focus on addressing these limitations, enhancing narrative and interactivity, and localizing materials for Finnish and Swedish-speaking classrooms.

Preface

This report is the result of the European Project Semester (EPS) conducted at Novia University of Applied Sciences in Vaasa, Finland, during Autumn 2024. Our project, The Evolution of Energy Technology in Virtual Reality, aimed to create an immersive educational tool that combines historical and technological learning, providing Finnish classrooms with an engaging way to understand the evolution of energy technology while adhering to LUMA principles.

Participating in EPS has been a transformative experience, fostering collaboration within a multidisciplinary team blending IT, physics, and business management. The program challenged us to bridge diverse perspectives, navigate cultural differences, and produce a cohesive, high-quality outcome under real-world constraints. The project spanned research, prototyping, testing, and final implementation, emphasizing teamwork, effective communication, and problem-solving.

This report highlights the dedication of all team members, detailing technical and methodological aspects while showcasing iterative learning and adaptation. From leveraging VR capabilities to designing inclusive content for neurodivergent students, this project has deepened our appreciation for interdisciplinary collaboration.

We extend our deepest gratitude to our supervisor, Josefin Stolpe, for her guidance, and to the EPS coordinators, Mikael Ehrs and Roger Nylund, for providing this enriching opportunity. We are also grateful to the LUMA Centre Finland, teachers, students, and external advisors for their contributions, which shaped our final product. Lastly, we thank our EPS peers for their camaraderie and constructive feedback.

This report reflects both our technical achievements and the personal growth we experienced throughout this journey. We hope it serves as a foundation for future innovations in STEAM education and a testament to the collaborative spirit of EPS.

Vaasa, Finland, December 2024

Ernest Anguera, Jelmer Sijbers, and Jesse van den Ende

List of Acronyms

Acronym	Definition
ADHD	Attention-Deficit/Hyperactivity Disorder
ASD	Autism Spectrum Disorder
CGI	Computer-Generated Imagery
CPU	Central Processing Unit
ECTS	European Credit Transfer and Accumulation System
EPS	European Project Semester
LUMA	Refers to the Finnish educational organization promoting STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. (Also, this project's sponsor)
RAM	Random Access Memory
STEAM	Science, Technology, Engineering, Arts, and Mathematics
TVO	Teollisuuden Voima Oyj (related to the Olkiluoto nuclear power plant)
UAS	University of Applies Sciences
VR	Virtual Reality
VRAM	Video Random Access Memory
WBS	Work Breakdown Structure

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1. Introduction

Every student taking part in the EPS minor must prepare and turn in two reports. The first report, submitted midway, offers a comprehensive update on the project's progress during the initial term, which they present to their supervisors. It covers the methods applied, early findings, and alternative approaches considered for different tasks. The second, final report builds on this midterm document, detailing all advancements made in the latter part of the EPS program.

The goal of this project is to create an educational VR experience for students aged 12-14 that illustrates the evolution of energy technology. This VR lesson, designed with ClassVR headsets, immerses students in the history and progression of energy sources, fostering a deeper understanding of scientific advancements in a captivating way. LUMA, an organization committed to inspiring Finnish youth in STEAM (Science, Technology, Engineering, Art and Mathematics) fields, proposed this project to introduce innovative and interactive learning methods. By leveraging VR technology, LUMA aims to enhance engagement and motivation in STEAM education, encouraging young people to explore these fields and develop a passion for scientific discovery.

This final report encompasses all relevant content regarding the project, beginning with the methods employed in its execution. Following the methodology, a detailed action plan is presented to outline the tasks deemed essential for achieving the project's objectives. Subsequently, the report provides a project plan that addresses key project management aspects, including team composition, project objectives, timeline, and allocated resources.

In addition, this final report builds upon the progress outlined in the midterm report, where the foundational research and initial development stages were documented. In the midterm report, early tasks included defining the educational goals, researching the Finnish educational system, and understanding the technical capabilities and limitations of the ClassVR headsets. The team also developed a historical timeline and script to guide the VR experience, which highlighted key stages in the evolution of energy technology, from the discovery of fire to modern renewable energy sources. Feedback from initial user testing sessions was collected, which informed revisions to enhance the educational experience.

This report integrates these early findings with the final stages of development, including adjustments based on feedback, improvements to VR scene design, and completion of the teacher handbook to support lesson implementation. By incorporating feedback and refining the VR prototype, the project aims to deliver an engaging, immersive, and pedagogically sound tool for teaching energy technology in Finnish classrooms.

1.1. The European Project Semester (EPS)

The European Project Semester, or EPS for short, is a semester-long exchange program organized by many universities across Europe. Its main purpose is to provide students with the opportunity to study abroad and collaborate on multidisciplinary projects with peers from diverse cultural and educational backgrounds.

The program is composed of two key components:

- **The Project**: This is the core of the program, where students are tasked with tackling a specific challenge or developing a solution in the form of a product or prototype.
- **Lectures**: These sessions are designed to provide additional knowledge and insights, covering topics such as team dynamics, project management, and other skills necessary for successful collaboration. The lectures also compensate for any missing ECTS credits and provide additional support to the project work.

Throughout the semester, the team has been tasked with setting clear goals, establishing milestones, and working together to develop a functioning product or prototype by the end of the program. The project centres on developing an educational tool using ClassVR, a virtual reality platform, to teach students about the evolution of energy technology.

1.2. The Project Team

Ernest Anguera

Ernest **(Figure 1)** is a 4th-year IT Engineering student at Universitat Politècnica de Catalunya, Spain. His role in the team is primarily as an Implementor and Shaper, ensuring that tasks are executed efficiently and keeping the team motivated. He also takes on the responsibility of ensuring that the project's practical aspects are delivered to a high standard.

Figure 1: Ernest Anguera

Jelmer Sijbers

Jelmer **(Figure 2)** is a 3rd-year Applied Physics student at Saxion University of Applied Sciences, Netherlands. His responsibilities include monitoring the project progress and contributing specialized knowledge for technical tasks. He plays a key role in overseeing the technical details of the project.

Figure 2: Jelmer Sijbers

Jesse van den Ende

Jesse **(Figure 3)** is a 4th-year Business IT & Management student at Avans University of Applied Sciences, Netherlands. As the Project Manager, Jesse is responsible for organizing the project plan, coordinating the team, and ensuring smooth communication with stakeholders. He serves as the main point of contact for external parties and ensures that the team adheres to the project timeline.

Figure 3: Jesse van den Ende

1.3. Belbin tests

As part of the EPS program, one of the things that the team had to conduct was making the Belbin test. This test was to help identify preferred and avoided team roles for this semester and how to utilize them. (SmartT Strategies., sd) The assessments involved answering questions about work-related and personal situations, encouraging honest self-reflection. The results provide insights into each member's strengths and areas for development. Furthermore, the team took the initiative to complete a personality test, allowing for a deeper understanding of individual traits, strengths, and weaknesses. More information about the Belbin test and other team results can be found in the project management Report in **Appendix A.**

Ernest thrives in roles like Completer Finisher and Shaper, focusing on task precision and motivating the team to achieve goals. (**figure 4**) His preference for independent work is reflected in lower scores as a Team Worker and Coordinator, as he is less inclined toward collaboration or managing group dynamics. While Ernest excels in logical and structured thinking, he is less comfortable with creative roles like Plant or exploring external opportunities as a Resource Investigator.

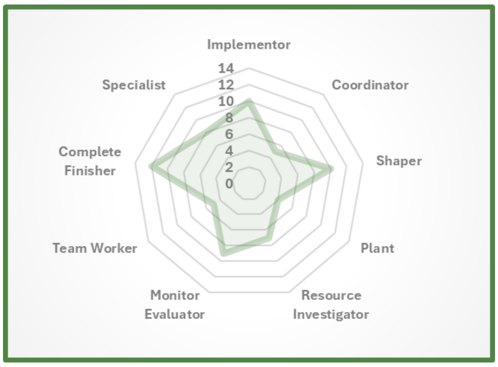


Figure 4: Ernest's Belbin Results

Jelmer is strongest in roles like Monitor Evaluator and Implementer, showcasing his analytical abilities and his talent for transforming ideas into actionable plans. **(Figure 5)** His versatility extends to creative and detail-oriented roles, such as Plant and Completer Finisher, which balance his logical approach. However, Jelmer prefers working independently, scoring low as a Team Worker and Coordinator, which may pose challenges in collaborative environments. autonomy and foresight.

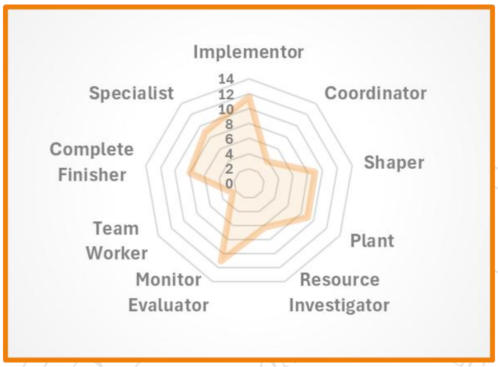


Figure 5: Jelmer's Belbin Results

Jesse's Belbin results highlight his strengths as a Coordinator, excelling in uniting the team under a shared vision and ensuring clear communication. **(Figure 6)** His ability to foster collaboration and mutual understanding is complemented by his role as a Completer Finisher, striving for precision and delivering high-quality outcomes. However, Jesse's perfectionism and occasional struggles with self-expression present challenges he is actively working to address, such as trusting others with tasks and voicing concerns effectively.

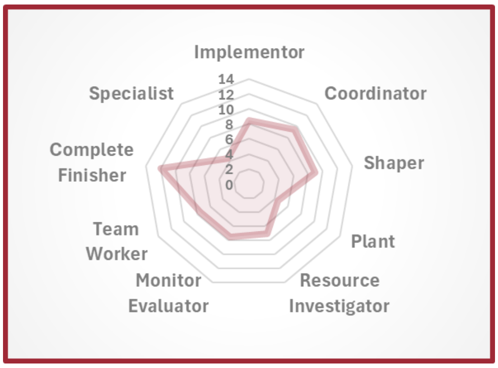


Figure 6: Jesse's Belbin Results

2. Project Overview

2.1. Objectives

As part of the presentation mentioned earlier, LUMA proposed a project with a clearly defined objective: to develop a lesson plan for students aged 5 to 18 using ClassVR headsets and incorporating the principles of STEAM. However, this objective was too broad for the team to generate a concrete and focused lesson plan. Consequently, several brainstorming sessions were organized to refine the scope and direction of the project.

During the initial brainstorming session, the team explored various concepts to determine which would best align with both the LUMA and STEAM principles. Following this session, it became evident which type of content would be most suitable for integrating LUMA's approach and fulfilling the objectives of the project. **(Figure 7)**

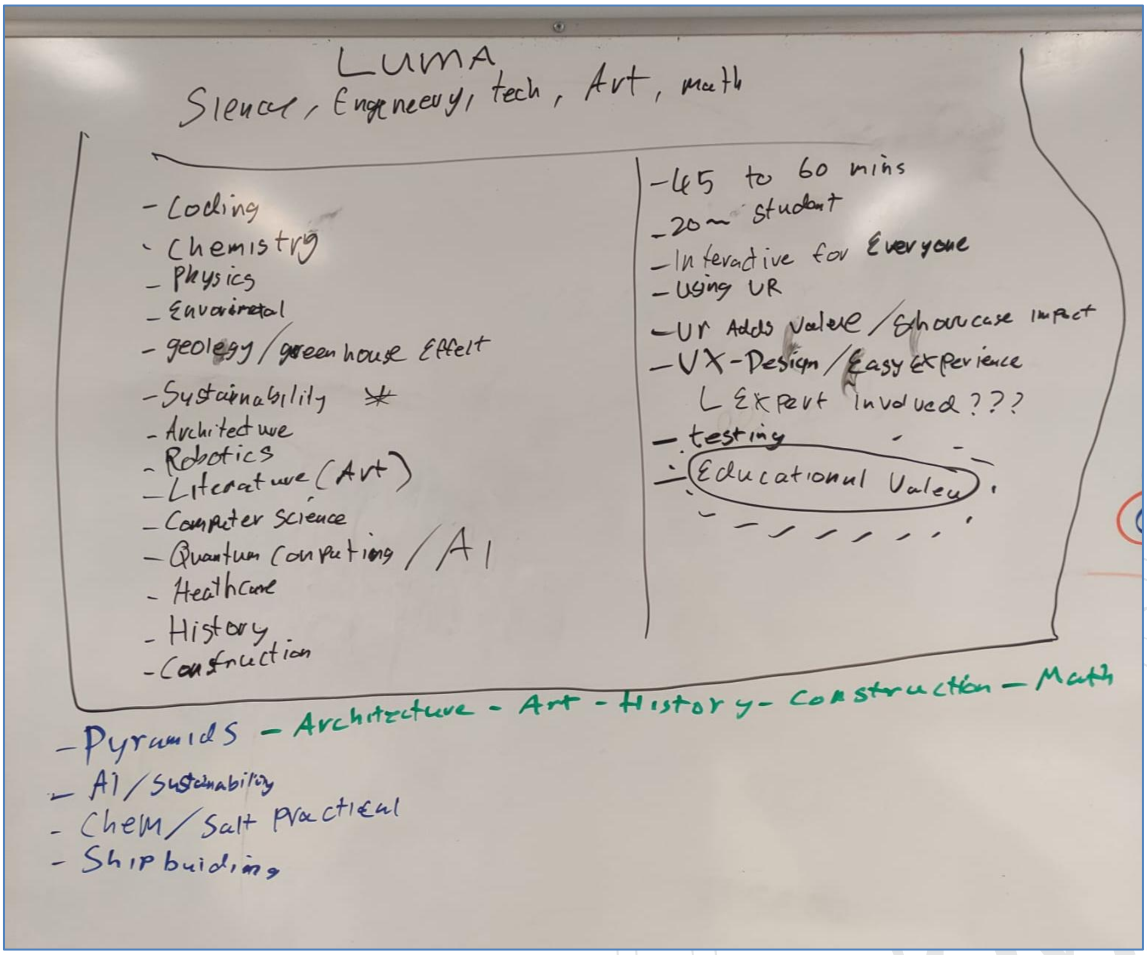


Figure 7: Brainstorm result of LUMA's principles.

After gaining a comprehensive understanding of the principles of the LUMA methodology, the team elected to engage in further discussions to refine the overarching objective into a series of smaller, more achievable goals. These goals would facilitate the development of the lesson's structure and aid in selecting a specific focus topic. To accomplish these aims, multiple brainstorming sessions were conducted:

First Session

In the first session, the team prioritized the exploration and development of foundational ideas to address essential considerations that would be critical throughout the project's lifespan. The meeting commenced with a structured brainstorming activity designed to promote a broad range of ideas on potential directions and focal points for the project. Each team member was allocated three minutes to independently generate as many ideas as possible, fostering an environment of individual creativity before collective deliberation. Following this ideation period, the team reconvened to review and assess the proposed ideas, engaging in a collaborative discussion to refine their scope and focus. Ideas were then organized systematically into distinct categories corresponding to specific project deliverables, allowing for a clearer understanding of the project's multifaceted requirements and ensuring that all proposed directions were evaluated within a cohesive framework.

Figure 8: Team discussing the ideas.

Second Session

The second session involved a series of focused discussions aimed at refining and streamlining the tasks identified during the initial meeting. The primary objectives were to identify any duplicate or closely related tasks and to exclude objectives deemed irrelevant to the project's scope (**Figure 9**). To facilitate this process, each team member was given five minutes to review the list of assignments independently, assessing which tasks were redundant or unnecessary. After this individual analysis, the team engaged in a structured discussion to clarify the essential deliverables and determine which tasks were critical for each one. This

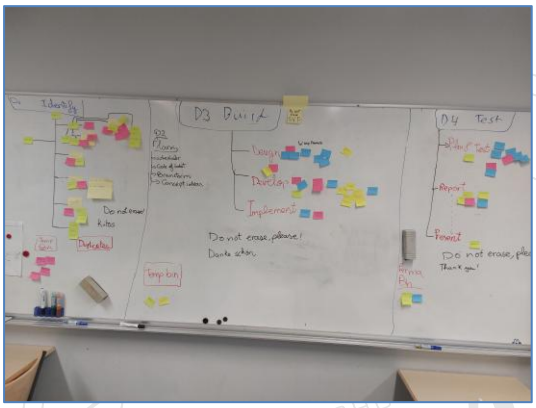


Figure 9: Result of the second session

collaborative approach enabled the team to prioritize tasks effectively, aligning each one with a specific deliverable to establish a well-organized framework for moving forward.

Third Session

The third session focused on finalizing the layout of the Work Breakdown Structure (WBS) to establish a comprehensive workflow for the project's execution. During this meeting, the team reviewed and refined initial ideas, discarding several that no longer aligned with the project's evolving scope. After thoughtful deliberation, new tasks were proposed, and some were designated as key objectives within their respective deliverables. Each deliverable was given a clear and descriptive title, enhancing clarity and making it easier for the team to understand the specific aim and purpose of each section of work. This systematic approach provided a cohesive structure, ensuring that each deliverable supported the overarching project goals and facilitated a streamlined workflow for the team moving forward. (**Figure 10)**

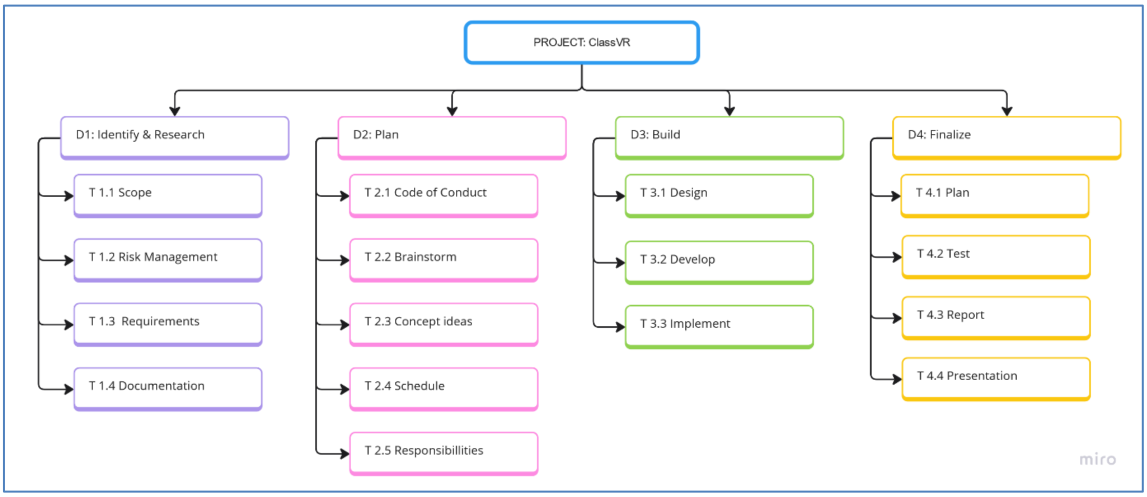


Figure 10: Work Breakdown Structure

Objective 1 focuses primarily on tasks related to **identification and research**, as the title suggests. In this phase, the team must conduct thorough research to define the complete scope of the project. This research setting the scope and stakeholders of the project, potential risk factors, the required resources for the project and setting up the overall documentation of these findings.

Objective 2 involves creating a comprehensive **workable plan of action**. that includes concept ideas, the code of conduct that establishes project team norms and the assignment of responsibilities among team members. scheduling the project with start and end dates, the required resources for completing this project, the estimated costs if necessary.

Objective 3 is the actual **build** of the project. During this phase, the team will design and develop a working prototype based on one of the concepts outlined in the previous deliverable. This hands-on stage is crucial for translating ideas into a tangible product.

Objective 4, "**Finalize**." This final phase involves setting up testing plans, completing the project, and presenting the final product to the client and other stakeholders involved. This ensures that the project is thoroughly reviewed and approved before it is fully implemented.

In conclusion, the structured approach adopted across these sessions allowed the team to transform an initially broad concept into a set of well-defined, achievable objectives, establishing a strong foundation for the development of a ClassVR lesson plan that aligns with LUMA's principles and the STEAM framework. As a result of this iterative process, our defined objectives are as follows: first, to conduct comprehensive research and clearly define the project scope, stakeholders, and resource requirements; second, to establish a practical plan of action that includes concept ideas, team norms, scheduling, and resource allocation; third, to design and construct a functional prototype that effectively embodies the educational goals; and finally, to rigorously test, finalize, and present the completed product to stakeholders. These objectives provide a cohesive roadmap, ensuring the project meets both educational standards and LUMA's methodological expectations, guiding the team toward a high-quality, impactful learning tool for students aged 5 to 18.

2.2. Scope

When constructing the Work Breakdown Structure, the comprehensive scope of the project became apparent:

- **Develop** a lesson plan tailored for students aged 5 to 18.
- **Create** a virtual reality (VR) environment reflecting LUMA's educational philosophy.
- **Design** a lesson focused on STEAM (Science, Technology, Engineering, Arts, and Mathematics).
- **Emphasise** interactive learning throughout the lesson.
- **Ensure** the lesson duration aligns with typical Finnish class lengths, ranging from 45 to 62 minutes.

The project involves designing an interactive, STEAM-focused lesson for students aged 5 to 18, delivered within a VR environment that adheres to LUMA's educational philosophy and conforms to standard Finnish class durations of 45 to 62 minutes.

2.3. Project Sponsor

The LUMA Centre Finland, **Figure 11**, is an educational organization in Finland focused on fostering interest and engagement in STEAM (science, technology, engineering, arts, and mathematics) disciplines among children and young people. Its mission is to develop a robust foundation of scientific knowledge and curiosity, with the goal of equipping students with the skills and motivation necessary to pursue careers in STEAM fields. Operating through a network of universities, educational institutions, and partner organizations, the centre provides teaching resources, programs, and workshops designed to make science education accessible and engaging for young learners. One such university within this network is the University of Vaasa, which hosts the LUMA Centre Ostrobothnia. For the purposes of this document, 'LUMA Centre Ostrobothnia' will be referred to as 'LUMA,' unless otherwise stated.

Figure 11: Logo LUMA Centre Finland

A defining feature of LUMA's initiatives is its emphasis on hands-on, interactive learning, frequently integrating advanced technologies such as virtual reality, augmented reality, and experiential workshops. This innovative approach modernizes traditional STEAM education by fostering deeper engagement with scientific concepts, enabling students to explore and experiment in highly interactive environments. Through these programs, LUMA actively promotes student participation in scientific discovery, cultivating future generations of innovators and problem-solvers.

2.4. Code of Conduct

The Code of Conduct for the project establishes a structured framework to ensure professionalism, accountability, and effective teamwork. The key reasons behind its formulation are as follows:

1. **Promoting Collaboration**
   The code emphasizes equal participation, ensuring all members contribute meaningfully to achieve a high-quality deliverable. This fosters teamwork and shared responsibility, which are essential for success.
2. **Maintaining Organisation and Accountability**

Clear guidelines on attendance, task allocation, and deadlines are designed to ensure all participants remain engaged and responsibilities are distributed fairly. This structure prevents delays and reduces conflicts.

3. **Encouraging Respect and Professionalism**
   The inclusion of respectful communication, constructive criticism, and professional handling of frustrations creates a positive environment. This is critical for maintaining harmony and focusing on objectives.
4. **Ensuring Transparent Communication**
   The emphasis on regular updates, predefined agendas, and centralized platforms (e.g., Microsoft Teams and WhatsApp) ensures clarity and minimizes misunderstandings.
5. **Managing Conflicts Constructively**
   By addressing conflicts through majority consensus and promoting constructive criticism, the code ensures that disputes do not hinder progress and are treated as opportunities for learning.
6. **Adaptability and Fair Workload**
   Provisions to accommodate absences and reassign tasks equitably demonstrate a commitment to flexibility while maintaining productivity.
7. **Commitment to Quality**
   The mandatory review of deliverables by all team members before submission highlights the commitment to maintaining high standards.

This comprehensive code not only mitigates risks like miscommunication and underperformance but also aligns the team's efforts with professional and educational expectations.

2.5. Roles and Responsibilities

To ensure an equitable distribution of workload, roles and responsibilities were allocated to each team member based on their individual strengths and Belbin profile results. This method was employed to enhance efficiency and capitalize on the unique competencies of each member.

Jesse van den Ende assumed the role of Project Manager, leveraging his strengths as a Coordinator and Completer Finisher. His responsibilities included developing and managing the overall project plan and ensuring alignment with the project objectives. Additionally, he acted as the primary liaison with stakeholders, addressing inquiries and maintaining effective communication. Jesse facilitated team meetings, ensured adherence to agendas, and resolved conflicts and delays. Furthermore, he oversaw the finalization and submission of project deliverables, including the VR prototype and accompanying materials.

Jelmer Sijbers took on the dual role of secretary and project monitoring, drawing on his abilities as a Monitor Evaluator and Specialist. His primary duties involved maintaining accurate and comprehensive records of meetings, decisions, and actions. He monitored the progress of the project and ensured that the milestones were achieved as planned. Jelmer also contributed to the preparation of the detailed technical reports and documentation. In addition, his creative and analytical skills were utilized to implement technical and content-related tasks, thereby enhancing the overall quality of the project.

Ernest Anguera served as Vice-Secretary and Quality Assurance Lead, reflecting his strengths as a Completer Finisher and Shaper. Ernest supported documentation efforts and played a key role in organizing meetings. He ensured that all project tasks were executed at a high standard, with meticulous attention paid to detail. In his capacity as a Quality Assurance Lead, he conducted systematic testing of the VR prototype to identify and resolve potential issues. Furthermore, Ernest provided logical and structured input during problem-solving and planning activities with a particular focus on practical implementation. The allocation of these roles ensured that the project benefited from the individual strengths of each member, fostering effective collaboration and successful completion of project objectives.

2.6. Methods

To ensure consistent quality throughout the semester, the team will hold weekly scrum meetings. These meetings, scheduled for 30 minutes every Monday, will address key project updates and provide a platform for team coordination. The project manager is responsible for organizing these meetings and preparing an agenda, which includes: reviewing tasks completed the previous week, outlining tasks for the upcoming week, identifying any required support, discussing other scheduled meetings, and addressing additional topics raised during the session.

Although a physical scrum board was not used, the project manager utilized digital tools to effectively monitor and manage tasks. These tools enabled clear oversight of ongoing activities, ensuring accountability and smooth collaboration within the team.

The project is divided into distinct phases, as outlined in the Work Breakdown Structure (WBS). The four main deliverables correspond to these phases: Identifying, Planning, Building, and Finalizing.

Overall project management is primarily the responsibility of the project manager. This role involves maintaining a structured and transparent workflow for the team, as well as leveraging a task management method that provides visibility into all team activities. This approach allows the project manager to monitor progress, redistribute workloads as needed, and ensure the project stays on track.

2.7. Stakeholders

The stakeholder register identifies key individuals and organizations involved in the ClassVR Project, detailing their roles, influence, interest, communication expectations, and contact information. This analysis will categorize stakeholders into internal and external groups, assess their power and interest, and discuss their communication needs and contributions to the project.

Internal stakeholders include LUMA, the client, who holds a strong influence and interest in the project. LUMA requires weekly meetings via email to discuss lesson structure and materials. Novia UAS, the program manager, has a weaker influence but a strong interest, necessitating six-monthly email communications regarding the working space. ClassVR, the supplier of the product, has both weak influence and interest, with communication occurring as needed via email to address any issues with the VR headset. **(Table 1)**

Josefin Stolpe, a supervisor, is another internal stakeholder with strong influence and interest, participating in weekly meetings via email to provide information about team management and lesson structure. Phil Hollins, an advisor, has weak influence and interest, with communication occurring as needed via email to discuss project management. Mikhael Ehrs, another supervisor, shares similar characteristics to Josefin Stolpe, with strong influence and interest, and communicates six-monthly via email about team management and lesson structure. Jenny Ronnqvist-Norrby, an advisor, has weak influence and interest, requiring only one meeting via email to provide insights into the Finnish educational system and contacts. Hanna Hankaniemi, also an advisor, has weak influence but strong interest, necessitating one meeting via email to discuss lesson structure.

External stakeholders, **(Table 1),** include Vaasan Yliopisto, the program manager, who has weak influence and interest, with communication occurring as needed via email regarding the ClassVR account. Lab21, an advisor, also has weak influence and interest, with communication scheduled as needed via email to provide information about science, energy, and VR lessons. Universitat Politècnica de Catalunya, an information provider, has weak influence but strong interest, requiring communication as needed via email to provide general information. Saxion University of Applied Sciences, another information provider, shares similar characteristics, with communication occurring as needed via email. Avans Hogeschool, also an information provider, has weak influence but strong interest, with communication occurring as needed via phone. Zittau Görlitz University of Applied Sciences, another information provider, has weak influence but strong interest, with communication occurring as needed via email.

Table 1: Stakeholders Registry

Stakeholder Name	Role	Category	Power/Influence	Interest
LUMA	Client	Internal	Strong	Strong
Novia UAS	Program Manager	Internal	Weak	Strong
ClassVR	Supplier of Product	Internal	Weak	Weak
Josefin Stolpe	Supervisor	Internal	Strong	Strong
Phil Hollins	Advisor	Internal	Weak	Weak
Mikhael Ehrs	Supervisor	Internal	Strong	Strong
Jenny Ronnqvist-Norrby	Advisor	Internal	Weak	Weak
Hanna Hankaniemi	Advisor	Internal	Weak	Strong
Vaasan Yliopisto	Program Manager	External	Weak	Weak
Lab21	Advisor	External	Weak	Weak
Universitat Politècnica de Catalunya	Information Provider	External	Weak	Strong
Saxion University of Applied Sciences	Information Provider	External	Weak	Strong
Avans Hogeschool	Information Provider	External	Weak	Strong
Zittau Görlitz University of Applied Sciences	Information Provider	External	Weak	Strong

The power and interest grid categorizes stakeholders into different groups. High power and high interest stakeholders include LUMA, Josefin Stolpe, and Mikhael Ehrs. Low power and high interest stakeholders include Novia UAS, Hanna Hankaniemi, Universitat Politècnica de Catalunya, Saxion University of Applied Sciences, Avans Hogeschool, and Zittau Görlitz University of Applied Sciences. Low power and low interest stakeholders include ClassVR, Phil Hollins, Jenny Ronnqvist-Norrby, Vaasan Yliopisto, and Lab21.

The communication strategy for the project involves frequent communication with high power and high interest stakeholders, such as LUMA and Josefin Stolpe, to ensure alignment and address any concerns promptly. Periodic communication is recommended for stakeholders with low power but high interest, such as Novia UAS and external information providers, to keep them informed and engaged at key project milestones. Minimal communication is sufficient for stakeholders with low power and low interest, focusing on specific issues or contributions as needed. **(Figure 12)**

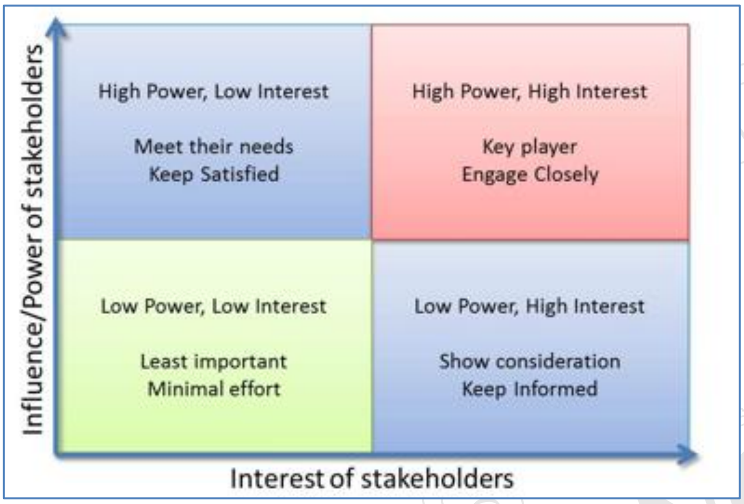


Figure 12: Stakeholders matrix

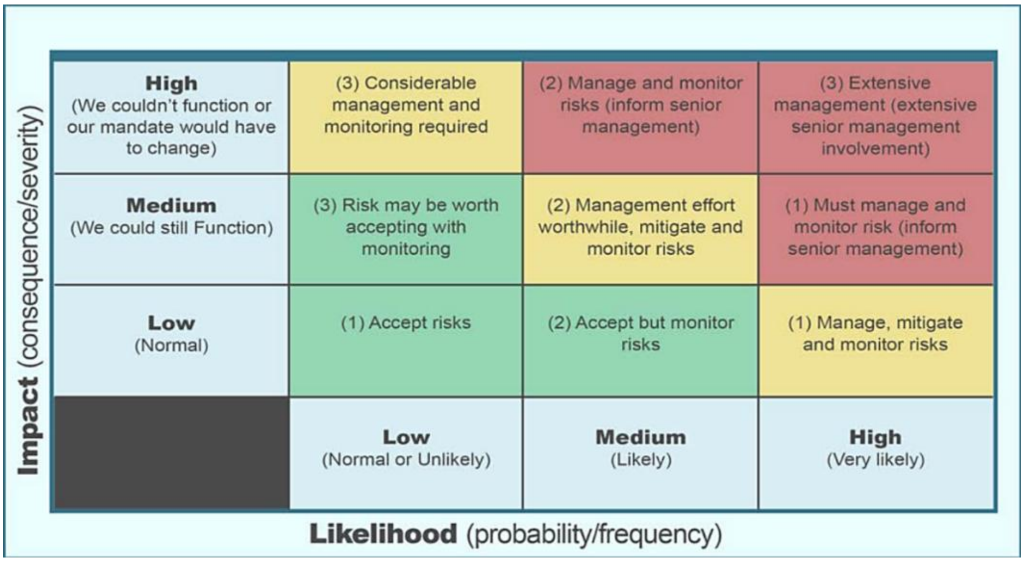
2.8. Risks & Challenges

A project may encounter various risks throughout its lifecycle. To effectively manage and prepare for these risks, a risk matrix is employed. This tool allows the project team to evaluate potential risks by analysing their likelihood of occurrence and potential impact, while also identifying appropriate mitigation strategies. The Matrix uses 3 different values: Low, Medium and High. In comparison to numbers, these methods provided a simple yet insightful way of estimating risks of their likelihood and impact. Quickly indicating what needs to be done if one of those risks should occur. **Table 2** and **Figure 13** below present the identified risks, their probability of occurrence, potential effects on the project, and recommended mitigation measures.

For a more comprehensive analysis and response plan for each identified risk, please consult the accompanying Excel document. This file provides an in-depth overview of the risk management strategies, ensuring the team is adequately prepared to address challenges that may arise during the project's execution.

Table 2: Risk Register

ID	Risks	Likelihood	Impact
1	Internal hardware malfunction (development tools or equipment)	Low	High
2	Software crashes or malfunction	Medium	High
3	Damage or destruction of equipment	Low	High
4	Limited access to essential resources and equipment.	Low	Medium
5	Extended absence of team members due to illness	Low	Low
6	Internal communication breakdown	Low	High
7	(External) Stakeholder communication breakdown	Low	High
8	Missed project deadlines	Low	Medium
9	Complete project failure	Low	High
10	Force majeure events	Low	High
11	Theft of equipment or resources	Low	High
12	Changes in the project's scope	Medium	High
13	Lack of user engagement during testing	Medium	Medium
14	Not enough expertise on technical front	Low	Medium



Impact (consequence/severity)			
High (We couldn't function or our mandate would have to change)	(3) Considerable management and monitoring required	(2) Manage and monitor risks (inform senior management)	(3) Extensive management (extensive senior management involvement)
Medium (We could still Function)	(3) Risk may be worth accepting with monitoring	(2) Management effort worthwhile, mitigate and monitor risks	(1) Must manage and monitor risk (inform senior management)
Low (Normal)	(1) Accept risks	(2) Accept but monitor risks	(1) Manage, mitigate and monitor risks
	Low (Normal or Unlikely)	**Medium** (Likely)	**High** (Very likely)

Likelihood (probability/frequency)

Figure 13: Risk Matrix

During the project, several challenges regarding the headsets have been encountered. Most of these challenges can be classified under two main categories: hardware and software challenges. Besides these main categories, which are directly caused by the headsets, neurodivergence has also been investigated. As neurodivergent students have a different sensory processing pattern, they might experience a different level of discomfort.

3. Research introduction

This chapter provides an overview of the research plans and conducted research carried out during this semester. It outlines the scope of research, the methodology employed, and the processes undertaken in pursuit of answers to key questions of importance for the success of the project. The chapter further expresses how brainstorming sessions, interviews, and testing phases informed the development of the educational VR experience.

3.1. Research Scope

It was an important requirement that the project needed a clear definition of the main questions that would have to be addressed before any development commenced. These critical areas of research were the result of analysis from the objectives and constraints within the project:

Target Age Group

- Who is the target audience for the VR program and supporting activities?
- What are their learning needs, cognitive abilities, and preferences?
- What adjustments in content and interaction levels may better suit their age and year of schooling?

Understanding the target demographic was vital in tailoring the program for optimal engagement and learning. This research focused on exploring cognitive development and educational interests in students aged 12–14, while making sure that both VR experiences and supplementary activities align with their capabilities and learning styles.

Hardware and Software

- What are the capabilities and limitations of the selected hardware, and how can they influence the program design?
- Which software platforms and tools will best support the development of an interactive and educational VR experience?
- Value and Relevance of VR. Exploring effective ways to utilize VR into the classroom settings while keeping it fun and engaging.

The Finnish Educational System & Curricular Alignment

- What are the main principles and methods of Finnish education?
- How does the VR application help fit curriculum intents with relevant methodologies of Finland? (STEAM)
- What are the expectations for student engagement and outcomes in Finnish classrooms?

3.2. Research Plan

The research design describes the methods applied and logical flow of activities conducted in view of responding to the project's objectives. The following are some of the essential components of the research design. The following points will be explored in greater detail in the subsequent chapters of this final report.

Preliminary Brainstorming Sessions:

- Potential ideas on the theme and structure of the VR program were identified.
- Key areas of focus were mapped out, including content delivery, interaction design, and curriculum integration.

Stakeholder Interviews:

- Interviews were conducted with educators, students, and industry professionals to gather insights into how VR integration might be realized in classrooms.
- Gathered feedback on early concepts, emphasizing engagement, clarity, and hardware considerations.

Testing and Iteration:

- Conducted testing of the VR experience with students and teachers, integrating feedback for future iterations.
- Focused on usability, motion sickness mitigation, content delivery, and hardware functionality.

Documentation and Reflection:

- Summarized findings and integrated them into the development process.
- Reflected on feedback to refine the educational and interactive elements of the program.

4. The Headsets

This lesson aims to use ClassVR headsets, these headsets are designed to be used in a classroom environment and offer great controls for the teachers. A picture of the VR headset can be seen in **Figure 14**.

Figure 14: The ClassVR headset

In comparison to other VR headsets, the functionality of ClassVR is relatively limited. The primary limitation lies in the inability of users to physically walk through 3D environments, as they are restricted to using "walk" buttons located on the sides of the headset. This restriction significantly decreases the immersiveness of the scenes.

The headsets do provide buttons for interacting with the scene, such as selecting objects, returning to a previous scene, and enabling gesture control. However, another notable drawback is the maximum recommended usage time, which is limited to 5–10 minutes (ClassVR, 2024). This is considerably shorter than the two-hour usage durations supported by modern VR glasses (Meta, 2024).

The main benefit of using the ClassVR headsets is the excellent teacher control options, as it is possible to control all ClassVR headsets on the local internet network from The Portal. In this portal, teachers can see live what all the students are doing and help them if required, resulting in an optimal teaching environment. The headsets are stored in a robust and secure charging case, as shown in **Figure 15**. This case facilitates the safe transport and charging of the headsets, ensuring their protection during transport and charging.


Figure 15: The ClassVR charging and carrying case

5. Designing software

There are three primary options for designing environments that can be displayed in a ClassVR headset. The first option is to use the built-in ClassVR 360° image (scene) display. Another option involves using ThingLink as the scene display method, which allows for the addition of interactive buttons within the scene. Both of these methods enable the use of high-resolution images, enhancing the immersiveness of the scene. The third option is to use CoSpaces, which offers lower resolution but supports TypeScript, providing high interactivity at the cost of reduced graphical immersion. The financial costs associated with these options are also considered.

In addition to these three display environments, the design of the environments themselves must be addressed. Paid VR sculpting environments can cost up to €100 per month (Adobe, 2024) or even €150 per month for more advanced design tools (Autodesk Maya, 2021). As a result, a decision was made to use free software, narrowing the options to Blender or Unreal Engine. Blender remains free even for commercial use (Foundation, Requirements — blender.org, 2019), while Unreal Engine is free only for small businesses and educational purposes (Engine, 2024). Given these conditions, both Blender and Unreal Engine were considered as potential design tools for the scenarios.

5.1. CoSpaces

The environment created in CoSpaces, referred to as a CoSpaces, enables the development of graphically stylized, cartoon-like 3D environments (scenarios). Within these scenarios, a basic version of TypeScript is used, providing high interactivity (CoSpaces, 2024). As a result, scenarios created in CoSpaces offer significant interactive features. An example of a CoSpaces scene is shown in **Figure 16**. (CoSpaces Edu, 2019)

Figure 16: Visualisation of a CoSpaces scene

The ability to use TypeScript in the scenario enables real-time calculations and moving elements. This display environment is particularly suited for concepts such as *Terra Nova*, *The "A Maze-ing Runner"*, and ionizing radiation, all of which require real-time calculations and/or dynamic elements.

An early example of one of these scenarios is shown in **Figure 17.** This scenario was created as a test for the ionizing radiation concept, where students could navigate the environment and experience "radiation damage" as they approached the source. In this example, the displayed text would update in real time, reflecting the distance between the student and the radiation source.

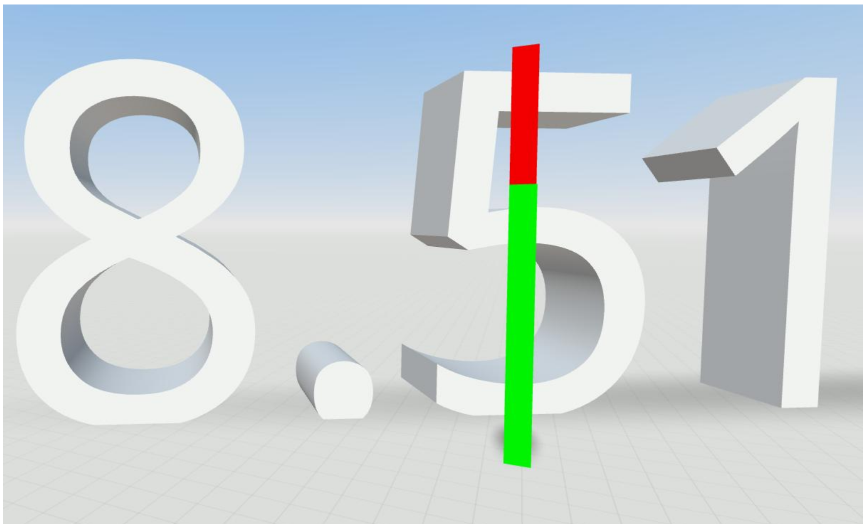


Figure 17: Example of a CoSpaces scenario

Pricing

The annual cost for CoSpaces is €50, which provides access for one account to develop scenarios. Additional developer accounts are available at a cost of €7 per year per account.

Challenges

There are several limitations in using CoSpaces, including the fact that it does not support all TypeScript functions (Paiva, 2017), and issues arise when loading a CoSpaces onto a ClassVR headset.

Limited TypeScript functionality

A primary limitation encountered with TypeScript in CoSpaces is the lack of support for connecting to external servers. As a result, it was not possible to create an external server to monitor students or enable interaction between students within the classroom via the internet or other headsets.

Loading issues

Another issue identified during the initial research was the headsets becoming stuck in a loading lobby before successfully connecting to a CoSpaces. This prevented a full evaluation of CoSpaces' functionality when used with ClassVR headsets.

5.2. ClassVR's built-in display

The built-in display allows for the viewing of 360° images, with the teacher having full control over which scene the students are viewing and when to transition to the next scene. This setup enables a more traditional lecture format, where the teacher speaks while the students observe and look around within the scene.

However, due to the similarity between this method and a conventional lecture, the added value of virtual reality (VR) is limited, especially when compared to other VR options. Furthermore, the interactivity in this method is minimal, as students are only able to look around without additional interactive elements.

The availability of VR headsets is also restricted, with only eight headsets available, one of which is currently not functioning properly, leaving only seven students able to participate in VR at a time. With an average class size of around 20 students, this limits the number of participants, leaving most of the class unable to join the lesson. Additionally, as the teacher is focused on delivering the VR lecture, supervision of the non-participating students is limited, assuming no other instructors are present.

Since this option is integrated into the headsets and the software is provided, there are no additional costs involved in using this method.

5.3. ThingLink

This option is similar to the built-in display, as it also allows for the viewing of 360° images. However, it offers the added functionality of interactive tags within the scenes. These tags, an example of which is shown in **Figure 18**, can be activated by the VR headsets using a button located on the left side of the headset.

