Injecting Hydrogen Education for the Acceleration of the Energy Transition

Using ENTRANCE's Expertise to Engage HAVO Students in the Northern Netherlands

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Hanze University of Applied Sciences | MSc Energy for Society
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On behalf of ENTRANCE – Centre of Expertise Energy

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by

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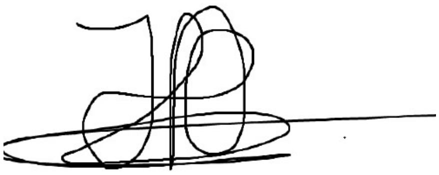

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ENTRANCE CENTRE OF EXPERTISE ENERGY

List of Abbreviations

Abbreviation	Meaning
Autonomy	The ability to make your own decisions about what to do
BT	Bloom's Taxonomy
Competence	The ability to use knowledge, skills and/or abilities confidently
DOI	Diffusion of Innovations (Theory)
EBN	Energie Beheer Nederland
EU	European Union
ELT	Experiential Learning Theory
H2	Hydrogen
HAVO	Senior general secondary education
HBO	Higher professional education
Intrinsically	Things that are a vital, important, or natural part of something
MBO	Secondary vocational education
MOA	Motivation Opportunity Ability (Framework)
NECP	National Energy and Climate Plan
O&O (O en O)	Research and Design, subject of Technasium schools (translation of 'Onderzoeken en Ontwerpen')
Primary data	Data that has been generated by the researcher him/herself
Relatedness	The feeling of connection and support from others
SDT	Self-Determination Theory
ST	Stakeholder theory
STEM	Science, Technology, Engineering and Mathematics
Technasium	The formula for secondary STEM education in the Netherlands
TPB	Theory of Planned Behaviour
VBN	Value-Belief-Norm (Theory)
VO	Secondary education (translation of 'Voortgezet onderwijs')
VWO	In Dutch: 'Voorbereidend Wetenschappelijk Onderwijs' <secondary school level for pre-university education>
WO	University education

1. Problem Analysis

ENTRANCE – centre of expertise energy was initially set up by the Hanze, the Energy Academy Europe, and the Rijksuniversiteit Groningen (RUG). It focuses on connecting students, educators, and professionals to create practical solutions for the energy transition (ENTRANCE, 2023; Hanze, 2024; New Energy Academy, 2023; RUG, 2024a).

ENTRANCE has recently set its sights on Vocational, Bachelor's and Master's degrees, but also on interesting and engaging secondary school students with the potential of hydrogen in the energy transition. ENTRANCE does this with the intent to interest more students in studies and work fields related to the energy transition, and to create a basic awareness and understanding among citizens about the energy transition and how hydrogen could advance the energy transition. Hydrogen represents an important area of focus for ENTRANCE due to the role it could play in the energy transition. As an energy carrier, hydrogen could store renewable electricity, which could then be transported and used as hydrogen for heating, industry or mobility, or turned back into electricity. (Aué et al., 2018). This research focusses on hydrogen in a general way, looking to create awareness for not just green hydrogen, but different types and uses.

ENTRANCE offers expertise and facilities, creating a unique opportunity to introduce secondary school students to hydrogen as a key element of the energy transition (ENTRANCE, 2023). Tasked by ENTRANCE, this research will utilise the expertise and facilities of ENTRANCE for the design and piloting of an educational intervention. This educational intervention will be designed to increase HAVO secondary school students' awareness of, and interest in, hydrogen and how hydrogen could advance the energy transition. ENTRANCE works in close collaboration with Hanze at the HBO university level in the Northern Netherlands. Because of this, the focus is put on HAVO-level secondary school students in the Northern Netherlands, as 90% of HAVO students go on to HBO universities (Oppers, 2024).

This research follows Cambridge Dictionary's (2024a) definition of awareness; 'Knowledge that something exists, or understanding of a situation or subject at present based on information or experience' and Cambridge Dictionary's (2024b) definition of interest; 'The feeling of wanting to give your attention to something or of wanting to be involved with and to discover more about something'.

1.1 Current Situation

Following EU targets to reduce greenhouse gas emissions by 55% by 2030, the Netherlands aims to transition to sustainable energy with its NECP focussing on targets including: renewable energy, research, and innovation (European Commission, 2021; European Commission, 2024). Amidst this transition, almost 39% of job positions related to the energy transition remained unfilled across the Netherlands. As seen in Figure 1, when looking at the northern Netherlands, these numbers are even higher, with 73% of positions unfilled in Groningen and 68% in Leeuwarden (ABN AMRO, 2023).

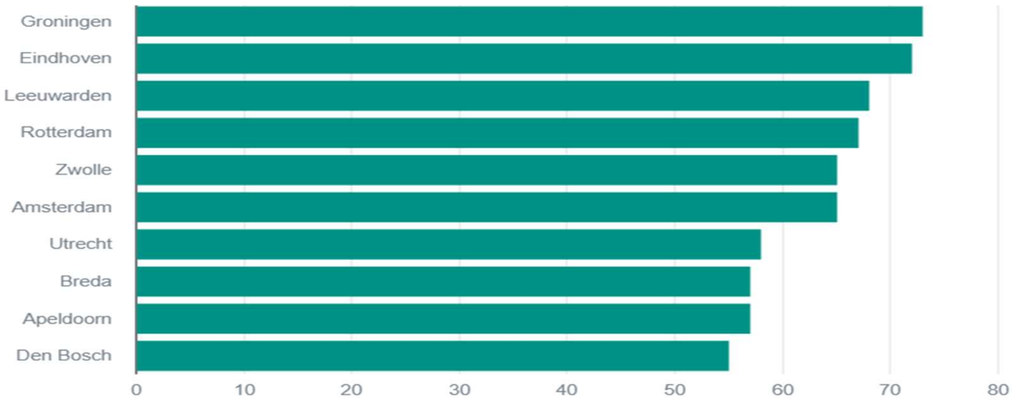


Figure 1: Percentage of unfilled vacancies for personnel in the energy transition (ABN AMRO, 2023)

Hydrogen has become a big focus in the region, with the HEAVENN project working towards a fully operational hydrogen economy in the northern Netherlands, involving 31 parties from 6 EU countries (HEAVENN, 2022). In the provincial development program of Groningen for 2024 until 2029, one of the province's main focuses is the energy transition and the need for skilled workers therein (Nationaal Programma Groningen, 2024). One of the main focus points of this program is hydrogen, and schooling for knowledge and skills around hydrogen within the energy transition, for MBO, university (HBO and WO) and post-university students and workers (Provincie Groningen, 2023). The Waterstof Werkt: H2 Train and Learn Hub is an educational project in the provincial program, focussing on boosting regional energy transition knowledge, with a focus on hydrogen (New Energy Coalition, 2024).

In the Netherlands, the national curriculum includes core objectives or 'Kerndoelen' for lower secondary education, and final objectives or 'eindtermen' for upper secondary education (SLO, 2023). The core objectives for lower HAVO education only mention energy as a concept, with no set focus on hydrogen. Though the concepts of hydrogen and energy saving are noted in the final objectives for HAVO students, there is no mention of the energy transition or the relation to hydrogen (SLO, 2024).

Even though schools can choose to include energy transition-related topics in their curriculum, research on a national level found that 60% of teenagers indicated that the energy transition was never discussed in classes in any way. Only 11% of the questioned teenagers indicated that the energy transition was discussed regularly (Energie Beheer & PanelWizard). In recent years, independent projects like Darel Education have also started working to bring awareness of the energy transition to secondary schools. Though students and teachers indicate that the interventions provide a good introduction to the energy transition, no long-term results are provided about their effectiveness (Darel Education, 2023). A more detailed sketch of the current situation is included in Appendix 1.

1.2 Desired Situation

In the desired situation, HAVO students in the northern Netherlands are more substantially involved with hydrogen and its potential in the energy transition. Because of this, more HAVO students would end up participating in the energy transition and working with hydrogen. This would include various roles within the energy transition, from consultancy and stakeholder engagement to operational and technical activities. However, this would not only mean that HAVO students would choose to study subjects or work in jobs related to the energy transition, but also be a positive influence as citizens when not actively working in the energy transition.

ENTRANCE would be a connection point between secondary education and the energy transition, preparing students to work with hydrogen in the energy transition and also bringing a foundation of knowledge to those who would not. ENTRANCE would receive more higher education students who are interested in the energy transition, whom they can then further educate to produce a skilled workforce. The increase in students and workers participating in the energy transition would help address the shortage of skilled workers, further marking ENTRANCE as a supporting pillar for the advancement of the energy transition.

1.3 Problem Statement

The gap between the current and the desired situation lies within ENTRANCE's desire to educate more skilled workers for hydrogen works within the energy transition, and the lack of education in the HAVO curriculum focussed on hydrogen within the energy transition.

The cause of this desire for ENTRANCE lies in the shortage of skilled workers in the Netherlands, especially in the northern region, where ENTRANCE operates. As described in the current situation, hydrogen plays a big role for ENTRANCE and the northern Netherlands, but 73% of energy transition positions remain unfilled in Groningen (ABN AMRO, 2023). These shortages include a variety of roles in the energy transition and hydrogen within it, from consultancy and stakeholder engagement to operational and technical jobs. Due to these shortages, the progress of hydrogen projects like HEAVENN and regional sustainability goals is at risk.

This triggers ENTRANCE's willingness to interest and engage secondary school students with the potential of hydrogen in the energy transition, as more higher education students with an interest in hydrogen are needed for the energy transition. This supports the energy transition in general and strengthens ENTRANCE's role in it. The lack of experience in secondary school could obstruct interest in pursuing studies or careers in the energy transition (Dierks et al., 2016).

Problem statement
The following is the problem statement for this thesis:

"The lack of students interested in hydrogen within the energy transition hinders ENTRANCE's efforts to educate skilled workers."