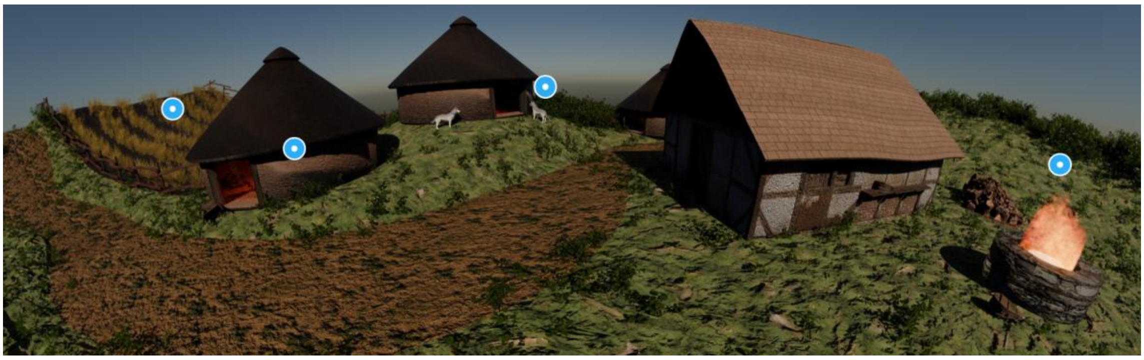


Figure 18: Sample scene created using ThingLink

By using these tags, the scene becomes interactive, allowing students to navigate through the content at their own pace. The tags serve three primary functions: providing information, enabling movement within a scene, and transitioning to the next scene.

The blue tags provide informational content about the object to which they are attached. For example, clicking the blue tag above the fire reveals an information block explaining that basic forging techniques were discovered during the time period depicted in the scene.

The orange tags allow students to move either within the scene or to a new scene. This functionality enhances the immersiveness of the experience, enabling users to explore the virtual environment at their own speed while using the VR glasses.

However, this option comes at a significantly higher cost, priced at around €39,- per month for the full package (Thinglink, A complete solution for accessible visual learning in the cloud, 2023), compared to the previously mentioned alternatives.

5.4. Unreal Engine

Unreal Engine is a CGI software package, but it is mainly designed for creating interactive 3D environments, such as video games, virtual reality experiences and simulations. Unreal Engine excels at real-time rendering, allowing designers to create immersive scenes that can adjust themselves to user interactions. This focus on real-time performance means that it requires powerful hardware on the user side, particularly for larger and/or highly detailed scenarios.

Unreal Engine has a steep learning curve. It offers a broad range of tools and features, with additional customization available in its visual scripting system, visible in **Figure 19**. This system is called “blueprints”, or traditional coding in C++ (Games, 2023).

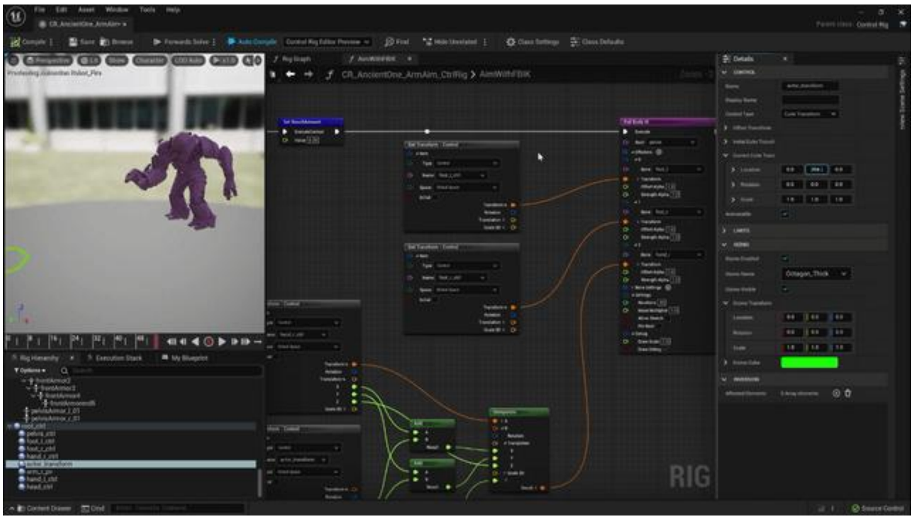


Figure 19: The unreal engine “blueprint” scripting system (madebyayan, 2021)

As Unreal Engine contains a lot of tools, developers can create anything they can envision, but due to the large number of options, this initial complexity can result in a negative experience for beginners.

5.4.1. Importing models

It is possible to import pre-existing models that fit the needs of the developers, using the Fab marketplace (Fab, 2024). By using this marketplace both free and paid models can be added to any scenario to create the required results. In addition to this, the creator of Unreal Engine releases new assets monthly (Epic games, 2023). Fab can be integrated directly into Unreal Engine, resulting in a good developer experience.

5.5. Blender

Blender is, like Unreal Engine, a CGI software package. Allowing designers to create complete custom scenes on their computers. As the main purpose of Blender is to create models, short videos and special effects for movies, it tries to be as realistic as possible. This results in the program being very intensive for computers, requiring very high-end hardware on the developer’s side.

Blender has a very steep learning curve, an example of this can be seen in **Figure 20**. There are a lot of options, with more options being hidden behind every option. Because of this, it is possible to create anything, once the developer has learned all the possibilities of the program. However, like Unreal Engine, this steep learning curve is a significant drawback for beginners (Foundation, blender.org - Home of the Blender project - Free and Open 3D Creation Software, 2019).

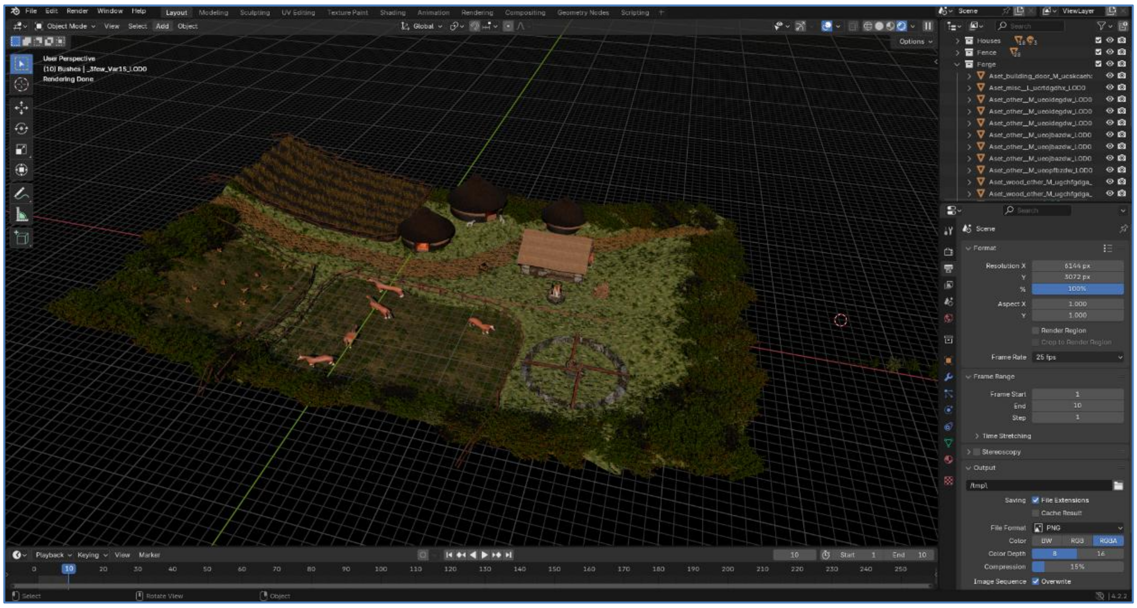


Figure 20: the main designer interface of blender

5.5.1. Importing models

As Blender is open source, it is possible for third parties to achieve a good implementation in the program itself. BlenderKit is an example of this, the extensive BlenderKit asset library, consisting of over 60 thousand additional assets (BlenderKit, 2024), which the developers can directly import from a user interface within Blender. There are similar libraries such as BlenderKit, each with their own specialties, these libraries add a lot of flexibility to the developers' specific needs.

6. The Finnish Education System

Understanding the structure, principles, and expectations of the Finnish education system was important for the development of a VR-based educational program that would be in line with its objectives. The research involved direct interviews with educators and experts; these provided valuable insight into how VR can be effectively integrated into classroom settings. This chapter explores the interview process, summarizes key findings, and presents conclusions that shaped the project's development.

6.1. Interviews

The interview opportunities came about with the help of **Jenny Rönnqvist-Norrby,** who supported the identification of the right stakeholders to be interviewed. Her guidance had a lot of value in insights related to the Finnish educational system, thus enabling the team to understand its structure, principles, and how it works in real life. This collaboration has added much value to the development of a curriculum-aligned and contextually relevant VR educational program. Interviews were conducted with four different stakeholders:

Markus Norrby

Teacher of physics and mathematics at Vasa övningsskola. Teacher in Physics and Mathematics at Vasa övningsskola (Gymnasium). Markus contributed his experience in teaching and his involvement in school-based development projects. He provided detailed insights into the Finnish curriculum, particularly in science education, and discussed how VR could support interdisciplinary learning. Markus also shared his experience with VR hardware, such as Meta Quest 3, offering valuable technical recommendations.

Mikaela Nickull

Teacher of mathematics, physics, and chemistry at Borgaregatans Skola (year 7–9). Mikaela brought her expertise in teaching younger students and emphasized the importance of hands-on activities and group collaboration in learning. Her suggestions about fostering creativity through practical projects and integrating energy education into daily lessons were pivotal for designing complementary activities outside of VR.

Maiju Rintala

Digi-pedagogical developer for the City of Vaasa. Maiju shared her expertise in digital pedagogy and curriculum development, particularly in integrating energy education into the Finnish curriculum. She highlighted the role of Vaasa's energy cluster in providing a local context for learning, as well as the importance of aligning VR content with curriculum goals to maximize its educational impact.

Leena Nyqvist

Leena introduced the team to the project supervisor and gave a guided tour of the Ostrobothnia Museum. With her guidance, innovative concepts were explored: a VR-based historical escape room or a guided museum-like tour. These ideas combine storytelling, historical education, and interactive technology, thus forming the basis for the unique approach of this project in tying history with VR.

Objectives of the Interviews

- To explore how energy education is currently taught in Finnish schools.
- To identify opportunities for VR to enhance learning outcomes.
- To gather feedback on the curriculum alignment, hardware usability, and classroom integration.

Key Topics Discusses

- Finnish curriculum expectations and the integration of interdisciplinary learning.
- Practical applications of VR in classrooms, including its benefits and limitations.
- Challenges related to hardware, software, and classroom dynamics.
- Suggestions for content design and inclusivity.

6.2. Results

The information that came from the interviews and consultations with stakeholders provided such valuable insights into the development of the VR educational program. These are then categorized for the curriculum alignment, practical applications of VR, classroom dynamics, and hardware/software challenges to show how this project has addressed such critical areas.

Curriculum Alignment

- **Energy Education Across Grade Levels:** The Finnish national curriculum integrates energy education at multiple levels (e.g., grades 2, 5, and 9) with objectives focusing on energy concepts, sustainability, and STEM integration. These themes align with the VR program, which explores energy advancements across historical eras, from the discovery of fire to modern sustainable solutions. (Rintala, 2024), (Norrby, 2024)
- **Curriculum Mapping:** Teachers recommended mapping VR content explicitly to Finnish curriculum goals, such as promoting inquiry-based learning, scientific literacy, and cross-disciplinary collaboration. By focusing on key milestones in energy history, such as the use of windmills, steam engines, and renewable energy sources, the VR program can serve as an educational tool that complements lessons in physics, history, and technology. (Norrby, 2024), (Nickull, 2024)

- **Regional Relevance:** Maiju Rintala emphasized the importance of connecting the program to Vaasa's energy cluster, a leading hub in sustainable energy innovation. This local focus not only adds real-world relevance but also introduces students to potential career paths in energy and technology. (Rintala, 2024)

Practical Applications of VR

- **Enhanced Engagement:** VR was identified as a powerful tool for increasing student engagement. By allowing students to immerse themselves in historical environments and interact with points of interest, the program fosters curiosity and makes abstract concepts tangible. Teachers emphasized the importance of pairing VR experiences with hands-on activities to reinforce learning. (Nickull, 2024)
- **Accessibility Options**: Recognizing that not all students may be able to use VR headsets due to motion sickness or other limitations, stakeholders suggested creating alternatives using tablets or laptops. This ensures inclusivity while preserving the program's educational goals. (Nickull, 2024)

Hardware and Software Challenges

Hardware Limitations: The ClassVR headsets used for the project were noted as outdated, with limited resolution and static environments that could cause discomfort for users. While functional as a proof of concept, these limitations highlighted the need for more advanced hardware, such as Meta Quest 3 headsets, which offer better graphics, interactivity, and usability. (Norrby, 2024)

Privacy Concerns: GDPR compliance issues with ClassVR were flagged as a major barrier to adoption in Finnish schools, as their data management processes do not meet the stringent privacy standards required for minors. Stakeholders recommended transitioning to more compliant platforms for broader implementation. (Norrby, 2024)

Technological Constraints: Despite the challenges posed by ClassVR, the program was designed to be adaptable across platforms using ThingLink, a tool that enables the creation of 360-degree environments. This ensures that the content can be deployed on more versatile and powerful devices in the future. (Norrby, 2024)

6.3. Conclusion

The VR-based education program was developed with deep insights into the Finnish education system through interviews with key stakeholders. The discussions have given invaluable insight into aligning the program with the curriculum goals, integrating innovative teaching methods, and dealing with challenges relating to hardware and inclusivity.

Energy education, historical storytelling, and interactive technology merged through educators and experts into an engaging VR experience that could be scaled. Not without its challenges, such as hardware limitations, the program offers a very practical and impactful tool to enhance classroom learning and support Finland's emphasis on interdisciplinary, inquiry-based education. This collaboration shows how VR has the potential to revolutionize traditional teaching while adhering to modern educational standards.

7. Developed Concepts for VR

The team was tasked with developing three potential concepts that align with the objectives of LUMA, aimed at finding a practical use for the ClassVR headsets and creating a lesson based on a STEAM-related topic. As a result, the group proposed three distinct concepts, each focused on a different area within STEAM.

7.1. A-Maze-ing Runner

Developing the concept for "A Maze-ing Runner" was an engaging yet challenging process that required extensive brainstorming. The team aimed to teach coding through gaming, focusing on making programming accessible and enjoyable for children aged 8 to 12. A hands-on, interactive approach was chosen, utilizing a Kubo bot to navigate a maze. This design simplified coding structures and transformed the learning experience into a playful activity. **(Figure 21)**

During the brainstorming phase, various directions were considered: Should the activity emphasize individual problem-solving or collaboration? Would incorporating virtual reality (VR) enhance or detract from the learning experience? To refine these ideas, the team relied on sketches, post-it notes, and group discussions, documenting every thought visually a process that proved invaluable during later stages.

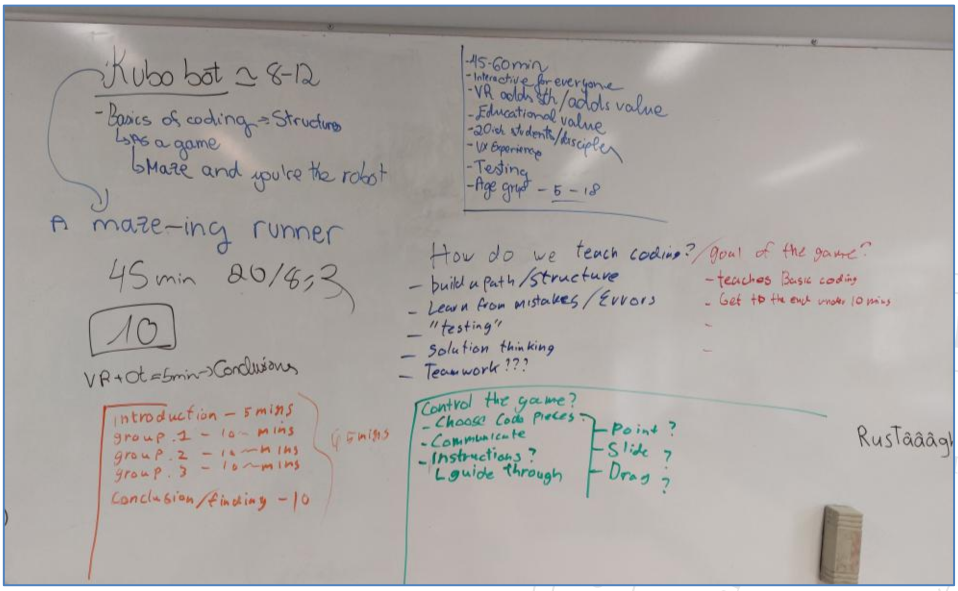


Figure 21: A-Maze-ing Runner Brainstorm

The strength of game-based learning emerged as a key factor. The maze design provided an engaging and intuitive metaphor for coding principles, capitalizing on children's natural affinity for games. However, not all ideas were successful. Initial concepts centered on purely digital coding platforms, but these lacked the tactile, trial-and-error experiences essential for younger learners. Similarly, early VR concepts proved too advanced and overwhelming for the target age group, leading to a simplified VR component designed to complement rather than dominate the activity.

The final structure achieved a balanced approach: beginning with a VR maze challenge to ignite curiosity, transitioning into collaborative programming of the bot, and concluding with a reflection phase to consolidate learning. This iterative process mirrored the nature of coding itself—debugging and refining until the concept effectively fostered logical thinking, teamwork, and problem-solving in a fun and memorable manner.

7.2. Ionizing Radiation

Developing the "Ionizing Radiation" lesson concept proved to be the most challenging brainstorming session undertaken by the team. The goal was to create an immersive learning experience for students aged 15 to 18 that balanced the intricate scientific principles of radiation with hands-on activities and virtual reality (VR). However, translating such an abstract and technical subject into an engaging and age-appropriate format required numerous iterations.

From the outset, the complexity of the topic presented significant obstacles. Introducing concepts such as nuclear decay, half-value thickness, and radiation protection without overwhelming students was a persistent challenge. The inclusion of VR added further difficulty—adapting such intricate ideas into a virtual format that was accurate, safe, and educational demanded careful planning.

During brainstorming, the team explored various approaches, utilizing diagrams and flowcharts to break the lesson into manageable segments. An early idea focused entirely on VR, but it became evident that achieving the necessary realism to represent radiation effects might render the activity too abstract or disconnected from real-world applications. Alternatively, relying solely on physical experiments felt too restrictive, as safely exploring the full spectrum of radiation concepts was not feasible.

What ultimately succeeded was combining the strengths of both approaches. VR was employed to simulate environments and phenomena, such as nuclear decay and radiation shielding, allowing students to explore high-risk scenarios safely. These simulations were paired with physical assignments involving low-intensity radioactive materials. Hands-on experiments, such as observing particles in a cloud chamber or simulating carbon dating, provided tangible experiences that grounded the theoretical concepts.

The brainstorming process was characterized by trial and error. Simplifying the VR tasks to make them accessible while preserving scientific accuracy required multiple refinements.

To mitigate the risk of information overload, the lesson was structured into rotating assignments that integrated theory, experimentation, and reflection.

Ultimately, the concept coalesced into a balanced blend of VR and physical activities. This structure enables students to develop a comprehensive understanding of radiation's properties, applications, and risks through interactive and inquiry-based learning. Although the development process was the most demanding, its complexity drove the creation of a lesson that is innovative, immersive, and scientifically rigorous.

7.3. Evolution of Energy Technology

Unlike some previous concepts, the development of the "Evolution of Energy Technology Through the Years" lesson progressed with notable ease. From the outset, the team recognized the importance of creating a visually compelling and interactive experience to make the history of energy technology both accessible and engaging for students aged 12 to 14.

The concept of utilizing a VR rollercoaster ride to guide students through historical epochs emerged as a particularly suitable approach. This method seamlessly integrated storytelling with technology, immersing students in pivotal moments of energy innovation—ranging from early human discoveries, such as fire and the wheel, to industrialization and renewable energy advancements. During the brainstorming process, this idea was received with enthusiasm, as it fulfilled key objectives of being both educational and entertaining.

The structure of the lesson was also quickly established. It incorporated an introductory session to provide context, followed by the VR experience to captivate students, a quiz to reinforce understanding, and hands-on activities to deepen exploration of key concepts. This multimodal approach—combining visual, practical, and reflective elements—was designed to accommodate diverse learning styles and ensure the material was memorable.

The brainstorming process benefited greatly from the clarity of the central theme and the straightforward execution of the ideas. The VR rollercoaster concept served as a robust framework around which the other activities were developed. The primary challenge lay in ensuring the VR segments were both age-appropriate and rich in educational value. However, the interactive nature of the experience effectively conveyed the progression of energy technologies without overwhelming students.

In summary, this lesson was one of the most seamless concepts to develop. The integration of VR with practical activities resulted in a cohesive and engaging approach to teaching the historical and modern contexts of energy technology. The ease of both brainstorming and refining this concept underscored the effectiveness of a clear and captivating theme in the lesson design process.

7.4. The Chosen Concept

The "Evolution of Energy Technology" lesson was selected by LUMA because it aligns perfectly with the organization's mission and educational goals. Several factors made this topic an ideal choice:

1. **Alignment with STEAM Education:** The lesson embodies the principles of STEAM (Science, Technology, Engineering, Arts, and Mathematics) by integrating scientific concepts with technological innovation and creative storytelling. It introduces students to the historical and technical aspects of energy development while engaging them through immersive VR technology, hands-on activities, and reflective discussions. This multidisciplinary approach makes it a perfect fit for LUMA's commitment to promoting STEAM education.
2. **Relevance to Vaasa's Energy Sector:** Vaasa is a hub for energy technology and innovation, making this topic particularly significant for the region. By exploring the evolution of energy technology, students gain an appreciation for the role energy plays in shaping societies, with a focus on how these advancements impact their own community. The lesson also fosters awareness of the challenges and opportunities in sustainable energy, which aligns with Vaasa's focus on being a leader in green energy solutions.
3. **An Engaging and Innovative Concept:** The idea of taking students on a historical journey through energy technologies, enhanced by cutting-edge VR tools, is both engaging and innovative. The combination of immersive experiences and practical activities creates a dynamic learning environment that sparks curiosity and fosters critical thinking. The original rollercoaster VR idea and its modified storyline version both deliver a memorable experience, making this lesson stand out as a unique educational tool.
4. **Importance of Energy Education for the Future:** Energy is a fundamental topic for students to understand, as it directly influences global challenges like climate change, resource management, and technological innovation. This lesson helps students grasp the historical context of energy use while encouraging them to think critically about the future of energy.

By selecting this topic, LUMA not only supports its goals of fostering interest in science and technology but also highlights an issue of great local and global significance, inspiring the next generation to think creatively and critically about energy and its role in society.

8. Evolution of Energy Technology

The concept of "Energy Technology" was developed through extensive and constructive team discussions, aiming to create a comprehensive lesson that explores the evolution of energy across eras. The central idea was to frame each significant energy transition—fire, animal power, windmills, steam, and electricity—as distinct "eras," providing a narrative structure that students aged 12 to 14 could easily follow and engage with.

The decision to define an "era" as a period marked by a new dominant energy source emerged from discussions about how to simplify complex historical transitions. The team recognized that while technological advancements often overlap, categorizing them by their primary energy driver would offer clarity. This approach also allowed the team to emphasize the transformative impact of each energy source on human society and technological progress.

During brainstorming sessions, the team debated various ways to represent these transitions. Early discussions highlighted the need to balance historical accuracy with accessibility. Visual aids, such as timelines **(Figure 22)** and diagrams, were proposed to illustrate how each era introduced new possibilities and challenges for humanity. For example, the "fire era" was defined not just by the discovery of fire but by its applications in cooking, warmth, and protection, which fundamentally shaped early human life. Similarly, the era of "animal power" marked the first energy transition, enabling greater agricultural productivity and societal organization.

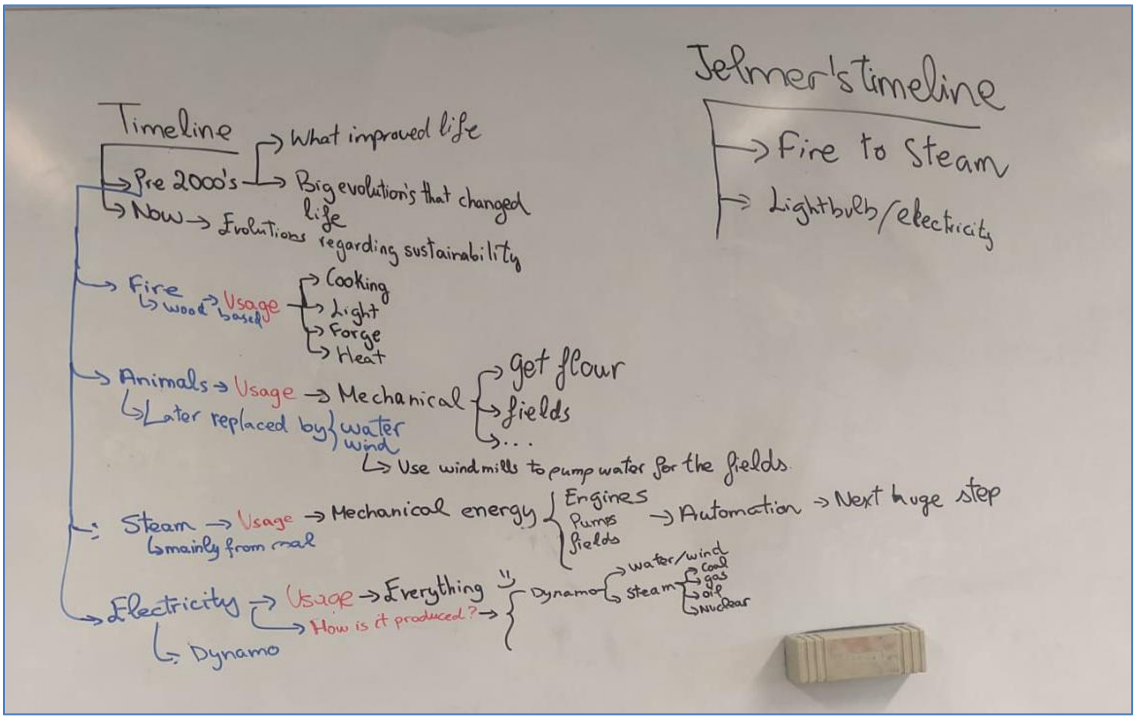


Figure 22: Initial Timeline for the lesson.

The team reached these conclusions by evaluating the educational objectives of the lesson alongside the developmental stage of the target audience. Constructive dialogue ensured that each proposed idea was critiqued and refined. For instance, the inclusion of a script explaining "What is an era?" arose from the recognition that students might struggle to grasp abstract concepts. The script was designed to contextualize each era within a broader historical framework, using relatable examples to bridge the gap between abstract concepts and tangible outcomes.

Ultimately, this collaborative process resulted in a structured lesson that uses the concept of eras to make the evolution of energy both accessible and engaging. The integration of historical narratives, interactive activities, and VR experiences ensures a multi-faceted approach that caters to diverse learning styles while maintaining educational rigor.

8.1. The story

The development of the narrative for the "Time Glasses" concept was a carefully considered outcome of collaborative team discussions, aimed at creating an engaging and immersive framework for teaching energy technology. Recognizing the potential limitations of presenting historical developments as isolated facts, the team sought a dynamic storytelling approach that could simultaneously captivate and educate students aged 12 to 14. This led to the creation of the EvoTech storyline, which integrates the imaginative use of virtual reality (VR) to provide historical context and foster a sense of active participation in solving modern energy challenges.

The concept of EvoTech—a visionary energy solutions company—arose from discussions about how to bridge past advancements with the present need for sustainable practices. By placing students in the role of EvoTech scientists, the lesson encourages critical thinking and problem-solving, aligning the narrative with real-world applications. The decision to introduce "Time Glasses" as a narrative device stemmed from the team's exploration of how to effectively incorporate VR technology. The glasses serve as a mechanism for time travel, allowing students to observe pivotal moments in energy history firsthand. Additionally, creating a logo for EvoTech using LogoAI.com adds a layer of realism that can further immerse students in the storyline. **(Figure 23**) There is no significant meaning behind the design of the logo. Only that it should resemble how logos are designed today. Minimalistic and easy to recognize.

Figure 23: Logo EvoTech

The narrative begins with students joining EvoTech as new scientists tasked with addressing global energy challenges. As part of their induction, students are introduced to the revolutionary Time Glasses, which grant access to key historical periods in energy development. Through these glasses, students journey to observe critical milestones, including the discovery and early uses of fire in the Pleistocene, the domestication of animals during agricultural advancements, the utilization of windmills and watermills in medieval times, the industrial revolution driven by steam engines, and the emergence of electricity and nuclear power. The journey culminates in an exploration of modern renewable energy sources such as solar, wind, and hydrogen technologies, emphasizing their role in addressing contemporary sustainability concerns.

The narrative design emphasizes the iterative nature of technological progress, illustrating how each era built upon prior advancements while solving new challenges. The immersive framework enables students to contextualize these transitions within a broader historical and societal framework. Moreover, the narrative reinforces the mission of EvoTech by encouraging students to reflect on how lessons from the past can inform innovative solutions for the future.

The development of this narrative was the result of an iterative brainstorming process that prioritized both creativity and pedagogical objectives. Through constructive discussions, the team ensured the storyline was deeply integrated with the lesson's educational goals, providing students with an engaging, imaginative, and academically rigorous learning experience.

8.2. Environment Design

For each era, an environment was designed with specific requirements, while employing a consistent methodology throughout. The design process began with thorough research to identify the significant energy evolutions characteristic of the era. Once these key evolutions were established, a brainstorming session was conducted to determine how best to represent these changes visually and to select the optimal surrounding environment for each scenario.

The design phase involved choosing the most suitable computer-generated imagery (CGI) software. Blender and Unreal Engine were evaluated for this purpose. Blender was ultimately selected due to its superior graphical capabilities for static images, robust open-source community support (Nguyen, 2024), and its simpler rendering process for virtual reality (VR) glasses compared to Unreal Engine.

To achieve optimal results, several of Blender's technical features were utilized during the creation of the scenarios. However, significant hardware limitations were encountered during the design process. These challenges were mitigated by using a remote computer and leveraging Blender's built-in asset management tools, which helped streamline resource usage and enhance overall efficiency.

Following the design of the 3D environments (scenarios), 360° images (scenes) were rendered for each era. Depending on the complexity and content of the scenario, multiple scenes could be created for a single scenario. This rendering process was completed using Blender's built-in rendering tool.

8.3. Designing the scenes

The design of each scenario and the corresponding scenes adhered to a consistent process. The initial step involved identifying the major changes within the era and determining how these changes should be visualized in the final scene. Next, the surrounding environment was conceptualized to complement the primary elements of the era. Finally, the scenario was developed, integrating the established elements into a cohesive design.

A key feature utilized across all scenes was the ability to import materials along with their associated attributes, such as surface displacement, roughness, and opacity, using

Blender's shader editor. This tool provided flexibility and precision in creating realistic textures and visual effects. An example of the shader editor interface is shown in **Figure 24**.

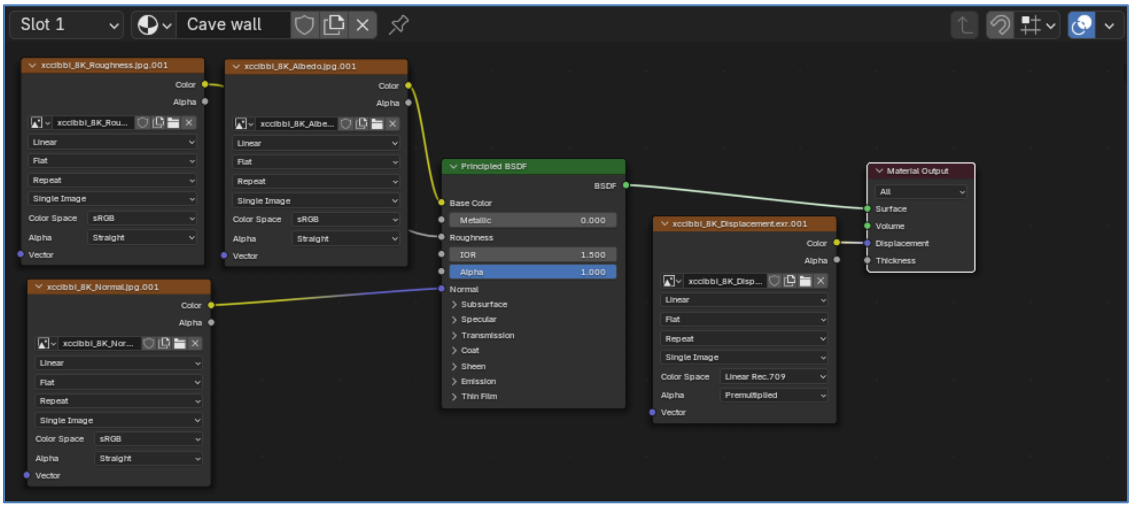


Figure 24: The shader editor

The shader editor in Blender enables the importation of various types of surface information, such as the Albedo texture (the base colour of a surface), normals, which Blender uses to calculate light reflection on the surface, and other properties essential for a specific model (ALL3DP, 2021). This process is accomplished using the Image Texture node, represented by the brown nodes in **Figure 24.** These nodes are combined in the green Principled BSDF shader to define the material properties, and the displacement values are integrated through the Material Output node to complete the material setup.

8.3.1. The Cave Scene (Prehistory)

Following the brainstorming session, it was determined that displaying the scene in a cave-like environment would be the most suitable option. This design choice reflects how humans lived approximately 300,000 years ago while being relatively straightforward to model in Blender. The cave includes a fire and a torch to symbolize fire as both a primary heat/energy source and a source of light during that era. A section of the final cave scene is presented in **Figure 25**.

Figure 25:The Cave scene

Used techniques

The primary tools used in Blender for this scenario included the sculpting tool, which was essential for creating the rough and uneven surfaces of the cave walls, as well as fluid baking tool for designing the fire.

The sculpting tool

The interface for Blender's sculpting tool is shown in **Figure 26**. This tool enables users to manipulate 3D models as if working with digital clay, making it particularly effective for designing organic forms such as environments, surfaces, and characters. By utilizing various brushes, the tool allows for precise adjustments to the model's surface, enabling diverse manipulations to achieve the desired texture and detail.

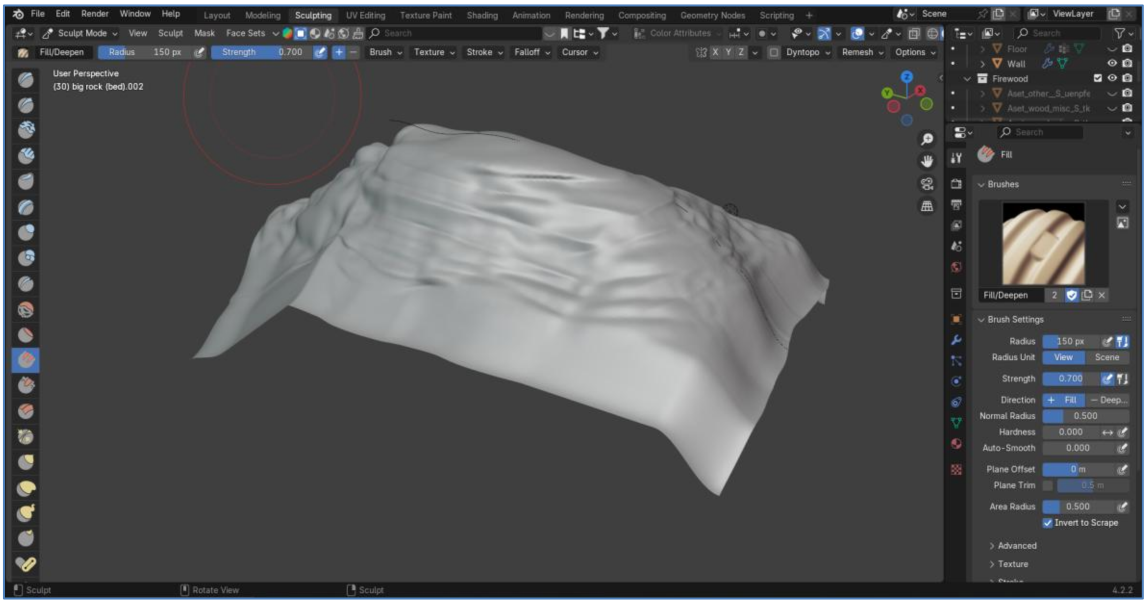


Figure 26: The blender sculpting tool

The primary brushes utilized for designing the cave were the Draw Sharp and Scrape brushes. The Draw Sharp brush was employed to create the line-like indentations along the cave walls, contributing to the rough, overhanging texture characteristic of natural cave surfaces. The Scrape brush, on the other hand, was used to craft the top of the cave, providing a scraped yet flat appearance. The combination of these brushes, along with the built-in displacement properties of the imported surface textures, resulted in the creation of a realistic and visually detailed digital cave.

The fluid baking tool

Blender provides a feature for creating realistic fire effects through a process known as baking. This process involves placing fire sources within a defined domain. The fire sources are set as fluid inflows with the inflow type configured to "fire + smoke," and the domain is specified as a gas, as highlighted in **Figure 27.** Once the inflow and domain are defined, various parameters can be adjusted to refine the fire's characteristics. These parameters include vorticity, buoyancy, and noise, the latter of which is added to introduce randomness to the flames. The resulting baked fire effect, as displayed in the editor, is shown in **Figure 27**.

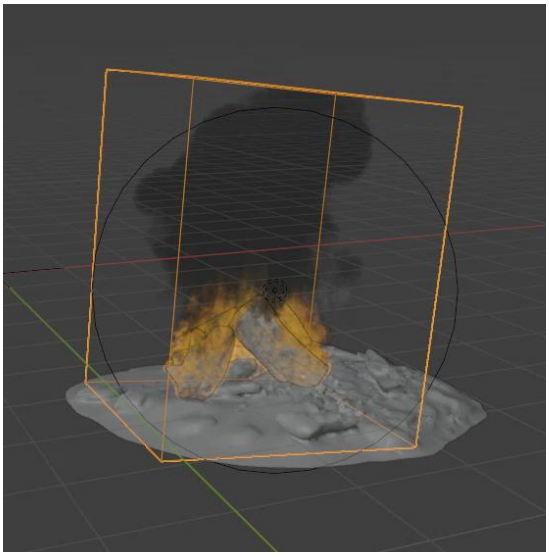


Figure 27: Result of Baking Process in Blender Editor

After completing the fire baking process, it was observed that the fire appeared more visually effective without the inclusion of smoke. This adjustment emphasized the primary goals of showcasing the evolution of fire as a source of light and heat. To achieve this effect, the smoke was removed by assigning an orange flow exclusively to the flame attribute of the fire, leaving the smoke attribute unutilized.

8.3.2. The Farm scene (First Civilizations)

Similar to the fire era, the design of this scenario began with a brainstorming session to determine the content requirements. During this period, animals were increasingly used to assist with human labour, allowing individuals to perform more tasks and leading to the emergence of the first small villages. Additionally, the first rudimentary forges were developed.

To visually represent these advancements in energy technology, the second scenario is set in a farm environment. This setting features a relatively large farm, made possible using animals for ploughing the fields, as well as an animal-powered mill to process the grain. The environment also includes a small town, an old forge, and domesticated dogs to assist in hunting. A depiction of the farm scenario is shown in **Figure 28**.

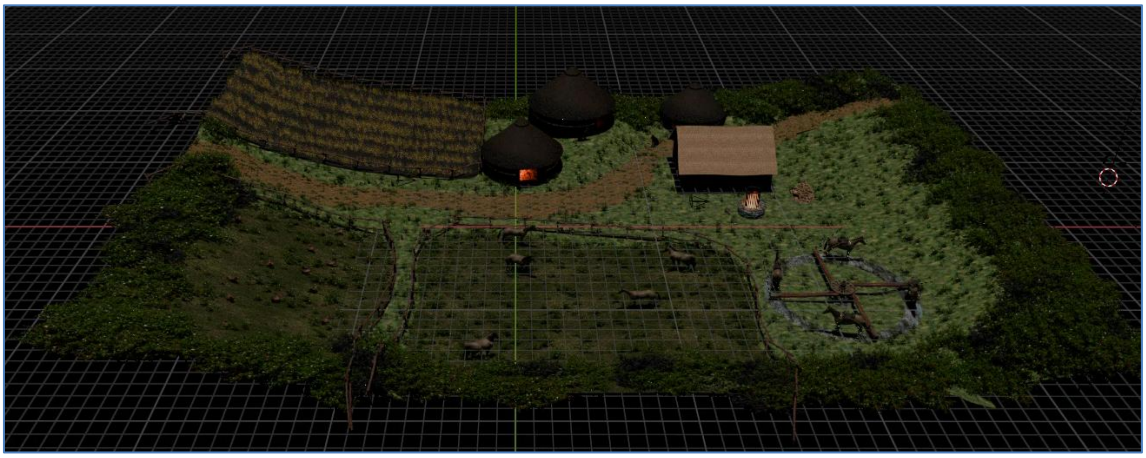


Figure 28: Farm scene in the Blender viewport

Used techniques

The primary feature used in Blender for this scenario was the ability to surface scatter models using geometry nodes. This is the only scene to incorporate a skybox— a large, cube-shaped image that surrounds the environment to simulate distant horizons, skies, or other expansive backgrounds. The use of a skybox creates the illusion of a vast and immersive world without the need for rendering distant objects (Smith, 2024). In addition to these new techniques, the fluid baking tool, as used in the fire era, was employed for the fire in the forge.

Surface scattering

In Blender, surface scattering is achieved by distributing points across a surface, a process that can be done within the Geometry Nodes tab. This begins with basic geometry as the group input and is transformed into a combination of points positioned on the face of the model. By using a series of nodes, this technique allows for complex, organic surface details.

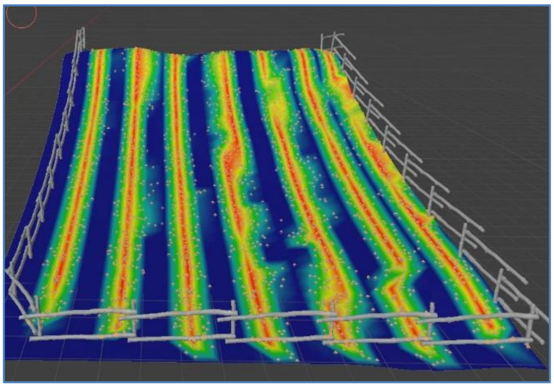


Figure 29: Weight painting in Blender

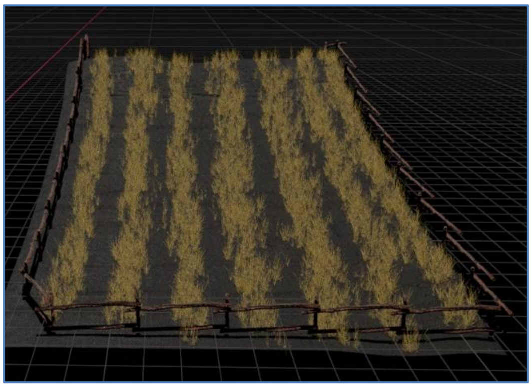


Figure 30: Final result of the surface scatter

When using weight painting, as shown in **Figure 29,** the position of the points can be controlled to align with specific patterns, such as creating lines. These lines represent the ploughing tracks made by animals in these times.

These points can then be converted into objects, in this case, wheat. The wheat models are imported into the scene and placed out of sight from the user, as only the instances of the wheat are positioned on the predefined points. Once the wheat is placed on the points, the final result is shown in **Figure 30**. The node layout in the geometry nodes can be found **[Appendix H].**

Adding a skybox

A skybox can be added by directly importing a texture from BlenderKit. This process is straightforward but significantly enhances the immersion of a scene. The difference between having and not having a skybox is illustrated in **Figures 31 and 32**.

Figure 31: farm scene with skybox

Figure 32: farm scene without skybox

8.3.3. The Village Scene (Middle Ages)

Following the farm scene, the medieval era focuses on the harnessing of natural forces, such as wind and water, and converting them into mechanical energy. This advancement significantly improved the efficiency of processing wheat into flour and cutting logs into timber, facilitating the growth and prosperity of large cities.

This era was represented through the creation of a detailed scenario, which included a larger farm than in the previous era, a sizable town relying heavily on assets imported from the BlenderKit library, and a sawmill adjacent to a partially deforested area.

Each of these elements was rendered as a distinct scene, separated by a procedurally generated river. Each element has their own painted surface, to decrease the total amount of elements in the scene. This approach provided a unique immersive experience for each scene while maintaining a cohesive connection between them. The full scenario is depicted in **Figure 33.**

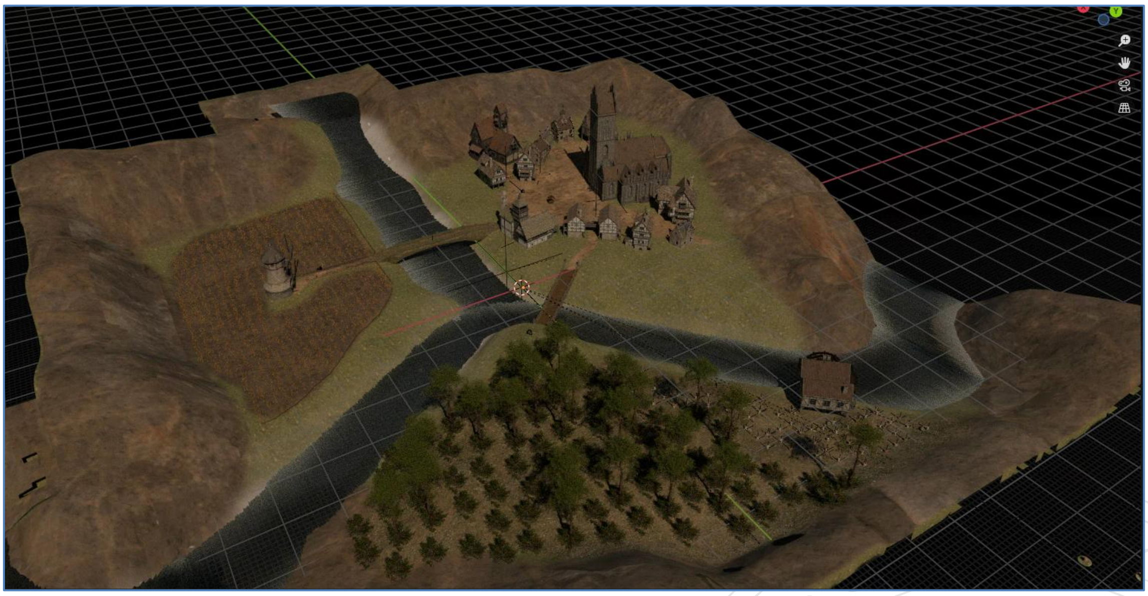


Figure 33: The medieval scene from the blender viewport

Used techniques

Some of the techniques previously described, such as a skybox, surface scattering and sculpting, were also utilized in this scenario. However, additional Blender tools were employed to achieve optimal results.