1.4 Objectives
Table 1 states the objectives for this thesis.

Table 1: Final Research Objectives

Nr.	Objective
1	Analysing what is currently being taught at Dutch secondary schools, and evaluating HAVO students' knowledge, awareness, and interest in hydrogen within the energy transition.
2	Identifying what are effective ways to create awareness, and interest HAVO students in hydrogen within the energy transition.
3	Analysing how ENTRANCE's current educational programs and expertise align with what is needed to engage HAVO students in hydrogen within the energy transition.
4	Designing and piloting an educational intervention that will allow ENTRANCE to bridge the gap between its current efforts and the needs of HAVO students, actively working towards its goal of interesting HAVO students in hydrogen within the energy transition.
5	Analysing if the intervention has influenced the awareness and interest of the participating HAVO students, taking into account ENTRANCE's goal of not only interesting HAVO students to work in the energy transition, but also to have a better understanding to collaborate better as informed citizens.

1.5 Research Question
"How can ENTRANCE's facilities and expertise be used and extended to increase HAVO students' awareness of and interest in hydrogen for accelerating the energy transition?"

1.5.1 Sub-questions
1. "What is currently being taught at participating secondary schools about hydrogen within the energy transition, and what is the HAVO student's level of knowledge, awareness, and interest?"
2. "What are effective ways to create awareness and interest in hydrogen within the energy transition among HAVO students?"
3. "How do ENTRANCE's current educational programs and expertise align with what is needed to engage HAVO students in hydrogen within the energy transition?"
4. "How can the facilities and expertise of ENTRANCE be used to create an engaging educational intervention?"
5. "What barriers or challenges could arise when implementing a successful educational intervention on the energy transition in secondary schools, and how can these be overcome?"

1.6 Potential Intervention

ENTRANCE would like to interest and engage secondary students, hoping to bridge the gap and bring an experience with hydrogen to HAVO students. Educational projects like Waterstof in de Klas and Energie(K) Onderwijs try to fill the gap by providing energy-related guest lessons or hands-on experiences (Interreg Vlaanderen-Nederland, 2023; Alles over waterstof, 2022). By analysing these and similar projects, this research aims to use the findings of these initiatives to create an educational intervention that addresses both awareness and interest in hydrogen within the energy transition, using the expertise and facilities of ENTRANCE.

To ensure that not just ENTRANCE, but also students, teachers, and schools see value in this intervention, each participating party's input will be incorporated into the design process. The intervention could be built up of various possibilities, depending on the various inputs from the involved parties and design research. For this intervention, two schools will be selected to participate. A set of possible interventions that could be a solution to ENTRANCE's problem is listed below:

- An intervention where schools, or specific classes, are invited to ENTRANCE to experience a variety of hydrogen projects could be a way to introduce and excite HAVO students. At ENTRANCE the students could be shown a variety of hydrogen projects, in combination with an informative session where students could learn and participate. This experience at ENTRANCE could be half a day up to a day, and would require schools to have that availability.

- If schools have a lower availability or willingness to come to ENTRANCE, an intervention in which ENTRANCE brings a hydrogen experience to schools could be a more applicable solution. In this intervention, there could be a short introduction to hydrogen and what hydrogen can mean for the energy transition, followed by an interactive part for students to either work in groups on a game or, for example, a plan on what hydrogen could be used for in their school. This type of intervention could be scalable to the time available per school, possibly being more applicable for more schools.

The exact intervention will be designed based on the research outcomes and what is possible for the schools and ENTRANCE, further clarifying the best possibilities.

1.7 Demarcation

This project's scope includes designing, piloting, and evaluating an educational intervention for HAVO students in the northern Netherlands, focusing on increasing awareness and interest in hydrogen and the energy transition. The intervention will be conducted together with two selected secondary schools, using the facilities and expertise of ENTRANCE.

The scope of this research is limited to the design and pilot phase of the intervention, and it will not extend to large-scale implementation or long-term follow-up beyond the evaluation of the pilot. The project will not include changes to the national curriculum or broader educational policies, nor will it address the economic feasibility of scaling the intervention.

2. Design Research Approach

This chapter describes the approach for the research and design of the intervention. This chapter includes theories, models and/or frameworks, a section on the methodologies and their connection to the sub-questions, the validity and reliability of the research, and finally, a time plan.

2.1 Research Design

This project will be an explorative research project, including intervention design research. This research will be done through various methodologies, theories, models and frameworks to design an educational intervention for secondary school students. This intervention research consists of an initial problem analysis phase, a research phase, a design phase, and a testing and feedback phase, as visualised in Figure 2. The research and design phase will focus on answering the sub-questions through data collection and analysis, and the design of an intervention.