Surface painting

The main surface of this scenario is composed of multiple textures, as shown in **Figure 34,** where each element features a unique surface texture. Each surface was defined individually by applying a surface paint to the primary object. This process involved manually painting the object with a black-and-white mask, after which the actual surface texture was imported and applied to the white areas of the mask. An example of a surface paint is provided in **Figure 35**.

Figure 34: painted surface of the medieval scenario

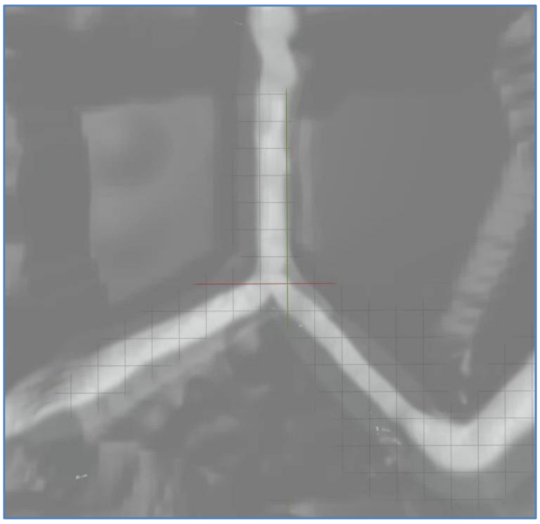


Figure 35: surface paint indicating where a riverbed texture is to be displayed

These surface paints were then combined in Blender's shading editor by linking a series of node setups such as **Figure 35** to create an intricate node tree. This full intricate node tree is presented in **[Appendix H]**.

Importing models

Nearly all detailed models featured in this scenario, including the church, houses, woodcutter, windmill, bridges, and trees, were imported from BlenderKit. Utilizing this asset library significantly reduced the workload during the design process while maintaining the quality of the final result.

The procedural river

Generating the river in this scenario posed a significant challenge. Initially, the fluid baking tool was used; however, this caused water to spill across the entire scenario rather than remaining within the riverbed, as shown in **Figure 36**.Since fluid baking was not viable, the river was procedurally created using a Bézier curve, a mathematical curve commonly employed in computer graphics to draw smooth, curved shapes using the Bézier algorithm (Lens & Adriaensen, 2023).

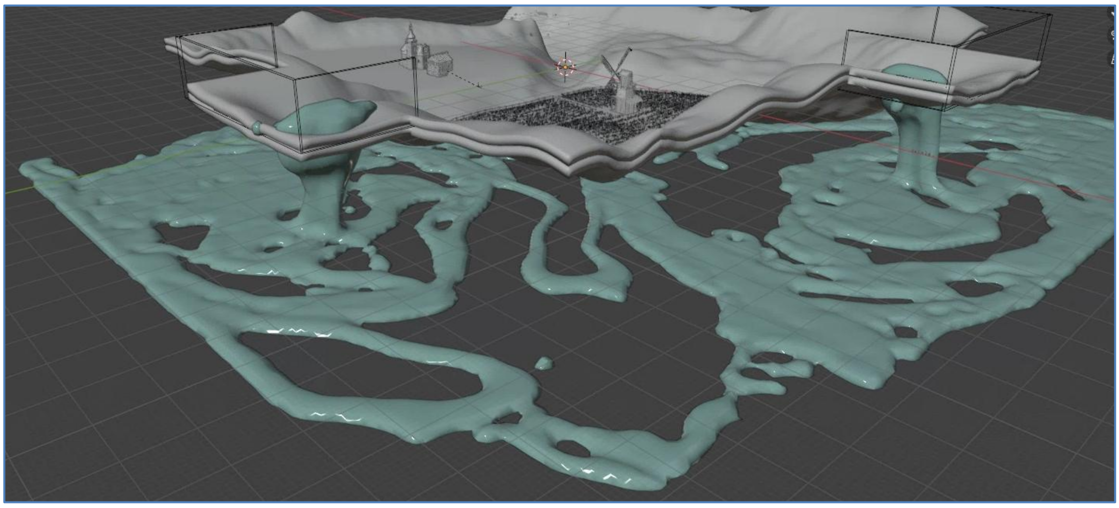


Figure 36: The water not working properly in the medieval scene

The process began with placing a Bézier curve along the desired riverbed path. This curve was then perpendicularly extruded to form a mesh that followed the curve's trajectory. As the mesh was initially flat, a river-like texture was added. Noise Textures were applied to the mesh, designed to simulate realistic wave behaviour by varying the flow speed, faster in the center and slower near the edges. By combining two Noise Textures with different heights and flow speeds, an almost realistic appearance for the river was achieved.

Once the river texture was complete, the river material was created by making the surface both reflective and transmissive. This was combined with a distinct riverbed texture, resulting in a water-like appearance. To simulate the movement of flowing water, white highlights were added to the edges and peaks of the river. Due to a lack of design experience, imperfections were noticeable, particularly at the junction where the rivers meet, as shown in **Figure 37**. However, these issues were mitigated in the final product by carefully positioning the camera to avoid displaying these areas.

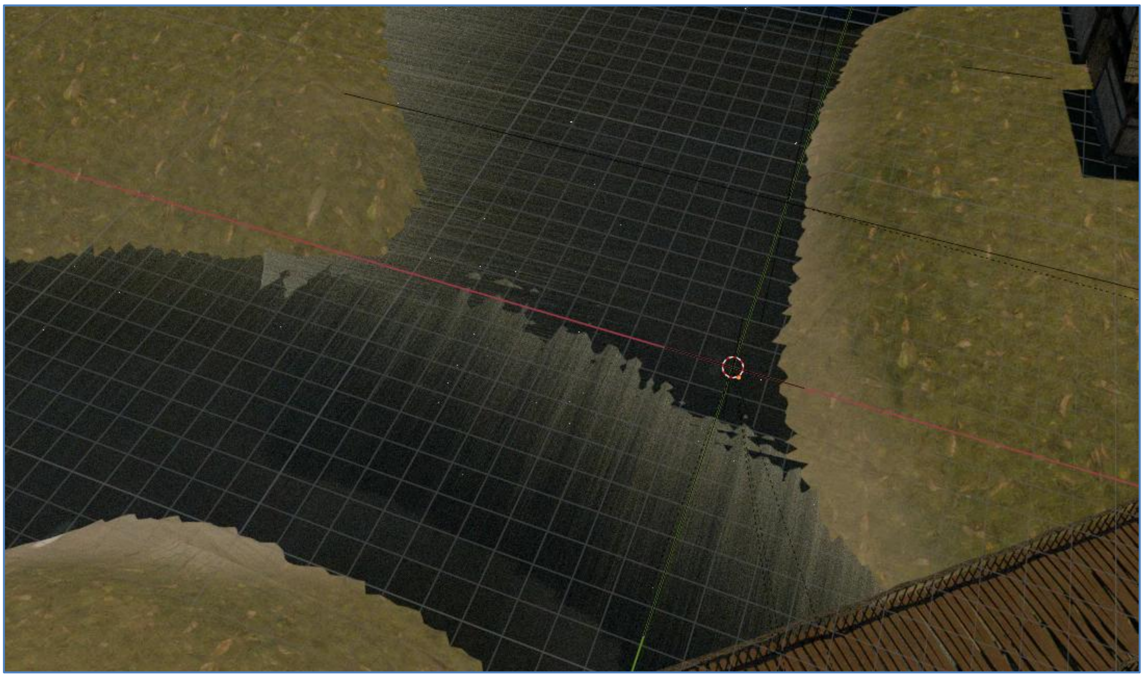


Figure 37: the imperfect meeting point of the two rivers

Main challenges

This scenario was the first to present significant design challenges, primarily due to the limitations of the hardware used in combination with the large scale of the environment. These constraints resulted in the scenario having a slightly lower overall quality compared to the other eras.

The most notable challenge was the limited availability of GPU memory. For example, it was not possible to add decorative grass sprouts to the grass texture, leading to a flatter and slightly less realistic appearance in the environment. However, this decrease in realism was mitigated by the inclusion of highly detailed imported models within the town, which helped maintain an immersive experience for the user.

8.3.4. The Factory Scene (Industrial Revolution)

The next significant evolution in energy technology was the use of steam engines to generate mechanical energy. The primary distinction between this scenario and the previous three is the shift in focus, not only on what creates the energy but also on how this energy is utilized. While steam was generated using various fuel sources during this period, only the primary fuel source, coal, is depicted in the scene.

The main applications of steam-powered mechanical energy included steam locomotives, which revolutionized the transport of people and goods, and the development of early electrical appliances such as streetlights and telegraphs. These advancements are represented in the scene, which is divided into two parts: an outdoor factory area and an indoor office area. Both scenes are shown in **Figure 38 and Figure 39**.

Figure 38: The inside scene of the industrial scenario

Figure 39: The outside scene of the industrial scenario

Used techniques

Similar to the medieval scene, several previously employed techniques were utilized in this scenario. A variation of surface scattering was applied to create the coal piles, while procedural generation was used to generate multiple windows, reducing graphical intensity. The baking of smoke was employed to simulate locomotive emissions, and a few models were imported from BlenderKit. Additionally, to create the impression of smog in the air, a scattered volume was added to the environment.

Volume scattering

As coal burning was the primary fuel source for steam engines, the atmosphere often contained a significant concentration of microscopic smoke particles. These particles refract light, creating a smog-like texture in the sky. This refractive effect was implemented in the scenario by introducing a low-density orange volume. This volume simulates the presence of light-refracting particles throughout the scene, effectively recreating the smog-like appearance of the sky.

Multi layered surface scattering

Piles of coal, as shown in **Figure 40,** were created using three layers of surface scattering. Four slightly different types of coal were applied to a sculpted surface, resulting in a randomized placement pattern that enhances the immersive experience for the user.

However, the random placement created gaps in some areas, allowing the piles to appear unrealistic. To address this, the underlying sculpted surface, which was previously hidden, was assigned a black texture. This effectively concealed the surface while preventing the user from seeing through the coal piles.

To further increase realism, small amounts of coal were scattered along the street surface using the regular surface scattering method, adding additional detail to the scenario.

Figure 40 The coal pile in the industrial scenario

8.3.5. The House scene (Modern Times)

This is the first scene where the focus shifts predominantly from energy production to energy utilization. Additionally, the scene emphasizes sustainable, or "green," energy, aligning with the lesson's objective of encouraging students to think creatively and design the energy solutions of tomorrow.

To achieve this goal, a modern house serves as the environment, featuring two distinct points of view. The first perspective is set in a modern kitchen, highlighting methods of electrical energy utilization. Examples include smaller appliances, such as electric kettles, and larger appliances, such as cooktops, refrigerators, and washing machines.

The second perspective is in the living room, shown in **Figure 41**, offering multiple viewpoints of green energy production methods, such as solar panels and wind turbines. On the television screen, the Olkiluoto 3 nuclear power plant is displayed (TVO, 2024), providing an additional example of energy innovation. This setup is designed to inspire students to think outside the box, fostering creativity in their approach to future energy solutions.

Figure 41 The modern living room

Used techniques

For this scene, few new techniques were employed. The primary design method involved importing assets and textures from BlenderKit. The only new approach used was the addition of imported images, such as a depiction of the power plant, a picture of a cat, and a painting, to enhance the scene's immersion.

Importing images

By creating a two-dimensional pane in Blender, an image can be added using the shader editor, following the same method used for importing surface textures. Once the image is imported, a wooden box with imported surface textures is added around the pane to simulate a picture frame, enhancing the realism of the scene.

8.4. Rendering the scenes

To create the scenes within a scenario, one to three cameras were positioned at significant viewpoints. These cameras were strategically placed to highlight the essential information in each scene. By incorporating multiple viewpoints, students can "walk" through a scene, enhancing the immersive experience.

For rendering 360° images, specific Blender settings were applied, and the image resolution was maximized to achieve the highest possible quality. In most cases, the resolution limit was determined by the file size of the image, while in others, it was constrained by the available hardware.

8.4.1. The Render Settings

To create 360° images, the cameras in each scene were configured to a panoramic equirectangular projection, with longitude limits set to (+/-)180° and latitude limits set to (+/-)90°. Due to these settings, the resolution of each scene was required to maintain an aspect ratio of 2:1 in X:Y (Gützkow, 2019). The highest achievable resolution within ThingLink's 25 MB file size limit turned out to approximately 6000x3000 pixels (Thinglink, A complete solution for accessible visual learning in the cloud, 2023).

8.4.2. The Hardware Challenges

During the design process, it became evident that the laptop initially used for creating the scenarios was unable to run the CGI software effectively. As a result, a remote connection to a more powerful computer was established to complete the designs. Although this computer encountered certain limitations, the use of advanced Blender techniques enabled the generation of the final results.

The laptop

CGI development relies on hardware components such as the CPU, RAM, and VRAM because these determine how efficiently and quickly the computer can handle complex tasks like creating and rendering 3D models, textures, and animations.

1. **CPU (Central Processing Unit)**:
   The CPU functions as the "brain" of the computer, performing calculations and managing tasks. A CPU with multiple cores can divide tasks effectively, which is particularly useful for rendering and simulations in CGI. Higher processing speeds make operations like rendering and animation editing significantly faster. Modern CPU's can support hyper-threading, allowing two "threads" to run in one "core",

allowing one core to essentially act as two cores (Intel, What Is Hyper-Threading?, 2002).

2. **RAM (Random Access Memory)**:
   RAM serves as temporary storage for data the computer needs to access immediately. In CGI projects with detailed textures and models, sufficient RAM is crucial to prevent slowdowns or crashes. Without enough RAM, the computer has issues to process large files or multiple operations simultaneously.
3. **VRAM (Video Random Access Memory)**:
   VRAM is a specific memory on the graphics card, dedicated to handling images, textures, and visual effects. More VRAM allows for higher-resolution images, detailed textures, and smoother rendering, particularly in high-resolution or real-time previews. Insufficient VRAM can lead to rendering errors.

The minimum recommended and specific values that the used hardware have been listed in **Table 3.**

Table 3: Minimum & recommended hardware & specifications of laptop and remote computer

Hardware type	Minimum	recommended	laptop	(remote) computer
CPU cores	4	8	6 cores 12 threads	6 cores 12 threads
RAM	8 GB	32 GB	16 GB	32 GB
VRAM	2 GB	8 GB	4 GB	8 GB

As shown in **Table 3**, both the laptop and the computer fall short of the recommended number of cores for CGI development (Foundation, Requirements — blender.org, 2019). However, they possess a sufficient number of threads, partially compensating for this limitation. The most significant issue is the laptop's specifications failing to meet the recommended requirements. This shortfall became evident during the scenario design process, as the laptop was unable to run the CGI software effectively. To address this issue, a remote connection to the more powerful computer was established, enabling the successful design of the scenarios.

The computer

Although this computer meets the recommended specifications for CGI development, it does so only marginally. This limitation needed to be considered during content creation, particularly given the designer's limited experience. While this was only a minor issue, it resulted in significantly long rendering times for the scenes, with some renders taking up to twelve hours.

8.4.3. Additional challenges

were encountered due to hardware constraints. The available (V)RAM, though meeting the recommended amount, turned out to be insufficient for certain tasks, particularly in later scenes. In the medieval scenario, the high number of detailed models caused some renders to fail due to VRAM limitations. Similarly, in the industrial scenario, RAM became a limiting factor as the smoke simulations consumed considerable memory. This issue was mitigated by simplifying the models and reducing the smoke quality to a lower, but still acceptable, level.

8.5. Finishing the scenes in ThingLink

Once all the scenes were rendered, they were finalised by uploading them to ThingLink and incorporating interactive elements. To achieve the project objectives, three main different types of tags were utilised, two different tags were used only in the final scene in order to create an ending. Audio was added to enhance the user experience. An example can be seen in **Figure 42**.

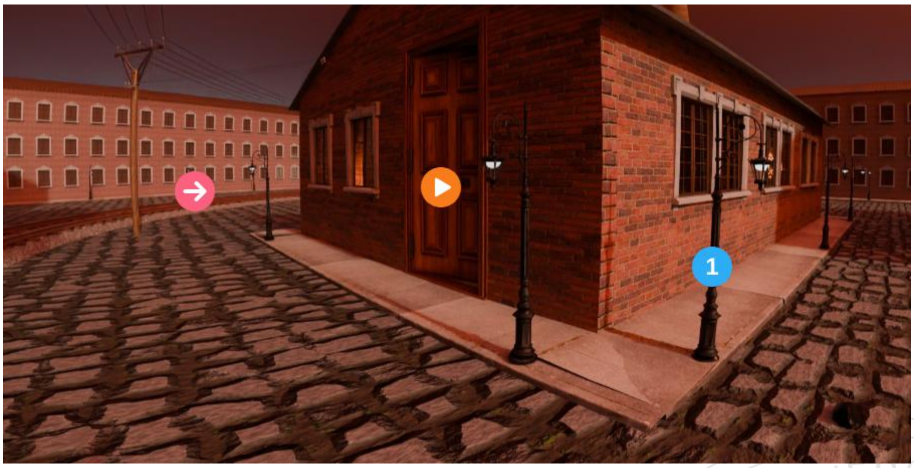


Figure 42 The industrial outside scene with tags

The blue numbered tags function as information tags. When a student hovers over these tags, a brief 100-character informational line is displayed. Since 100 characters are often insufficient, an object requiring additional details may include up to four separate informative tags.

The orange tags enable students to navigate within a scene. For instance, in this specific scenario, it is possible to move into the small office building. This movement increases the immersivity. Once in the new location, another orange tag allows users to return to the original position, should they wish to do so.

The final tag colour is pink, and these tags allow students to progress to the next era. To prevent disorientation, the pink tags do not permit students to move backwards in time. In the final scene, two white tags are included to mark the conclusion of the VR experience. One tag informs students that it is now their turn to take on the role of the engineers they have been simulating, while the other provides a credits overview, acknowledging the content creators and intended audience.

Additionally, a black tag is placed at the end, enabling users to return to the prehistoric cave if they wish to revisit any missed information.

Adding sound

In order to increase the immersive experience to a maximum, a sound is added to all the scenes that matches the environment of the students. These sounds can be found in **Table 4**, the addition of these sounds is critical for the user experience.

Table 4 The chosen sounds for the scenes

SCENE	SOUND
CAVE	Crackling fire
FARM	Generic animal sounds
MEDIEVAL (FARM/WOODCUTTER)	Water flowing in a creek
MEDIEVAL (TOWN)	Marketplace sounds
INDUSTRIAL	Locomotive train sounds
MODERN HOUSE	Cars passing, keyboard presses

8.6. Uploading the Scenes to ClassVR

After uploading the scenes to ThingLink, they can be tested using the ClassVR headsets. To facilitate this, the headsets must be connected to the same Wi-Fi network as the laptop accessing the teacher control panel.

Figure 43: The Raspberry PI

Initial attempts to use the local network (Eduroam) revealed that it was not a viable option due to security restrictions. These limitations prevented the teacher portal from controlling the headsets effectively when connected through this network. To address this issue, a dedicated network hosted by a Raspberry Pi, shown in **Figure 43**, was utilised. This network was employed throughout the development process to provide a reliable connection between the control panel and the headsets. Using this

Raspberry is not a requirement, any router able of hosting a network without security restrictions that negatively affect the control panel can be utilised.

After connecting the headsets to the control panel, it is possible to easily upload the ThingLink scenes to the VR glasses by clicking the ThingLink section from within the portal and pasting the link to the ThingLink scene.

9. Side Activities

Once the concept was finalized and the constraints regarding the limited availability of VR headsets (8 units) and the typical class size (18–20 students) were identified, the team quickly recognized the necessity of incorporating a supplementary activity. This additional activity was designed to ensure an interactive and engaging experience for all students, including those not actively utilizing the VR headsets at any given time.

9.1. Concepts

The development of the side activity concepts for the "Energy Technology" lesson was the result of extensive team discussions, driven by the necessity to accommodate all students while addressing the logistical limitation of having only eight VR headsets for a class of 18–20 students. These supplementary activities were carefully designed to complement the VR experience, ensuring that all students remained engaged and actively participated in the learning process. The team focused on creating activities that aligned with the lesson's objectives while catering to diverse learning styles. Three primary side activities were developed: "Energy Quest: A Journey Through Time," "Energy Sprint," and "The Race for the Nobel Prize."

9.1.1. Energy Quest: A Journey Through Time

This activity was designed as an interactive board game, where students explore the timeline of energy evolution from prehistory to modern renewable energy sources. During brainstorming, the team emphasized the importance of creating a hands-on, collaborative activity that would allow students to reinforce their knowledge while having fun.

Students progress through the timeline by answering trivia questions about energy technology. For instance, they might answer questions about the uses of fire, the role of windmills, or the innovations of the industrial revolution. Each correct answer allows the player to advance further on the game board. The board itself was conceived as a visual representation of key historical energy milestones, enhancing students' understanding of energy transitions. The team opted for this design to provide a structured yet engaging method for students to review and consolidate knowledge from the VR session.

9.1.2. Energy Sprint

"Energy Sprint" is a fast-paced quiz game that focuses on short, rapid-answer questions related to energy technology. This idea arose from team discussions about how to engage students who might prefer quick, dynamic challenges. During these discussions, the team agreed that incorporating time constraints would add excitement and urgency, motivating students to think on their feet.

The activity involves students taking turns drawing cards with simple questions, such as "What powered early windmills?" or "What is the byproduct of hydrogen fuel cells?" Correct answers earn Energy Tokens, while incorrect or delayed responses result in token loss. The activity was designed to last only a few minutes per student, allowing for high participation and multiple rounds. This game format was selected to ensure all students could engage with the content actively and repeatedly during the lesson.

9.1.3. The Race for the Nobel Prize

In this activity, students compete to answer questions and complete creative tasks to "win" a Nobel Prize. The team developed this idea after recognizing the value of integrating both knowledge-based and creative components into a single game. Inspired by the concept of scientific achievement, this activity encourages students to engage with energy concepts in a competitive yet collaborative environment.

The game is structured as a spiral track representing scientific eras, with students advancing based on correct answers or successful completion of tasks. Questions cover key energy milestones, while tasks might involve drawing energy-related concepts, such as a steam engine or an imagined hydrogen-powered car. This creative element was included to ensure the activity catered to students with visual or artistic strengths, providing a more inclusive learning experience. The Nobel Prize framework was chosen to add an aspirational element, motivating students to showcase their understanding and creativity.

9.2. Final Concept (Energy Sprint)

To determine the best option for a side activity, the team conducted several discussion sessions. Initially, the concept of "The Race for the Nobel Prize" emerged as the most entertaining option. This concept had a compelling storyline that allowed students to fully immerse themselves in the game's world, making it highly engaging. The narrative was designed to simulate the journey of competing for a prestigious award, which added an element of excitement and motivation for the participants.

However, as the team delved deeper into the logistics of implementing this activity, it was realized that it was not a viable option as a side activity. The primary issue was that "The Race for the Nobel Prize" required constant participation from the students. Given the duration of the game, it could not be effectively played in the intervals between VR sessions. This continuous engagement was impractical within the constraints of the overall schedule.

After carefully considering the required duration and the need for a more flexible activity, the team identified only one feasible option: the Energy Sprint game. This game was better suited as a side activity because it could be completed in shorter bursts, fitting well between the VR sessions without requiring prolonged attention from the participants.

Upon selecting the Energy Sprint game, the team decided to enhance its appeal by incorporating a storyline similar to that of "The Race for the Nobel Prize." The team modified the game to include a narrative where participants would compete in a race to win the Nobel Prize. This adaptation involved creating a point system where the participant who accumulated the most points by the end of the game would be declared the winner of the Nobel Prize. This modification not only made the game more entertaining but also maintained the educational and motivational elements that were central to the original concept.

By integrating this storyline, the Energy Sprint game became more engaging and enjoyable for the students. The competitive aspect of racing for a prestigious award added an extra layer of excitement, encouraging participants to fully engage with the activity. This approach ensured that the side activity was both fun and educational, aligning with the overall goals of the program.

After developing the concept, the team commenced the design of the cards and the development of the ruleset. The objective was to create a card design that embodied the steampunk style, which was deemed the most representative of an "industrial/energy" aesthetic. Following careful consideration and research, a card game template was created that met the team's specifications. Once the front design of the cards was finalized, the team utilized AI to generate the back design, ensuring it adhered to the desired steampunk style. The initial designs for both the front and back of the cards were as follows:

Figure 44: Back and front of the card.

To facilitate the identification of each epoch within the categories, specific icons were created for each era. Initially, attempts were made to design these icons independently. However, after encountering difficulties in producing effective designs, Sanne Hoozemans, an external artist, was commissioned to design these icons. Hoozemans assisted in designing both the icons to represent each epoch and the energy tokens required for scoring points in the game.

Figure 45: Icons to identify each era

Following several meetings with Hoozemans, it was agreed that the token design should be a battery, as it is a primary representation of energy. Consequently, the token was named "Energy Token" to align with the game's title, "Energy Sprint."

Figure 46: Energy Token

Once the template design of the card was completed, the creation of a set of questions and answers to fit the cards began. The goal was to ensure that the questions aligned with the game's mindset, which required them to be concise and suitable for short answers. This requirement added a significant layer of complexity to the task.

Two primary challenges were faced. First, crafting questions that could be answered succinctly often meant distilling complex concepts into brief, clear queries. Second, and perhaps more daunting, was the need to ensure that these questions were appropriate for students aged 12-14. This age group has a specific range of knowledge and cognitive abilities, so the questions had to be carefully calibrated to be neither too difficult nor too simplistic. Striking this balance was crucial to maintain the educational value and engagement of the game.

Despite the best efforts to create questions that were not too hard, some of them ended up being at a higher level than the knowledge typically possessed by students aged 12-14. This added an additional layer of difficulty, as continuous adjustments and refinements were necessary to better match the students' capabilities.

The difficulty lay in finding questions that were challenging enough to stimulate the students' thinking but not so complex that they would become frustrated or disengaged. Additionally, the questions needed to be relevant and interesting to the students, covering topics that would capture their attention and encourage them to participate actively.

Extensive research was conducted to identify suitable topics, and educational resources were consulted to ensure the questions were age appropriate. Various questions were tested with a small group of students to gauge their difficulty and engagement levels, adjusting based on the feedback received.

Ultimately, due to the time constraints in developing the project, it was decided to create 10-12 questions for each epoch. This decision was made to ensure that the questions were of high quality and met the necessary criteria. The limited number of questions also allowed for a focus on crafting well-thought-out queries that would provide a meaningful and enjoyable experience for the students.

By the end of the process, a set of questions was developed that were not only suitable for the target age group but also aligned with the educational goals of the game. This careful and deliberate approach ensured that the final product was both engaging and educational, providing a valuable learning tool for the students.

The full set of questions and the ruleset sheet can be found in **[Appendix C].**

The development of the ruleset for the game "Energy Sprint" involved several key steps and considerations by the team. The team divided the development of the ruleset in the following steps:

- **Conceptualization**:
    - The team started with the core idea of creating an engaging quiz game centered around energy-related questions. The goal was to make the game both educational and entertaining, with the ultimate prize being a Nobel Prize, which added a competitive edge.
- **Designing the Game Mechanics**:
    - The game was designed to accommodate 2-6 players aged 12-15, with each game session lasting approximately 10 minutes.
    - Players compete by answering energy-related questions, earning or losing Energy Tokens based on their answers. The player with the most tokens at the end of the game wins.
- **Materials and Setup**:
    - The necessary materials include Energy Tokens, Question Cards, and a Timer.
    - The setup involves shuffling the Quick Question Cards and placing them face-down in the center. Each player starts with 3 Energy Tokens.
- **Gameplay**:
    - The game is played in turns, with each player having a 1-minute turn to draw a Quick Question Card and answer the question within 10 seconds.

- Correct answers earn the player Energy Tokens from the center pile, while incorrect answers or failure to answer within the time limit result in losing tokens.
- The game continues with players taking turns until the timer runs out. The player with the most tokens at the end wins the Nobel Prize.

- **Variations**:
  - A quick variation called the "Lightning Round" was introduced for added excitement, where players have only 5 seconds to answer each question, making the game more fast-paced.
- **Question Development**:
  - The team created questions spanning different eras of energy development, such as the Fire Era, Windmills, Industrial Revolution, and Modern Energy.
  - Sample questions include topics like the first use of fire in cooking, the energy source for early windmills, the fuel for steam engines, and the byproduct of hydrogen fuel cells.
- **Collaboration and Finalization**:
  - The ruleset and game design were developed by the EPS Group of Autumn Semester 2024, in collaboration with the LUMA Centre Ostrobothnia and Novia University of Applied Sciences.
  - The final ruleset ensured that the game was educational, engaging, and suitable for the target age group.

Figure 47: A close-up of the game and ruleset.

10. Lecture overview

As part of the requirements for the final product, the team was tasked with creating a comprehensive lecture for the students. The initial concept for the lesson structure focused solely on the VR journey and the side activity, with the VR experience planned to last between 45 to 60 minutes. However, after conducting several interviews with teachers from different schools, including Jenny Rönnqvist-Norrby, who has 13 years of experience as an Upper Primary lecturer, and Markus Norrby, a physics lecturer at Vaasa Övningsskola, it became clear that the lecture should be divided into two parts. Additionally, it was recommended that the VR portion of the lesson should not exceed 30 minutes in length. More detailed information about the set-up can be found in **[Appendix B].**

After considering the recommendations gathered from the interviews, research was conducted on the recommended duration of a VR session. This research indicated that for safety reasons, VR sessions should not exceed 10 to 15 minutes continuously. Based on the feedback from the interviews and the findings from the research, it was decided to structure the lesson into two 30-minute parts: a research phase and a development phase. See **figure 48** below.

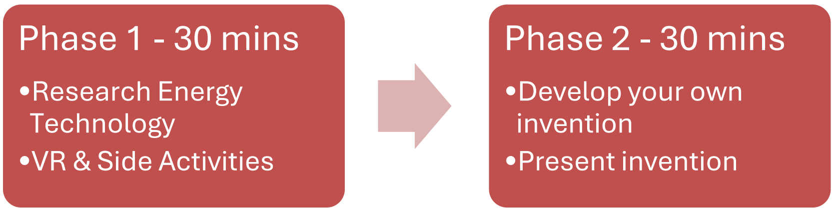


Figure 48: Lecture concept

This image served as a concept guide throughout the past few weeks, shaping the approach to structuring the lecture. This image was used to showcase the potential of the lecture structure itself during interviews and meetings with stakeholders and experts. It inspired an exploration of the phases and the potential learning outcomes for students in each. For example, the first phase focuses on research—a relatively new experience for Grade 6 and 7 students, who often have limited exposure to research practices in their school curriculum. This lecture introduces basic research techniques in a manageable and engaging way. The development phase, however, builds on familiar territory, as many schools already incorporate hands-on experiments in subjects like chemistry and physics. An example given by Ms, Nickull, students would make their own self-driving cars using bottles, straws and balloons.

Based on these assumptions and insights from interviews, a fully developed lecture plan was finalized shortly afterward. **Figure 49** (below) illustrates how the final concept evolved, drawing from earlier theories and informed by practical feedback. More information about the lecture phases will be given in chapters 9.1 and 9.2.

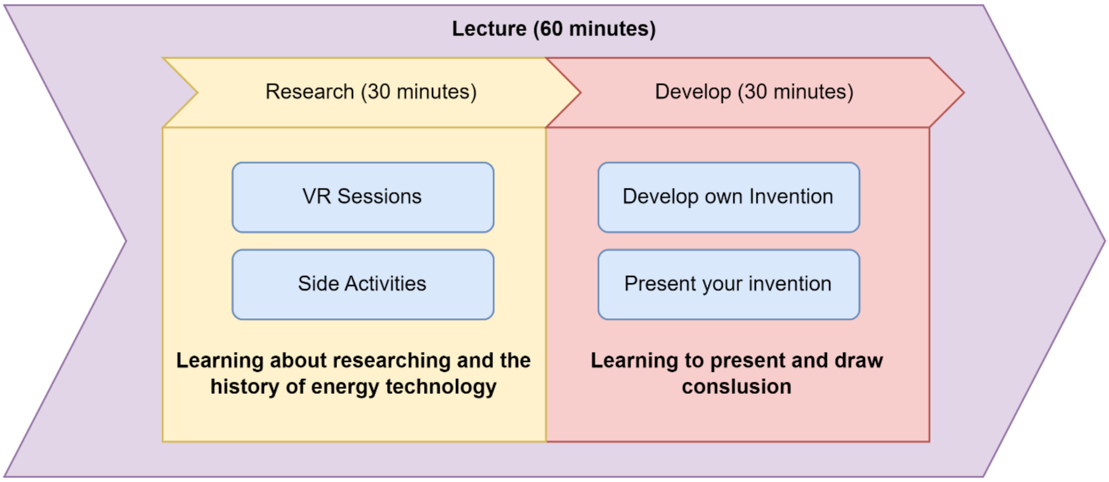


Figure 49: Definitive lecture set-up

10.1. Research phase of the lecture

After understanding the maximum recommended duration for a VR session and reducing the total length of the VR experience to 30 minutes (**figure 50**), it was decided that each student would use the headset for only 5 consecutive minutes (one scene) before passing it to another student in the group. This approach ensures that no student exceeds the recommended safe duration for continuous VR use. The rotation continues until all students in the small group have viewed the scene. Only after all the students have experienced that particular scene will they be able to proceed to the next one.

This method not only adheres to safety guidelines but also promotes collaborative learning. While one student is engaged in the VR experience, the other members of the group will participate in the Energy Sprint side activity game. This game serves as an engaging and educational complement to the VR session, keeping the students actively involved and reinforcing the learning objectives.

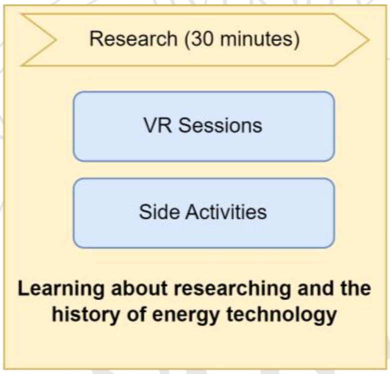


Figure 50: Research Phase

The Energy Sprint game, designed to be both fun and informative, allows students to answer energy-related questions and earn points. This activity not only keeps the students occupied while waiting for their turn with the VR headset but also enhances their understanding of the subject matter in an interactive way. The combination of

VR and the Energy Sprint game ensures that all students remain engaged and benefit from a varied learning experience.

By structuring the research phase of the lesson in this way, the team aimed to maximize the educational impact while ensuring the safety and engagement of the students. The thoughtful integration of VR sessions with the Energy Sprint game reflects a balanced approach to modern educational methods, catering to different learning styles and maintaining a high level of student interest and participation.

10.2. Development phase of the lecture

To develop the concept for the second phase of the lecture, a brainstorming session was conducted. The general idea for this part of the lesson was clear: students needed to apply what they had learned during the research phase in the development phase **(figure 51)**. The challenge was to determine how to effectively encourage students to apply the knowledge gained during the VR session. See **[Appendix D]** for a more detailed report.

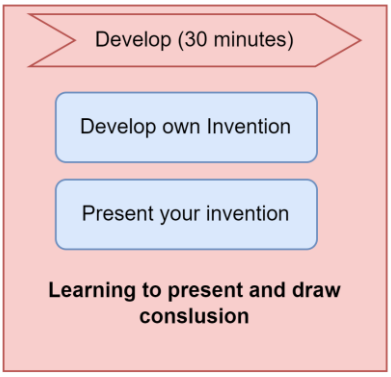


Figure 51: Develop Phase

The development phase of the lesson was structured into four distinct parts:

1. **Introduction**:

Students were introduced to their new role as "energy inventors" and given 20 minutes to produce innovative ideas for future energy generation. This segment aimed to foster creative thinking by posing questions such as:

- What current energy problems do we face (e.g., pollution, limited resources)?
- What future technologies might solve these problems?
- Could energy come from new sources (e.g., space, other dimensions, within our bodies)?

It was emphasized that there were no wrong answers, encouraging imagination and innovation.

2. **Invention Creation**:

This part was divided into three steps:

- **Step 1 – Brainstorming (5 minutes)**: Students brainstormed individually or in small groups, writing down their ideas for future energy inventions. A table was provided to help them focus, requiring information such as the invention's name, energy source, functionality, advantages over current technologies, and additional details.
- **Step 2 – Sketching (5 minutes)**: Students then created simple sketches or diagrams of their inventions. If time allowed, they could add labels or brief explanations. For younger students needing help visualizing, an example invention (e.g., "an energy generator powered by wind from space") could be provided.
- **Step 3 – Create the Invention (10-15 minutes)**: Using available materials, students brought their inventions to life and prepared a 1–2-minute presentation to explain their creation to the class.

3. **Presentations**:

Students are invited to present their inventions, encouraged to be confident and enthusiastic. After each presentation, classmates could ask a couple of quick questions to keep the activity interactive.

4. **Conclusions**:

The lesson concluded with a reflection on the different ideas presented. The instructor highlighted particularly interesting or creative inventions and encouraged students to continue thinking about how their generation might contribute to solving future energy challenges.

This structured approach will allow students to apply creatively and engagingly what they have learnt from the VR session. It helped reinforce their understanding through hands-on activities and interaction with their peers.

10.3. Learning objectives

The main focus of this lecture is to teach students about identifying and understanding the different energy sources. Such as Fire, Steam, Electricity etc. and how it could evolve at some point to be used in a more efficient way. Think of how coal was burned to create steam. Making Locomotives and steam engines possible. It would help them to connect these energies and understand its progression. This chapter will also contain some examples of what came out of the testing sessions and what some students have created.

What this does is encouraging students to think critically about their later inventions. While it doesn't have to be as spectacular as the telegraph or the steam engine, but it allows them to for example think of everyday items they use themselves and how could they use the information they gathered to improve those.

11. A look into neurodivergence

Given the seamless integration of neurodivergence in the Finnish school system, it is assumed that neurodivergent students are part of the final target group. This presents a challenge, as neurodivergent students have different processing patterns and may experience the VR equipment differently, potentially negatively.

Although neurodivergence encompasses conditions such as autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), dyslexia, dyspraxia, epilepsy, obsessive-compulsive disorder, and others (Lukava, Morgado Ramirez, & Barbareschi, 2022), this project will primarily focus on ASD, dyslexia, and ADHD, as these are most frequently reported in educational settings (Wang, McCool, & Wieman, 2024). Neurodivergent students often face unique challenges in educational environments, which can impact their learning experiences and outcomes.

Research and development of VR applications have predominantly been conducted by and for male, white, educated, industrialized, and wealthy individuals. Consequently, the effects of VR on neurodivergent individuals have not been extensively studied. Research indicates that neurodivergent individuals often experience sensory overload when using VR (Lukava, Morgado Ramirez, & Barbareschi, 2022). This sensory overload can manifest as heightened sensitivity to visual and auditory stimuli, which can be overwhelming and distracting (Dahlstrom-Hakki, Alstad, Asbell-Clarke, & Edwards, 2024). However, this negative experience can potentially be mitigated by using simplistic immersive virtual experiences, as neurodivergent individuals, particularly those with ASD, tend to prefer these simpler scenarios (Savickaite, 2024).

While creating a completely inclusive lesson is beyond the scope of this project, the scenarios will be designed with inclusivity in mind. This approach aims to reduce the sensory intensity of the scenarios, thereby minimizing discomfort for neurodivergent students. Simplifying the virtual environments can help in making the VR experiences more accessible and less overwhelming for these students (Butcher & Lane, 2024).

Moreover, it is essential to consider the broader implications of using VR in educational settings. The design of VR applications should incorporate feedback from neurodivergent individuals to ensure that their needs and preferences are adequately addressed (Dahlstrom-Hakki, Alstad, Asbell-Clarke, & Edwards, 2024). This participatory approach can lead to the development of more effective and inclusive educational tools (Butcher & Lane, 2024).

In conclusion, integrating neurodivergent students into VR learning offers challenges and opportunities. By addressing their specific needs and incorporating their feedback, VR experiences can become both inclusive and engaging.

12. Teachers Handbook

This project aimed to develop an educational lecture that integrates virtual reality (VR) into a classroom setting. Alongside the lecture, the team was tasked with creating a Teacher's Handbook to provide teachers and guardians with comprehensive preparation for delivering the lecture. The complete handbook can be found in the appendices of this report. **[Appendix E]**

This handbook is made in collaboration with some teachers from different faculties located in different schools throughout Vaasa. This was done by having multiple interviews and showcasing the progress of the project. Including this handbook.

Before creating the handbook, it was crucial to understand how lectures are typically conducted in Finland. The handbook focuses on specific aspects of the lecture while also reflecting on general teaching practices to ensure it is practical and culturally aligned. The primary purpose of the handbook is:

- ***To provide clear instructions on how to deliver the developed lecture.***
- ***To articulate the rationale behind its design and implementation***.

The handbook is designed to guide educators to use the VR headsets provided safely for the students to use. It provides clarity about the structure of the lecture, its objectives and it's the lectures alignment with the LUMA principles. Lastly, it helps educators notice how this lecture supports certain learning objectives such as critical thinking, collaboration, presenting and understanding Energy Technology.

Why creating this?

To make this lecture as effective as possible, it is important for the educator to understand its purpose and value that the VR experience is going to add to the lecture. Aside from that, the educators must also understand how these devices can be used in general and to use them safely. Especially for the age group it is meant for.

Some teachers may lack the technical knowledge about how to use these VR headsets. With simple instructions such as turning them on or how to charge them are included in this handbook.

Feedback points on the Handbook

For this handbook it was necessary to provide clear instructions and provide insight into the lecture. During interviews, the most feedback received was more about certain elements that were missing from what you'd expect from a typical lecture.

The most common feedback or request was the localisation of the handbook. Since Finland is a bilingual country, comprising of Finnish, Swedish and English, it was requested that the handbook and lecture in general should be provided in these languages. Using AI, the handbook can be easily translated into those languages, while the current project team can not check its authenticity, someone that knows those languages would be able to help with the translation. (Nickull, 2024) & (Rintala, 2024)

Another point feedback was the Curriculum integration. How does this lecture tie in with the Finnish education system and how does it focus on the learning objectives. It would also provide an easier way to pitch this to other teachers and other school administrators. (Norrby, 2024)

13. Testing

For the final phase of the project, the team conducted a testing session for the VR program and lecture. During this session, one team member was present to introduce the project and explain the purpose of the testing phase. Participants were encouraged to share any thoughts or feedback that came to mind, whether positive or negative.

Each testing session is documented in detail on the following pages. The records include key information such as the number of participants, location, age range, date, and a summary of the general feedback collected during the tests.

13.1. Testing Plan / strategy

In preparation for the testing sessions, a test strategy was developed to ensure that all necessary elements are addressed and the maximum value is extracted from these opportunities. The test strategy includes key topics such as the testing objectives, which outline the primary focus and goals of the tests. These objectives pinpoint the areas where the results will be most valuable and impactful, guiding the overall direction of the testing process. The complete test strategy will be included in the appendices. [**Appendix F**]

13.2. Conducting Tests

The lecture tests were conducted by delivering the developed session to participants. Minimal introduction was provided to encourage a natural exploration of the lecture, assessing whether it is intuitive and self-explanatory. The process began with a brief explanation of the lecture's objective and an overview of the activities, allowing us to identify any areas requiring improvement.

Testing Procedure

- **Introduction**: Participants received a concise introduction to the lecture, outlining the goals and the activities they would undertake.
- **Exploration**: Students and educators were given the freedom to independently explore the lecture content, with the project team on stand-by to aid if needed.
- **Recording Observations**: During the session, the following aspects were monitored and documented:
  - Any challenges or limitations encountered.
  - The level of engagement and enjoyment experienced by participants.
  - Participant feedback gathered via a questionnaire or an open feedback round.
  - Technical issues or limitations.

13.3. Testing Session #1 – (Peer Testing Sessions)

Date:	Several moments throughout the semester
Location:	The EPS Room
No. of Participants:	5
Age Range:	21 - 25
Facilitator(s):	Ernest Anguera, Jelmer Sijbers, Konrad Michel & Jesse van den Ende

Summary of the session

The purpose of this session was to test the VR program and gather initial feedback from peers. Participants were asked to provide honest, constructive feedback on their experience, focusing on both positive aspects and areas for improvement.

Feedback

Blurriness Issue

Some participants reported that the visuals appeared blurry during their VR experience. They were uncertain whether this issue stemmed from the headset itself or the lenses, recommending further investigation to identify and address the cause.

Camera Position

The positioning of the camera was highlighted as a significant concern. Participants noted that it seemed significantly off-angle, which resulted in an intense and, at times, nauseating experience. Adjusting the camera angle was suggested to improve the perspective and enhance user comfort.

General Impression

Despite these technical challenges, participants emphasized that the concept behind the VR program is solid and shows significant potential. This positive feedback highlights the foundation's strength and the opportunity for further refinement.

13.4. Testing Session #3 - (Vasa Övningskola)

Date:	November 23rd, 2024
Location:	Vasa Övningskola
No. of Participants:	7, 2 Students, 5 Teachers
Age Range:	16 – 18 (Students)
Facilitator(s):	Ernest Anguera, Jelmer Sijbers

Summary of the session

The purpose of this session was to test the VR program and gather initial feedback from peers. Participants were asked to provide honest, constructive feedback on their experience, focusing on both positive aspects and areas for improvement.

Feedback

Navigation and Interaction

Participants highlighted the importance of a navigation feature to allow students to return or backtrack if they become disoriented or stray from the intended path within the VR environment. Additionally, the exit to the next scene in the medieval era was noted as difficult to locate. Participants suggested making this transition point more intuitive to enhance the overall user experience and flow of the VR program.

Hardware and Performance

The Meta Quest 2 headsets delivered significantly better results, offering fantastic controls through ManageXR and providing a smoother, more reliable experience. However, participants noted that the viewpoint was too high, which made the experience feel less natural and immersive. Adjusting the viewpoint to a more realistic height is recommended to enhance the overall usability and engagement. Compared to the ClassVR, Participants noted a better experience that felt less disorienting and much smoother.

Story and Scene Design

Participants suggested incorporating an ending scene to provide the VR experience with a sense of closure and completeness. The graphics were widely praised for their detailed and immersive quality, particularly in VR.

User Interface

The ThingLink scroll buttons used for navigating up and down were described as awkward and not well-suited for VR interaction. Participants recommended redesigning these elements to ensure smoother and more intuitive usability within the VR environment.

Audio and Text Feedback

The absence of sound was identified as a significant shortcoming, with participants noting that adding audio would greatly enhance immersion and engagement within the VR experience.

The prompts presented in the scenes were described as too vague, leaving participants uncertain about their purpose. It was suggested that the questions should be revised to be more specific and focused, improving clarity and alignment with the learning objectives.

Participants also found the text content in the scenes overwhelming. To address this, they recommended replacing large blocks of text with smaller bullet points and incorporating visual figures to convey information more effectively, making it easier for users to process and engage with the content.

Proposed Alternative Methods for Text Presentation

To reduce reliance on reading and improve engagement within the VR experience, participants suggested several alternative methods for presenting text and information:

- **Talk-aloud options**: Implement an audio feature where the text is read aloud, allowing users to focus on the visuals while receiving the necessary information.
- **AI-generated speech**: Introduce dynamic, time-appropriate narration generated by AI, making the experience feel more interactive and immersive.
- **Talking images**: Replace static, factual text with interactive or animated images that "speak," providing information in a more engaging and visually appealing manner.

13.5. Testing Session #4 – (Borgaregatans Skola)

Date:	December 4th, 2024
Location:	Borgaregatans Skola
No. of Participants:	2 teachers, 2 7th graders, 2 8th graders
Age Range:	12 – 14 (Students)
Facilitator(s):	Jesse van den Ende

Summary of the session

This testing session aimed to evaluate both the VR experience and the accompanying card game designed to enhance the educational value of the lesson. While the VR headsets faced reliability issues, participants used tablets with gyroscopes to simulate the VR environment. Alongside the VR activity, the card game was introduced as a supplementary activity for participants.

Feedback

VR Experience

The VR simulation was praised by students as "very well-built and cool," showcasing its ability to engage and captivate participants. Despite technical challenges with the VR headsets, the tablet-based workaround served as a satisfactory alternative, allowing users to interact with the virtual environment effectively and ensuring the session maintained its educational and engagement objectives.

However, the unreliability of the VR headsets posed a significant challenge, necessitating the use of tablets as a substitute. While functional, the tablets were unable to provide the full immersive experience that the VR headsets were designed to offer, ultimately limiting the potential depth and impact of the VR interaction.

Card Game

The card game faced several challenges during the session. Many participants found it difficult to play due to the complexity of some questions. Additionally, a number of questions were overly open-ended, causing confusion and making it harder for players to engage fully with the game as intended. However, these open-ended questions, though unintentional, sparked meaningful collaborative discussions among participants.

On a positive note, the discussions generated by the card game added a valuable social and interactive element to the session, demonstrating its potential as a tool for fostering teamwork and engagement.

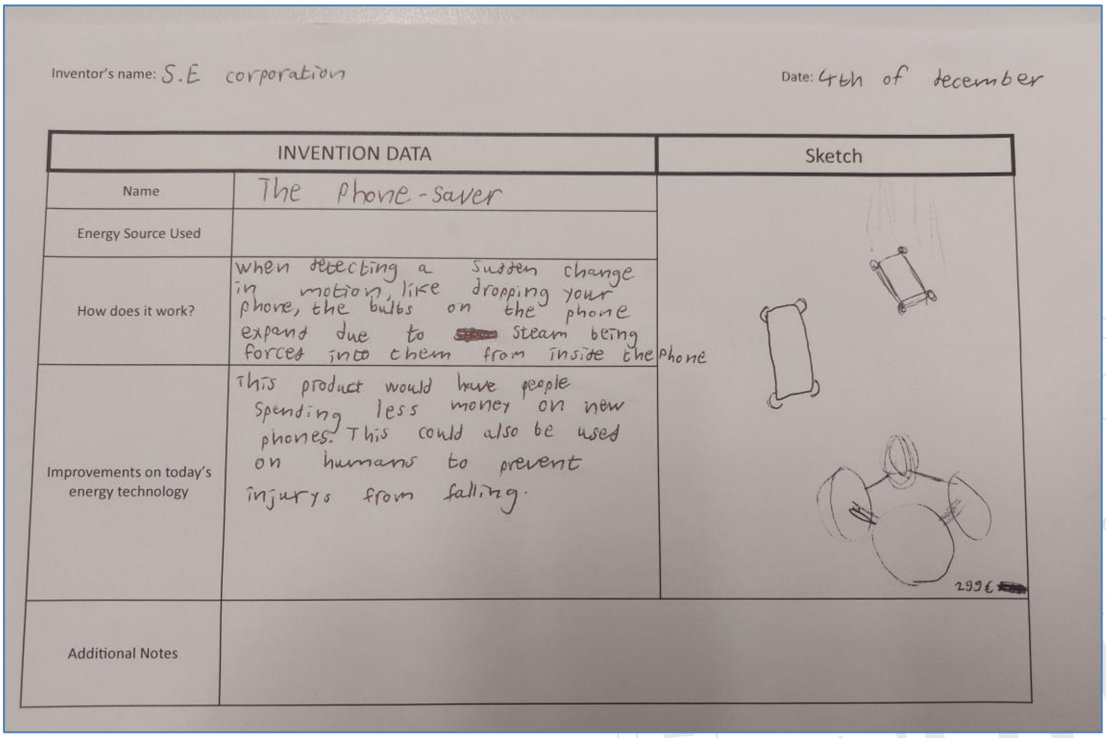
Develop Phase

This session introduced a new activity called the develop phase, which involved participants in creative and critical thinking. Participants were tasked with designing and presenting their own inventions, inspired by what they had learned through the VR program and card game. In this practical way, students applied their knowledge in an innovative manner, reinforcing the educational objectives of the project.

The phase went wonderfully, and the participants were very happy and proud of what they had created. For added effect, students were also tasked with thinking of a unique company name for their invention. A summary of the results of their work is shown below:

Student Creations:

"Phone Saver" by "SE Corporation":
A steam-powered bag designed to prevent phones from breaking during a fall. Sensors release steam to cushion the impact, allowing a phone to survive a fall from several meters high.



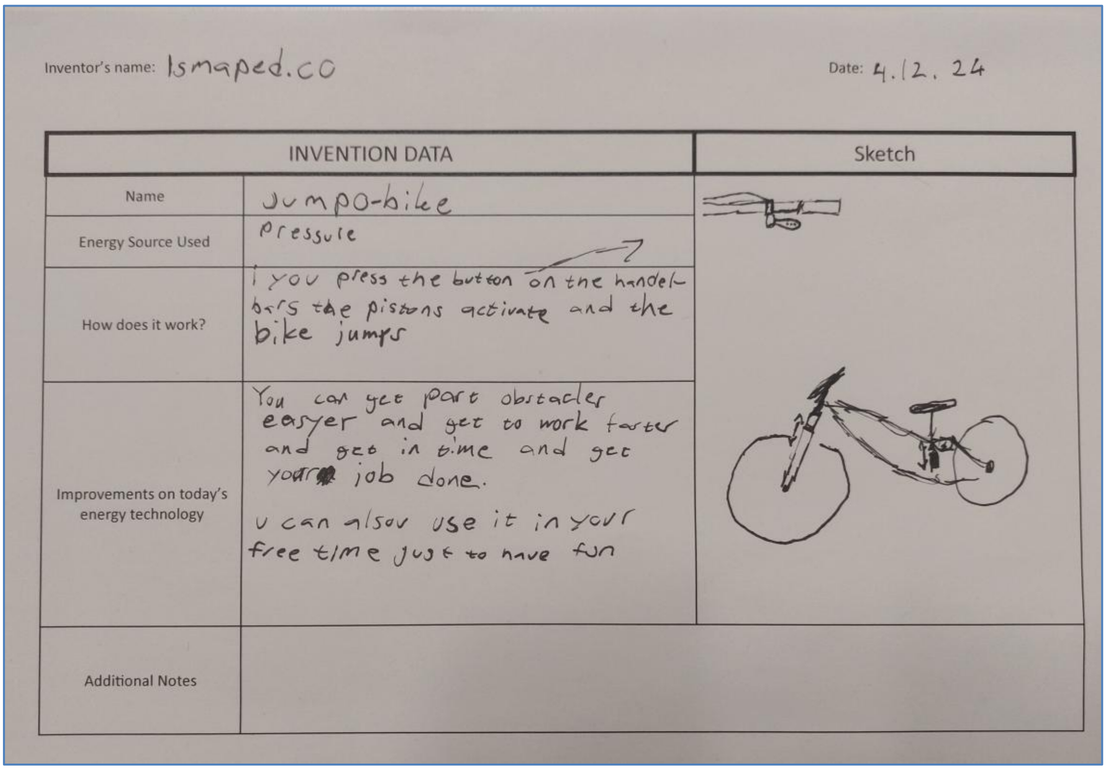
Inventor's name: S.E corporation
Date: 4th of december

INVENTION DATA		Sketch
Name	The Phone-Saver	
Energy Source Used		
How does it work?	when detecting a sudden change in motion, like dropping your phone, the bulbs on the phone expand due to steam being forced into them from inside the phone	
Improvements on today's energy technology	This product would have people spending less money on new phones. This could also be used on humans to prevent injurys from falling.	
Additional Notes		

Figure 52: The Phone Saver by SE Corporation

"Jumpo-Bike" by "Ismaped.co":

A bicycle equipped with steam-powered pistons, enabling the bike to jump over obstacles. This invention was designed to help people reach work on time by avoiding delays caused by roadblocks.



Inventor's name: Ismaped.co Date: 4.12.24

INVENTION DATA		Sketch
Name	Jumpo-bike	
Energy Source Used	Pressure	
How does it work?	i you press the button on the handel-bars the pistons activate and the bike jumps	
Improvements on today's energy technology	You can get part obstacles easyer and get to work faster and get in time and get your job done. U can alsov use it in your free time just to have fun	
Additional Notes		

Figure 53: Jumpo-Bike by Ismaped.co

13.6. Testing Session #5 - (Vasa Övningskola)

Date:	December 13th, 2024
Location:	Borgaregatans Skola
No. of Participants:	3 Students
Age Range:	16 (Students)
Facilitator(s):	Jesse van den Ende

Summary of the Session

This session involved testing the VR experience and card game with older students to gather feedback on usability, engagement, and areas for improvement. The participants provided thoughtful feedback on both the strengths and challenges of the program.

Feedback

General Impressions

The VR experience was widely praised by participants, who described it as fun and engaging. They highlighted its appeal to students in their age group, emphasizing that it successfully captures attention and fosters interest. Participants also commended the effort and creativity behind the project. They acknowledged that, while it reflects some lack of experience, the outcome is impressive, especially considering the limited time available to develop it.

However, participants noted that with additional time and experience, the VR experience could have been further refined and elevated. They recognized the potential for greater polish and depth, suggesting that the project could achieve even higher levels of immersion and engagement with extended development.

Card Game

The concept of the card game was well-received, with participants appreciating its alignment with the overall aesthetic of the project. They found the design visually appealing and fitting within the broader educational theme. However, several challenges were noted. Some questions were either too easy or too difficult, creating an imbalance that affected the flow of the game. Additionally, certain questions were not worded clearly, leading to confusion among players. To address these issues, participants suggested refining the questions to ensure a more balanced difficulty level and improving clarity to enhance the overall gameplay experience.

Points of Interest

Participants highlighted the potential to enhance the VR experience by introducing elements of adventure and interactivity. They suggested incorporating tasks or objectives, such as finding a sword to silence an annoying rooster, which would add a fun and engaging layer to the experience. These elements would not only make the environment more dynamic but also create a sense of progress, increasing the overall appeal and engagement.

Additionally, while the static imagery was praised for its realism and immersive quality, participants felt that adding mobility would significantly enhance the experience. Allowing users to explore the environment, rather than remaining stationary, would deepen the sense of adventure and provide a more interactive and engaging experience overall.

13.7. Testing Conclusions

The testing sessions have thus given insight into the strengths and areas of improvement for the VR program along with the accompanying activities. There was however some miscommunication within the team for the meeting on November 22nd. This was later addressed on December 4th in a follow-up session where the team set up new session. Hence the absence of session #2.

Despite this, the sessions conducted showed great potential for the program in terms of student engagement and creativity due to the VR experience and hands-on activities. Feedback was given on refining navigation, interactivity, and content delivery, and addressing technical limitations of the hardware. With these improvements, the program is well-positioned to become an impactful and immersive educational tool.

VR Experience

Participants described the VR experience as both engaging and immersive, commending its ability to captivate students across various age groups. However, several challenges were identified, including technical issues with the headsets, the need for improved navigation features, and recommendations for enhanced interactivity, mobility, and a more intuitive user interface. Despite these challenges, the program demonstrated strong potential, particularly through its detailed and immersive graphics. Areas such as sound design, overly vague questions, and overwhelming text were highlighted as key opportunities for refinement to further enhance the overall experience.

Card Game

The concept and design of the card game were well-received, with participants appreciating its alignment with the overall educational goals. However, its execution presented challenges. The questions varied significantly in difficulty, with some being too easy and others too complex or unclear, leading to confusion among players.

Despite these shortcomings, the card game demonstrated its potential as a valuable educational tool by successfully fostering collaboration and sparking meaningful discussions among participants.

Develop Phase

The introduction of the develop phase was a standout feature of the testing process, as it effectively encouraged creativity and critical thinking among participants. Students enthusiastically engaged in designing and presenting their own inventions, showcasing the educational value of integrating VR with hands-on activities. This phase not only reinforced learning outcomes but also provided an enjoyable and memorable experience for participants.

14. Recommendations for future development

14.1. Further Improving Reliability and Immersion in VR Scenarios

The ClassVR headsets demonstrated reliability issues during testing, likely due to software limitations, prompting the recommendation to explore alternative hardware like the Meta Quest 3 for improved performance and teacher control options. Scenario improvements were identified, including enhanced realism for the cave, farm, medieval, industrial, and modern environments. Key suggestions involve better lighting, realistic textures, improved object placement, and historical accuracy, some of these suggestions can be seen in **[Appendix G].** Implementing these changes would require more powerful hardware, such as Nvidia RTX GPUs, AMD CPUs, and 64GB of RAM, to support advanced rendering techniques.

14.2. Further Looking into Neurodivergence

During the design phase, the use of colours known to heighten sensory triggers (e.g., red, orange, and neon (DeGuzman, Abooali, Sadatsafavi, Bohac, & Sochor, 2024) was deliberately minimised. However, besides this specific example, time constraints limited the extent of research conducted on this topic and restricted the implementation of similar methods aimed at reducing sensory intensity.

This lack of research and implementation may adversely affect the experience of neurodivergent students. Therefore, it is recommended that further research be conducted on this topic to better accommodate their needs and enhance inclusivity.

14.3. Improving Accessibility in Lecture Pieces and VR Program

Since Finland is a bilingual country, the lecture and program should be improved upon when it comes to languages to increase accessibility when it comes to languages. Translating this lecture further into Finnish and/or Swedish should and will improve the impact of this lecture on more students who are more familiar with these languages.

14.4. A potential Easier Way to Present the Lectures.

While this project has numerous benefits, it is not without its challenges. As mentioned earlier, ensuring seamless functionality can be quite a hassle. Additionally, the teacher's handbook would benefit from further refinement based on ongoing research and feedback. Furthermore, having a prepared presentation ready at the start would simplify the process for educators, making it easier to introduce the lecture effectively.

14.5. Side Activity | Card Redesign

Due to time constraints during the development of the card game, much of the feedback received focused on the way questions were presented and the type of questions being asked. Many found the original questions too difficult, prompting a proposed redesign of the cards. The new design incorporates multiple-choice questions—a highly requested feature—while still maintaining the core design elements, such as the icons provided by Hoozemans. **(Figure 54)** However, the updated card design significantly deviates from the initial version. Efforts should be made to refine the design further to ensure it aligns with the original theme and maintains visual consistency throughout the game.

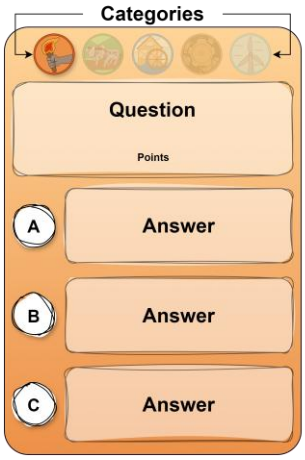


Figure 54: New card design supporting multiple choice

14.6. Long-Term Strategy

Although it may seem far-fetched, it is important to monitor the long-term results of this lecture. Observing how students learn from this experience and how they benefit from it over time can provide valuable insights. Since students at this age rarely engage with the topic of research, it is worth exploring how this lecture can inspire them to take initiative and begin their own research journeys. Activities such as post-lecture quizzes or surveys, student reflections, and follow-up assignments can provide more information about their experience and help identify how the lecture influences their interest and ability to conduct research independently.

15. Conclusion

This has been evident in the development of the VR-based educational program focusing on the evolution of energy technology. Based on serious research, stakeholder involvement, and iterative testing, the project team produced an engaging VR experience supported by interactive side activities and a structured teacher's handbook.

Key achievements include the creation of immersive VR scenarios depicting milestone moments in energy history, the inclusions of a narrative mechanism to drive student engagement, and design considerations for a complementary card game and invention phase targeting a wide array of learning styles. The testing sessions did yield useful feedback: strengths found in the interest of students and the program's ability to let their creative juices flow, while aspects needing reworking included things like navigation, interactivity, and accessibility.

Despite challenges such as hardware limitations, the project was able to deliver a prototype well-matched to LUMA principles and Finnish educational objectives. The lessons learned and recommendations for future development, such as increased inclusivity for neurodiverse students, hardware performance improvements, and localization for bilingual classrooms, provide a good basis for further development.

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APPENDIX

European Project Semester | Project ClassVR

Authors

Ernest Anguera

Jelmer Sijbers

Jesse van den Ende

Supporting member

Konrad Michel

Final Report - Appendixes

Autumn 2024

Vaasa, Finland

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YRKESHÖGSKOLAN NOVIA

APPENDIX A

Project Management Report | ClassVR

European Project Semester: 2024 Autumn Semester

Authors:

Ernest Anguera, Jelmer Sijbers, Konrad Michel, Jesse van den Ende

Project Management Report

Vaasa 2024

Project Management Report

Authors: **Ernest Anguera, Jelmer Sijbers, Konrad Michel & Jesse van den Ende**
Degree Programme and place of study: **European Project Semester, Vaasa**
Specialization: **Engineering**
Supervisor(s): **Josefin Stolpe**

Title: “The Evolution of Energy Technology in Virtual Reality”

Date: 12.10.2024 Number of pages: 24 Appendices: 0

Abstract

This project focuses on developing an educational VR lesson for students aged 12-14, centered on the evolution of energy technology. Using ClassVR headsets, the lesson provides an immersive learning experience that aligns with LUMA principles, particularly in engineering and technology. The project includes a fully functional VR prototype, a teacher's handbook, and thorough quality assurance measures. Effective communication, guided by a code of conduct, ensures smooth collaboration. Decisions are made through a structured process, and the project manager oversees progress. The aim is to deliver an engaging, informative, and well-supported educational tool for Finnish classrooms.

Language: English
Key Words: Evolution, Energy, Technology, Virtual-Reality, Education

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1 Overview & Background

The purpose of this report is to document the project management. In the past four weeks the team has worked on several tasks that set the foundation of the teams' roles assignments and supports the delivery of the thesis: "The Evolution of Energy Technology in VR"

1.1 The project

As part of the European Project Semester (EPS), a team of four has been tasked with identifying, developing, and integrating an educational VR experience into the Finnish education system.

The goal of this project is to create an educational VR program using the ClassVR headsets available at Novia, incorporating LUMA principles to enhance student learning. The program aims to add value to traditional educational methods by leveraging immersive technology to engage students in innovative and interactive ways.

The aim is to create an interactive and immersive VR-based educational experience that not only captivates students but also aligns with the **LUMA (Or STEAM (Science, Technology, Engineering, Arts and Mathematics))** educational framework. This experience will be designed to make concepts more accessible and enjoyable, offering a hands-on, engaging approach to learning.

The following objectives for this project:

1. **Identify** the possibilities of the project by researching the Finnish education system, the available hardware and software and the stakeholders

2. **Build** the program and implement it into an educational lecture.

3. **Test** the build and improve where necessary based on feedback.

1.2 The Team

This chapter outlines the team role assessments and the responsibilities that each member will take on for the upcoming project. It begins by introducing each team member, providing a brief overview of their background, studies, and their specific role in the project for this semester.

The Belbin test helps identify the preferred and avoided team roles that the project group plans to utilize in the upcoming project. These roles are divided into three categories: Thinking, Action, and People roles. (**Figure 1**)

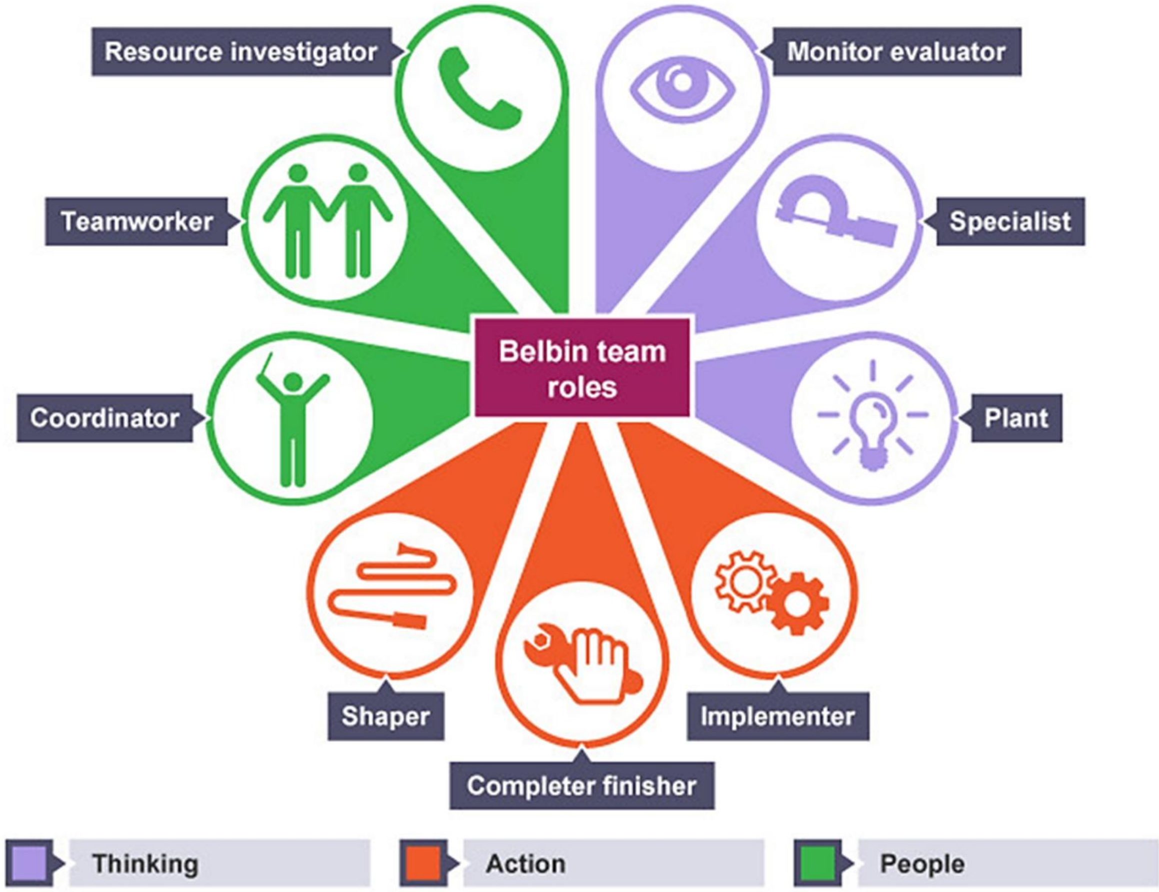

Figure 1: Belbin diagram

In addition to the Belbin test, the leadership assessment is used to identify specific skills among project members. While it does not necessarily designate someone as a leader, it highlights their abilities in particular scenarios and how they can effectively manage those situations.

These assessments consist of various questions about work-related and personal scenarios, asking each member for their honest perspective. Based on the responses, the tests provide results that highlight each member's strengths and potential areas for improvement. On their own initiative, all members have also taken a personality test to dive deeper into getting to know each other better and learn from their potential strengths and weaknesses.

Ernest Anguera

Ernest is currently a 4th year student, studying IT Engineering at Universitat Politècnica de Catalunya in Vilanova, Spain.

While studying IT, Ernest has gained knowledge in Computer Science, Coding and Logical and Structured thinking. As in Ernest's university problem solving is considered an important topic, Ernest has acquired experience in being able to think fast on how to solve problems, which are reflected in his strengths as an implementor, shaper and complete finisher.

Figure 2: Ernest

His weaknesses lie in team working, coordinating, and planning, even though Ernest can work in a team, he would rather work on his own.

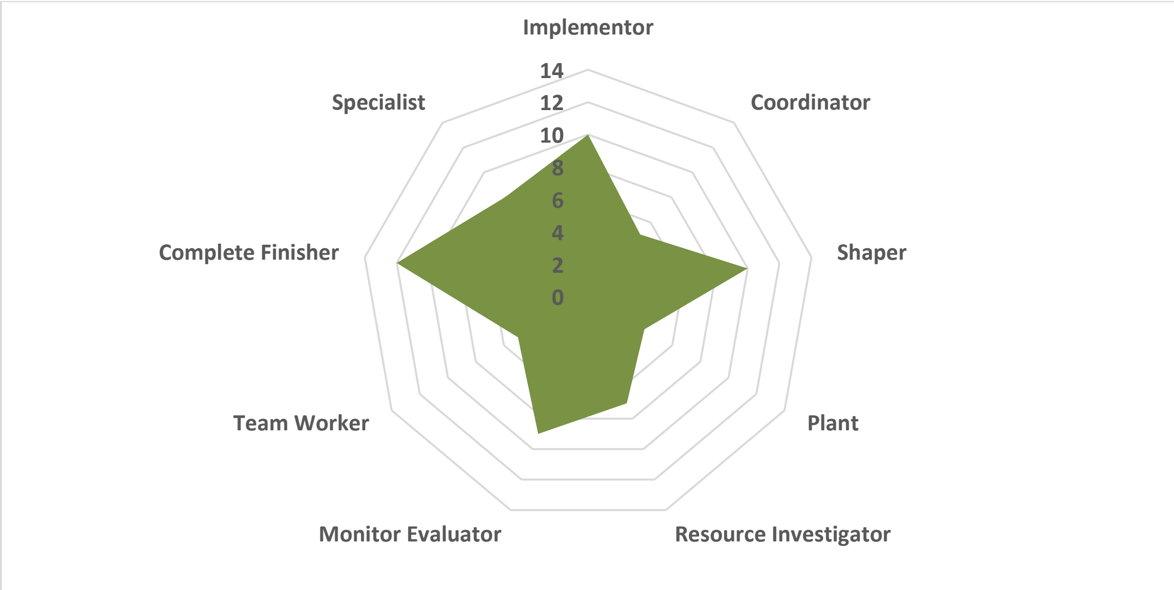

Figure 3: Ernest's Belbin results

Ernest is strong in ensuring tasks are completed to a high standard, which is reflected in his high score as a Completer Finisher. (**Figure 3**) He excels at pushing the team forward and staying motivated, aligning well with his role as a Shaper. While he feels confident in turning his own ideas into practical actions, he acknowledges that translating others' ideas into practical steps is more challenging, which is why he wouldn't rate his Implementer role as high as Completer Finisher.

Ernest believes that he objectively analyses situations and provides logical evaluations, so he doesn't fully agree with the Monitor Evaluator result. He recognizes that while he can explore external opportunities (Resource Investigator), leadership roles (Coordinator) and managing group dynamics (Team Worker) are not his natural focus. Creativity and idea generation (Plant) aren't his strengths either, but he values collaborating with people who are stronger in those areas. He thrives in roles that emphasize precision, execution, and driving the team toward its goals.

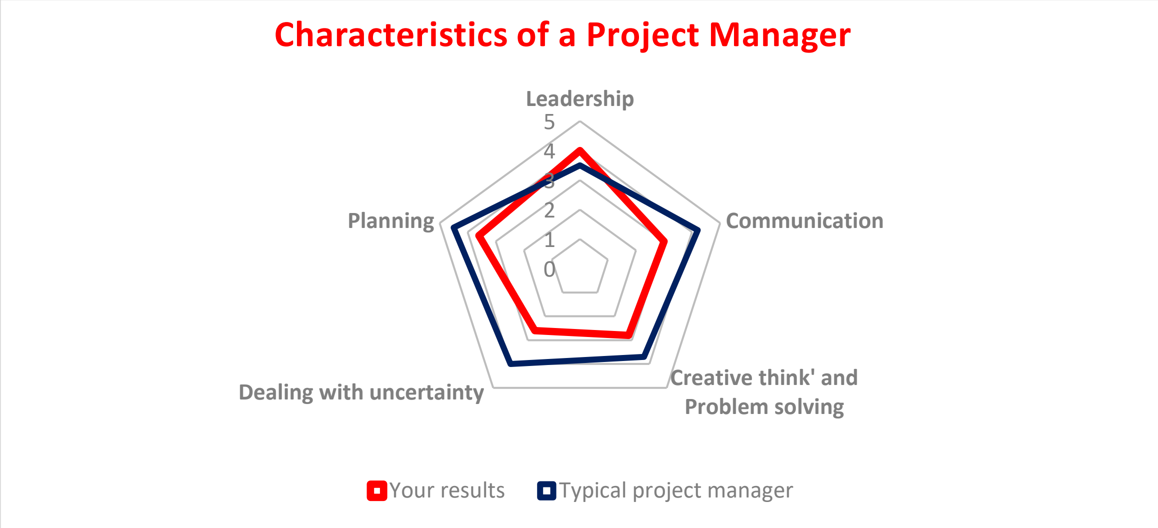

Figure 4: Ernest's leadership results

Ernest’s leadership test results highlight several key strengths and areas for improvement. (**Figure 4**) With a **Leadership** score of 4, he demonstrates a solid ability to take charge and guide others effectively, indicating strong leadership potential within teams and projects. His **Planning** score of 3.6 further supports this, showcasing his skill in organizing tasks and ensuring structured execution.

His **communication** score of 3 suggests that while he is competent at conveying ideas and interacting with others, there is room for enhancement, particularly in terms of clarity and influence. The **Creative Thinking and Problem-Solving** score of 2.8 indicates that Ernest may find tasks requiring innovative approaches or unconventional thinking more challenging, and he may feel more comfortable in structured or familiar environments.

Finally, with a **Dealing with Uncertainty** score of 2.6, Ernest tends to prefer predictable situations and might need additional support when navigating ambiguity or unpredictable scenarios. Overall, Ernest excels in leadership and planning but may benefit from development in creative problem-solving and managing uncertainty.

Jelmer Sijbers

Jelmer is a 3rd year applied physics student, studying at Saxion University of Applied Sciences in Enschede, the Netherlands.

Figure 5: Jelmer

As applied physics is a relatively broad study, it does not specifically offer knowledge to a specific field but can be useful in most types of research. This gives him the ability to oversee the project from a background position whilst also having the knowledge to implement specialised information. Also, as his study is highly focused on writing scientific reports, he can contribute a lot during the final report.

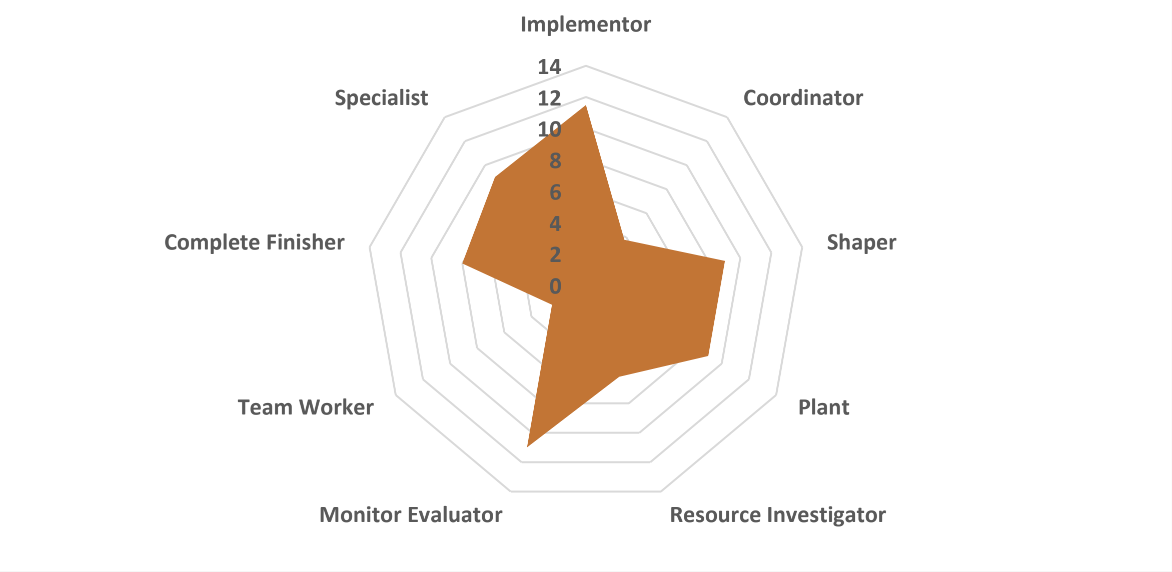

Figure 6: Jelmer's Belbin results

This is also visible in his Belbin test; (**Figure 6)** his strengths are found in the monitor evaluator and implementor side. He has a high score in those areas whilst also scoring high in the specialist, complete finisher, shaper and plant categories. This makes him perfect for a monitoring task.

His weakness is working in a team, as he scores exceptionally low in that category. This is caused by him preferring to work alone, without being disturbed. This does work for him as a monitor, as he can work on his own whilst keeping a nice oversight of the project. He also scores low on Coordinator, which can be explained by the results of his project manager test. As he has an exceptionally low score on dealing with uncertainty there, which is required if you want to be able to be good at coordinating.

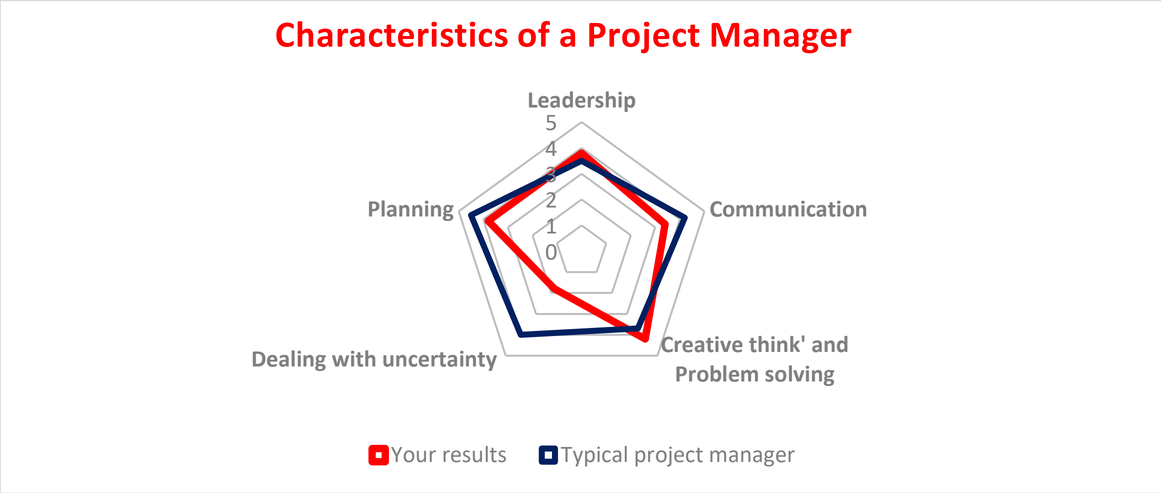

Figure 7: Jelmer's leadership results

His main weakness there is dealing with uncertainty, but due to his high creativity that should not become too much of a problem. This does however does not make him a particularly good fit for a project manager, but more of an implementor/specialist which combines well with his creativity.

This information is also shown in his 16personalities test, where he was classified as an Architect. This group is made for his creative, yet rational way of thinking. He always can produce a plan for everything and loves to perfect the details of a design, to get the best result. He has the strategic mindset, known in this Architect group, to look at several steps ahead and plan for various contingencies. He values his autonomy and prefers to work alone.

After going over the results of this test, with his main strengths lying in having oversight, being able to spot contingencies and working alone, Jelmer has taken the task of secretary and monitor for this project, whilst also doubling as implementor.

Konrad Michel

Konrad is a 2nd year student of cultural management, studying at the HSZG University of applied sciences in Görlitz in eastern Germany.

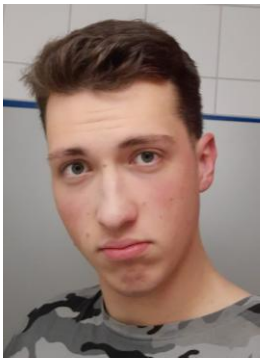

Figure 8: Konrad

His study subject contains a wide variety of economical, management related and cultural subjects. But it relies mostly on management and economics.

The main goal of the study subject is, to provide an efficient training in a general set of management and economical business skills, but also in project management and cultural related economical skills. Another important part of that taught skill set is understanding and managing cultural and subcultural related projects and its related kind of industry.

Although he is not so far advanced in his studies at his home university, he can bring some proper value to the group work.

Although his main skill field lies in economics and administration, he can contribute to proper research regarding historical, economic-technical and cultural concepts. Communication with external stakeholders, risk management concepts, project testing and its related administrative tasks are also potential fields of work, he could contribute to.

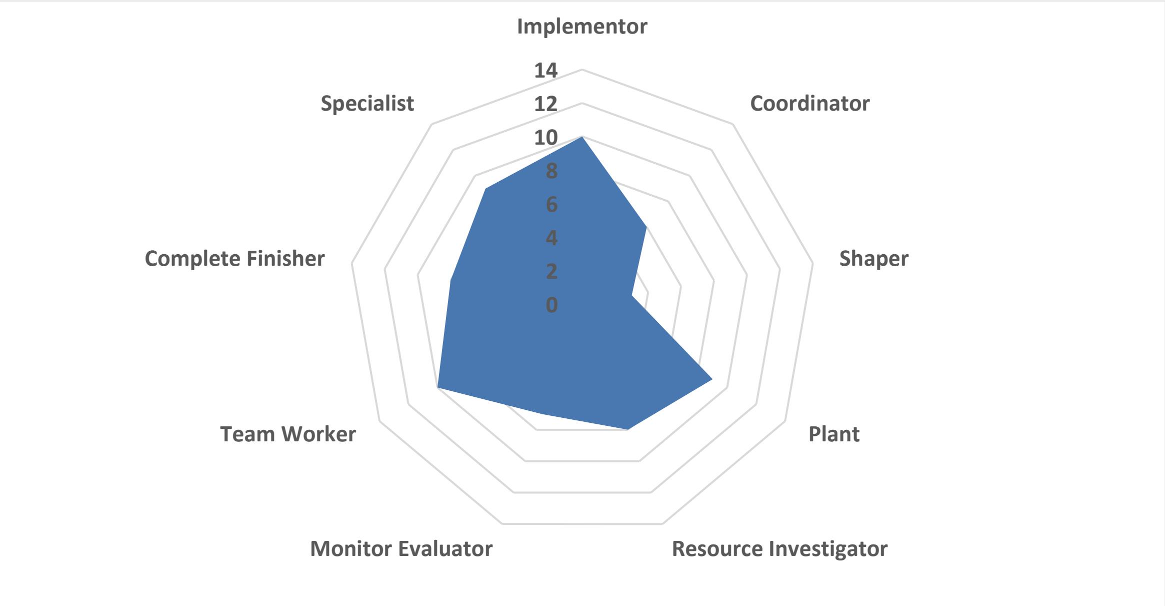

Figure 9: Konrad's Belbin results

The Belbin Test shows almost the same kind of strengths, his home study subject is enforcing in a certain level. (**Figure 9**)

Konrad seems to have a high tendency for implementation, team working and being a “plant” in a productive context.

His weaknesses appearing to be a monitor evaluator, a coordinator and a shaper.

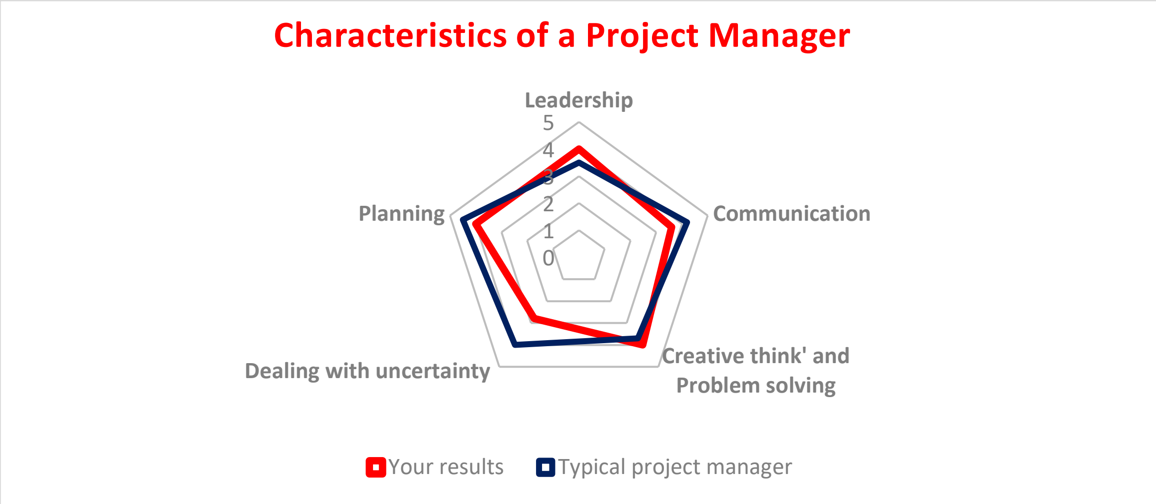

Figure 10: Konrad's Leadership results

According to the results of Konrad´s leadership test shows different outcomes, which are different to the typical project manager. (**Figure 10**)

In terms of leadership skills, he seems to tend to a higher sense of leadership. This is resulting in a 4-point rating instead of an average 3-point.

But this sense for leadership in a project highly depends on the situation, the project itself and the structure dynamics within the group.

Another over average strength seems to be his creative thinking and problem solving.

This is rated as a 4 instead of a 3.8 on the test.

Konrad can indeed deliver a different variety of approaches, to solve a problem or complete a task. But this could sometimes lead to an overcalculation of ideas and too complex problem-solving methods.

The sections, in which he currently appears got a skill ratio under the typical manager´s attainment, are the dealing with uncertainty (point 3 instead of average point 4), planning (point 4 instead of point 4.5) and communication (point 3.7 instead of point 4).

At least his under average results of the dealing with uncertainty got its roots in his study and working history as well as in the working culture of the society in his home country. Konrad prefers a more detailed and manageable approach to potential imponderables, which potentially could have a negative impact on the project, product etc.

Jesse van den Ende

Figure 11: Jesse

Jesse is currently a 4th year student, studying Business IT & Management at Avans University of Applied Sciences in s'-Hertogenbosch, the Netherlands.

While not majoring in engineering, Jesse has had some hand on experience with software engineering in the past. Giving him the basic knowledge and logic behind software structure and building. His expertise lies in project management, stakeholder relations and analytic thinking. His strengths lie in his critical thinking and problem solving, making sure everything is covered before the group proceeds with the project.

As the project manager, his primary responsibility will be to organize the project plan and ensure that all team members understand and adhere to it. He will also serve as the main point of contact for stakeholders, addressing their questions and concerns.

His challenges include a tendency toward perfectionism and difficulties with self-expression. Though committed to delivering the best possible results for both the project and the team, he often neglects his own well-being in the process. Aware of this as a limitation, his personal goal for the semester is to improve his ability to voice concerns about the project and to trust others with tasks, particularly when he feels he may not be able to meet expectations.