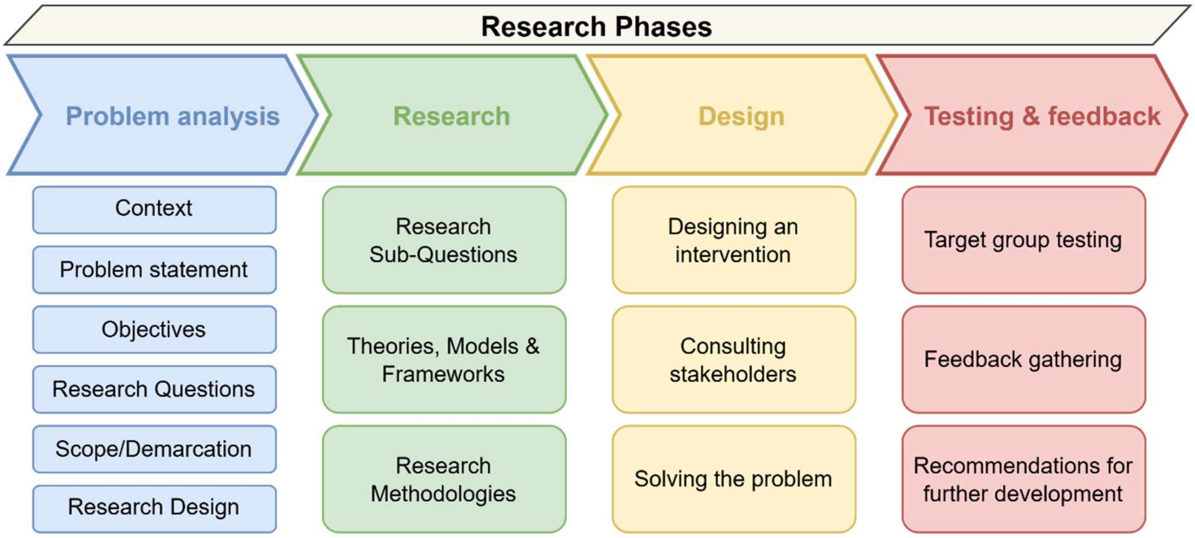


Figure 2: Research phases

2.2 Analysis of theories, models and frameworks

This section shows the relevant theories, models, and frameworks, and summarises how they could be useful to support the research process in Table 2. A more detailed explanation and analysis are added to Appendix 2 for further clarification.

Table 2: Theoretical Foundation; Frameworks and Theories

Theories and Frameworks	Purpose
Stakeholder Theory (ST) (Mitchell et al., 1997)	To include the interests and insights of different stakeholders in the research.
Bloom's Taxonomy (BT) (Mcdaniel, 2010)	To structure the survey questions using different learning levels, from basic recall to higher-order critical thinking, helping to improve data collection.
Experiential Learning Theory (ELT) (Institute for Experiential Learning, 2023)	To analyse the possible use of practical, hands-on learning methods to engage students.
Self-Determination Theory (SDT) (Ryan & Deci, 2000)	To analyse how to motivate students and create engagement for the intervention.
Theory of Planned Behaviour (TPB) (Ajzen, 1991)	To analyse what creates student interest and engagement.
Motivation Opportunity Ability (MOA) Framework (MacInnis et al., 1991)	To analyse how motivation, opportunity, and ability can engage students in the intervention.

2.3 Methodologies

This research design includes both qualitative and quantitative research methodologies to analyse and answer the research sub-questions. These methodologies can build on the theories, models, and frameworks, using them to understand the research topic and how the methods can be used for the collection and analysis of data.

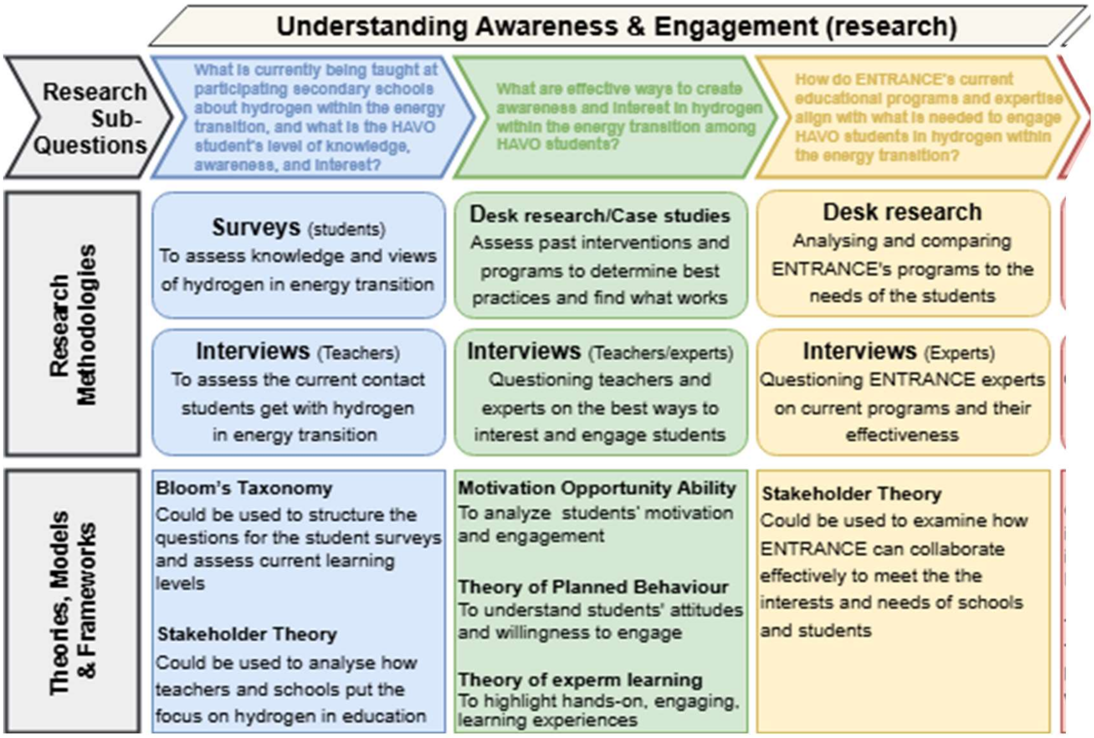
This research will include the methods of desk research, case studies, surveys, interviews, and observations, and use the method of triangulation to combine them. Table 3 summarises the purpose of these methodologies for the research, with a more detailed explanation and analysis added to Appendix 3 for further clarification.