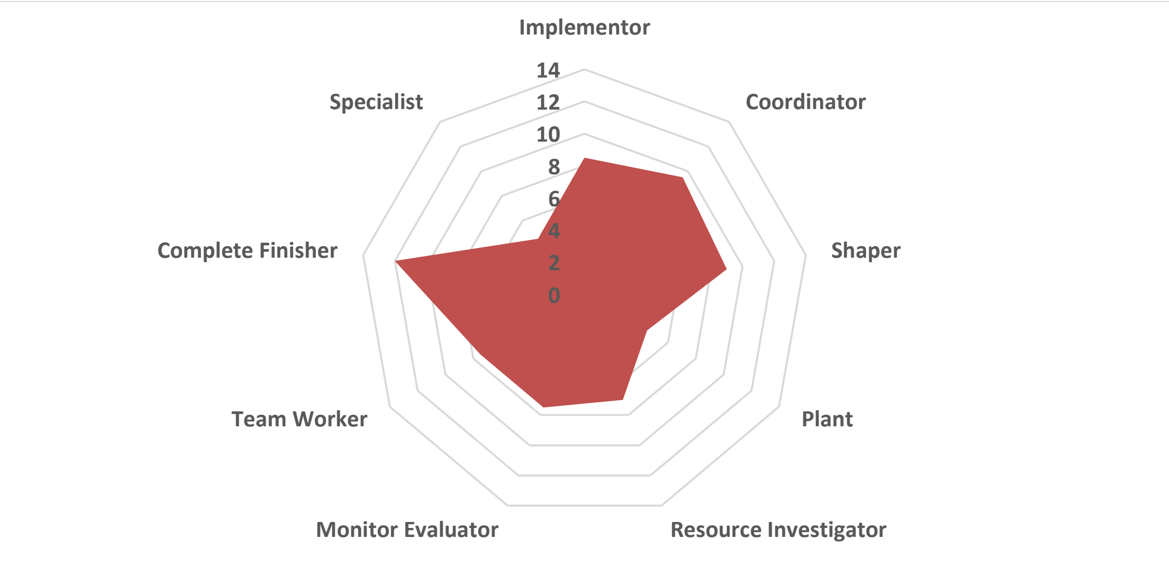

Figure 12: Jesse's Belbin results

As a Coordinator, Jesse excels at uniting the team and driving them towards a shared goal that everyone understands. He prioritizes clear communication, ensuring that all members know their roles and feel comfortable offering and seeking help when needed. For Jesse, it's crucial that the team shares a common vision, fostering collaboration and mutual support. In combination with coordination, as a complete finisher, Jesse sees the task done as perfect as he can get it.

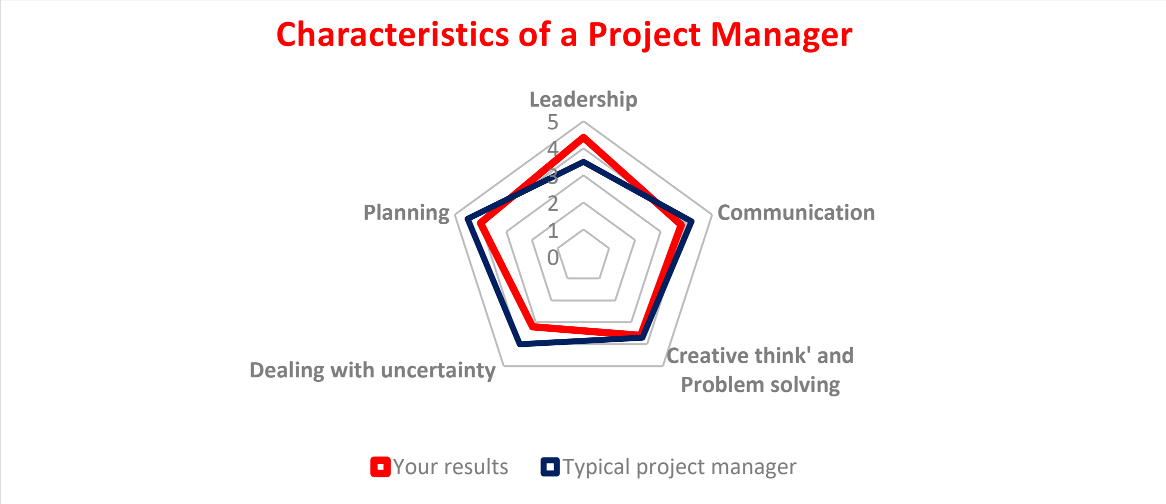

Figure 13: Jesse's leadership results

According to Jesse's leadership test, (**figure 13**) 1 major aspect turns out to be above the average project manager. With 4.4 points out of 5, Jesse has the highest rating when it comes to **leadership**. This was something he was expected to have in the beginning, hence why he got the role as project manager of this project. However, while he does have the highest rating, he is not referred to as the leader. Merely the manager and is as equal as the others.

In areas like **planning**, **communication**, and **creative thinking**, Jesse's results are comparable to that of an average manager. His home university places a strong emphasis on planning and team communication from the start of the program, which has provided him with a solid foundation in managing these aspects effectively. This experience has equipped him with the skills to handle team dynamics, organize tasks, and think creatively when solving problems, making him well-prepared for managing the project's demands.

The only area where Jesse scores slightly lower is in **dealing with uncertainty**. While his score is somewhat below the average for typical project managers, it's important to note that this is a common challenge faced by everyone in the group. To address this, Jesse's goal is to ensure that all team members are well-prepared for any potential challenges that may arise during the project.

1.3 Hofstede Theory

The Hofstede cultural dimensions theory is a framework that talks about different cultural dimensions in workplaces of different places and cultures around the world. These dimensions are: Power Distance, Collectivism vs individualism, uncertainty avoidance, motivation towards achievement & success (previously known as Masculinity vs. femininity), short-term vs. long-term orientation and indulgence vs. restraint. (**figure 14**)

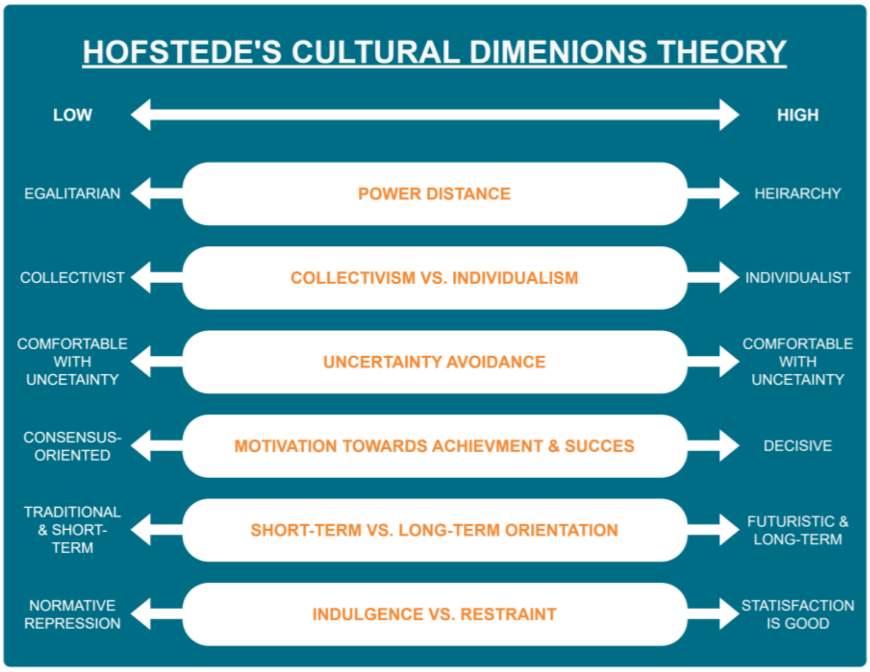

Figure 14: The 6 cultural dimensions

In this project, 3 different countries are present for this semester. Spain, Germany and the Netherlands respectively. The image below shows the difference in cultural dimensions. (**figure 15)**

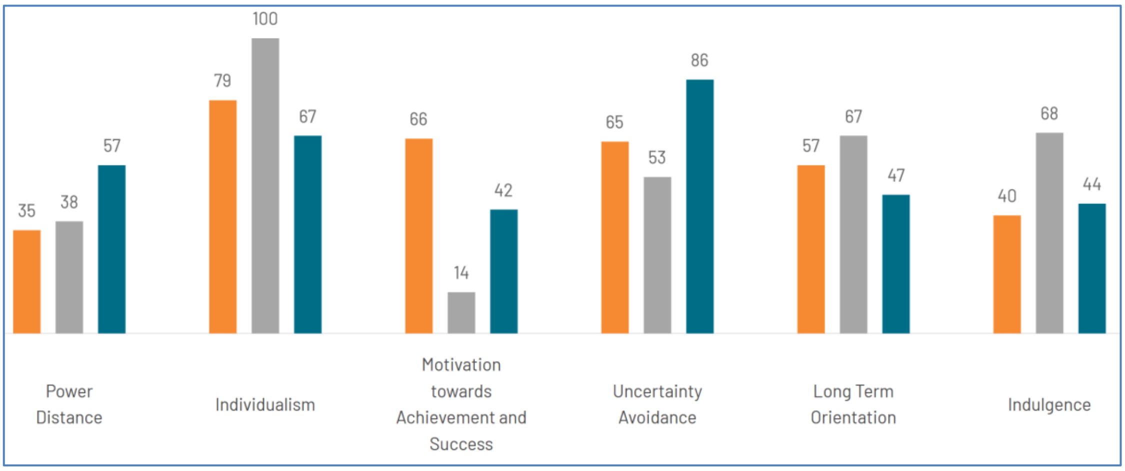

Figure 15: Germany (Orange), The Netherlands (Gray), Spain (Blue)

To explain how each of these dimensions are related to the project, the team has given each their own opinion on the results and how it could influence their way of working in this project.

Spain (Ernest)

Ernest: “I mostly agree with the cultural overview of Spain from the culture factor tool. In Spain, we do have a clear hierarchy that helps us understand our roles in society, and people often prioritize taking care of themselves and their close family. However, I don’t fully agree that Spain is always a consensus-based society. While we do aim for agreement at times, there are many situations where one person—usually a superior at work or an older family member—decides, and everyone else must follow, even if they don't agree.

As much as I dislike it, it's true that Spaniards can be loud, and we like to create rules that we don’t always follow. The idea that Spanish people only live in the moment and don’t think about the future is, in my view, not entirely accurate. That mindset is more typical of certain regions, not the whole country.

I also don’t think Spaniards are generally pessimistic or cynical. While this might be true for some areas, I believe we are more realistic about our limitations. If something seems too difficult or demanding, we accept that it might be beyond our abilities, which I think reflects realism rather than pessimism.

In conclusion, while I agree with much of what is said, I strongly believe these descriptions shouldn’t be applied to the entire country. Spain is diverse, and not all these statements are universally true.”

Germany (Konrad)

Konrad: “I agree with the cultural overview in most parts. But I disagree with the power distance section.

While in Finland, employees might communicate with their superiors in a more unformal way, in Germany, it is (from my experience as a graduated office clerk) more common to keep a stricter formal and professional manner of interaction.

The kind of Individualism is in a non-work-related environment quite fitting to the Hofstede's Individualism section. But a sense of work-related commonality, is mostly expected in a work-related environment. But it differs highly in relation to the company and branch.

The common appearance of the motivation of achievement and success is from my personal experience and point of view less decisive as in the survey stated. The urge to work hard to be successful in a proper way, is still highly engraved in our society and working culture.

I further agree mostly with the section of long-term orientation. I prefer in this case to refer to the long-term development plans of big German companies. The Rheinmetall conglomerate of the defence sector might here be a good example.

But the Hofstede's results regarding to be comfortable with uncertainty is nearly the opposite of my personal experience. And I'm quite sure, that a lot of Germans might agree with me in that matter. It is better to have everything planned beforehand (even with more flexibility), than face the results of unorganized and unconditioned management. But at last, I must admit, that the German society seems to be more restraint in the matters of indulgence."

The Netherlands (Jelmer & Jesse)

Jelmer: "I do agree with the comparison tool for the most part, even though the Netherlands score the absolute maximum in "individualism" (which seems not true) the explanation the website gives is quite accurate. We only care about ourselves but are more than willing to help others if the investment of our time seems worth it. For example, I am willing to help people do a certain thing, if that means I do not have to do that thing myself. To me, the more "individualist" countries score around 80, at which point they only care about themselves without those people being willing to help others for their own benefit.

The power distance makes sense, being quite low but not extremely low. This is especially true when compared to our neighbour Germany, where the power distance is significantly higher. In Dutch universities it is quite normal to have an "open door" policy in my experience. where the students can always walk to their professors to ask questions. I do study more in the technical areas, where this policy is "more normal" compared to the more business focused areas.

The motivation towards achievement/success is low, which does not instantly seem correct to me. However, when I saw the explanation it made sense, "our" motivation towards achievement/success is more focused on finding a success goal that everyone agrees with, instead of individual success, which Hofstede measures.

The uncertainty avoidance also checks out, we do not want everything boxed up to the point there is no uncertainty, but we like to ensure there is not too much uncertainty, especially the explanation sentence "In these cultures there is an emotional need for rules (even if the rules never seem to work)" (theculturefactor.com) really is applicable to the Netherlands.

I also agree with the long-term orientation from a personal perspective, I like to think I am a pragmatic person, and I strongly believe the truth depends on the context of the situation. However, I do not think that a similar thing can be said about the average Dutch person, look for example at our latest political voting and the current absence of any long-term vision of the current parliament.

The last category is about indulgence, which the Netherlands also score quite high on. The explanation is quite accurate to me. I really like realising my impulses especially if they regard just having fun and are not necessarily (cost-)effective.

Overall, even though I do not necessarily believe the scores given to the Netherlands are accurate, the explanation for those "inaccurate" scores are quite accurate."

Jesse: "From a first glance, I completely agree with this cultural overview. It gives me a better understanding of the diversity in the group but also gives an image of how I would want my working environment to be. From my experience it is as Hofstede theorizes, we are all working for ourselves and for our family but won't rest until we get to a consensus. The following statements below are from my own experience so far.

Power distance is one of the aspects I appreciate most about Dutch culture. We are treated as equals, working together toward a common goal. Managers offer guidance, when necessary, but there's no need to address them formally or call them 'boss.' While they hold responsibility and authority, the dynamic feels equal. Everyone learns from one another and is free to grow in their chosen expertise and beyond. Individualism is in my opinion mostly connected to the power distance. Like I mentioned earlier while people hold responsibility to certain tasks or projects it is up to you as someone that took the job to see it through its life cycle. You work towards something in common.

My motivation comes from the ability to learn at my own pace and on my own terms if it aligns with established agreements. This freedom doesn't lead to laziness; rather, it encourages both individualism and the pursuit of a common goal. If the task is completed and benefits both parties, reaching consensus becomes possible.

We like to take on more uncertain situations. We have many rules to live by which are mostly common-sense rules. Though it is never written anywhere it's something that we all know how to live. I find it nice to have such rules. To have a basis of what is expected of me while still having the opportunity to grow. From personal experience, I like to look to the future and think about every possibility that would come my way. I like to plan a couple of weeks ahead to make sure I'm prepared for anything. Even when people want to come over for a visit, I'd like to have that noted down a week ahead at the least."

2 Team communication plan

The team will conduct a meeting for about 30 minutes every Monday morning. The meeting reviews the tasks at hand, what has been done so far and if any help is required. During this meeting members can also mention

If necessary, the team will also conduct an ad-hoc meeting. These meeting will take place if unexpected issues or changes arise during the project. The severities of these issues are mentioned in risk management.

During the meetings there will be 3 different roles. The project manager will also take on the role as the **facilitator**. He will make sure that the meeting will start on time, a location is set, and everyone required is attending. During the meetings, the facilitator will make sure that every member in the meeting is also actively participating. Lastly, the facilitator is responsible for ensuring that all points in the published agenda are mentioned within the meetings time frame and that any side-tracking is prevented.

The **vice-secretary** will take on the role as the note taker. Any highlights ATM's (Additional Topics Mentioned) mentioned during the meeting will be noted down and turned into a summary after the meeting has concluded.

Lastly, the **secretary** plays a key role in ensuring that meetings stay on track. Their responsibility is to monitor the progress of the meeting, making sure it follows the agenda provided.

Decisions during meetings will be made using a voting system, where each team member votes for their preferred approach. The option with the majority vote will be chosen. In cases where disagreements arise and no consensus can be reached, the facilitator (typically the project manager) will make the final decision. The facilitator will make their decision based on each argument presented, taking into consideration the context and overall project scope.

Team communication will primarily take place through Microsoft Teams and WhatsApp, as outlined in the code of conduct established at the start of the semester.

WhatsApp will serve as the main channel for day-to-day communication between team members, including discussions about meetings, questions, and conversations happening outside the classroom. It will also be used for quick updates and phone calls when necessary.

Microsoft Teams will be utilized mainly for scheduling and tracking meetings using its agenda function. Before each meeting, an agenda will be provided to all attendees, ensuring that everyone is prepared and aligned on discussion points.

Before every meeting, the project manager will provide an agenda to all attendees. These agendas will be prepared at least one hour before the meeting and will include the key discussion points. This ensures that everyone is informed about the topics to be covered, allowing for focused and productive discussions during the meeting.

OneDrive will be used as the main hub for uploading, sharing and working on documents.

3 Scope Management & Deliverables

3.1 Work Breakdown Structure (WBS)

As mentioned in the first chapter of tis report, the objectives are three main deliverables: Identify, Build and Test. Staying consistent with these 3 objectives, a WBS, or work breakdown structure, has been developed that can put emphasis on the idea of what to deliver exactly.

The WBS (**figure 16**) provides information about the deliverables and the tasks that are associated with them. Giving the team and stakeholders an indication of what is to be expected during the delivery.

Deliverable 1 focuses primarily on tasks related to **identification and research**, as the title suggests. In this phase, the team must conduct thorough research to define the complete scope of the project. This research setting the scope and stakeholders of the project, potential risk factors, the required resources for the project and setting up the overall documentation of these findings.

Deliverable 2 involves creating a comprehensive **workable plan of action.** that includes concept ideas, the code of conduct that establishes project team norms and the assignment of responsibilities among team members. scheduling the project with start and end dates, the required resources for completing this project, the estimated costs if necessary.

Deliverable 3 is the actual **build** of the project. During this phase, the team will design and develop a working prototype based on one of the concepts outlined in the previous deliverable. This hands-on stage is crucial for translating ideas into a tangible product.

Deliverable 4, "**Finalize**." This final phase involves setting up testing plans, completing the project, and presenting the final product to the client and other stakeholders involved. This ensures that the project is thoroughly reviewed and approved before it is fully implemented.

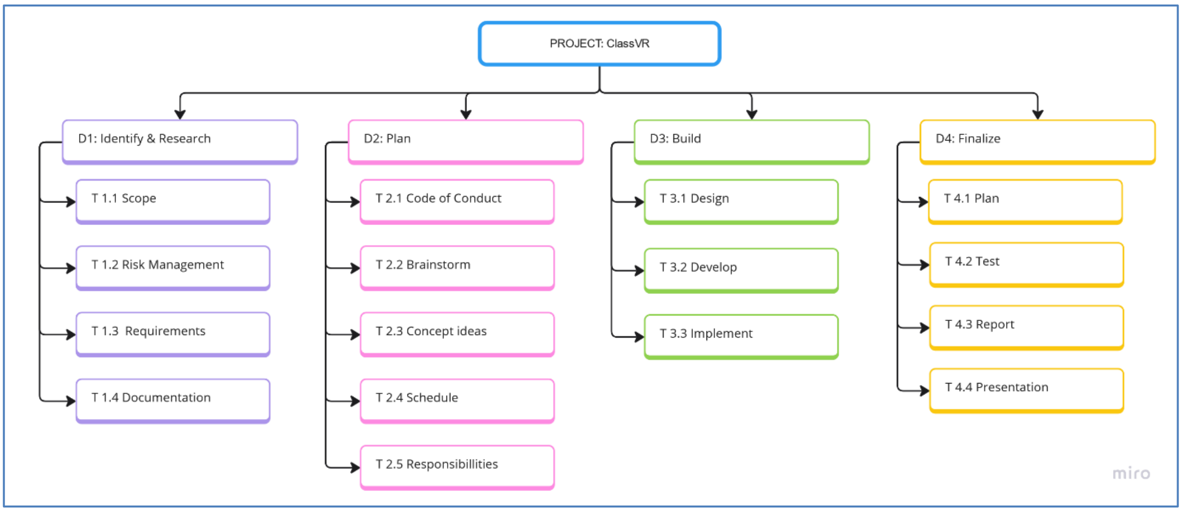

Figure 16: Work-breakdown structure

3.2 Timeline & Gantt-chart

For setting up the timeline, a Gantt-chart* for the coming semester has been set up to show an estimation of deadline based of the earlier mentioned deliverables. This chart indicated the time it is expected to be worked on and when it should be finished It also shows what needs to be done first before the project can move forward to the next task at hand. (**Figure 17**)

On the next page the Gantt-chart provided is displayed sideways in other to be able to fit inside the documents. An excel file will be provided as well containing the full Gantt-chart.

Initial planning and research | September

- Forming the team and defining the project's goals.
- Researching educational VR technologies (ClassVR).
- Aligning the project with LUMA principles and Finnish educational goals.
- Initial brainstorming of concepts, deciding to focus on the evolution of energy technology.

Concept development | Late September – Early October

- Finalizing the target age group (12-14 years old).
- Deciding on the core theme of the lesson (evolution of energy technology).
- Drafting the first iteration of the lesson plan and structure for the VR experience.

Prototype development | Mid October – Early November

- Developing the prototype of the VR lesson.
- Creating a simple version of the VR experience for testing.
- Start working on the teacher’s handbook.

Testing and feedback | Mid November

- Conducting initial tests of the VR lesson with students or teachers.
- Gathering feedback on usability, engagement, and learning outcomes.
- Refining the prototype based on feedback.

Final adjustments & Submissions |Late November – December

- Implementing final adjustments to the VR lesson and the teacher’s handbook.
- Preparing the final deliverables (VR program, teacher’s handbook, and presentation).
- Submitting the project by the deadline in December.

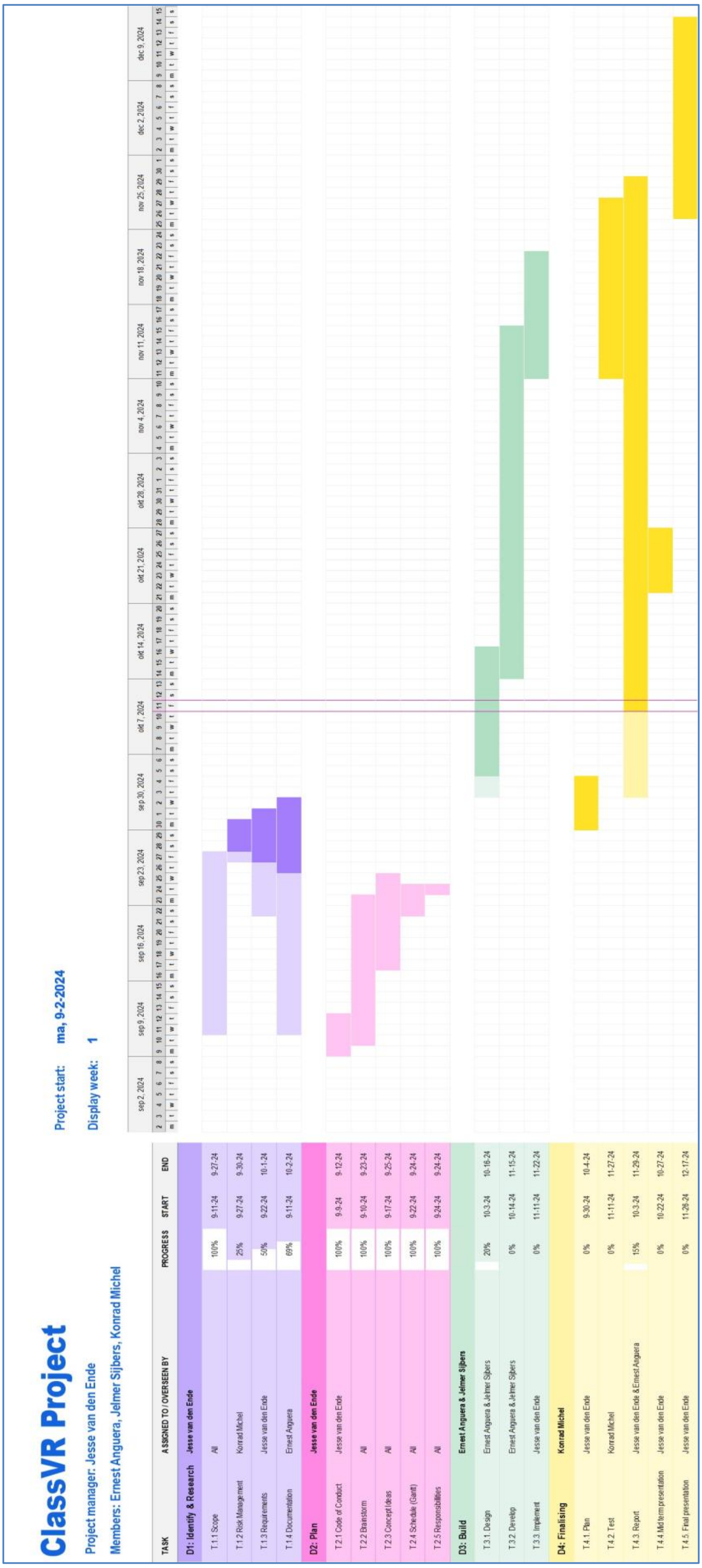

Figure 17: Gantt-chart

3.3 Project Scheduler

Table 1: Project Charter

<table>
<tr><th colspan="3">1. General Project Information</th></tr>
<tr><td>Project Name:</td><td colspan="2">The Evolution of Energy Technology in Virtual Reality</td></tr>
<tr><td>Team leader:</td><td colspan="2">Jesse van den Ende</td></tr>
<tr><td>Sponsor:</td><td colspan="2">LUMA</td></tr>
<tr><td>Date:</td><td colspan="2">03/09/2024 – 20/12/2024</td></tr>
<tr><th colspan="3">2. Project Team</th></tr>
<tr><td>Name</td><td>Title</td><td>Responsibilities</td></tr>
<tr><td>Jesse van den Ende</td><td>Project Manager</td><td>Accountable, responsible</td></tr>
<tr><td>Jelmer Sijbers</td><td>Secretary</td><td>Responsible</td></tr>
<tr><td>Ernest Anguera</td><td>Vice-secretary</td><td>Responsible</td></tr>
<tr><td>Konrad Michel</td><td>Testing</td><td>Responsible</td></tr>
<tr><td>Philip Hollins</td><td>Documentation Supervisor</td><td>Responsible, consulted, informed</td></tr>
<tr><td>LUMA</td><td>Sponsor</td><td>Informed</td></tr>
<tr><th colspan="3">3. Project Scope Statement</th></tr>
<tr><td colspan="3">Project Purpose</td></tr>
<tr><td colspan="3">The direct goal of this project is to provide a basis for an immersive learning environment to teach the energy history in Vaasa in a more memorable manner. A benefit of this is the improved utilization of the currently underutilized headsets, to increase the benefit of the original investment. This will also help with showcasing the potential of using VR for educational purposes and stimulate innovation in the lessons.</td></tr>
<tr><td colspan="3">Objectives</td></tr>
<tr><td colspan="3">Understand the educational goals, target audience and content for the lesson.
Develop the VR lesson prototype focusing on the evolution of energy technology.
Conduct trials with students to gather feedback and refine the lesson.
Finalize the prototype and materials based on testing feedback.</td></tr>
<tr><td colspan="3">Deliverables</td></tr>
<tr><td colspan="3">VR lesson prototype for students aged 12-14.
Teacher’s handbook.
ClassVR program for the lesson.</td></tr>
<tr><td colspan="3">Scope</td></tr>
<tr><td colspan="3">Develop prototype for an interactive lesson for the students of ages 12-14
Presenting final product to all teachers involved in the creation
Creating handout for the teachers with information about the lesson
Out of Scope*
Developing an AR project
Developing an own engine for ClassVR
Conduct research outside the age range of 12 between 14
Teaching students on how to use the headset / Participate in lessons</td></tr>
</table>

** These tasks will **NOT** be conducted during this project semester*

4 Stakeholders & Reporting

4.1 Stakeholder identification and communication

To effectively understand the stakeholders involved in the project, it is crucial to first identify them. In this case, stakeholders are categorized into two groups: External and Internal. See table below. (**table 2**)

Each stakeholder plays a specific role in the project and can offer valuable insights on various aspects. The IDis used to uniquely identify or reference each stakeholder for easier communication and tracking. The frequency indicates the expected number of interactions with each stakeholder throughout the project, helping to ensure that necessary communication and engagement are maintained. This structured approach allows for better management of relationships and a more comprehensive understanding of stakeholder needs and contributions.

Table 2: Stakeholder identification

ID	Stakeholder Name	Role	Category	Frequency	Communication	Provides
1	LUMA	Client	Internal	Weekly meeting	Email	Lesson Structure & Materials
2	Novia UAS	Program Manager	Internal	six-monthly	Email	Working space
3	ClassVR	Supplier of Product	Internal	None	Email	Any issues with the VR Headset
4	Josefin Stolpe	Supervisor	Internal	Weekly meeting	Email	Team Management & Lesson Structure
5	Phil Hollins	Advisor	Internal	None	Email	Project Management
6	Mikhael Ehrs	Supervisor	Internal	six-monthly	Email	Team Management & Lesson Structure
7	Jenny Ronnqvist-Norrby	Advisor	Internal	One meeting	Email	Finnish Educational System & Contacts
8	Hanna Hankaniemi	Advisor	Internal	One meeting	Email	Lesson Structure
9	Vaasan Yliopisto	Program Manager	External	None	Email	ClassVR account
10	Lab21	Advisor	External	When scheduled	Email	Science, Energy & VR Lessons
11	Universitat Politècnica de Catalunya	Information Provider	External	None	Email	Provides Information
12	Saxion University of Applied Sciences	Information Provider	External	None	Email	Provides Information
13	Avans Hogeschool	Information Provider	External	None	Phone	Provides Information
14	Zittau Görlitz University of Applied Sciences	Information Provider	External	None	Email	Provides Information

4.2 Stakeholder interest & influence

Now that the stakeholders are identified, it is important to know what their interest and influence is in this project.

Their power or influence suggests how much of an impact the stakeholder can have on the project. (**table 3**) It tells whether the stakeholder is a key player in this project and how engaged they are. **Figure 18** below shows the stakeholder matrix which gives an indication of the different stakeholder and their influence and interest.

Table 3: Stakeholder interest and influence

ID	Stakeholder Name	Power/Influence	Interest
1	LUMA	Strong	Strong
2	Novia UAS	Weak	Strong
3	ClassVR	Weak	Weak
4	Josefin Stolpe	Strong	Strong
5	Phil Hollins	Weak	Weak
6	Mikhael Ehrs	Strong	Strong
7	Jenny Ronnqvist-Norrby	Weak	Weak
8	Hanna Hankaniemi	Weak	Strong
9	Vaasan Yliopisto	Weak	Weak
10	Lab21	Weak	Weak
11	Universitat Politècnica de Catalunya	Weak	Strong
12	Saxion University of Applied Sciences	Weak	Strong
13	Avans Hogeschool	Weak	Strong
14	Zittau Görlitz University of Applied Sciences	Weak	Strong

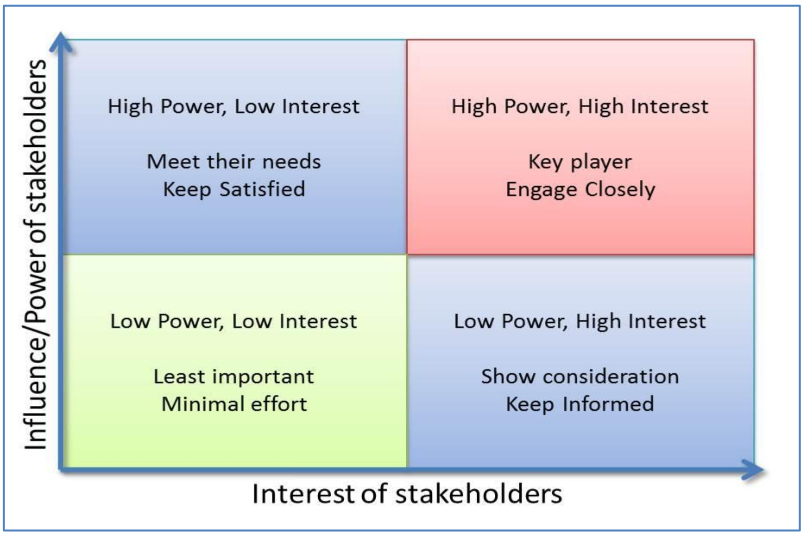

Figure 18: Stakeholder influence matrix

5 Risk Management

Lastly, a project can encounter risks during its lifecycle. To manage and prepare for these risks, a risk matrix is utilized. This matrix enables the team to evaluate potential risks by assessing their likelihood and impact, as well as determining appropriate responses.

The table (**table 4**) and accompanying image (**figure 18**) below illustrate the identified risks, their likelihood of occurrence, potential impact on the project, and suggested mitigation strategies.

For a more detailed description and response plan for each identified risk, please refer to the external Excel sheet provided. This excel sheet offers a better overview of the risk management strategies to address each specific risk, ensuring that the team is well-prepared to navigate any challenges that may arise during the project.

Table 4: Risk resister

ID	Risks	Likelihood	Impact
1	Internal hardware malfunction (development tools or equipment)	Low	High
2	Software crashes or malfunction	Medium	High
3	Damage or destruction of equipment	Low	High
4	Limited access to essential resources and equipment.	Low	Medium
5	Extended absence of team members due to illness	Low	Low
6	Internal communication breakdown	Low	High
7	(External) Stakeholder communication breakdown	Low	High
8	Missed project deadlines	Low	Medium
9	Complete project failure	Low	High
10	Force majeure events	Low	High
11	Theft of equipment or resources	Low	High
12	Changes in the project's scope	Medium	High
13	Lack of user engagement during testing	Medium	Medium
14	Not enough expertise on technical front	Low	Medium

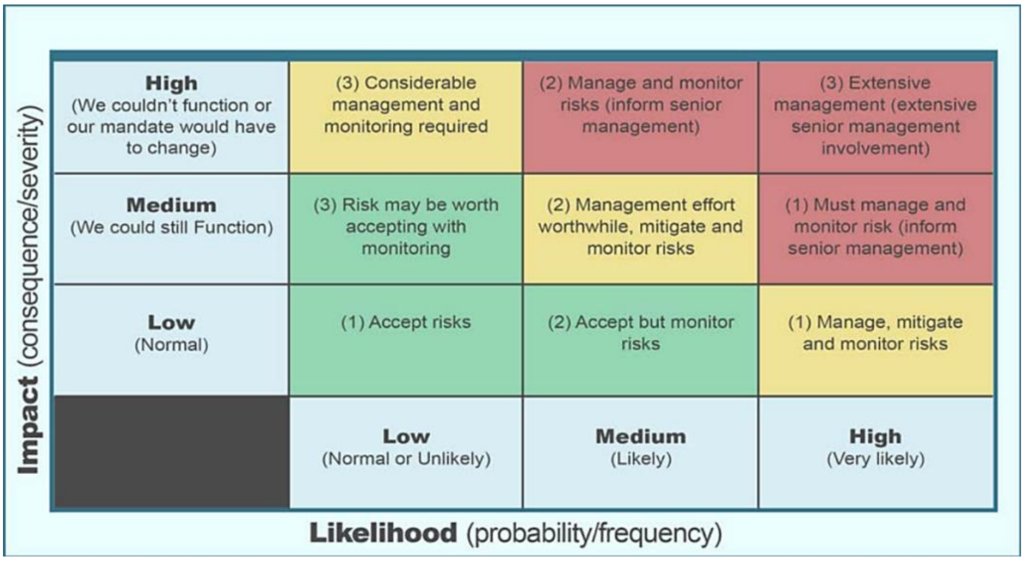

Figure 19: Risk matrix

6 Quality Assurance & Project Closure

To ensure consistent quality throughout the project, regular communication will be maintained with the client/supervisor on a weekly basis. During the development phase, ongoing testing of both the program and the VR headsets will be conducted. This includes:

- **Testing**: Regular functionality tests to ensure the VR experience operates as intended and meets educational objectives.

- **Feedback**: Gathering input from team members and stakeholders to identify any issues or areas for improvement.

- **Documentation Reviews**: Periodic reviews of project documentation to ensure clarity and alignment with project goals.

A final presentation will be held to showcase the results of the project. This presentation will summarize the project's objectives, outcomes, and a step-by-step introduction of how to use it, how it can be implemented into the school and lectures and the research behind it.

The project will be officially considered closed once the final deliverables are handed over to LUMA. These deliverables include the VR prototype itself and a comprehensive teacher's handbook detailing how to set up, use, and guide students in utilizing the VR headsets effectively.

Appendix B

Table of Contents

Lesson Structure

1 VR lesson

The Discovery of fire (Pleistocene era)

In this part of the lesson, the discovery of how to control fire will be explained as well as the uses that fire had.

1. **Natural Fires and Early Humans:** Fire existed long before humans and was mostly caused by natural events like lightning. Early humans, like savanna chimpanzees today, were aware of fire but couldn't control it at first.
2. **Learning to Use Fire:** Over time, early humans learned to use fire for cooking, warmth, and protection. They may have first used it by taking advantage of wildfires, where animals were easier to catch, or food was accidentally cooked.
3. **Sources to produce fire:** Early humans did not know how to produce fire as soon as the first saw it, so they relied on natural sources, like wildfires caused by lightning. Once they started to understand the usefulness of fire, they learned to maintain and transport it, possibly using slow-burning materials like plant fibers or animal dung. Eventually, humans discovered methods to create fire themselves. They used two main techniques:
    a. **Friction:** Rubbing sticks together to generate heat, which eventually creates sparks and ignite dry material like grass
    b. **Striking stones:** Using flint or other hard stones to strike sparks onto a tinder bundle, which would catch fire
4. **The Importance of Fire:** Fire helped humans in many ways, from cooking food to improve digestion to keeping them safe at night. Eventually, they figured out how to make fire, which led to advancements in technology, like making tools, pottery, and even the ability to live in colder places. Fire was mainly used for
    a. **Cooking:** The first use of fire for cooking likely happened by accident. Early humans encountered natural fires, probably started by lightning, and noticed that food exposed to fire, like roots, plants, or animals, became easier to eat and tasted better. This accidental cooking improved the food's digestibility, making it easier to chew and more nutritious. As they observed these benefits, humans started using fire more intentionally. They began cooking food on purpose by controlling fire, which allowed them to eat a wider variety of foods, including meat, roots, and tubers. Cooking also helped break down tough plant fibers and kill harmful bacteria, making food safer and more nourishing. This change had a big

impact on their health, enabling them to get more energy from food, which supported the growth of bigger brains over time.

b. **Light:** When early humans discovered fire, they quickly noticed that fire not only provided warmth and cooked food but also produced light. This light became essential for their survival, especially during nighttime. As they began to control fire, humans used it to extend their activities after dark, allowing them to stay awake longer than other animals. Fire gave them light to see at night, helping them avoid predators and work together in groups. It also provided social time, where they could gather around the fire, communicate, and strengthen their bonds. Over time, firelight became a central part of their nightly routine, allowing them to stay awake and alert for longer periods than other primates, who usually sleep at sundown.
c. **Heat:** Fire became an essential source of heat, allowing humans to survive in harsh, open environments and eventually colder regions. By gathering around fire, they could protect themselves from the cold, which was particularly important as humans began to move into areas with more extreme seasonal changes. As they learned to maintain and control fire, it provided consistent warmth during the night and colder seasons, enabling them to expand their territories and survive in different climates.
d. **Forge:** The use of fire in forging began as humans observed how fire could alter the properties of materials. Early humans initially used fire for simple purposes like cooking and warmth, but over time, they realized that fire could also be used to heat materials like wood and stone, making them easier to work with. The discovery that fire could change the hardness of materials led to the development of more advanced tools. For example, fire was used to harden wooden spears or shape stones for better tools. Eventually, humans learned to use fire to work with metals, marking the beginning of forging. This process involved using fire to melt or heat metal ores, like copper, which could then be shaped into tools and weapons. These early uses of fire for forging laid the foundation for more complex technologies, such as pottery and metalworking ***forging did not happen until ~7.000-4.000 BC***

Animals at Work

In this part of the lesson, we will focus on the domestication of animals, the use of fire for materials, and how this transformation shaped human society, this epoch will be referred as *The First Energy Transition*.

1. **The Start of Agriculture and Animal Domestication:** Around **10,000 years ago**, humans began to shift from hunting and gathering to farming. This period is known as the **First Energy Transition**. Before this, humans relied on their own strength and simple tools to gather food and survive. But with the domestication of animals like **oxen, horses, and donkeys**, humans could use animal power for farming and transportation, dramatically increasing the amount of work they could do. These animals were used to plow fields, pull carts, and carry heavy loads, reducing the physical burden on humans.
2. **Harnessing Animal Power:** As agricultural societies grew, people began to realize that animals could be used to **increase energy throughput**. By using animals to plow more fields and transport more goods, humans could produce more food, which allowed their populations to grow. The animals provided much more energy than humans alone, leading to a significant boost in farming productivity. This new source of energy helped humans settle in one place, build communities, and develop more complex **social structures** like villages and towns.
3. **The Role of Fire in Material Production:** At the same time, fire was being used for more than just cooking and warmth. Humans had already learned to control fire, but now they began using it to make materials, particularly **metals**. By heating metal ores like copper, early humans learned to shape these materials into tools and weapons. This process of **forging** with fire allowed them to create stronger and more durable tools than those made of stone or wood. The ability to work with metal was a huge leap forward in technology, leading to better farming tools and new forms of construction, which made communities even more successful.
4. **The Impact on Society:** The combination of **animal power** and **fire-based technology** had a profound effect on human life. With animals doing the heavy lifting and metal tools improving efficiency, humans could produce more food, build larger settlements, and organize their societies in more complex ways. The growth in population and resources also led to **specialized jobs**—some people could focus on farming, while others became craftsmen, making tools, weapons, and pottery.
5. **Social Structures and Population Growth:** This transition wasn't just about better tools and more food—it also led to the development of **hierarchies** and **governments** as societies became more organized. With a surplus of food and resources, leaders and rulers emerged to manage and protect their communities. This period marked the start of **civilization**, as humans began living in larger, more organized groups with defined roles and social structures.
6. **Long-term Effects:** The **First Energy Transition** laid the foundation for all future human progress. By learning to harness the power of animals and fire, humans set

the stage for further technological advancements, population growth, and the development of cities and trade. Without this critical period, the complex societies we live in today wouldn't exist.

Usage of mills

In this part of the lesson, will be focused on demonstrating how mills, especially watermills and windmills helped human society evolve do hard works with ease as well as automate this type of works, such as grinding flour or driving sawmills.

1. **Windmills:** Even though the first windmills were developed in Persia around 500-900 AD, it was not until the 1180s that the first windmills as we know them, Vertical windmills, were created in Northwestern Europe and used for grinding flour.
    a. **First Vertical Windmills:** The horizontal-axis or vertical windmill (so called due to the plane of the movement of its sails) is a development of the 12th century, first used in northwestern Europe, in the triangle of northern France, eastern England and Flanders.
    b. **Types of windmills:** There are several types of windmills but in this lesson, we are going to focus on the following types: *post mill, tower mill* and *smock mill*
        i. **Post Mill:** A post mill is one of the oldest types of windmills in Europe! Imagine a house sitting on a big wooden pole that can spin around. This lets the sails catch the wind from any direction. To make it turn, some mills have a long wooden arm that people can push, while others use a cool gadget called a fantail to spin the mill automatically. These windmills started showing up in England way back in the 12th century. One of the oldest working post mills is in Outwood, Surrey, built in 1665 – that's over 350 years ago! Post mills were super popular until the 1800s, but then a new type of mill called the tower mill took over. Tower mills didn't need to spin the whole building, just the top with the sails, making it easier to store things inside. There are several types of post mills, each one being an evolution of the older version:
            1. **Sunk Post Mill**: Early post mills were small and unstable in strong winds, so the trestle was buried in a mound of earth for support. These mills existed in England but are now extinct.

2. **Open Trestle Post Mill**: Larger post mills that didn't require burying the trestle. Surviving examples are found in the UK, France, Belgium, the Netherlands, Germany, and the USA.
3. **Post Mill with Roundhouse:** A roundhouse was built around the trestle to provide storage space and protect the structure from the weather. Some mills in Suffolk had taller roundhouses.
4. **Midlands Post Mill**: In the Midlands and Northwest England, the roundhouse was fitted with a curb and rollers to bear some of the mill's weight, giving it more stability.
5. **Alternative Protection (Apron)**: In Eastern Europe, an "apron" enclosed the trestle instead of a roundhouse to protect it from the elements.
6. **Hollow Post Mill**: These mills had a hollow main post that housed a driveshaft, allowing machinery to be driven in the base or roundhouse. They were rare in the UK but common in the Netherlands and France.
7. **Composite Mill**: Resembling a post mill, but without a central post, these mills had a post mill body mounted on a short tower or roundhouse.
8. **Paltrok Mill**: A type of mill mainly used for sawing wood, common in the Netherlands and Germany. Dutch paltrok mills were built on a central post with a rim bearing for stability, while German paltrok mills were often converted from post mills and featured large diameter bases.

ii. **Tower mill:** A tower mill is like the fancy upgrade of the old wooden windmills! While earlier windmills were made mostly of wood, tower mills were built from strong stone or brick, making them way more durable. Instead of turning the whole mill like in post mills, only the top part (called the cap) spins to catch the wind, which made them more reliable in rough weather and allowed them to have bigger sails. The first tower mills popped up in England around the 12th century, but they really took off in the 1300s and 1400s. They were super expensive, so only rich nobles or the government could afford to build them at first. Sometimes they even used old castle towers to save money! But these mills were important because they didn't just grind grain—they powered all sorts of industries like cutting wood, making paper, and even producing spices! Tower mills became so popular that people started competing to build the tallest and best-looking ones. Some of them had more than just the usual four sails; they added six or eight! And they didn't have to manually move the sails to face the wind—many had cool gadgets called fantails to do that automatically. The tallest tower mills today are over 30 meters high, like the "Moulton Windmill" in England and "De Nolet" in the Netherlands! These mills were not only useful but also became stylish symbols of their regions. Everyone wanted to build bigger and better ones, leading to all sorts of design improvements over time!

iii. **Smock mill:** A smock mill is a type of windmill that looks like it's wearing an old-fashioned farmer's outfit, called a smock—hence the name! These mills are shaped like a tower with six or eight sides, usually made of wood, and topped with a rotating cap that helps the sails catch the wind. Unlike tower mills, which are usually round and made of stone or brick, smock mills are often octagonal or hexagonal and built from timber. They were most common in England, especially in the county of Kent, where you can find the tallest one, Union Mill, in Cranbrook. Smock mills became really popular in the 1800s but started to disappear when steam power took over. One of the oldest surviving smock mills is the "Old Mill" on Nantucket Island in the U.S., built in 1746. It's still working today! There's also another one in Orleans on Cape Cod that was restored and is open to visitors. These mills were used mainly for grinding grain, but over time they became historical landmarks and symbols of their regions, especially in places like Long Island, New York, where there are many still standing today. Smock mills are not only fascinating for their unique shape but also for the history they carry with them, from Europe to the U.S., showcasing the importance of windmills in the past!

c. **Usage of windmills:** During medieval times, windmills were incredibly useful for many tasks, helping people harness the power of the wind to make everyday jobs easier. Here are some of the main ways windmills were used:

   i. **Grinding Grain:** This was the most common use of windmills. Farmers would bring their wheat, barley, or corn to the mill to be ground into flour or meal. Wind power turned large grinding stones that crushed the grain, making it easier to store, cook, or sell. This was crucial for producing bread, a staple food during that time.

ii. **Pumping Water:** In areas like the Netherlands, where much of the land is below sea level, windmills were used to pump water out of low-lying areas to prevent flooding. They helped drain swamps and marshes, turning them into usable farmland.

iii. **Sawmilling:** Windmills were also used to power saws, cutting timber into planks for building ships, houses, and furniture. This was especially important in places with a lot of forests, where wood was a key resource.

iv. **Crushing and Pressing:** Some windmills were used to crush seeds, like olives or flax, to extract oil. The wind-powered mechanisms pressed the seeds to release oil, which was then used for cooking, lighting lamps, or making soap.

v. **Manufacturing:** As technology advanced, windmills were adapted for more industrial purposes. They helped power machinery for tasks like producing paper, processing spices, or even making textiles. This marked the beginning of their role in larger-scale manufacturing.

2. **Watermills:** A watermill is a building that uses the power of flowing water to perform various tasks. It works by channelling water over a large wheel, which turns the wheel and drives machinery inside the mill. This allows the energy of the moving water to be converted into mechanical power, which can be used for tasks like grinding grain into flour, cutting wood, or processing cloth. Watermills were a key technology during medieval times, helping people save time and effort on important jobs. Watermills were an essential part of life during medieval times, as they used the natural flow of water to make hard tasks easier. This is how they worked and what they were used for:
    a. **How did they work?** Watermills were powered by water flowing over a large wheel. As the water pushed the wheel, it turned gears and shafts that powered other machines inside the mill. This allowed people to use the energy from rivers to get their work done without relying on human or animal power.
    b. **Main uses:**
        i. **Grinding Grain**: Watermills were mostly used to grind grain into flour for bread, which was a big part of people's diet. Instead of doing this by hand, the watermill made it much faster and easier.

ii. **Sawmills**: Watermills were also used to cut wood into planks. The moving water would power large saws that could cut through logs, helping to build houses, boats, and furniture.
iii. **Metalworking**: In some places, watermills helped in blacksmithing, using hammers powered by water to forge metal tools and weapons.
iv. **Fulling Mills**: Watermills also processed wool by pounding it to make cloth stronger, in a process called fulling.
v. **Paper Mills**: As technology advanced, watermills helped in making paper, using the power of water to press and shape the material.

c. **Types of watermills:** There are several types of watermills, each designed to make use of waterpower in different ways. Here are the main types:
   i. **Horizontal Watermill**: In this simpler type, the waterwheel lies flat and rotates around a vertical axis. Water flows directly onto the wheel's paddles, causing it to spin. Horizontal mills were mostly used in places with fast-moving water. These mills were not very efficient but were cheaper and easier to build.
      1. **Flutter Wheels**: These wheels were used when there was a large supply of water. They were small, low and wide – about 92 cm in diameter and up to 244 cm wide. The name of this wheels comes from the sound they made, as the wheel went around, the blades cut through the entering water, making a noise like the fluttering wings of a bird. These wheels were used to power early sawmills.
   ii. **Vertical Watermill**: The waterwheel in this type is positioned vertically on a horizontal axis. The water hits the wheel from the side, making it turn. This type is more complex but much more efficient because it could be adapted for different types of water flow. Vertical watermills can be further divided into different kinds depending on how the water hits the wheel:
      1. **Undershot Mill**: In this type, the water flows underneath the wheel, pushing the paddles at the bottom. It's used where the water is shallow and doesn't have much force.
      2. **Overshot Mill**: Water is poured over the top of the wheel, filling buckets attached to the wheel's rim. The weight of the water pulls the wheel down, which makes this type of mill more powerful and efficient. It works well in places with steep rivers or waterfalls.

3. **Breast Mill**: Water strikes the wheel at its middle or "breast" height. It uses both force of the water and gravity to move the wheel. This type is more effective than the undershot mill but requires more engineering to build.

iii. **Tide Mill**: A special kind of watermill that doesn't use rivers but relies on the movement of the ocean tides. Water is trapped in a basin during high tide, and as the tide goes out, the water is released through the mill, turning the wheel.

iv. **Ship Mill**: In this unique type, the watermill is mounted on a boat, which floats on rivers. The boat's waterwheel is turned by the river's flow, providing a mobile milling operation. Ship mills were often used in places where water levels were unpredictable.

Industrial revolution

The Industrial Revolution was a time when people started using new machines that could do a lot of work very quickly. Factories became big and could make lots of items cheaply. Most of these machines were powered by coal, and later on, gas and oil. This was also when electricity began to be used!

1.1 Steam power

Steam power was one of the most important inventions of the time. Here's how it works: when water is boiled, it turns into steam. This steam is pushed into a cylinder with a piston inside. The steam's force moves the piston, which creates energy. This energy can then be used to power things like machines. For example, when the piston is connected to a wheel, it can make the wheel spin and power something like a water pump. This process is called energy transmission.

People knew about steam power as far back as the 1st century AD, thanks to a Greek mathematician named Heron of Alexandria. But it wasn't until over 1,500 years later that we figured out how to use steam to power machines. In 1712, a British inventor named Thomas Newcomen built the first useful steam engine. It had a piston inside a cylinder that moved up and down, which was used to power water pumps in British mines.

Then, in 1769, a Scottish inventor named James Watt made a much better steam engine. His new design allowed steam engines to power even more machines in factories, starting a huge change in how things were made, known as the Industrial Revolution.

1.2 More Ways Steam Power Changed the World

1.2.1. Locomotive

Trains are common today, but they first appeared more than 220 years ago! The first train was built in 1804 by a British engineer named Richard Trevithick. He improved on Watt's steam engine design, creating a smaller and more powerful engine. His invention made it possible to move heavy goods and lots of people without needing horses or muscle power. Trains helped people travel long distances faster and cheaper than ever before.

1.2.2. The Steamboat

Around the same time, inventors were also trying to use steam engines to power ships. The first steam-powered boat was built in 1783 by a French inventor named Claude François Jouffroy d'Abbans. At first, these boats still had sails, but eventually, by 1889, British engineer Alexander Carlisle made the first steam-powered ship that didn't need sails at all. These steamboats made it easier to transport people and goods over water.

Steam power changed the world forever, making travel faster and production easier, and it paved the way for all the amazing technology we have today!

2. Electrical Energy

Electrical energy is really important in our lives. It's the power that makes almost everything work! The first time people saw electricity was probably in the form of lightning. But even the ancient Greeks knew about static electricity, as proven by archaeologists. Since the 1600s, scientists in Europe and North America have studied electricity to understand how it works and how we can use it.

2.1 The first usable electrical Battery (The Kleist Capacitor)

One big question scientists had was how to store electrical energy. A German scientist named Ewald von Kleist came up with an answer. After studying law, he became interested in how nature worked. In 1744, he invented the "Leiden jar," which was the first device that could store electrical charges. This was an early form of a battery!

2.2 The lightning conductor

A lightning conductor was an early way to "catch" electricity, but it only worked during storms with lightning. Benjamin Franklin, one of the founders of the United States, discovered in 1752 that the electricity from rubbing things (static electricity) was similar to the electricity in the sky. This helped him invent the lightning conductor, which protects buildings from lightning strikes by guiding the electricity safely into the ground. Franklin also came up with the idea of positive and negative electrical charges, which we still use today in batteries!

2.3 The concept of the electrical locomotive

The idea of using electricity to power trains is older than you might think. In 1834, an American inventor named Thomas Davenport created the first electric motor that could be used for trains. He called it the "commutator motor." However, people still preferred steam-powered trains because they were more efficient at the time. Electric trains only became common much later, in 1882, when they were first used to move carts in mines in Germany.

2.4 The first telegraph

Before phones, people used telegraphs to send messages. A telegraph could send short electrical signals, like a very early form of email. The messages were sent using Morse code, a system of dots and dashes that represent letters and numbers. In 1774, a French scientist named Georges-Louis Le Sage built the first electrical telegraph. But it wasn't until the 1800s that Samuel Morse, an American inventor, created the Morse code and a working telegraph system. This made it possible for people to send messages over long distances quickly.

2.5 The first electrical illumination system

We use electric lights all the time, but before they were invented, people used candles, oil lamps, or fire. The first electric light, called a carbon arc lamp, was invented by two Frenchmen, Henri Archereau and Louis-Joseph Deleuil, in the 1840s. Their invention was first used to light up a famous square in Paris. Before that, in 1810, a British scientist named Humphry Davy discovered that electricity could create a bright light by passing through two pieces of carbon. This led to the invention of electric streetlamps.

2.6 First electrical transfer attempt

Today, we get electricity through power lines, but this wasn't always the case. The first major attempt to bring electricity to a city happened in 1882 in Germany. Engineers built a power line to carry electricity from the city of Miesbach to Munich. This was a huge step toward making electricity available to everyone.

2.7 Radio transmission

Radio is a big part of life today, whether it's for listening to music or hearing the news. But like the telegraph, the first radios were used for communication. Italian inventor Guglielmo Marconi made the first radio communication in 1895. Two years later, in 1897, the first official radio message was sent in England. Marconi showed British officials how useful radio communication could be, and soon, radios became a common way to send messages without wires!

Current times

Today, the focus is on transitioning from old, non-renewable fossil fuels to eco-friendly, renewable power sources. The shift is driven by environmental concerns like the greenhouse effect. While there's no definitive solution yet, many energy options are being explored

1. Crude oil

Since the late 19th century, oil has been one of the most important resources of the industrial age. It remains crucial for energy production and is a key material for making fuels, plastics, and even medications.

1.2. Usage of Oil in an Oil fuelled power plant

Oil-fueled power plants use petroleum products to produce electricity. The first such plant started operating in 1912 in California, USA. These plants typically use gas or steam turbines. The oil is burned to produce heat, which powers the turbines. However, today, these plants are considered outdated and contribute only a small portion of the energy mix in most countries.

1.2.1. Sustainable Oil fuelled plant

A unique oil-fueled plant in Schwedt, Germany, produces energy using waste products from oil processing. This plant is considered the only environmentally friendly oil-fueled facility.

1.3. Oil as a fuel for vehicles

Petrol, which powers most cars and trucks, is refined from crude oil in large industrial facilities called refineries. The first petrol engine was invented in 1853 by Italian engineers Eugenio Barsanti and Felice Matteucci. However, it wasn't until 1876 that German inventors Nicolaus Otto and Gottlieb Daimler developed a petrol engine light enough to be used in cars.

2. Nuclear energy

Nuclear energy is one of the major innovations of the 20th century, though it carries risks. The first experiments with radioactivity were conducted by Marie and Pierre Curie in the 1890s. In 1939, Lise Meitner and Otto Frisch achieved the first small-scale nuclear fission. During World War II, nuclear research focused on weapons, but after the war, efforts shifted toward peaceful uses of nuclear power. The first civilian nuclear power plant was built in Obninsk, Soviet Union, in 1954.

2.1.1. The use of nuclear power outside of the powerplant concept

Nuclear energy was also used for other applications. In 1954, the U.S. Navy launched the first nuclear-powered submarine, the USS Nautilus. The Soviet Union followed in 1959 with the Lenin, the first civilian ship powered by nuclear energy.

2.2. Nuclear Fusion

Nuclear fusion, which involves combining two atomic nuclei to form a new one, is considered the future of nuclear energy. However, experts estimate that the commercial use of fusion energy won't be possible until around 2050 due to technical and political challenges. Scientists in South Korea are aiming to make breakthroughs in fusion technology before 2030.

3. Hydrogen Energy

Hydrogen energy represents one of the most promising and innovative technologies in the push toward sustainable energy solutions. The main objective of hydrogen energy is to store large amounts of usable energy in hydrogen, which can then be converted into electricity or other forms of power without producing harmful emissions. As the world seeks to move away from fossil fuels, hydrogen is emerging as a key player in the future of clean energy, with applications ranging from transportation to industrial uses.

3.1. Storage technology

One of the critical challenges with hydrogen energy is efficient and safe storage. Hydrogen, being a very light and reactive element, requires specialized methods for storage that maximize safety and efficiency. Current developments in hydrogen storage technologies show significant promise, with several methods already in use and others under development.

3.1.1. Pressure accumulator

In this method, hydrogen is stored in plastic or composite containers under high pressure, making it ideal for small-scale applications such as hydrogen-powered vehicles. These containers are designed to withstand the extreme pressure needed to compress hydrogen into a small volume. This method is already being used in hydrogen cars like the Toyota Mirai and has potential for wider adoption as hydrogen fueling infrastructure becomes more widespread. In the future, pressure accumulators may power personal vehicles, buses, and even airplanes, providing a zero-emission alternative to gasoline and diesel.

3.1.2. Liquid Storage

Hydrogen can also be stored in liquid form at extremely low temperatures (around -253°C). Liquefying hydrogen allows for larger quantities to be stored, making this method ideal for hydrogen fueling stations or industrial applications. Liquid hydrogen is already being used in some pilot projects and is expected to play a key role in sectors where large energy demands exist, such as long-haul transportation and even space travel. In the future, hydrogen fueling stations could become as common as petrol stations, supporting a network of hydrogen-powered vehicles.

3.1.3. Metal hydride storage

Metal hydride storage involves trapping hydrogen within the lattice structure of a metal alloy, creating a denser storage solution. This method, while resulting in heavier systems, allows for the storage of larger amounts of hydrogen and is highly safe and stable. It is particularly well-suited for larger machinery such as submarines or industrial equipment that requires a reliable and consistent power source. As this technology advances, it could be applied to long-term energy storage in power plants or renewable energy systems, where hydrogen could store excess electricity generated by solar or wind power for later use.

3.2. Usage technology

The potential of hydrogen energy is not only tied to storage but also to the ways it can be converted back into usable power. Several types of fuel cells are being developed to harness hydrogen energy efficiently, and each type has distinct advantages for different applications.

3.2.1. Alkaline Fuel Cell

Alkaline fuel cells were once widely used in space missions, such as NASA's Apollo program, where they provided electricity and drinking water for astronauts. They work by converting hydrogen and oxygen into water, producing electricity in the process. Although these fuel cells are considered outdated today, their design remains a foundation for modern hydrogen fuel cell technology. Looking ahead, alkaline fuel cells could be adapted for use in remote or off-grid locations, where reliability and sustainability are key concerns.

3.2.2. High-Temperature Polymer Electrolyte Membrane (PEM) Fuel Cell

PEM fuel cells are among the most promising technologies for hydrogen-powered vehicles. These fuel cells operate at higher temperatures than traditional alkaline fuel cells, making them more efficient and suitable for use in cars, buses, and even trucks. Currently, several car manufacturers, including Toyota, Hyundai, and Honda, are investing heavily in PEM fuel cell technology, viewing it as a strong contender to electric vehicles

(EVs). In the future, these fuel cells could become a cornerstone of clean transportation, providing faster refueling times and longer driving ranges than battery-powered EVs.

3.2.3. Direct methanol fuel cell

Direct methanol fuel cells (DMFCs) represent a new frontier for portable energy. Unlike other hydrogen fuel cells, DMFCs use methanol as a fuel source, which can be converted into hydrogen on demand. This makes them an attractive option for powering small electronics like laptops, smartphones, and other mobile devices. With growing consumer demand for longer-lasting, eco-friendly energy solutions, DMFCs could become the go-to technology for portable electronics in the future, providing a more sustainable alternative to conventional lithium-ion batteries.

3.3 Future Potential of Hydrogen Energy

Hydrogen energy holds immense potential to reshape the energy landscape. As the world strives to reduce carbon emissions, hydrogen can provide a clean, abundant, and versatile energy source. In the future, we may see hydrogen fueling not only vehicles but also entire cities, with hydrogen-powered grids storing renewable energy from solar and wind farms. Industrial sectors such as steel and chemical production could also transition to hydrogen as a cleaner alternative to fossil fuels.

Moreover, hydrogen's versatility could enable new innovations, such as hydrogen-powered aircraft or ships, reducing emissions in sectors where decarbonization has been difficult. Combined with continued advancements in fuel cells and storage technologies, hydrogen energy could play a central role in achieving global sustainability goals and creating a cleaner, more efficient energy system.

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2 Side Activities (Alongside VR)

While some students are using the VR headset, the rest of the class will participate in additional activities designed to expand their understanding of the evolution of energy technology. These activities will be set up as a game, so the kids can have fun while learning.

Game name: "Energy Quest: A Journey Through Time"

This activity will consist of a set of questions and answers related to the evolution of energy technology:

Game Overview

- **Name**: **Energy Quest: A Journey Through Time (Trivia)**
- **Theme**: The evolution of energy technology, from fire to modern renewable energy.
- **Objective**: Players will answer trivia questions and complete challenges to learn how energy shaped human history.
- **Target Audience**: Students or anyone interested in energy history and technology.

Game Setup

1. **Number of Players**: 2-6
2. **Materials**:
    - Trivia cards with questions and answers.
    - A game board representing a timeline from prehistory to modern times.
    - Dice or a spinner for movement.
    - Tokens representing each player.
    - Optional: VR station to visualize key moments in energy evolution (for an immersive experience).

Game Board Sections (Timeline)

1. **Discovery of Fire (Pleistocene Era)**
    - Questions focus on how early humans learned to use and create fire.
2. **Agriculture and Animal Domestication (First Energy Transition)**
    - Explore how animal domestication changed human energy use.
3. **Windmills and Watermills**
    - Learn about medieval technologies that used natural energy sources to automate work.
4. **Industrial Revolution**
    - How steam power and early engines transformed production and transportation.
5. **Electricity and Nuclear Power**
    - The discovery and use of electricity, from the first battery to nuclear power plants.

6. **Modern Renewable Energy**
    - Discuss solar, wind, hydrogen, and other clean energy technologies.

Trivia Questions by Era

Each player answers a trivia question to move forward on the timeline. Correct answers allow players to roll the dice again. Examples include:

Era 1: Discovery of Fire

1. **Question**: What chemical process occurs when early humans used friction to generate fire?
   Answer: The process of friction generates heat, which causes the temperature of dry material like grass to rise above its ignition point, initiating combustion.
2. **Question**: Why was fire essential in the development of larger human brains?
   Answer: Cooking food with fire made it easier to digest, unlocking more calories and nutrients, which contributed to the development of larger brains.
3. **Question**: What are the main products of combustion when burning wood?
   Answer: Carbon dioxide (CO_2), water vapor (H_2O), heat, and ash.

Era 2: The First Energy Transition

1. **Question**: Explain how animal domestication increased energy throughput in early agricultural societies.

   Answer: By harnessing the physical strength of animals like oxen and horses for tasks such as plowing fields and transporting goods, humans significantly amplified the amount of work they could perform compared to relying solely on human labour.
2. **Question**: What advantages did metal tools forged using fire provide over stone tools?

   Answer: Metal tools, made by heating ores like copper, were more durable and sharper, improving efficiency in farming and construction.
3. **Question**: Describe the role of fire in early metal forging.
   Answer: Fire was used to heat metal ores like copper until they melted, allowing humans to shape them into tools and weapons through forging.

Era 3: Windmills and Watermills

1. **Question**: What physical principle allows windmills to convert wind energy into mechanical work?
   Answer: Windmills operate on the principle of **aerodynamics**. The wind's kinetic energy rotates the sails, which are connected to gears inside the mill that perform work like grinding grain.
2. **Question**: How does an overshot watermill produce more energy compared to an undershot mill?
   Answer: An overshot watermill uses both the force of gravity and the water's

kinetic energy by allowing water to fall over the top of the wheel, increasing efficiency compared to an undershot mill, which only uses water flow from beneath.

3. **Question**: What technological advancement allowed tower mills to outperform post mills?
   Answer: Tower mills only needed to rotate their top (cap) to face the wind, which was more efficient and allowed for larger structures that could generate more power.

Era 4: Industrial Revolution

1. **Question**: What is the basic scientific principle behind steam engines that powered the Industrial Revolution?
   Answer: The steam engine operates on the principle of **thermodynamics**, where heat from boiling water is converted into mechanical work by the expansion of steam, which moves a piston inside a cylinder.
2. **Question**: What innovation did James Watt introduce to steam engines that improved their efficiency?
   Answer: James Watt introduced a separate condenser that improved the efficiency of steam engines by preventing the loss of heat, allowing the engine to use less fuel and produce more power.
3. **Question**: Why was coal important for the steam engine and the broader Industrial Revolution?
   Answer: Coal was used as a fuel source to produce the heat necessary to boil water, generating the steam that powered engines. It was abundant and provided a high energy density.

Era 5: Electricity and Nuclear Power

1. **Question**: Explain how a lightning conductor works to protect buildings from lightning strikes.
   Answer: A lightning conductor is made of a highly conductive metal, typically copper. When lightning strikes, the conductor provides a path for the electrical charge to travel safely into the ground, preventing damage to buildings.
2. **Question**: Describe the process of nuclear fission used in nuclear power plants.
   Answer: Nuclear fission occurs when the nucleus of an atom (usually uranium-235) is split into two smaller nuclei by a neutron, releasing a large amount of energy in the form of heat, which is used to produce steam and drive turbines to generate electricity.
3. **Question**: What role did the first electrical battery, the Leiden jar, play in the development of electricity?
   Answer: The Leiden jar was the first device capable of storing electrical energy,

allowing scientists to experiment with the generation, storage, and use of electricity, laying the foundation for modern batteries.

Era 6: Modern Renewable Energy

1. **Question**: What is the scientific principle behind hydrogen fuel cells?
   Answer: Hydrogen fuel cells work by converting chemical energy into electrical energy through a reaction between hydrogen and oxygen, which produces electricity, heat, and water as a byproduct.
2. **Question**: Why is hydrogen considered a promising alternative energy source for transportation?
   Answer: Hydrogen is abundant, produces zero emissions when used in fuel cells, and has a high energy density, making it a clean and efficient alternative to fossil fuels for powering vehicles.
3. **Question**: Explain how wind turbines generate electricity from wind energy.
   Answer: Wind turbines convert the kinetic energy of the wind into mechanical energy by rotating blades connected to a generator. The generator then converts this mechanical energy into electrical energy through electromagnetic induction.

Bonus Science Challenge Cards

- **Thermodynamic Challenge**: Explain how energy is conserved in a steam engine.
- **Chemistry of Fire**: Identify the elements involved in the combustion process and explain their roles.

Game Name: "Energy Sprint"

Overview:

- **Players**: 2-6
- **Objective**: Quickly answer energy-related questions to collect the most **Energy Tokens** before time runs out.
- **Game Time**: 1 – 3 minute(s) per player

Materials Needed:

1. **Energy Tokens**: Small tokens (coins, paper pieces, etc.).
2. **Quick Question Cards**: Each card contains a simple, fast question related to energy evolution.
3. **Timer**: A stopwatch or a phone timer.

Game Setup:

1. Shuffle the **Quick Question Cards** and place them face-down in the center.
2. Give each player 3 **Energy Tokens** to start with.

How to Play:

1. **Start the Timer**: Set the timer for 5 minutes.
2. **Player Turns**:
    - The first player draws a **Quick Question Card** and reads the question aloud.
    - If they answer correctly within 10 seconds, they **earn 1 Energy Token** from the center pile.
    - If they don't answer in time or answer incorrectly, they **lose 1 Energy Token**.
3. **Pass the Turn**: After answering, the player passes the question deck to the next player.
4. **Continue the Cycle**: Players continue drawing cards, answering questions, and collecting or losing tokens as they go.

Sample Questions:

- **Fire Era**: "What was the first use of fire in cooking?" (Answer: Accidentally cooking food during wildfires).
- **Windmills**: "What energy source powered early windmills?" (Answer: Wind).
- **Industrial Revolution**: "Which fuel powered steam engines?" (Answer: Coal).
- **Modern Energy**: "What is the main byproduct of hydrogen fuel cells?" (Answer: Water).

End of the Game:

- When the timer hits 1 – 3 minute(s) for the last player, the game ends.
- The player with the most **Energy Tokens** at the end wins!

Quick Variation:

- **Lightning Round**: For added excitement, give each player only **5 seconds** to answer their question before they lose a token.

This fast-paced version will keep the game moving quickly, while ensuring everyone gets a turn and learns a bit about energy evolution!

Game Name: "The race for the Nobel prize"

The Game Plot:

The Committee of the Nobel Prize wants to award new young scientists with a Nobel Prize of science.
To achieve the prize, young scientists must undergo a knowledge test conducted by the Prize Committee.
The smartest scientists who got the most questions right or the most taks properly done are winning the prize or prizes.
The game is also a playful journey of learning, which takes the player through the times and history of energy transmission and its different technologies.

The needed materials:

1. One sheet of A3 sized paper with 15 circles of 6 cm diameter on it.
The circles are put in a line, which furl itself in a spiralling manner.
The center marks the final point. The awarding of the Nobel prize.
The last circle on the other end marks the beginning of the journey.
Each circle marks a question, and gaming figures can be placed on it, when the previous answer is answered right.
Each scientific era is marked on both ends via a line and a number. (like the Era numbers on the cards)

2. 15 Cards on which fronts are written the question and the answer.
On the back shall be written "Nobel prize question", to standardize the design.
But every Card of each Scientific Era got a common "Era number" (1-6)
for quick sorting and preventing confusion.

3.Individual game pieces.

Each participant chose his own small gaming piece. This could be a coloured pen cap or other item which is small enough to fit in.

4. A timing device in form of a watch or smartphone alarm clock.

5. pen and paper for drawing

6.(Optional)

A "Nobel Prize" in Form of a sweet or little chocolate for further encouragement.

The Different Roles:

1. The Representant of the Nobel Prize Committee.
   One Player is in procession of the cards and asks the questions or drawing tasks about science.
2. The Scientists who attending the knowledge test in order to win the prize.

Amounts of players: 3-4
Time for Playing: max.15 minutes

How to play the game (win the prize):
The Players which are playing as scientists placing their gaming Icons in front of the first circle of the line.
The player which plays as the representant of the committee is keeping the cards.
The cards, with the questions and answers are facing always the "representant"
The cards are sorted in each scientifical era. (as marked with each ERA-number 1-6)
After the question or task is formulated, the other players have one minute, to give a correct answer or draw the picture.
After each right given answer or approved drawing, the player may move their Player item a circle further until the end of the game (Nobel price circle).

A wrong answer or a picture that has nothing to do with the task means, that the Item of the regarding player can´t move a circle further.
The player in question have then to wait for the next round, for his next chance.
So that means, that the smartest player is also the fastest. And the fastest player or players are winning the game.

Game set up:
The cards are sorted by era by the "Nobel prize committee representant"-player
The other players are placing their game Items in front of the first circle.

The different Eras of technology and their questions:

1. The discovery of the fire
1.1. (Question) From which first natural sources could get the early humans fire?
(Answer): from wildfires, fires caused by lightening

1.2. (Question): What could early humans do with fire?
(Answer): Cooking food, using for light (to lighten homes in general), using for warming.

1.3 (Task): Drawing a picture for the use of fire

1.4. (Task): Drawing how early humans would make fire

1.5. (Task): Drawing a picture of how the player imagines, how humans would have discovered the first fires and how to use them

2. First energy Transmission in the History of agriculturalism and animal domestication.

2.1. (Question): What are the first domesticated animal, which where usable for work?
(Answer): Oxen, horses, donkeys

2.2. (Question): For what kind of work could these animals be used for?
(Answer): plowing fields, working on mills and oil presses.
Or powering bellows for forging metal.

2.3. (Question): Which role had fire in Production?
(Answer): forging tools and weapons, which are made of metal
Baking of bread and cooking of food of more durability.

2.4 (Task): Drawing of a picture how energy transmission happened with the use of draft animals

2.5. (Task): Drawing of food or tools, which could get produced with the help of draft animals

2.6. (Task): Drawing of how fire could have been used back in the day

3. The Technologies of the Mills

3.1. (Question): Which type of windmills do you know?
(Answers): Post mills, sunk post mills, post mills with roundhouse, Tower mill, Hollow Post Mills.

3.2. (Question): How energy was transformed by windmills?
(Answer): Old windmills got huge round sails which transacted energy through a wooden gear system to use the moving power to grind grain into flour.

3.3. (Question): For which other productive purpose could mills have been used (more than just grinding grain?)
(Answer): Sawing wood (Sawmill), Metalworking (mill powering bellows for huge hammers)

3.4. (Task): Drawing simply how a water mill works

3.5. (Task): Drawing how water got used to grind grain.

3.6. (Task): Drawing of the energy transmission in mills

4. The industrial Revolution and its technologies.
4.1. (Question): Who invented the first usable steam engine?
(Answer): Thomas Newcomen in 1712

4.2. (Question): How does a steam engine works?
(Answer): Water get boiled to become steam; The steam is pushed into a cylinder with a piston inside. The steam moves the piston forward. That creates transformable energy.

4.3. (Question): For what transport technology could a steam engine be used?
(Answer): Steam boat, steam engine powered locomotive.

4.4. (Task) Draw a steam engine (only a simple basic Modell)

4.5. (Question) How changed electricity the daily life of humans?

(Answers): Quick communication through the telegraph and telephone
Electrical light (massive illumination of places and whole settlements)
Electrical power lines (for long range energy transfer)
Battery (for storing electrical energy)

4.6. (Question): Who was the Inventor of the “Leiden Jar”?
(Answer): Ewald von Kleist

4.7. (Task): Drawing a picture of one system or invention of this age, which got used in the 19th century.

4.8. (Task): Drawing a picture, how the player thought, how Ewald von Kleist would have looked like
(Funny pictures Only)

4.9. (Task): Drawing of the players imagination of the first car (funny pictures only)

5. The modern Age of current fossil and renewable energies.

5.1. (Question): Can you name a few energy resources of our current times?
(Answer): Oil as fuel or ressource for plastic products)

5.2. (Question): Name one specific use for hydrogen energy:
(Answers): Liquid storage of huge amounts of energy
Fuel cells for cars
Liquid hydrogen fuel for submarine or future plane concepts.

5.3. (Task) Draw your own imagious hydrogen energy powered car

5.4. (Task): Drawing how a nuclear reactor would look like.

5.5. (Task): Drawing of one example, how electrical energy is used today.

End of the game:
The first player or players of the “Scientists” who reaches the final circle, is the winner of the “Nobel prize”. Or when nobody reaches the last circle, The “noble prize” will be not awarded to anyone.

3 Second part of the lesson (30 minutes)

Task Introduction (5 minutes):

Once the VR session is completed, gather the students and explain the next task. Present the challenge: they will become "energy inventors" and will have 20 minutes to come up with their own ideas about how energy could be generated in the future. This will:

- Encourage creative thinking by asking questions like:
    - What problems with energy do we face today (e.g., pollution, limited resources)?
    - What future technology might solve these problems?
    - Could energy come from new places (space, other dimensions, inside our bodies)?
- Remind them that there's no wrong answer—it's about imagination and innovation.

Invention Creation (20 minutes):

- **Step 1: Brainstorming (5 minutes):** Give the students time to brainstorm individually or in small groups (depending on your class setup). They should write down their ideas for future energy inventions. To help them focus, you can provide prompts such as:
    - Name of the invention
    - What energy source it uses
    - How the invention works
    - Why it is better than today's energy technologies
- **Step 2: Sketching or Designing (10 minutes):** After brainstorming, the students should draw a simple sketch or diagram of their invention. If time permits, allow them to add labels or a brief explanation next to their sketch. For younger students who might need help visualizing, you could provide an example invention (e.g., "an energy generator powered by wind from space").
- **Step 3: Presentation Prep (5 minutes):** Each student or group will prepare a short explanation (1-2 minutes) of their invention, which they will present to the class. They should focus on explaining how their invention works and why it's important for the future of energy.

Presentations (5-10 minutes):

- Depending on time, invite students to present their inventions. Encourage them to be confident and share their ideas enthusiastically. After each presentation, you can allow a couple of quick questions from their classmates to keep the activity interactive.

Conclusion (5 minutes):

- Wrap up by asking the class to reflect on the different ideas presented. You can highlight a few interesting or particularly creative inventions and encourage them to keep thinking about how their generation might contribute to solving energy challenges in the future.

APPENDIX C

Energy Sprint

Overview

2-6 | 12-15 | 10 min

You are an energy enthusiast competing in a thrilling quiz game to win a Nobel Prize. Throughout the game, you will draw Quick Question Cards and answer energy-related questions. Depending on your answers, you will either gain or lose Energy Tokens. The player with the most tokens when time runs out wins.

Quick Variation:

For an added challenge, try the Lightning Round, where you have only 5 seconds to answer each question

Materials Needed

Energy Tokens

Question Cards

Timer

Game Setup:

1. Shuffle the Quick Question Cards and place them face-down in the center.
2. Give each player 3 Energy Tokens to start with.

How to Play:

1. Start the Timer: Set the timer to 1 minute per player (f.e. 4 players = 4 minutes of gametime).
2. Player Turns (1-minute turns):
    - The first player draws a Quick Question Card and reads the question aloud.
    - If they answer correctly within 10 seconds, they earn as much Energy Tokens from the center pile as the value shown on the card.
    - If they don't answer within 10 seconds or answer incorrectly, they lose as many Energy Tokens as the value shown on the card.
3. Continue the Cycle: Players continue drawing cards, answering questions, and collecting or losing tokens as they go.
4. After every player has their turn, the player with the most tokens wins the Nobel prize.

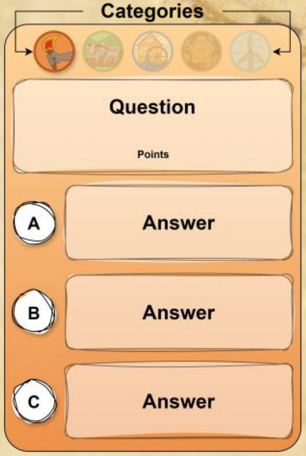
End of the Game:

When the timer hits 1 – 3 minute(s) for the last player, the game ends. The player with the most Energy Tokens at the end wins!

Sample Questions:

- **Fire Era**: "What was the first use of fire in cooking?" (**Answer**: Accidentally cooking food during wildfires).
- **Windmills**: "What energy source powered early windmills?" (**Answer**: Wind).
- **Industrial Revolution**: "Which fuel powered steam engines?" (**Answer**: Coal).
- **Modern Energy**: "What is the main byproduct of hydrogen fuel cells?" (**Answer**: Water).

Cards:



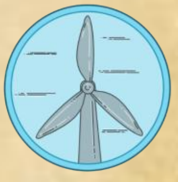
Categories:


Prehistory


First Civilizations


Middle Ages


Industrial Revolution


Modern Times

Information

Developed by:

EPS Group of Autumn Semester 2024
Ernest Anguera, Jesse van den Ende, Jelmer Sijbers & Konrad Michel

A Collaboration with:

LUMA Centre Ostrobothnia & Novia University of Applied Sciences

LUMA CENTRE FINLAND

YRKESHÖGSKOLAN NOVIA

What era saw the first use of fire by humans?

1 point

A — The Pleistocene

B — Medieval Ages

C — Star Wars

What was the first known cause of fire?

1 point

A — Microwave ovens

B — Lightning strikes

C — Rubbing sticks together

Name one chemical element essential for fire to burn

1 point

A — Wood

B — Water

C — Oxygen

Which was the first fire creation method?

1 point

A — Friction

B — Magic spell

C — Using a lighter

Earliest fuel source for fire creation?

1 point

A — Coal

B — Wood

C — Petrol

First use of fire?

1 point

A — Heating a bulding

B — Starting an engine

C — Cooking

What materials were used to maintain fire?

1 point

A — Plant fibers, animal dung

B — Metal shavings

C — Plastic

What stones were used to create sparks?

1 point

A — Granite

B — Flint

C — Marble

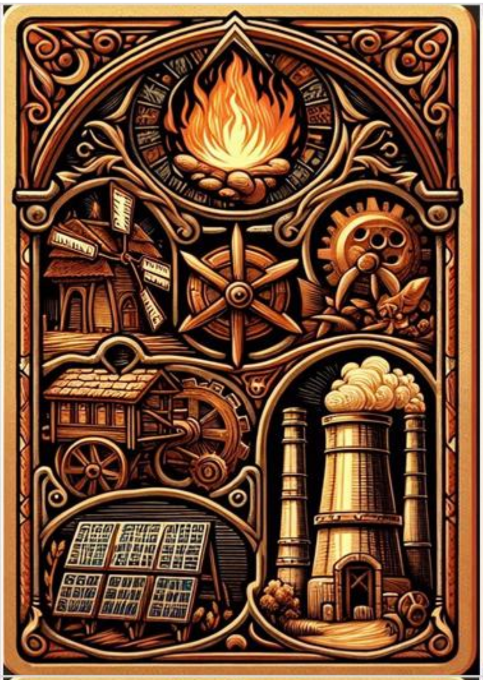
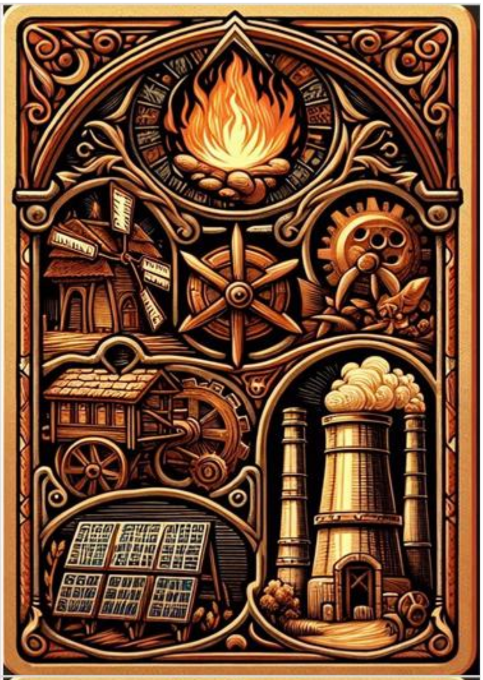
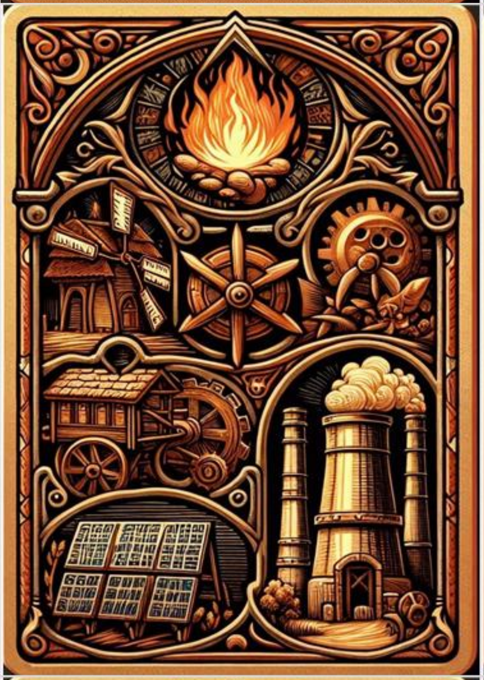
Early use of fire in art?

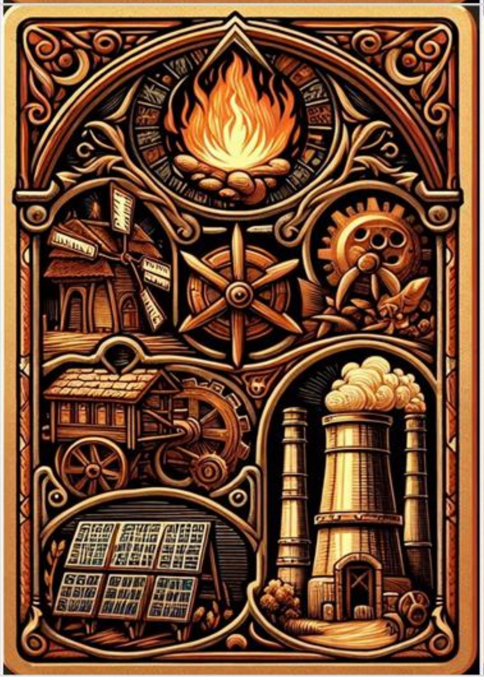
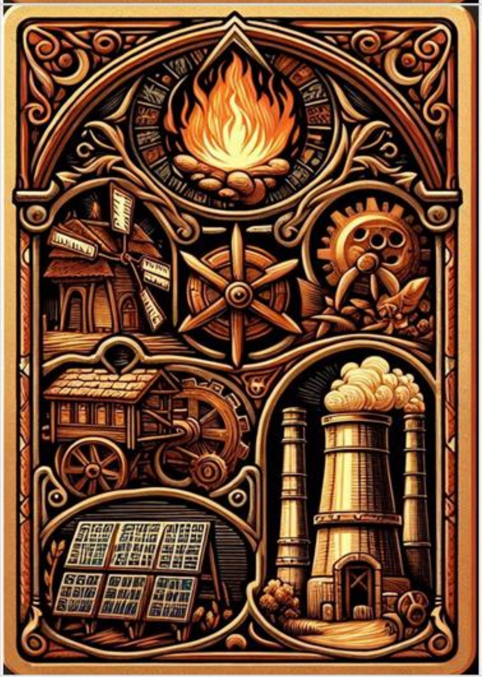
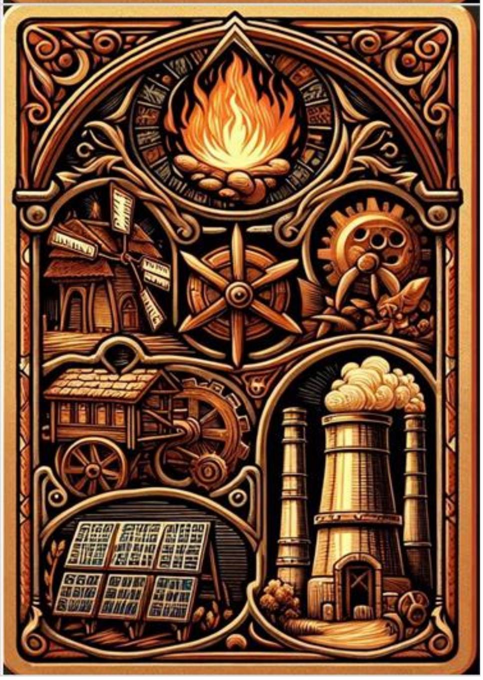
1 point

A — Sculpture

B — Painting

C — Pottery

What type of energy did animals provide?

2 points

A Mechanical

B Electrical

C Nuclear

What was the main use of the animals?

1 point

A Horse racing

B Plow fields

C Pets

Primary benefit of animal power?

2 points

A Company for humans

B Decrease productivity

C Increase productivity

Why were oxen efficient in energy terms for plowing?

3 points

A High power-to-feed energy ratio

B None of the others

C Fast learners

Which energy principle was exploited in animal-pulled mills?

3 points

A Nuclear fission

B Lever and rotational mechanics

C Fuel powered engines

How did domesticated animals increase energy throughput in agriculture?

3 points

A They made people feel better

B They did not help

C They amplified human labor force

How did animal powered mills help in forging?

2 points

A Provided consistent power source

B Provided cooling systems

C Provided lighting

What was used to lift water in ancient times before watermills?