Table 3: Methodologies

Methodologies	Purpose
Desk Research (Moore, 2018)	This method can help support the research and build a strong theoretical foundation by collecting data about hydrogen education, the energy transition, and existing education methods.
Case studies (Alex, 2024)	To analyse examples of existing educational interventions, using them to improve the research and design with their findings.
Surveys (Ponto, 2015)	This method can be used to understand initial and post-intervention levels of knowledge, awareness, and interest, and student learning preferences.
Interviews (Jamshed, 2014)	To collect insights from teachers and experts to understand educational challenges and to support the intervention design.
Observations (Baker, 2006)	To analyse the reactions, engagement, and behaviour of students during the pilot of the intervention.
Triangulation (MacInnis et al., 1991)	To cross-verify data from different methods (surveys, interviews, observations, and desk research) to strengthen the validity and reliability of the research findings.

2.3.1 Aligning research methodologies

To show how the methodologies are used to find answers to the sub-questions, the various methods are linked, together with theories, models and frameworks, to the sub-questions in the visualised model seen in Figure 3 below. The sub-questions are framed in their logical order of completion, for clarity Appendix 4 contains an enlarged, complete version of the model to enhance readability.



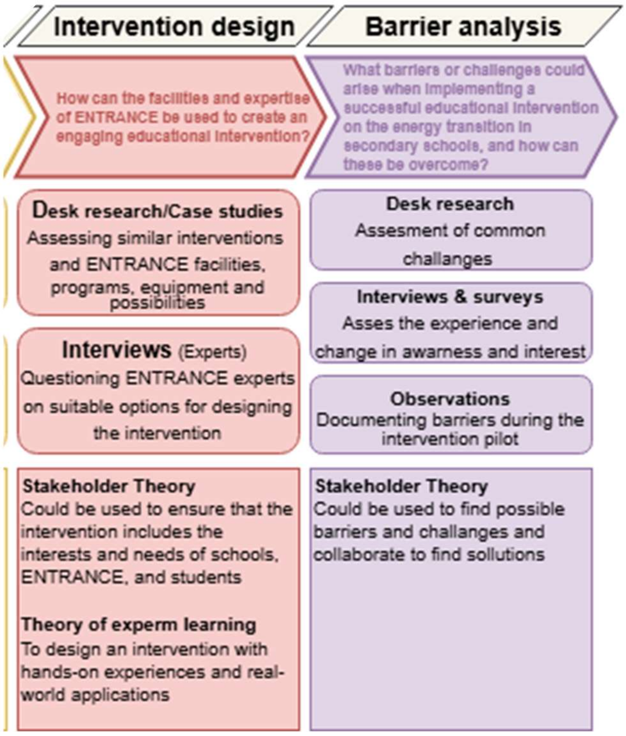


Figure 3: Research methodologies alignment and research flow

2.4 Validity and Reliability

To ensure this research's validity, various measures are used. Internal validity is ensured by aligning the intervention to raise interest and awareness in hydrogen within the energy transition. By using surveys and interviews, the constructs of interest and awareness are measured, both before the pilot of the intervention and after the intervention to assess its influence. The construct validity is improved by combining the findings from various research/data collection methods, such as desk research, interviews, surveys, and observations.

The external validity is addressed by working with two different schools in the northern Netherlands and working to make the findings applicable to more schools and similar situations in the region. In the analysis and the intervention's design, the potential for use in other educational institutions and settings is also considered.

To ensure the reliability of this research, the interviews will be conducted semi-structured way, with clearly stated questions, but room for deviation and a change of question order. The survey questions will be clear and consistent across the participants, and the returned answers will be analysed for possible incorrect or incomplete answers. The observations during the intervention will be taken based on predefined measures.

2.5 Planning

The final timeline planning for this project is worked out in the form of a Gnatt chart. Each phase is divided into deliverables and meetings, and connected to a timeframe. The visualisation of this planning is added to Appendix 5.

3. Data Collection and Analysis

This chapter outlines the methods of collecting and analysing data to answer the sub-questions. Various research methods, including surveys, interviews, desk research, case studies, and observations, are used to address the sub-questions.

3.1 Current state of hydrogen education

This section delves into the first sub-question: “What is currently being taught at participating secondary schools about hydrogen within the energy transition, and what is the HAVO student’s level of knowledge, awareness, and interest?”. This section includes data collection through desk research into the national and school-specific curricula, interviews to assess the current coverage of the curricula, and surveys with the students at the participating schools on their current knowledge, awareness, and interest in hydrogen within the energy transition.

3.1.1 Desk Research

In this section, the current focus on the energy transition and hydrogen in the Dutch education system was analysed through desk research. As described in Appendix 1, the Netherlands has a national secondary school curriculum that describes what secondary students need to be able to do and know at a nationwide level (Ministerie van Algemene Zaken, 2024). While sticking to the core and final objectives, schools have the option to create their curriculum to their liking, as long as these objectives are covered. To help schools along the SLO created ‘Leerplan in beeld’ at the request of the Dutch Ministry of Education, Culture and Science. This online tool supports the design and creation of educational programs, following the national objectives (SLO, 2024).

Neither the core nor the final objectives of the national curriculum mention more than the concepts of hydrogen and energy saving (SLO, 2024). This means that schools are not required to teach about the energy transition or its relation to hydrogen. The Participating secondary schools, Montessori Lyceum Groningen and the Hondsrug College Emmen, indicated that there is no published or unpublished data is available about hydrogen within the energy transition or related statistics from their schools. The research methods of interviews and surveys are used to gather more information on the teachings at the participating secondary schools.

3.1.2 Interviews

Interviews with teachers and (educational) experts were conducted for a better understanding of what is currently being taught about hydrogen within the energy transition and to assess the knowledge, awareness and interest of HAVO students at the participating secondary schools. Teachers play an important role in the education of students and bring valuable insight into the teachings, curriculum and educational challenges at the secondary schools. In addition to teachers, experts were also interviewed to gather broader information on the current state of hydrogen education and how hydrogen fits into national and regional education systems and trends.

These semi-structured interviews were used to collect qualitative in-depth data on whether and how hydrogen is currently being integrated into education, the level of understanding of hydrogen and the energy transition students have, and the focus on these topics within schools.

Stakeholder Theory

Due to their influence when it comes to shaping education into hydrogen within the energy transition, teachers and experts are seen as key stakeholders. While creating the interview questions, Stakeholder Theory, as described in Appendix 2, was used to highlight the importance of including the various stakeholders while developing an educational strategy (Nnadi & Mutyaba, 2023).

By applying Stakeholder theory, the insights from both teachers and experts are considered in this research, helping to create an intervention that is not only relevant but also realistic within the secondary school setting. Teachers give insight into the possibilities and practicalities of integrating hydrogen within the energy transition into the curriculum, and could provide insight into possible barriers. Experts provide a broader perspective of their field, giving insights into best practices, skill gaps or needs and their experiences.

Interview Question Formulation

Keeping stakeholder theory in mind, the interview question formulation focused on the interviewees' field and the relationship between their field and other stakeholders. As clarified in Appendix 3, this research aims for semi-structured interviews for qualitative data collection. To help establish suitable and strong questions, the article Qualitative Interview Questions: Guidance for Novice Researchers was analysed and applied (Roberts, 2020).

While formulating the interview questions for teachers, the current educational practices at their respective schools were a main focus. The base of questions used for interviewing teachers is added to Appendix 6, the original questions are in Dutch, with an added English translation. The questions start with an orientating question, followed by a slight build-up for the most important questions, with the least important questions at the end. Depending on the interviewee and school, the questions used for the interview have slight variations.

While formulating the questions for (educational) experts, more attention was placed on the connections between their respective fields and education. In Appendix 7, an example of the questions for the expert interviews is presented, in this case for the interview of a Technasium education expert. The questions change depending on the expert, with more deviations than the teacher interview questions due to the more diverse fields that experts are in.

The initial sets of interview questions for teachers and experts were examined by ENTRANCE, with minor additions/changes to the final versions in Appendix 8 and Appendix 9.

Interview Results

With the focus on the current state of education, the interviews provided valuable insights. The teacher interviews give further insights into how hydrogen and the energy transition are addressed in the curriculum, what the students already know, and how engaged the students are with these topics. The expert interviews revealed a wider view on educational developments and possible obstacles, providing insights into the interviewees' experiences.

Table 4 provides an overview/summary of the most important findings and insights gathered from the interviews. This table is split into three columns, containing insights from the two participating schools and experts. The insights from teachers of the Montessori Lyceum Groningen and the Hondsrug College Emmen are split into separate columns to show the schools' differences. The insights from experts compare the teachers' experiences to a broader perspective. The insights in Table 4 reference the teacher interview responses in Appendix 8 and the expert interview responses in Appendix 9.

Table 4: Interview results/insights on current educational practices and student knowledge, awareness and interest