2 points

A Wind turbines

B Animal driven mechanisms

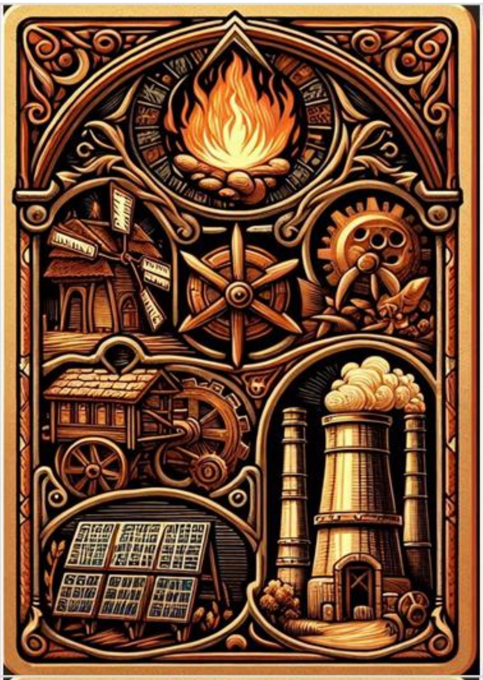
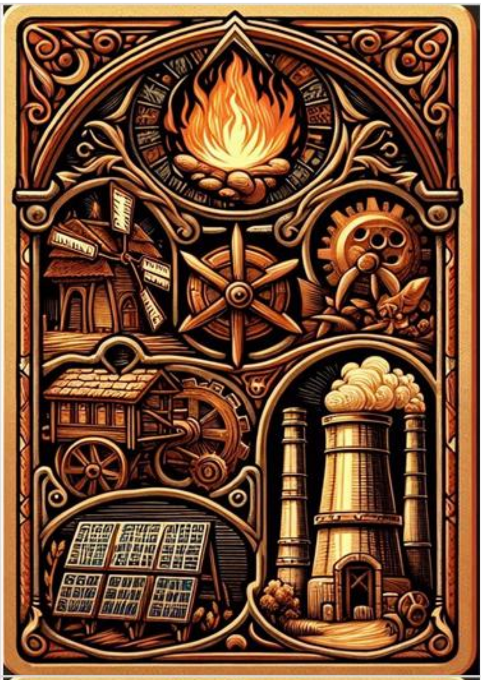
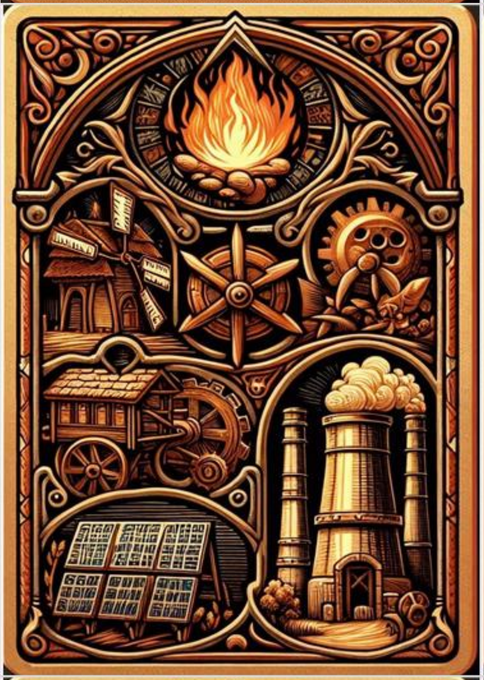
C Solar panels

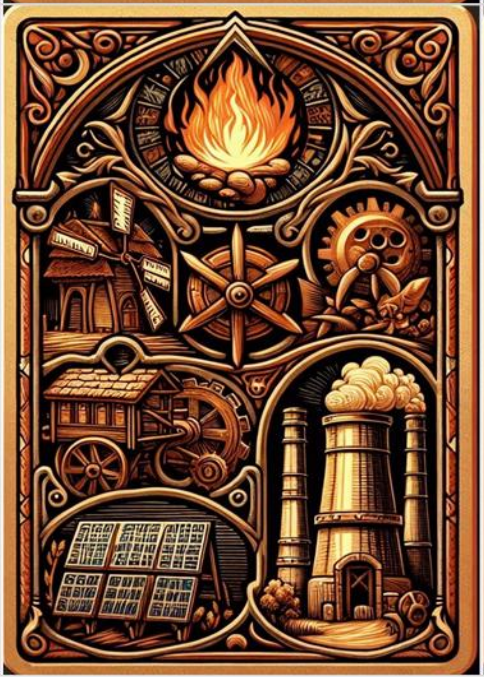
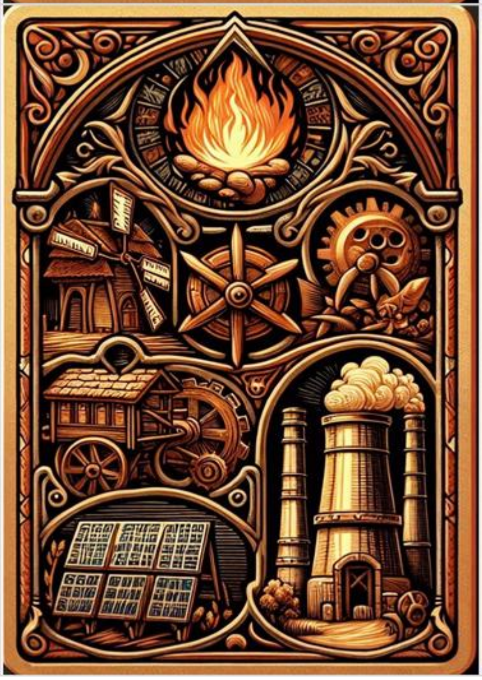
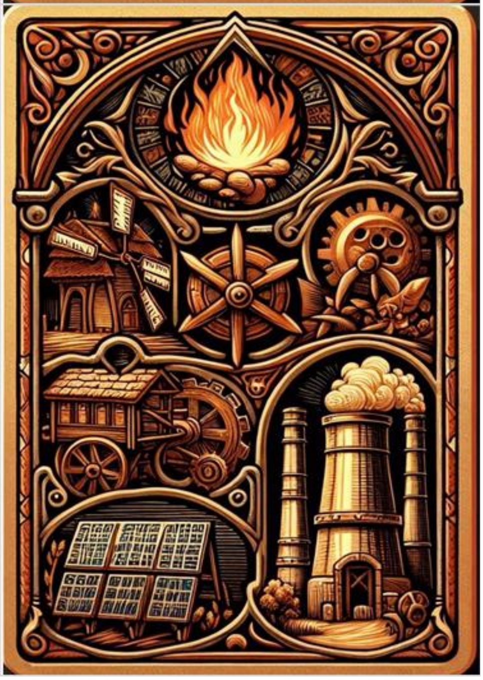
What mechanism was used in animal-powered mining?

A Hydraulic presses

B Conveyor belts

C Hoisting systems

What windmill use involves cutting timber into planks?

1 point

A. Sawing Wood

B. Move water

C. Feeding animals

What type of mill uses flowing water as power?

1 point

A. Windmills

B. Watermills

C. Animal mills

What is torque?

3 points

A. An animal

B. A videogame

C. Force that causes rotation

Which is the windmill's energy convertion?

2 points

A. Kinetic to mechanical

B. Mechanical to kinetic

C. Kinetic to thermal

What type of force powers millstones?

2 points

A. Electricity

B. Friction

C. Petrol

What part of windmill catches wind?

1 point

A. The roof

B. The mill

C. The blades

What did early mills use instead of engines?

2 points

A. Natural forces (water or wind)

B. Hired workers

C. Electricity

What powers the gears inside a watermill?

1 point

A. Wind

B. Turning waterwheels

C. Fire

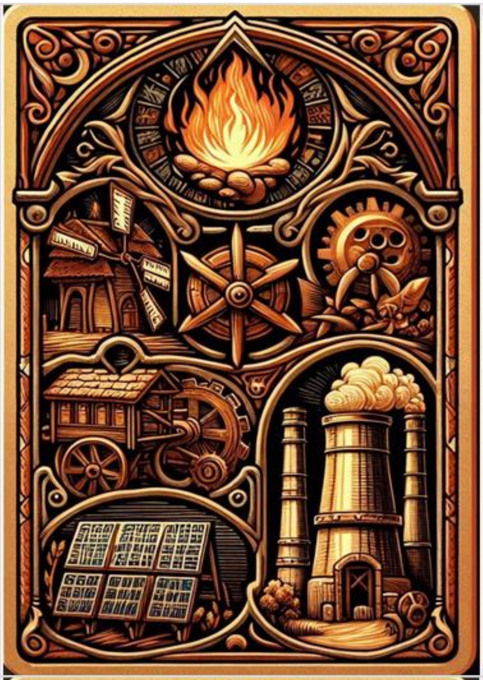
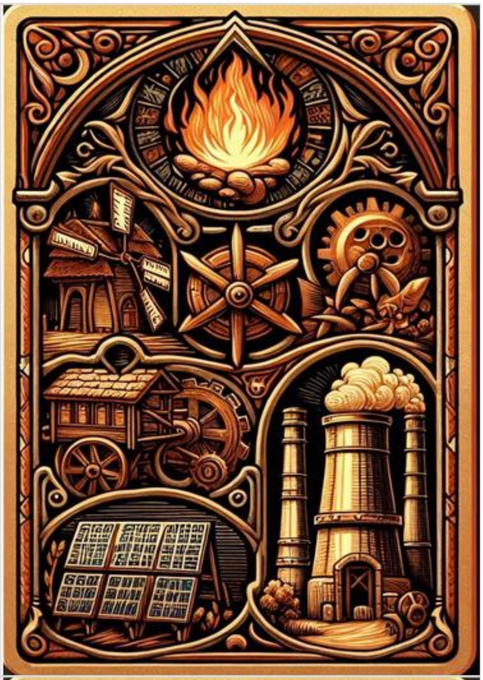
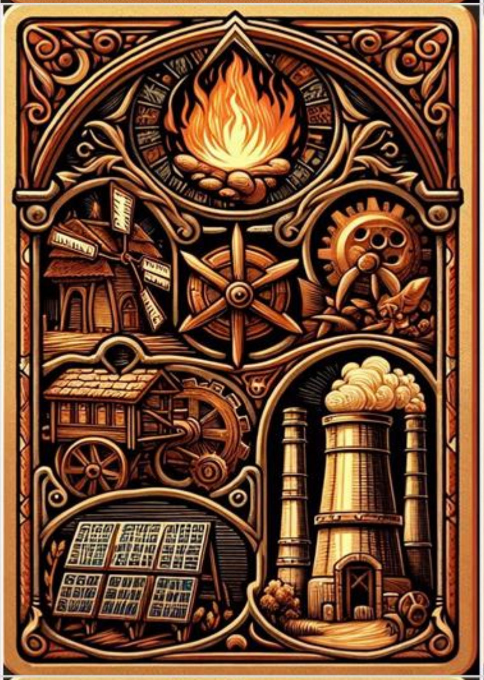
What feature allowed post mills to rotate into the wind?

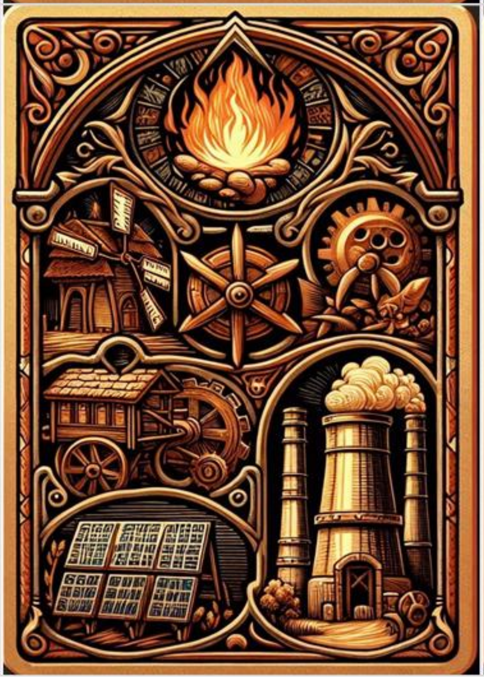
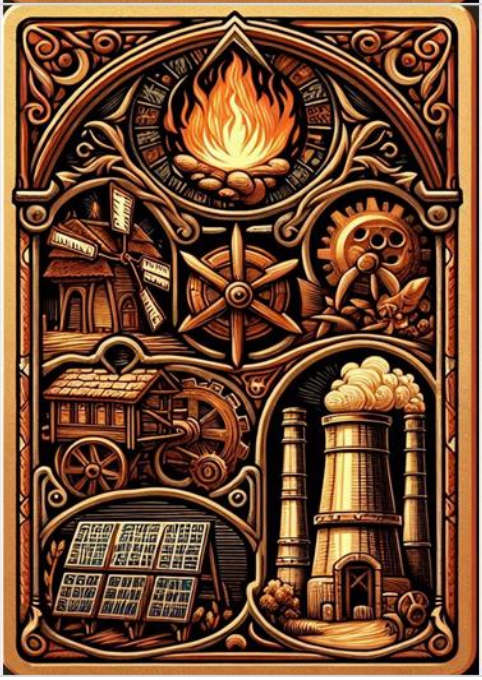
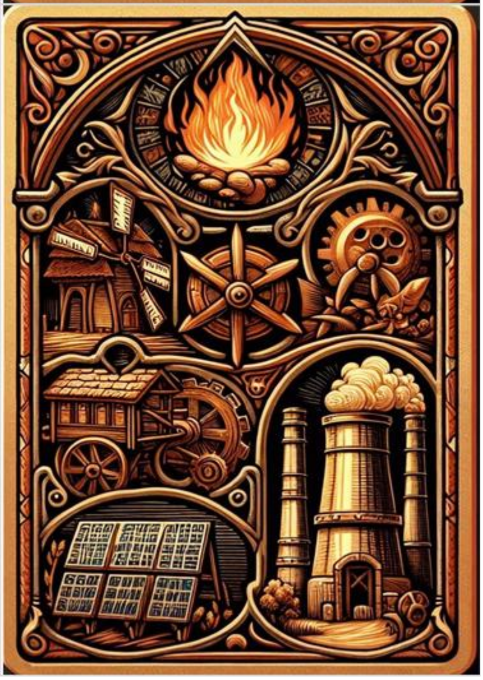
2 points

A. A person with a hex key

B. Wind

C. A central post

Solar cells convert sunlight to?

1 point

- A: Electricity
- B: Water
- C: Moonlight

Result of electrolysis?

3 points

- A: Fire and water
- B: Hydrogen and oxygen
- C: Hydrogen and CO2

What does nuclear fission produce?

2 points

- A: Wheat
- B: Fuel
- C: Heat

Which gas is a byproduct of burning fossil fuels?

2 points

- A: Carbon dioxide
- B: H_2O
- C: O_3

What material is commonly refined to make plastic?

2 points

- A: Cooking oil
- B: Crude oil
- C: CO_2

Which gas is the main component of natural gas?

2 points

- A: Argon
- B: Oganesson
- C: Methane

Which renewable energy source is most prevalent across the globe?

2 points

- A: Hydropower
- B: Solar power
- C: Wind power

What powers the turbines in a nuclear power plant?

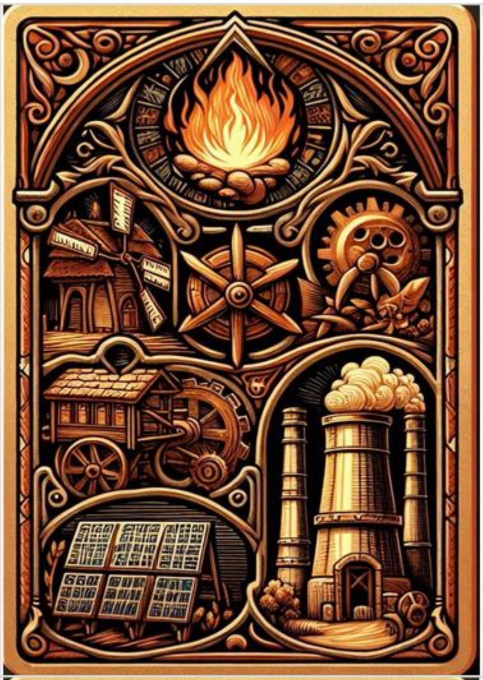
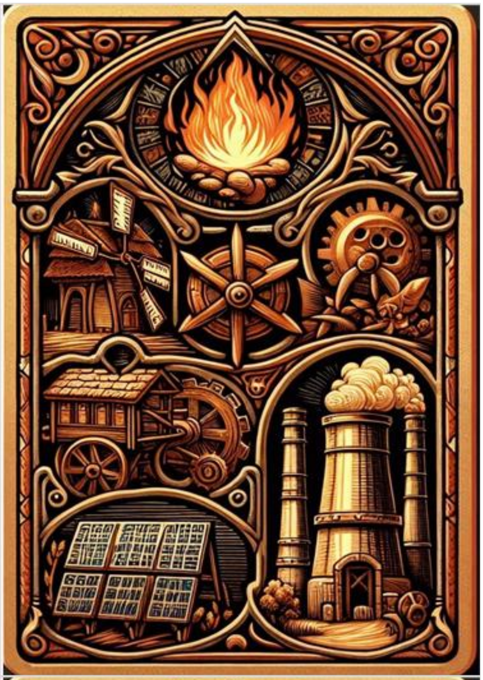
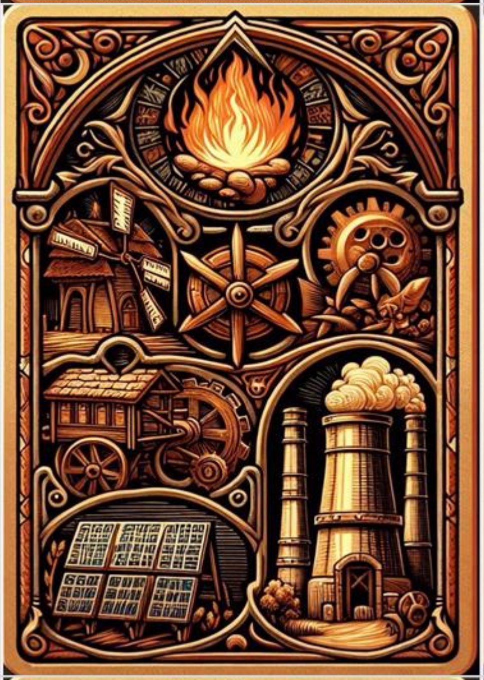
3 points

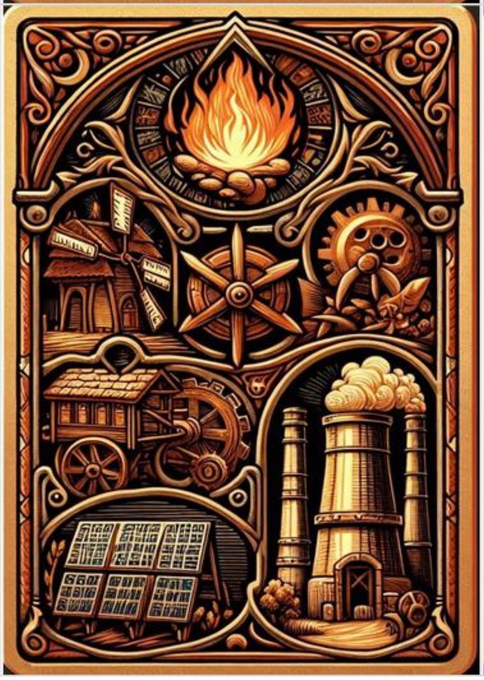
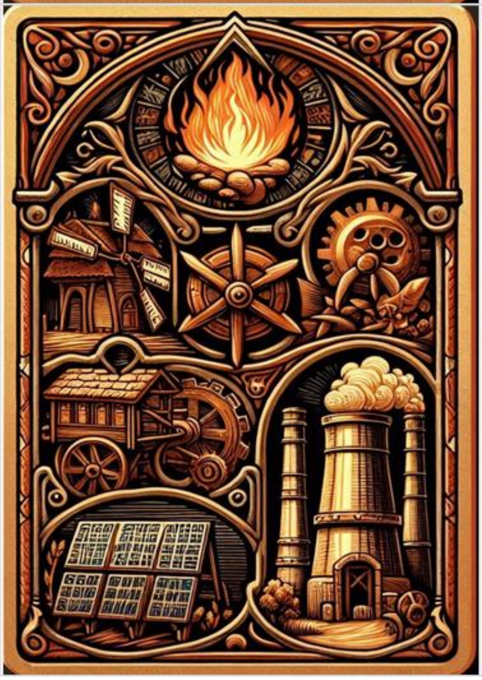
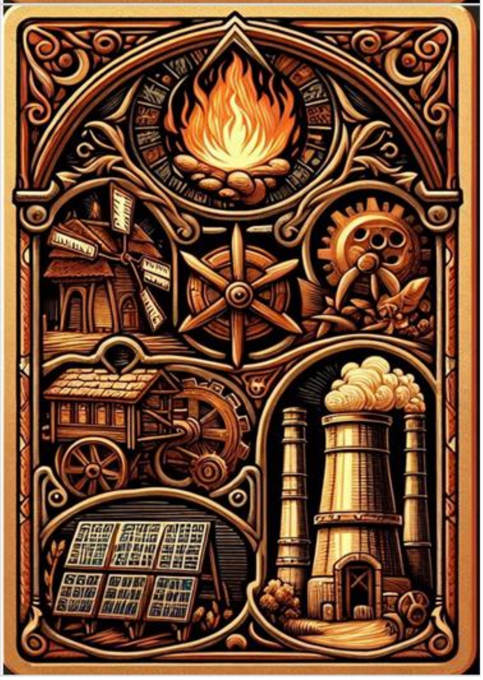
- A: Nuclear fission directly
- B: Steam
- C: Chemical reactions

What are the main benefits of using geothermal energy as a source of power?

3 points

- A: It is expensive and complex
- B: It is dependent on weather conditions
- C: It is almost inexhaustible, clean, and independent of weather conditions

Main fuel of steam engines during industrial revolution?

1 point

A Coal

B Electricity

C Patrol

Steam's energy transformation?

2 points

A Heat to cold

B Thermal to mechanical

C Thermal to electrical

Key benefits of coal?

2 points

A Low energy density

B Easy to transport

C High energy density, easy to extract, easy to transporrt

Which device converts steam to mechanical work?

2 points

A Piston or turbine

B Stearing wheel

C Hydropneumatic suspension

What type of reaction powers a steam engine?

3 points

A Endothermic chemical reaction

B Exothermic chemical reaction

C Nuclear reaction

Which mode of transportation did steam power enable?

1 point

A Railways

B Airplanes

C Bicycles

What is the function of a piston in a steam engine?

2 points

A Converts steam pressure into a straight motion

B Generates electricity

C Stores energy

Which law describes steam expansion in engines?

3 points

A Newton's Third Law

B Boyle's Law

C Ohm's Law

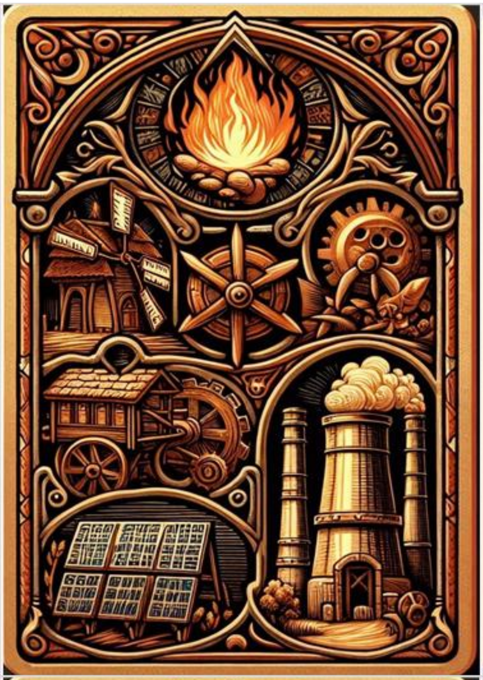
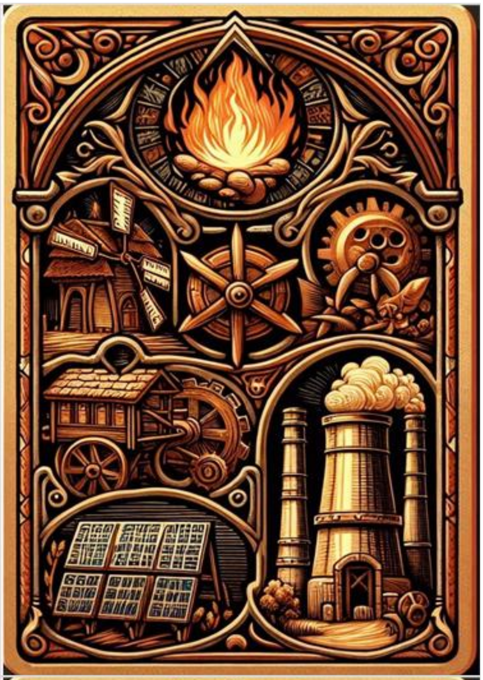
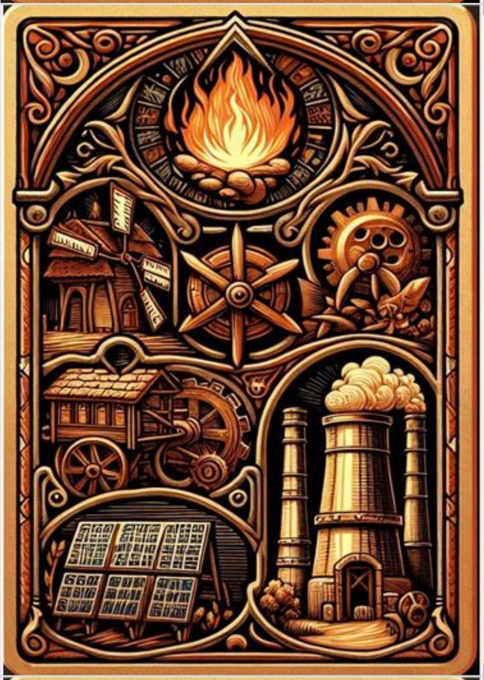
What was the name of the original steam engine?

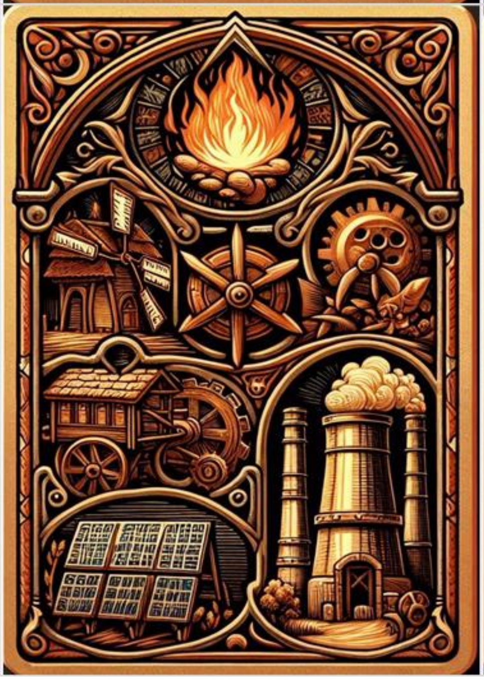
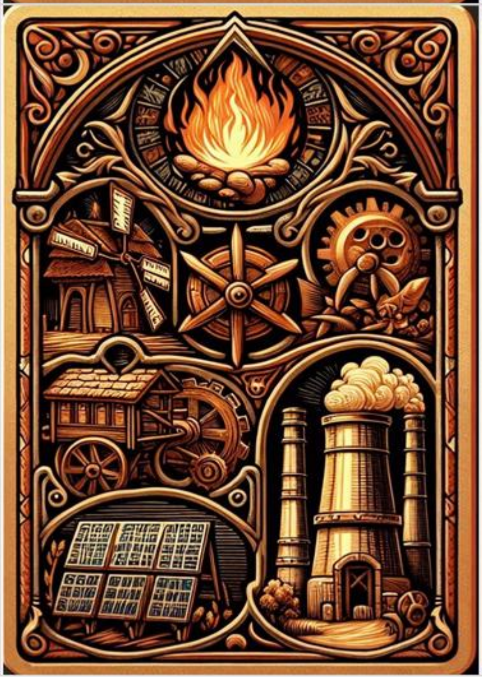
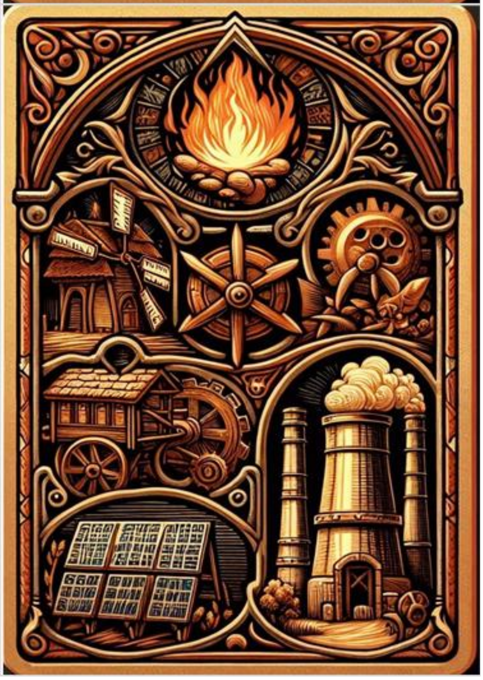
3 points

A Stephenson's Rocket

B Watt Steam Engine

C Newcomen Steam Engine

How did fire enable humans to survive in harsh environments?

1 point

A. Provided warmth and protection

B. Provided food storage

C. Provided transportation

When was geothermal energy first used?

1 point

A. Industrial revolution

B. Prehistoric times

C. Middle Ages

How does an overshot watermill operate?

2 points

A. Uses solar energy

B. Uses wind power

C. Uses gravity and water flow

Which mechanism was used in ancient water lifting to support animals?

3 points

A. Pulley Systems

B. Gears

C. Levers

What powers steam engines?

2 points

A. Electricity

B. Boiling water

C. Solar power

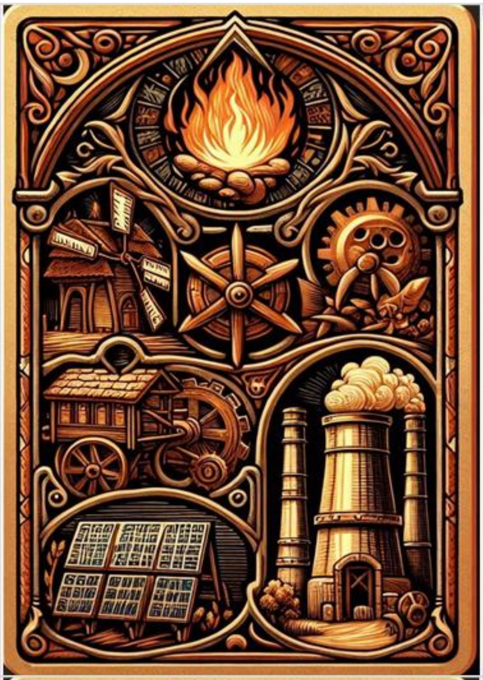
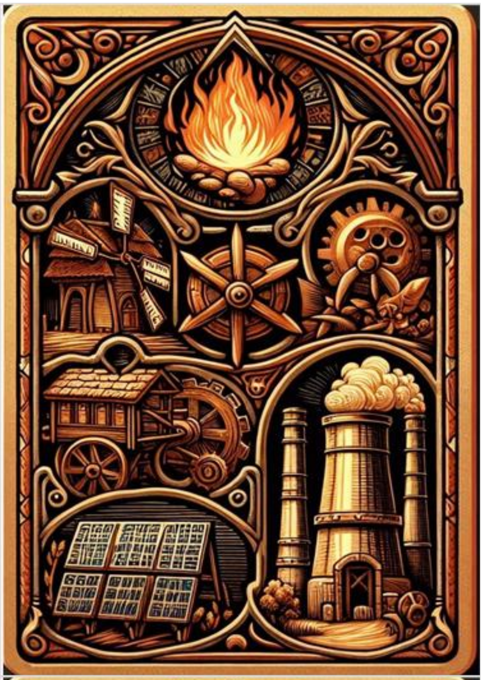
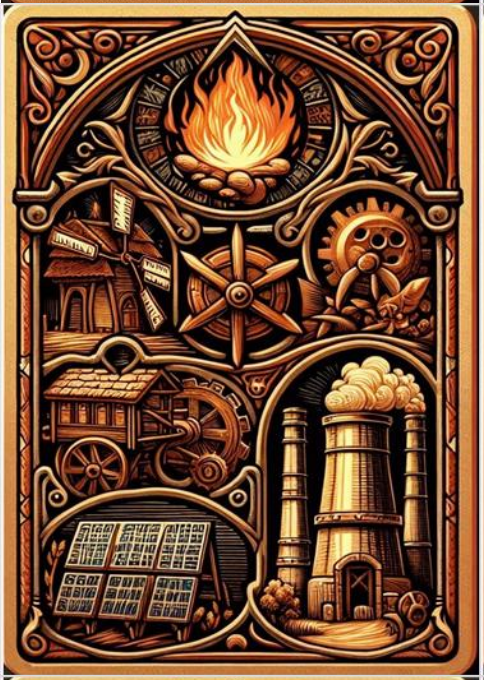
Do windmills use the wind force to generate movement to grind flower?

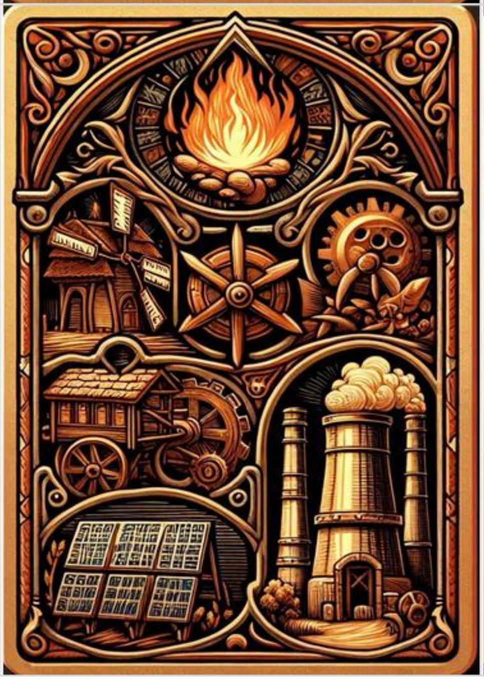
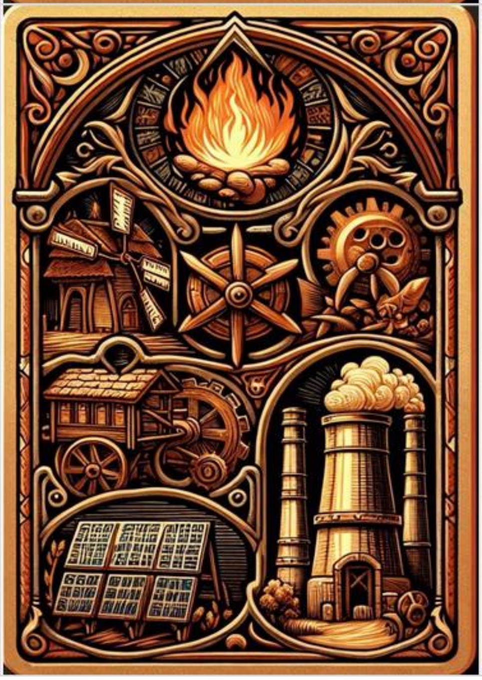
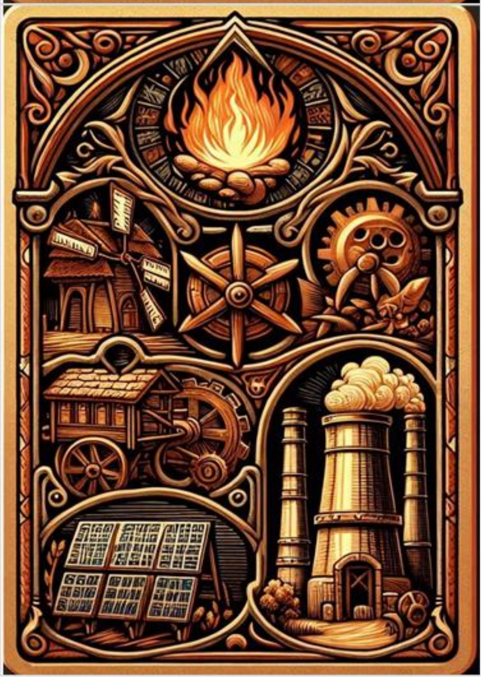
1 point

A. No, they use animals

B. No, they use water

C. Yes

Appendix D

Development phase of the lesson

Once the VR session is completed, gather the students and explain the next task. This part of the lesson will be divided in 4 different parts:

1 Introduction

The students will now become "energy inventors" and will have 20 minutes to come up with their own ideas on how energy could be generated in the future. This will:

- Encourage creative thinking by asking questions like:
  - What problems with energy do we face today (e.g., pollution, limited resources)?
  - What future technology might solve these problems?
  - Could energy come from new places (space, other dimensions, inside our bodies)?
- Remind them that there's no wrong answer — it's about imagination and innovation.

2 Invention Creation

In this part, the "inventors" will have a table that they will have to fill in with the information of their invention (see appendix 1). In this section, there are 3 separated steps:

- **Step 1 – Brainstorming (5 minutes):** Give the students time to brainstorm individually or in small groups (depending on your class setup). They should write down their ideas for future energy inventions. To help them focus, a table with required information will be provided:
  - Name of the invention
  - What energy source it uses
  - How the invention works
  - Why it is better than today's energy technologies
  - Additional information regarding the invention
- **Step 2 – Sketching (5 minutes):** After brainstorming, the students should draw a simple sketch or diagram of their invention. If time permits, allow them to add labels or a brief explanation next to their sketch. For younger students who might need help visualizing, you could provide an example invention (e.g., "an energy generator powered by wind from space").
- **Step 3 – Create The Invention (10-15 minutes):** Using available materials, students will bring their inventions to life. They will then prepare a 1–2-minute presentation explaining their creation to the rest of the class.

3 Presentations

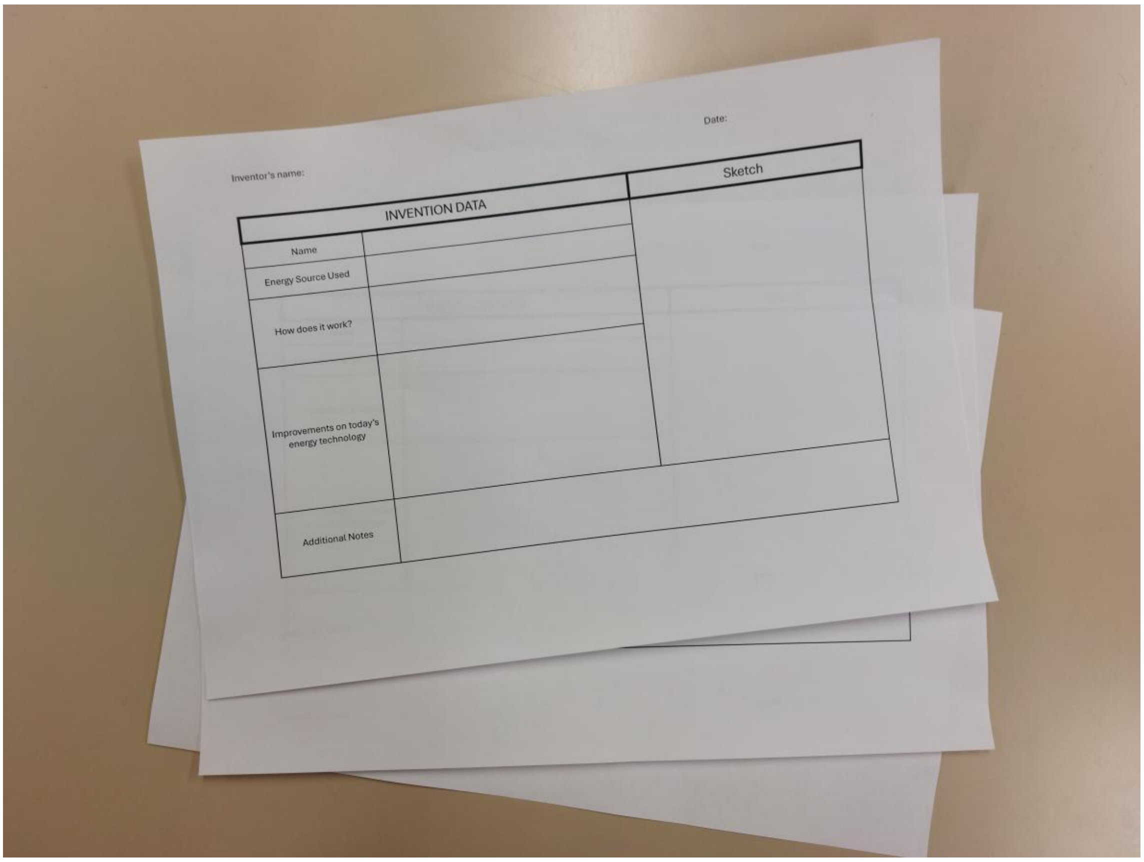
Depending on time, invite students to present their inventions. Encourage them to be confident and share their ideas enthusiastically. After each presentation, you can allow a couple of quick questions from their classmates to keep the activity interactive.

4 Conclusions

Wrap up by asking the class to reflect on the different ideas presented. You can highlight a few interesting or particularly creative inventions and encourage them to keep thinking about how their generation might contribute to solving energy challenges in the future.

Appendices

Appendix 1



Appendix E

TEACHERS' HANDBOOK

VR lesson on The Evolution of Energy Technology

A quick guide on how to prepare and give the lecture and tutorial on how use and set-up the VR headsets

Jesse van den Ende

A Collaboration with:

LUMA CENTRE FINLAND

YRKESHÖGSKOLAN NOVIA

PREFACE

This VR lesson on energy technology evolution was created by a team of students participating in the European Project Semester (EPS) program. EPS is an innovative, project-based initiative that brings together students from diverse backgrounds to collaborate on real-world challenges in a multidisciplinary setting. Our group of four students was tasked with developing an educational experience that aligns with the principles of LUMA—focusing on Science, Technology, Engineering, and Mathematics (STEM)—while integrating VR technology into the Finnish educational system.

The goal of our project is to create an engaging, story-driven VR lesson designed to help young students understand the evolution of energy technology and the importance of sustainable energy sources. Through VR storytelling and hands-on activities, students explore energy concepts in a structured, experiential format that enhances traditional classroom learning. By taking on the roles of scientists at the fictional company EvoTech, students become active participants in their learning journey, encouraging critical thinking and innovation in the realm of sustainable technology.

This teacher's handbook serves as a guide to implementing this VR lesson, providing insights into lesson structure, learning objectives, safety precautions, and effective ways to engage students throughout the experience.

Developed by:

EPS Group of Autumn Semester 2024

Ernest Anguera, Jelmer Sijbers & Jesse van den Ende

A Collaboration with:

LUMA Centre Ostrobothnia & Novia University of Applied Sciences

LUMA CENTRE FINLAND

YRKESHÖGSKOLAN NOVIA

Contents

1. Introduction

The VR glasses provide students with an immersive experience that enhances their understanding of energy technology by visually transporting them through historical developments and modern advancements in energy sources. This virtual journey enables students to explore energy concepts beyond traditional classroom methods, making complex topics more tangible and engaging. The lesson encourages critical thinking, exploration, and creative problem-solving, all aligned with LUMA principles in engineering, technology, and computer science.

1.1. Overview of the lesson

This VR-based lesson is designed to take students through the **evolution of energy technology** over time, showing how society has moved from basic methods of energy production to more complex, sustainable sources. The lesson comprises three main phases:

1. **Introduction to Energy and Technology:** Briefly discuss types of energy sources and technological advancements.
2. **VR Exploration of Energy Sources:** A 20-minute immersive experience where students see historical and modern energy sources firsthand in a VR environment.
3. **Post-VR Discussion and Hands-on Activities:** Students reflect on what they've learned and engage in hands-on activities that reinforce key concepts, allowing them to build simple models representing different energy technologies.

1.2. Learning objectives for the students

By the end of the lesson, students will be able to:

- **Identify different energy sources** and explain their historical significance and impact.
- **Understand the progression of energy technology**, from traditional to modern sustainable energy solutions.
- **Engage in critical thinking and creative design** by building models that reflect energy technology concepts.
- **Collaborate and communicate ideas effectively**, enhancing social and teamwork skills through discussion and group activities.

While students will gain knowledge about the history and future of energy technology, the primary focus of this lecture is on **cultivating skills in research, innovation, and presentation**. This experience encourages students to think like scientists and inventors.

By the end of this lesson, students will not only have learned about energy technology but also gained experience in developing, presenting, and sharing original ideas.

2. Lecture overview

2.1. Lecture information

The lecture is divided into distinct phases that guide students through understanding energy technology. The focus is to engage students both theoretically and practically, with an emphasis on interactive learning through VR and hands-on activities. This lesson is designed to last 45 to 60 minutes.

- **Lesson Topic:** The Evolution of Energy Technology
- **Intended Age Group:** 12-14 years
- **Lesson Duration:** 45 to 60 minutes (including VR experience and hands-on activity)
  - *The exact time is up to the teacher. This handbook presents a suggested timeframe.*
- **Materials included:** ClassVR headsets, Teachers' Handbook, Energy Sprint Card Game, invention sheets.
- **Materials Required:** building materials for the hands-on activity (LEGO, straws, paper, etc.), and a whiteboard for group discussions.

2.2. The Story

In this lesson, students will step into the role of scientists at **EvoTech**, an innovative energy solutions company. EvoTech is on a mission to develop cleaner and more sustainable energy sources to help create a better world. As part of their mission, students will act as EvoTech scientists conducting in-depth research on various energy sources through a unique invention known as the **Time Glasses** (ClassVR Headsets).