Category	Teachers Montessori Lyceum	Teachers Hondsrug College	Expert insights
Energy transition education in schools	Energy transition is discussed in chemistry but is not a focus in most subjects. It is often centred around fossil fuels and global warming instead of solutions and developments.	Energy transition is a recurring theme in Technasium projects. In physics and chemistry, students learn about energy theories but without further developmental context.	Energy transition is present in some school initiatives, but the link to hydrogen is weak. Industry experts emphasise the need for a more structured approach.
Hydrogen education in schools	No dedicated hydrogen lessons, a brief mention in chemistry for HAVO 4 and VWO5. Teachers mention it within broader discussions on climate change and sustainability, but there is no set focus on hydrogen.	Hydrogen is not usually covered in the curriculum but appears in some Technasium projects. When students could encounter energy transition topics in courses, hydrogen is not a main focus.	Hydrogen is generally absent in the national curriculum. Some schools include small energy-related projects, but hydrogen is rarely a focus area.
Student Knowledge	Basic knowledge at best. Some students may recognise hydrogen but do not understand its applications or relevance.	Some students know hydrogen through Technasium projects (like hydrogen cars), but overall understanding is low. HAVO students often struggle with complex concepts.	Students have little awareness of hydrogen's role in energy transition. Some may know about hydrogen cars, but broader applications are unclear.
Student Awareness	Some awareness due to climate change discussions, but students struggle to connect it to real-world applications. Topics feel abstract and distant from their daily lives.	Students are exposed to the energy transition and hydrogen in Technasium but do not always connect it to their personal future or career opportunities.	General awareness exists, but students often lack a connection to real-world applications. Many experts note that hydrogen is perceived as something "for the future," not the present.
Student Interest	Limited enthusiasm. It should be presented interactively. Students engage better when the topic is linked to news or everyday life.	Interest varies. Many HAVO students find it unrelatable unless tied to practical applications. Technasium students show more enthusiasm for hands-on projects.	Engagement improves with practical demonstrations. Interactive lessons, experiments, or real-world applications increase interest, but passive lessons fail to capture attention.

3.1.3 Surveys

The research method of surveying was used to analyse the current knowledge, awareness, and interest in hydrogen within the energy transition among students at both the Montessori Lyceum Groningen and the Hondsrug College Emmen. These surveys give further quantitative data to help understand the students' views, adding to the qualitative data gathered through the interviews.

Survey Design and Question Formulation

To make sure the survey questions were clear, structured and relevant for the students, the survey design and formulation of the questions were done with the help of survey methodology research. The questions were worded in such a way that they minimise possible bias and confusion, making sure that students understand the questions and can reflect their understanding and opinions (Fowler, Jr., 2014). To better align the survey questions to the students' understanding, the International Handbook of Survey Methodology was used to analyse different forms of questions, from open answers to multiple choice (De Leeuw et al., 2012). The indication from teachers to keep the questions easy to understand and to minimise open questions was also taken into account.

Bloom's Taxonomy
As introduced in Appendix 2, Bloom's Taxonomy was used to design a strong structure for the survey (Mcdaniel, 2010). The different learning levels of Bloom's Taxonomy, from basic recall of facts to higher-order critical thinking and application, helped structure the progression of the survey questions to assess the students' understanding at different depths. The final version of the initial survey that was sent out to the schools has been added to Appendix 10.

The survey starts with basic introductory questions to profile the participants, like their age, gender and study direction. After this, Bloom's Taxonomy comes into play, starting with the lower-order thinking questions on knowledge and comprehension. These questions focus on topics like assessing if students know what the energy transition and hydrogen are, and the role hydrogen could play in the energy transition. Following lower-order thinking comes mid-level thinking, seen as application and analysis. These questions get students to apply their knowledge, for example, to identify what they think hydrogen could be used for in the energy transition. Finally, the higher-order thinking comes forth, also known as evaluation and synthesis. These questions asses personal opinions and critical reflections.

By including Bloom's Taxonomy, not only is the existing knowledge met, but the survey could also help identify gaps in the students' understanding, helping to see what topics of hydrogen and the energy transition need more explanation and attention.

Survey Implementation
Both participating schools get the same pre-intervention survey to identify a baseline of understanding. After the intervention implementation at the Montessori Lyceum Groningen, the participating students will receive a second follow-up survey to analyse knowledge, awareness and interest changes.

The participating students at the Hondsrug College Emmen will also receive the second survey, even though they do not receive the intervention in class. The participants at the Hondsrug College Emmen will serve as a control group, giving the possibility to compare the impact of the intervention and to analyse if only the survey by itself has already had an effect. This will help analyse the impact of the intervention separately.

Survey Results and Insights
The responses from both schools to the surveys provided valuable information and insights into the current knowledge, awareness and interest of HAVO students. At the Montessori Lyceum Groningen, the HAVO students who will be participating in the intervention filled in the surveys, and at the Hondsrug College Emmen, where there will be no intervention, both HAVO and VWO students filled in the survey.

A table containing the answers to the initial surveys can be found in Appendix 11. The answers from HAVO students of the Montessori Lyceum and the Hondsrug College can be seen separately, as well as the answers from VWO students at the Hondsrug College. A visualisation and descriptive analysis of the survey answers related to this sub-question has been worked out in Appendix 12.

One of the survey questions on hydrogen knowledge asked participants if they had heard of hydrogen as an energy source. As hydrogen is an energy carrier, this question was wrong, but it was kept in as a trick question to use as an example of a misconception about hydrogen during the intervention. For this question, the idea was also that there might be a student who can correct it, leading to a sense of influence and knowledge for that student. However, no student noticed this mistake.

The overall analysis of the survey results is summarised in Table 5, split into the participants of the Montessori Lyceum and the HAVO and VWO of the Hondsrug College. This table summarises the survey findings on lessons, knowledge, awareness and interest among students.