The **Time Glasses** allow scientists to travel back to key historical periods to observe and learn from breakthroughs in energy technology firsthand. These time-traveling glasses offer scientists access to critical information from the past, where they can study everything from early uses of fire and wind to the emergence of modern sustainable energy sources like solar and wind power.

Storyline Features and VR Limitations

While the Time Glasses can provide an immersive view of historical periods, they have a few limitations. Instead of physical movement through the VR environment, the glasses only permit students to **look around and focus on key points of interest**. When they focus on a point, detailed information about objects or areas will be revealed, allowing them to collect insights without needing to move physically.

This storyline immerses students in the experience while making the best use of the ClassVR's stationary nature, maintaining engagement and focus as they "explore" the past to bring forward valuable insights on energy technology evolution.

3. Lecture Structure

The lecture consists of 2 phases. **See figure 1.** The first one is what is called the **"Research Phase"**, in which students take on the role of scientists and perform research surrounding the history of energy technology. During this phase the student will have to perform research in VR and participate in a side activity. A rapid-fire questionnaire developed by the EPS team.

The second phase is what is called the **"Develop Phase"**. In which students use their gained knowledge from the research phase to think about the future and encourages to invent their own vision of the future of energy technology. Using whatever they can to make their own project and be able to present and discuss about it.

The image below shows a sketch of the lecture structure.

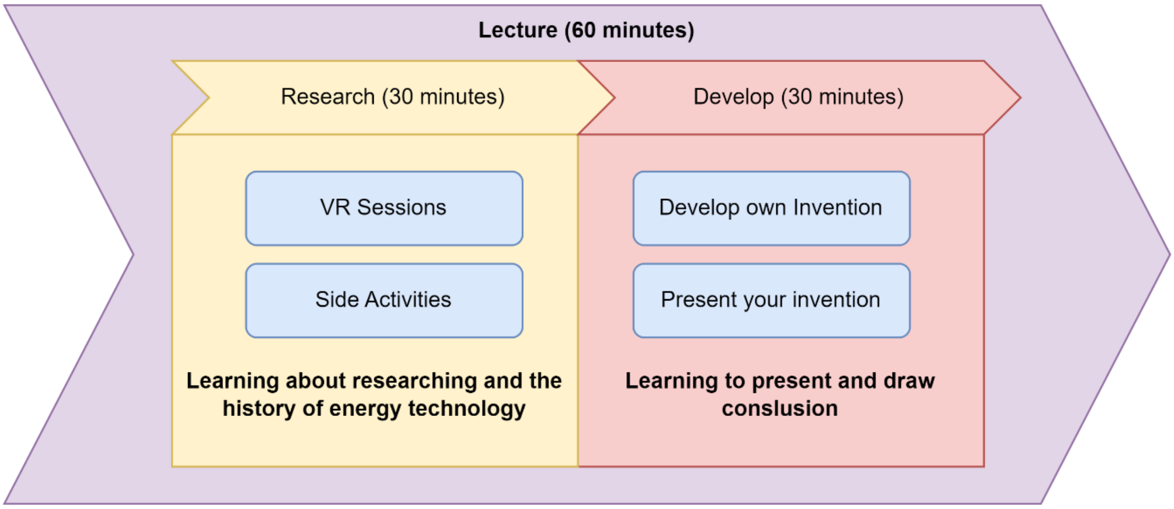


Figure 1: Lecture structure

3.1. Research Phase

In this phase, students will be tasked with researching the history and evolution of energy technology. This consists of learning about the different major energy sources that have been discovered throughout history and how it was utilized in that era.

This will be done using 2 distinct activities: **The VR Experience** and **the Side activities.**

The reason for these two activities is to make sure that the students don't stay inside the VR headsets for too long to prevent any dizziness and motion sickness. Encourage the students take turns in using the headsets. While some students are using the VR headsets, the other students can play the card game that comes with this set. "Energy Sprint."

3.1.1. Activity 1: VR Experience: "Energy Through Time"

The students will go, as mentioned before through different eras in which a revolution in energy was discovered. Those eras are:

- *The Prehistoric Era (~400.000 years BC)*

Students are transported to a prehistoric cave where they witness the discovery and use of fire. They learn how fire became essential for survival, providing warmth, protection, and a means to cook food.

Figure 2: "The Cave"

- *First Energy Transition (10.000 – 4.000 BC)*

Students are taken to one of the earliest known civilizations, where they observe people using animals for power, propelling mills, grinding grain, and ploughing fields. This scene highlights the first transition in energy use, as societies harnessed animal strength to increase productivity.

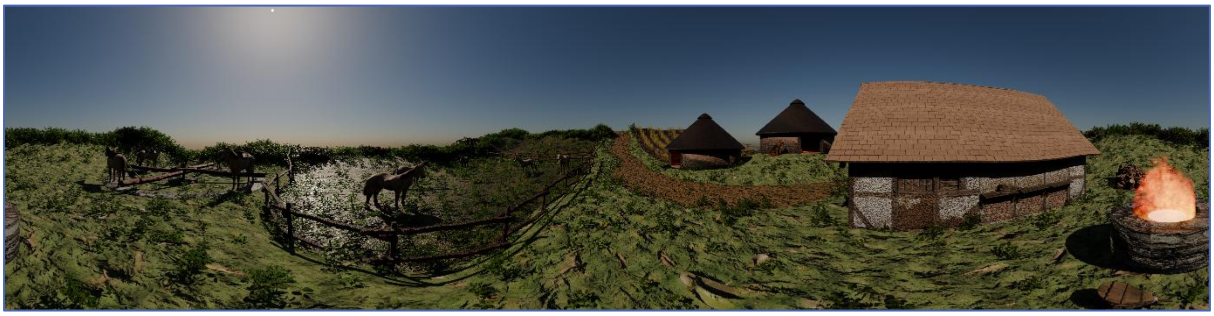


Figure 3: "The Farm"

The Middle Ages (500 – 1000 AD)

This setting showcases how wind- and waterpower transformed engineering mechanics, leading to the flourishing of towns, expansion of farmland, and growth in production. Students learn how renewable resources like wind and water enabled advancements that supported larger communities and enhanced agriculture.

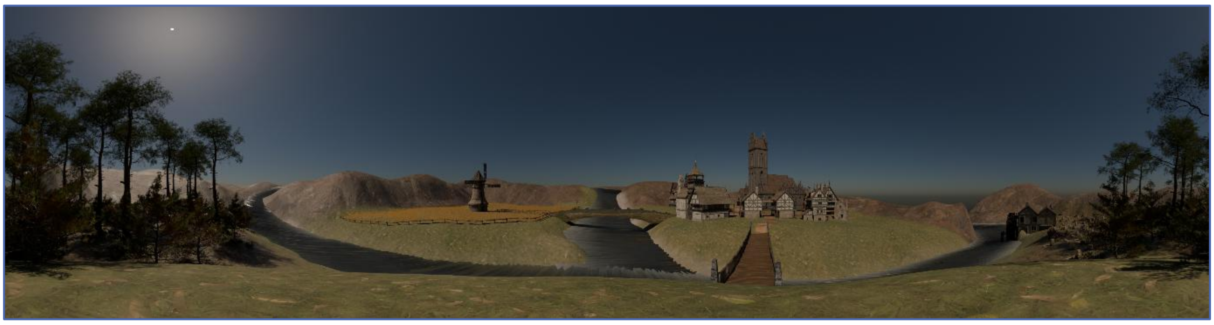


Figure 4: "The Village"

The Industrial Revolution (Late 1800's and early 1900's)

In the late 1800s, students explore the rise of steam power and early electricity experiments, witnessing innovations like steam engine vehicles and the first attempts at electrical transmission. They see how these technologies enabled mass production and long-distance communication via the telegraph, revolutionizing industry and so

Figure 5: "The Factory"

Modern Times (21st Century)

Set in todays time. Students will explore a modern house with home appliances such as kitchenware and gadgets they use themselves such as smartphones, tablets and laptops. In addition to that some information about sustainable wind-, solar- and radiation energy.

Figure 6: "The House"

3.1.2. Activity 2: Card Game: Energy Sprint (Side activity)

Overview
In this interactive and fast-paced quiz game, students take on the role of energy enthusiasts competing for a Nobel Prize. By drawing Quick Question Cards and answering questions about energy history and technology, players can gain or lose Energy Tokens. The player with the most tokens at the end wins the game!

This quiz game provides an alternative way for students to engage with energy history and technology, ideal for students who cannot or prefer not to use the VR headsets. Since recommended VR usage time for students aged 12-14 is limited to 5-10 minutes, this game offers an additional method for students to explore energy technology topics while staying involved in the lesson.

Included in this Card game is:

- Rules sheet (1x)
- Energy Tokens (20x for each era. 100x total)
- Trivia Cards (52x)
- 2-minute Timer (1x)

Quick Variation: For an extra challenge, try the **Lightning Round**, where players have only **5 seconds** to answer each question!

3.2. Develop Phase

The develop phases consists of inventing and presenting the student's own idea of the future

During this phase the students are encouraged to use the knowledge they gained in the previous phase to now use it to think about how they can invent their own idea of energy technology. This can be anything meaning all types of materials can be used to create something on their own.

The idea is that the students start thinking about how energy could function in their own project. Encourage this. Their invention does course does not have to work practically, the idea is that the student invents something and is able to present that idea to their peers. This lecture should encourage students to starting to think as a team, present their ideas and draw conclusions.

The develop phase goes as follows:

3.2.1. Activity 1: Introduction

The students will now become "energy inventors" and will have 20 minutes to come up with their own ideas on how energy could be generated in the future. This will:

- Encourage creative thinking by asking questions like:
  - What problems with energy do we face today (e.g., pollution, limited resources)?
  - What future technology might solve these problems?
  - Could energy come from new places (space, other dimensions, inside our bodies)?

Remind them that there's no wrong answer! — it's about imagination and innovation.

3.2.2. Activity 2: Invention Creation

Step 1: Brainstorming and Sketching (10 minutes)

Give the students time to brainstorm individually or in small groups (depending on your class setup). They should write down their ideas for future energy inventions. To help them focus, a "invention sheet" with required information will be provided:

- Name of the invention
- What energy source it uses
- How the invention works
- Why it is better than today's energy technologies
- Additional information regarding the invention

After brainstorming, the students should draw a simple sketch or diagram of their invention. If time permits, allow them to add labels or a brief explanation next to their sketch. For younger students who might need help visualizing, you could provide an example invention (e.g., "an energy generator powered by wind from space").

Step 2: Create the invention (10 – 15 minutes)

Using available materials, students will bring their inventions to life. They will then prepare a 1–2-minute presentation explaining their creation to the rest of the class.

3.2.3. Activity 3: Presentations

Depending on time, invite students to present their inventions. Encourage them to be confident and share their ideas enthusiastically. After each presentation, you can allow a couple of quick questions from their classmates to keep the activity interactive.

3.3. End of the lesson

The lesson can be concluded by doing different kinds of activities. All underlying activities have a hint of presenting their ideas to each other and encourages discussions about their inventions.

- **Presentations:** Allow the students to present their ideas using their inventions and their invention sheets.
- **Class discussion:** Have the class talk about their inventions in groups and guide them through
- **Peer feedback and Q&A:** Similar to the discussion, this one allows the other students to view their peers' invention more closely and ask questions while the

4. The VR Glasses

The VR glasses used in this lesson are **ClassVR headsets**, specifically designed for educational purposes. These standalone VR headsets offer an immersive experience, allowing students to engage in virtual environments without the need for additional equipment like smartphones or computers. ClassVR headsets are easy to use, with pre-installed educational software and intuitive controls, making them ideal for classroom settings.

For further information about how to use the headsets, navigation and set-up, a easy setup & user guide is provided in the box.

Figure 7: Charging Case

Figure 8: The Headset

For this lecture the following will be provided by LUMA:

This set includes:

- The Charging box (1x)
- A charging cable (1x)
- ClassVR Headsets (8x)
- Instruction manual for the headsets (in Finnish)
- Setup & User guide (in English)

4.1. The headsets

Quick overview of the controls. More information can be found in the Setup & Uder guide found inside the box.

Left Side

Power Button	
Volume control	
Confirm / Select	
Return	

Right side

The Swipe-Pad (+) allows you to move through the ClassVR menus and select different activities.

To select something simply press the middle circle.

Bottom

From left to right:

- Microphone
- Reset
- Headphones
- Micro-SD Card
- USB
- Charging port (Micro-USB)

4.2. Software

4.2.1. How to navigate in the Menu

Once you have booted up the VR headset, a selection menu appears in front of you. Within this menu you can select different environments and lectures available in the ClassVR library.

For this lecture we are looking for **"The Evolution of Energy Technology".**

***Pictures are not available yet at this moment. This will be added on a later date. ***

4.2.2. How to navigate in the world

Students will receive the "time glasses" that will be provided by LUMA. These glasses function as "time machines" in which student will visit the different era in history by simply looking around and interacting with different points of interest.

POI for short. Shown as blue indicators with a dot in the middle. as seen in **figure 9**. Students can interact with these POIs by simply looking at them.

Figure 9: Blue Icons

These POIs are premade by the developers and function as "sources" for the students. From these points student will see facts, questions and general information about the POIs. By interacting with these POIs. Students can learn more about the topics at hand and use this in future research with their teammates.

During this adventure, students can also move to different eras themselves. Similar to the blue icons, the orange icons, as seen in the image below, **figure 10**, allow the student to move around the area.

Figure 10: Orange Icons

Keep in mind that the student does **NOT** have to move make to get to the markers. The VR headsets can be worn while the student is either seated or standing in one place. By simply looking at the icon, it should transport them to that location.

5. Setup the VR Glasses

1

Preparing the Room

Before beginning the lesson, make sure the room is arranged to provide each student with a safe and comfortable experience. Arrange desks or chairs so each student has adequate space around them to move their head freely without obstructions and clear the area of any tripping hazards, cords, or other obstacles.

2

Charging the Headsets in Advance

To avoid interruptions, ensure all VR headsets are fully charged before the lesson. Charging may take several hours, so it's best to plug them in the night before. Verify each headset's charge level before distributing them to students.

3

Removing the Headsets from the Boxes

Check first of the headset is attached to the charger. Remove the VR headset from their boxes. Inspect each headset for any visible issues or damage and make sure each one has a headband attached for comfort. Keep the boxes nearby to safely store the headsets after the lesson.

4

Turning on the Headsets

Press and hold the power ⏻ button on each headset for a few seconds until the startup screen appears.

Ensure that each headset displays the startup screen correctly and has enough charge.

Note: Detailed instructions for operating the headsets are provided in the instruction manual included in this handbook. These instructions can be found in the charging box

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5

Adjusting the Headband

Each headset comes with an adjustable headband to ensure a comfortable fit for students.

6. Clear up after the activities

1. *Gathering the headsets*
After the lectures, make sure to gather all headsets and check for any damages.

---

2. *Turning them off*
Simply turn the headsets off by holding the power ⏻ button.

---

3. *Putting them in the boxes*
Carefully put the headsets inside of the box.

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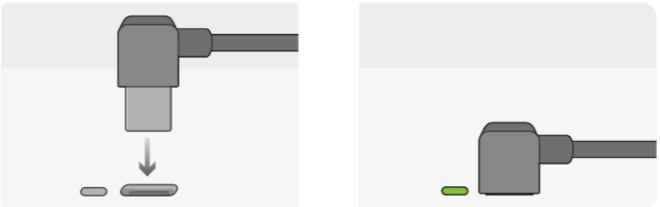
4. *Put them on the charger*
Once places in the boxes, make sure to put all headsets on charge so that they can be used for the next session.



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5. ***That's it!***
Close the box and store it away safely.

7. Safety and Health Information

This information is from the official manual guide from ClassVR Support (**Version 2.1)**

For more information visit **www.classvr.com/support** or **www.classvr.com/safety**

Before using the headset

- Read and follow all setup and operating instructions provided with the headset.
- Review the hardware and software recommendations for use of the headset. Risk of discomfort may increase if recommended hardware and software are not used.
- Your headset and software are not designed for use with any unauthorised device, accessory and/or software. Use of an unauthorised device, accessory and/or software may result in injury to you or others, may cause performance issues or damage to your system and related services.
- To reduce the risk of discomfort, adjust the viewing focus for each user before use of the headset.
- A comfortable virtual reality experience requires an unimpaired sense of motion and balance. Do not use the headset when you are: Tired; need sleep; under emotional stress or anxiety; or when suffering from cold, flu, headaches, migraines, or earaches, as this can increase your susceptibility to adverse symptoms.
- We recommend seeing a doctor before using the headset if you are pregnant, elderly, have pre-existing binocular vision abnormalities or other serious medical conditions.
- To charge the headsets, carefully ensure they are placed within their supplied case, with the USB cable connected to each headset. When the case is connected to the mains using the supplied power cable, the light on each headset should illuminate to show that it is charging. When the headsets are fully charged, we recommend switching the power supply off at the mains.

Children

Adults should make sure children use the headset in accordance with these health and safety warnings including making sure the headset is used as described in the Before Using the Headset section and the Safe Environment section.

Adults should monitor children who are using or have used the headset for any of the symptoms described in these health and safety warnings (including those described under the Discomfort and Repetitive Stress Injury sections) and should limit the time children spend using the headset and ensure they take breaks during use.

Prolonged use should be avoided, as this could negatively impact hand-eye coordination, balance, and multi-tasking ability. Adults should monitor children closely during and after use of the headset for any decrease in these abilities. We recommend that ClassVR is used for no more than 15 minutes in any one lesson. Short VR sessions are very engaging and are the perfect way to open a topic or reinforce a key point. The ClassVR player includes a notification to the teacher when any student has been in VR for longer than this recommended time, which is also the limit recommended for children by optometrists.

Seizures

Some people (about 1 in 4000) may have severe dizziness, seizures, eye or muscle twitching or blackouts

triggered by light flashes or patterns, and this may occur while they are watching TV, playing video games or experiencing virtual reality, even if they have never had a seizure or blackout before or have no history of seizures or epilepsy. Such seizures are more common in children and young people under the age of 20. Anyone who experiences any of these symptoms should discontinue use of the headset and see a doctor. Anyone who previously has had a seizure, loss of awareness, or other symptom linked to an epileptic condition should see a doctor before using the headset.

General Precautions

To reduce the risk of injury or discomfort you should always follow these instructions and observe these precautions while using the headset:

- Use only in a safe environment: The headset produces an immersive virtual reality experience that distracts you from and completely blocks your view of your actual surroundings.
- Always be aware of your surroundings before beginning use and while using the headset. Use caution to avoid injury and remain seated unless your content experience requires standing.
- Use of the headset may cause loss of balance.
- Remember that the objects you see in the virtual environment do not exist in the real environment, so don't sit or stand on them or use them for support.
- Serious injuries can occur from tripping, running into or striking walls, furniture or other objects, so clear an area for safe use before using the headset.
- Take special care to ensure that you are not near other people, objects, stairs, balconies, open doorways, windows, furniture, open flames, ceiling fans or light fixtures or other items that you can bump into or knock down when using - or immediately after using - the headset.
- Remove any tripping hazards from the area before using the headset.
- Remember that while using the headset you may be unaware that people may enter your immediate area.
- Do not handle sharp or otherwise dangerous objects while using the headset.
- Never wear the headset in situations that require attention, such as walking, bicycling, or driving.
- Make sure the headset is level and secured comfortably on your head, and that you see a single, clear image.
- Make sure any headphone cables if used are not tripping hazards.
- Ease into the use of the headset to allow your body to adjust; use for only a few minutes at a time at first, and only increase the amount of time using the headset gradually as you grow accustomed to virtual reality. Looking around when first entering virtual reality can help you adjust to any small differences between your real-world movements and the resulting virtual reality experience.
- Do not use the headset while in a moving vehicle such as a car, bus, or train, as this can increase your susceptibility to adverse symptoms.
- Take at least a 10-to-15-minute break every 30 minutes, even if you don't think you need it. Look away from the screen and move your eyes when resting. Each person is different, so take

more frequent and longer breaks if you feel discomfort. You should decide what works best for you.

- If using headphones, listening to sound at high volumes can cause irreparable damage to your hearing. Background noise, as well as continued exposure to high volume levels, can make sounds seem quieter than they actually are. Due to the immersive nature of the virtual reality experience, do not use the headset with the sound at a high volume so that you can maintain awareness of your surroundings and reduce the risk of hearing damage.

Discomfort

Immediately discontinue using the headset if any of the following symptoms are experienced: seizures; loss of awareness; eye strain; eye or muscle twitching; involuntary movements; altered, blurred, or double vision or other visual abnormalities; dizziness; disorientation; impaired balance; impaired hand-eye coordination; excessive sweating; increased salivation; nausea; light-headedness; discomfort or pain in the head or eyes; drowsiness; fatigue; or any symptoms similar to motion sickness.

Just as with the symptoms people can experience after they disembark a cruise ship, symptoms of virtual reality exposure can persist and become more apparent hours after use. These post-use symptoms can include the symptoms above, as well as excessive drowsiness and decreased ability to multi-task. These symptoms may put you at an increased risk of injury when engaging in normal activities in the real world.

- Do not drive, operate machinery, or engage in other visually or physically demanding activities that have potentially serious consequences (i.e., activities in which experiencing any symptoms could lead to death, personal injury, or damage to property), or other activities that require unimpaired balance and hand-eye coordination (such as playing sports or riding a bicycle, etc.) until you have fully recovered from any symptoms.
- Do not use the headset until all symptoms have completely subsided for several hours. Make sure you have properly configured the headset before resuming use.
- Be mindful of the type of content that you were using prior to the onset of any symptoms because you may be more prone to symptoms based upon the content being used.
- See a doctor if you have serious and/or persistent symptoms.

Repetitive Stress Injury

Using the device may make your muscles, joints or skin hurt. If any part of your body becomes tired or sore while using the headset or its components, or if you feel symptoms such as tingling, numbness, burning or stiffness, stop and rest for several hours before using it again. If you continue to have any of the above symptoms or other discomfort during or after use, stop use and see a doctor.

Electrical Shock

To reduce risk of electric shock:

- Do not modify or open any of the components provided.
- Do not use the product if any cable is damaged or any wires are exposed.

Damaged or Broken Devices

- Do not use your device if any part is broken or damaged.
- Do not attempt to repair any part of your device yourself. Repairs should only be made by Avantis Systems Ltd.

Contagious conditions

To avoid transferring contagious conditions like conjunctivitis (pink eye), do not share the headset with persons with contagious conditions, infections or diseases, particularly of the eyes, skin or scalp. The headset should be cleaned between each use with skin-friendly non-alcoholic antibacterial wipes and with a dry microfibre cloth for the lenses.

Skin irritation

The headset is worn next to your skin and scalp. Stop using the headset if you notice swelling, itchiness, skin irritation or other skin reactions. If symptoms persist, contact a doctor.

HEALTH & SAFETY WARNINGS: TO REDUCE THE RISK OF PERSONAL INJURY, DISCOMFORT OR PROPERTY DAMAGE, PLEASE ENSURE THAT ALL USERS OF THE HEADSETS ARE AWARE OF THE WARNINGS BEFORE USING THEM.

IT IS IMPORTANT TO REMAIN SEATED WHILST USING THE HEADSET UNLESS YOUR CONTENT EXPERIENCE REQUIRES STANDING.

All guides, manuals and health & safety warnings are periodically updated for accuracy and completeness. Please visit our website to view/download:

User manuals in alternative languages

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Appendix F

Test Strategy:

"Evolution of Energy Technology"

European Project Semester | Test Strategy for Prototype Lecture

Jesse van den Ende

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1. Introduction

This test strategy outlines the approach for evaluating the VR prototype designed to educate students (ages 12-14) on the evolution of energy technology. Testing will assess the program's engagement, usability, learning effectiveness, and hardware functionality within the classroom setting.

The testing will focus on students' ability to follow the storyline, interact with VR content, and comprehend educational milestones, considering hardware limitations of ClassVR headsets.

2. Testing objectives

Primary Goals

1. **Educational impact:** Making sure that participants understand what is presented in the VR experience and side activity.
2. **Engagement**: Making sure that the VR experience and Card game are fun engaging enough
3. **Usability**: Verifying that VR experience is accessible and easy to navigate and understand.
4. **Hardware performance**: Identifying and documenting any occurring hardware or software malfunctions. Including Safety measures like dizziness and disorientation.

3. Testing Approach

Methodology: During this test, EPS will provide some introductory information about the session. During this session, the team will give the lecture as if it is a real setting. In the meantime, the team will resort to note taking and guiding the participants if necessary.

The team is open to feedback through the entire session and will note this for future references in finalizing this project.

What will be recorded:

1. Any challenges or limitations regarding the usability of both the VR program and the card game. This includes assessing whether the experience is easy to understand or if certain instructions provided by the team are unclear.
2. Assess whether the experience is engaging and enjoyable for the target audience. Student engagement will be evaluated through ad-hoc interviews or a brief survey conducted immediately after the session. This feedback will provide insights into the students' level of involvement and enjoyment.
3. Based on the team's assumptions, a brief questionnaire will be administered after the session to assess what participants have learned from this specific lecture. Prior knowledge of certain aspects is not a concern in this context; the key focus is on confirming that the material presented in the lecture is effectively conveyed and understood. This aligns with the project's research objective of ensuring that the content developed by the team is genuinely educational and accessible.
4. The technical aspect of the experience. Any issues regarding the VR equipment that might impact on the user's experience.

4. Testing Environment

- **Equipment**: The ClassVR Headsets are configured to ensure a stable connection. Using the raspberry PI is necessary.
- **Location**: Testing location is situated in one of the appointed classrooms by the host. The classroom is to be used for both the VR experience and the lecture.
- **Duration**: The session is around an hour and fifteen minutes long (Different if specified by the host). During the first hour the prototype lecture will be given. Meaning that the first 30 minutes are about the VR experience, the next 30 minutes are the presentations. The last 15 minutes will be focused on gathering the feedback using the questionnaire provided.

5. Key Focus points & Metrics for success

- **Engagement**: Observe whether students are engaged and motivated while using VR and the card game and enjoy the storyline.
- **Usability**: Asses if students can easily follow the VR environment and understand the goal of the lecture.
- **Educational benefits and comprehension**: Asses whether the lecture was able to provide the students with knowledge regarding the topic of energy technology.
- **Added VR value:** Conclude the added value of the VR experience.
- **Technical stability**: Record hardware issues, disconnections or any other technical issues related to VR experience.
- **Comfort**: Note down any discomforts and disorientations. Make an estimate of the age of the participant.

A questionnaire (**Microsoft Forms**) will be distributed at the end of the prototype lecture. The primary focus of this questionnaire is to evaluate the key aspects mentioned above, determining the success of the test. Questions will center on participants' experience, engagement, and overall perception of the lecture. The questionnaire is designed to be concise, taking no longer than **5 minutes** to complete, and all participants are **required** to fill it out.

6. Stakeholders & Responsibilities

- **EPS Team:** Responsible for organizing and conducting the testing session. The team will collect data to evaluate the prototype and analyze the results for inclusion in the final report.
- **School Teachers/Instructors**: Participate in the test as "students" and offer valuable insights on lecture structure and its alignment with educational standards.
- **Students**: The primary participants, aged 10 to 18, will engage in the lecture and provide crucial feedback based on their experience, serving as the main source of information for evaluating the program.

7. Risk Management & Assumptions

Risks:	Mitigate:
Potential discomfort, disorientation, or fatigue	Limit the use to 5 – 10 minutes. Make sure to let the participants take breaks in the meantime or let them switch over to the side activity. Provide a short safety briefing beforehand on how to use the headsets and remind them to take breaks.
Technical issues or malfunctions • **Blurry visuals** • **Connection problems** • **Etc.**	**Blurry**: Pre-adjust the setting if necessary. Make sure everyone in our team knows how to adjust settings accordingly. **Test it yourself beforehand!** **Connection**: Before the session starts. Make sure to be on time and check for alternatives to be able to provide a smooth connection. Whether it is the raspberry pi or the school's own network. **A router from LUMA is provided too.** **Make sure all headsets are functional BEFORE the session!**
Confusion over instructions	Use simple and easy to understand English to provide instructions. Do not use words is too difficult. Remember, the age group is between 10 and 18. Make sure you help people one-on-one if possible.
Uncooperative participants	**Last resort**: In case of uncooperativeness, move the headset to another participant that could give some more feedback. There is only 1 hour available. Do this professionally or ask the teacher present for help.
Assumptions: • **Participants could potentially have some knowledge when it comes to basic VR but will still be briefed about the safety and instructions of the program.** • **Participants will be cooperative** • **The ClassVR set will be functional during the session.**	

2024

Appendix G

Recommendations for Improving VR Experience

PART OF PROJECT CLASSVR

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During the project, multiple issues arose while using the ClassVR headsets. These issues appear to be caused by the software within the devices, leading to hardware reliability that does not meet the desired standards.

This unreliability is a point that has come up during the final testing phases of this project, whilst testing with the LUMA team. To ensure the lesson remains consistently reliable, it is recommended to consider using a newer generation of VR headsets.

One potential alternative is the Meta Quest 3. During testing, the Meta Quest 2 was used to display the ThingLink environments, as the ClassVR headsets were not functioning properly at the time. The Meta Quest series offers options for teacher control software while providing improved reliability compared to the ClassVR devices.

1.1. Improving the scenarios

The created scenarios are finished and fully functional yet contains a few minor imperfections. It was not possible to implement these changes due to the limitations in the design software combined with a lack of time. A few recommendations to further improve the environments and some hardware recommendations are listed below.

Several potential graphical enhancements have been identified for all scenarios, aimed at increasing the overall immersiveness of the scenes. These improvements are outlined below.

Improvements for the cave scenario

The cave can be improved by making minor improvements to the small rocks that are placed on the floor and by changing the cave exit to use a skybox, instead of the current cave wall.

Improving the rocks on the floor

The cave scenario currently employs surface scattering for the placement of small rocks on the floor. This method prevents the rocks from adopting highly unrealistic angles, which would significantly detract from the realism of the scene. However, while surface scattering ensures that all rocks are placed uniformly, resulting in a consistent angle, this approach still introduces a degree of unnatural uniformity.

To enhance realism, the surface scattering technique could be replaced with a physics-based simulation. By using Blender's built-in physics functions, the stones could be allowed to fall naturally, interacting with the cave floor and any objects on it, which would act as hitboxes. This approach would produce a natural arrangement, mimicking the appearance of stones that had fallen from the ceiling.

Additionally, implementing this method could improve the transition between the cave floor and the walls. The current transition appears overly abrupt, diminishing the overall immersion of the scene. Allowing the stones to settle naturally along this transition area would create a more gradual and realistic blend between surfaces, further enhancing the believability of the cave environment.

Adding a skybox as cave exit

Another minor adjustment that could enhance the scene involves modifying the cave's exit. Currently, the cave slopes downward towards an exit that overlooks a clover field. While this approach effectively prevents students from viewing the void of Blender's workspace, an alternative solution could involve implementing a skybox, a method not utilised at the time.

To achieve this, the existing cave exit would need to be removed or restructured to allow the skybox to occupy the background more prominently. This adjustment would create the illusion of a broader and more immersive world, making students feel as though they are part of a larger environment rather than confined solely to the cave. This change would significantly enhance the overall sense of immersion and engagement within the scene.

Improvements for the farm scenario

The primary improvement for the farm scenario involves enhancing the lighting. Currently, the light source is positioned on the opposite side of the houses relative to the students' initial viewpoint. This configuration significantly reduces the visibility of detail within the scenes, as the intricately designed walls of the buildings are obscured in darkness, rendering their features invisible, as displayed in Figure [figure placeholder (below)].

This issue can be addressed by employing a skybox that provides lighting from the correct angle relative to the user's perspective. By aligning the light source appropriately, the visible details of the buildings and surrounding environment would be enhanced, resulting in a more immersive and visually engaging experience for the students.

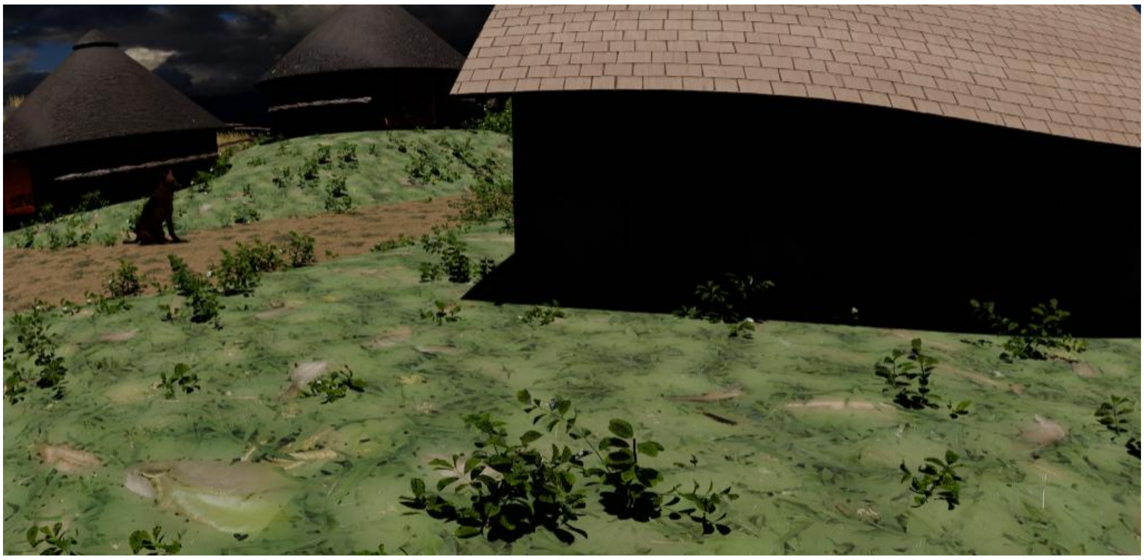


Figure 1 The lighting in the farm scenario

Improvements to the medieval scenario

The primary unrealistic element in the medieval scenario is the absence of grass on the ground. As illustrated in Figure [figure placeholder (below)], the ground lacks any vegetation, which is inconsistent with realistic depictions of cut-down forests, where grass would typically cover the surface.

Figure 2 The almost flat ground of the medieval scenario

This issue can be addressed by applying the same surface scattering technique for grass sprouts, as demonstrated in Figure [Figure placeholder (farm with mediocre lighting)]. Although this approach was not feasible within the scope of this project due to hardware limitations, its implementation would enhance the immersiveness of the scenes.

Improvements for the industrial scenario

The industrial scenario contains several minor flaws, including objects that are out of scale, the presence of unrealistic brand names, and the appearance of unfamiliar items on the floor, which unintentionally form the shape of a question mark. One of the bigger concerns that could be improved is the resolution of the smoke.

Objects being out of scale

In Figure [figure placeholder], a snapshot of the exterior of the industrial scene is presented. This figure highlights the scale discrepancy between the office door and the street lanterns, which appears unrealistic. This issue could be rectified by both reducing the size of the door or increasing the size of the streetlights. Such adjustments would enhance the realism of the scene, thereby improving the overall immersiveness.

Figure 3 The industrial scene on the outside

The brand name of the factory

Currently, the brand name displayed on the wall of the factory is "Mitsubishi." While Mitsubishi was founded in 1870, making it plausible for their factories to exist during the late industrial revolution, Mitsubishi Europe was not established until 1989, during the electrical revolution (Mitsubishi, 2020). The brand name was added to enhance the immersiveness of the scenario, as a blank brick wall appeared incomplete. The intention was to later change it to LUMA or EPS during the project. Unfortunately, due to time constraints near the project's conclusion, this modification was not made.

While implementing this change would not significantly increase the immersiveness of the scenario, it would enhance the historical accuracy of the lesson.

Unknown objects in the final scene

In Figure [figure placeholder], an unidentified plastic object, resembling a question mark, is visible on the floor of the industrial office scene. This object does not appear in any of the scenario files and is not present in the Blender editor.

Figure 4 Unknown object on the floor of the office of the industrial scene

As this object is unrelated to the scene and appears highly unrealistic, it significantly impacts the realism, and consequently, the immersiveness of the scenario. Due to time constraints, there was insufficient opportunity to address this issue thoroughly. As a result, the object was placed near the user's point of view to mitigate its visibility.

This solution assumed that looking straight down is an uncommon action, as most relevant points are positioned in the horizontal plane. During testing, this assumption was confirmed, as none of the testers noticed the object until it was pointed out.

The resolution of the smoke

The smoke emitted from the chimney and the locomotive currently has a resolution of 64. This resolution can be increased by adjusting the settings in the "smoke domain" within the physics settings and baking the fluid. A resolution of 256 or 512 is recommended for better results. However, this increase in resolution will significantly raise RAM usage during rendering. Despite the higher resource demands, this adjustment will enhance the overall immersiveness of the scene.

Improvements for the modern scenario

The modern scenario is relatively complete when compared to the other scenes. However, there remains one potential addition that could enhance the immersiveness of the scene and one that could serve as a smooth transition or preview for the second part of the lesson.

As shown in Figure [figure placeholder], the current windows and walls lack minor architectural features, such as baseboards, window trims, and crown moulding. These elements, though subtle, are not immediately noticeable but can subtly enhance the overall immersiveness that students experience during the lesson.

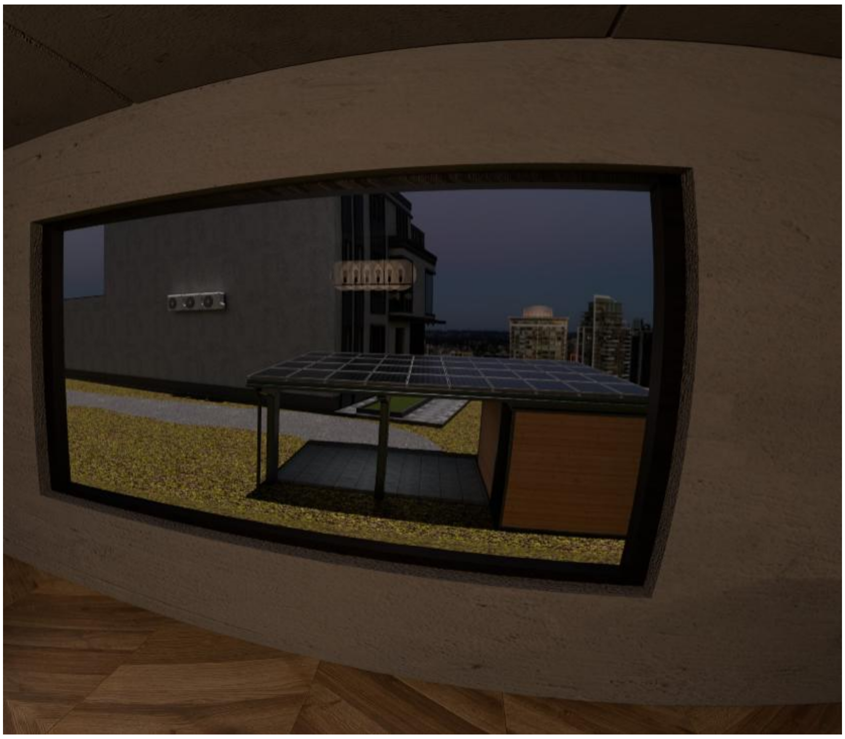


Figure 5 The view out of a window in the modern scene

Another potential enhancement involves adding a modern vehicle to the neighbour's carport, perhaps a futuristic hydrogen-powered car. This addition could serve as a seamless transition or preview for the second part of the lesson, where students may be tasked with designing the car of the future.

1.2. Hardware recommendations

In order to effectively implement these improvements, it is recommended to use some powerful hardware, preferably hardware that is above the recommendations of Blender. Another recommendation is using an RTX-series GPU made by Nvidia, those have optical ray-tracing cores that improve the lighting quality of a scene. Besides the GPU, the CPU and RAM also have to be considered.

The GPU

For the GPU, an Nvidia RTX-series card with a VRAM capacity of 12GB or more is recommended. (Nvidia, 2024) The cards that meet these specifications are listed in Table [table placeholder], arranged from the most affordable at the top to the more expensive options at the bottom.

Table 1: Possible GPU options

Card type	VRAM (GB)
RTX 4060 Ti 16GB	16 (Careful; 8 GB version does exist)
RTX 4070	12
RTX 4070 SUPER	12
RTX 4070 Ti	12
RTX 4070 Ti SUPER	16
RTX 4080	16
RTX 4080 SUPER	16
RTX 4090	24

It is worth noting that the RTX-50 series *is rumoured to come out in early 2025 (VideoCardz, 2024),* because of this, a price drop in 40 series cards is likely to happen. It is also possible to buy either of these cards, if they have the required amount of VRAM. These new cards will be significantly faster than the older generation.

The CPU

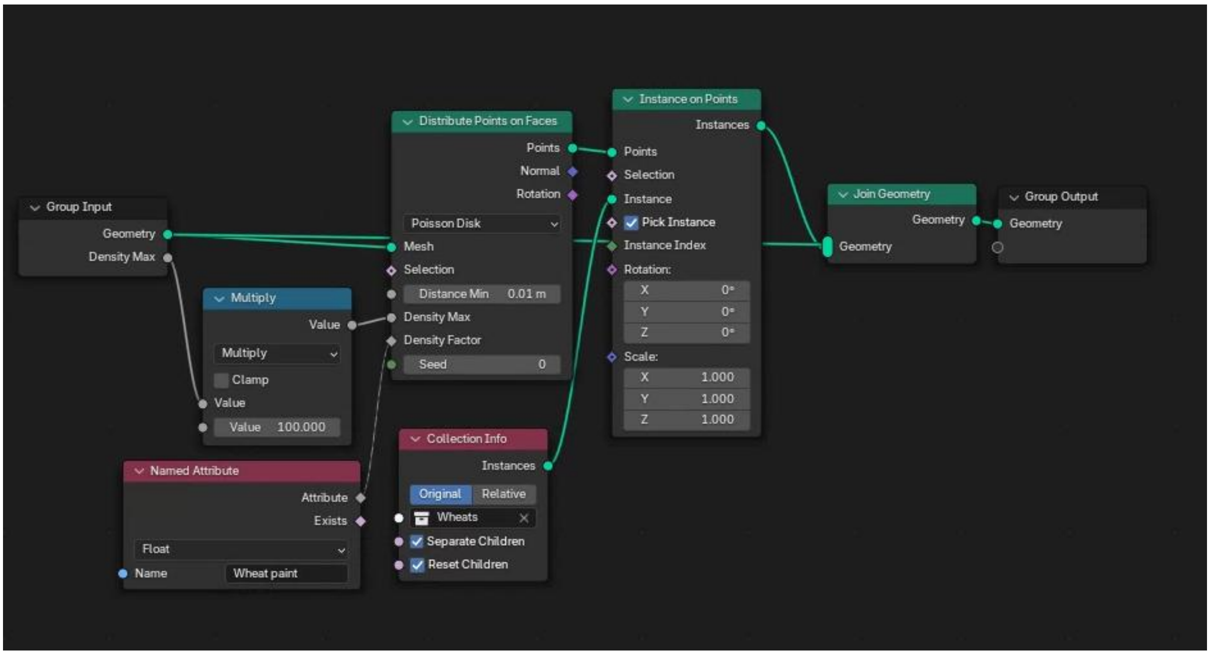
Modern CPUs are primarily produced by Intel or AMD, with AMD being the recommended option. This recommendation is based on the instability reports surrounding the latest generation of Intel CPUs in 2024 (Intel, 2024), coupled with the generally higher core count of AMD CPUs.

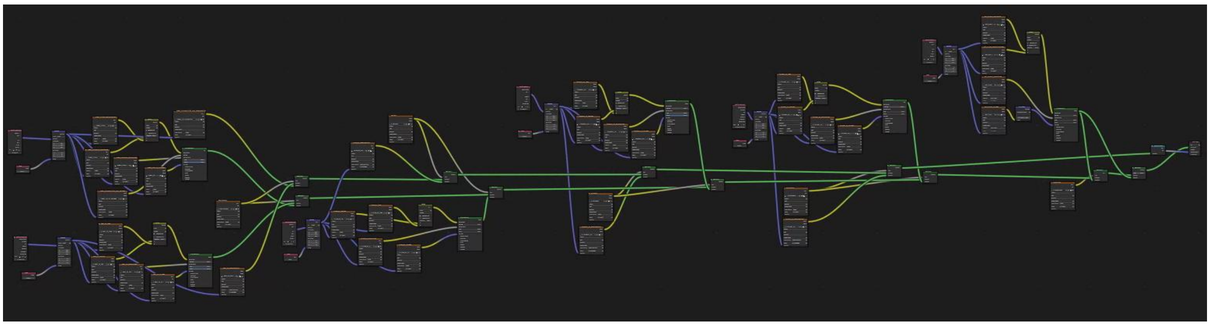
The most important factor to consider is the total number of cores, with a minimum of eight cores (sixteen threads) being preferred. A higher core count directly contributes to improved processing speed, enabling faster performance overall.

The RAM

When talking about RAM, two key factors must be considered: the amount and the speed. Of these two specifications, the amount is the more critical, as insufficient RAM will prevent renders from functioning, whereas slower RAM will only result in slower rendering times. A minimum of 64GB of RAM is recommended, as 32GB turned out to be insufficient for some tasks. Additionally, RAM is typically sold in quantities that follow the 2^n system (e.g., 8GB, 16GB, 32GB, 64GB), which should be considered when selecting the appropriate amount.

Appendix H





The shading nodes for the surface-painted texture of the medieval era are configured as follows. The green lines represent the surface texture connections, with the top green line defining the displacement values and the bottom green line defining the surface colours. The blue lines are used to uniformly scale the texture to the required size, while the yellow lines carry raw texture information, such as roughness, colours, reflectivity, and normals.

The data from the existing main texture and the newly applied texture are combined using a mixing shader. This shader blends the values of both textures based on the manually created surface paint data, ensuring that the resulting texture accurately reflects the desired surface details.