Table 5: Survey results analysis/summary on knowledge, awareness and interest

Category	HAVO Montessori Lyceum	HAVO Hondsrug College	VWO Hondsrug College
Energy transition and hydrogen in lessons	A majority of students indicate that the energy transition and hydrogen have in some way been seen in lessons, with the main subjects being chemistry, biology and geography.	HAVO students at the Hondsrug College show a lower interaction with the energy transition and hydrogen, with a few indications of the topic in chemistry, biology and geography.	VWO students had a higher interaction with energy transition and hydrogen, with once again chemistry, and here O&O was noted as a close second.
Student Knowledge	Basic knowledge at best, with most stating that the energy transition and hydrogen within it is important for the future.	Some basic knowledge of the energy transition and possible uses of hydrogen, a majority thinks the energy transition is important and hydrogen can play a big role.	More basic knowledge than the HAVO students with more diversified answers. Also, a larger share of students chose more hydrogen application possibilities.
Student Awareness	Most students do not know for sure what the energy transition is but do recognise the subject from lessons. More than 90% think the energy transition is important, and they all think hydrogen could play a big role.	More HAVO students at the Hondsrug College indicate that they know what the energy transition is, but often miss the main goals. 80% indicate they think the energy transition is important, with here also all students indicating they think hydrogen could play a big role.	VWO students are on the same line as the HAVO students but often have a better grasp of the main goals of the energy transition. 82% think the energy transition is important, with 10% not being sure. Once again, all students indicate that they think hydrogen could play a big role.
Student Interest	82% of the students would possibly like to learn more about hydrogen within the energy transition if it is taught in a fun way. When asked why they would like to learn more about it, most students note the future or the environment. 45% of students would not want to study or work with hydrogen or energy, and 55% do not know if they would want to.	80% of the students would be interested to learn more about hydrogen within the energy transition, with 20% being interested if it is taught in a fun way. When asked why they would like to learn more about it, students noted the real-life use and the view for the future. 80% of these HAVO students do not know if they would want to study or work with hydrogen or energy, and 20% indicate they would not want to.	93% of the VWO students would possibly like to learn more about hydrogen within the energy transition if it is taught in a fun way, with two noting they would not be interested. When asked why they would like to learn more about it, more students noted interest in the subject in general, and as with the other students, the future was a main reason. 43% of VWO students would not want to study or work with hydrogen or energy, 10% would, and 47% do not know if they would want to.

3.2 Engaging HAVO students in hydrogen

This section addresses the second sub-question: "What are effective ways to create awareness and interest in hydrogen within the energy transition among HAVO students?". The data collection and analysis in this section utilises the research methodologies of interviews, desk research and case studies to identify best practices from past interventions and the experiences of teachers and experts.

3.2.1 Desk Research

Through desk research, different theories and frameworks were analysed on their potential impact and effectiveness to help create interest and awareness.

Experiential Learning Theory

As described in Appendix 2, Kolb's Experiential Learning Theory, experiential learning is seen as essential for learning, focusing on hands-on and interactive education. In its four stages, this model emphasises how people learn better through experiencing, reflecting, conceptualising, and applying knowledge (Institute for Experiential Learning, 2023). Including practical experiences will allow students to actively engage with hydrogen, creating a deeper understanding and helping students to remember more.

Self-Determination Theory

The Self-Determination Theory by Deci and Ryan, described in Appendix 2, focuses on the psychological aspect of interest and engagement. This framework shows that people are more likely to be intrinsically (internally) interested and engaged when the three psychological needs of autonomy, competence and relatedness are met (Ryan & Deci, 2000).

Students could be more intrinsically motivated and engaged when these psychological needs are included in the intervention. Autonomy could be included by giving students options on how they want to learn, making them feel more in control of their learning process. Competence could be built up through the use of hands-on and practical experiences to help increase confidence in their skills. Adding a progression by increasing the difficulty of tasks could add a sense of progress for the students. Finally, the element of relatedness could be achieved by creating a learning environment where students work together on relatable projects, creating a feeling of connection and belonging.

Using the Self-Determination Theory in the intervention, the focus is taken away from external motivation, like grades and tests and put on internal motivation. Through internal motivation, students could feel personally interested and connected to the hydrogen within the energy transition. This could not only make learning more engaging and interesting but also improve long-term memory of the information and a continuing interest.

Theory of Planned Behaviour

By analysing the Theory of Planned Behaviour by Ajzen, described in Appendix 2, the students' willingness to participate in the intervention depends on three factors. Firstly, the students' attitude towards hydrogen within the energy transition depends on the value they see in the topic. The clearer the value for them, the higher their chance of interacting with it. Next to this, the subjective norms of students are influenced by the importance those around them put on the subject. As stated by Ajzen, the involvement of industry and guest lectured can improve this effect. Finally, the students' perceived behavioural control: if the information they receive seems too complex, students will often not be interested. To influence this behaviour, the information should be easy to understand at their level, any new topics should be well explained, and help should always be available (Ajzen, 1991).

Motivation Opportunity Ability Framework

As described in Appendix 2, the Motivation Opportunity Ability Framework states that individuals will be more likely to engage in behaviour if they are motivated, can carry it out, and have the opportunity to carry out the behaviour(MacInnis et al., 1991). Research has shown that digital interactive education tools, such as virtual experiments, gamified learning, and other digital experiences, can greatly increase interest and motivation in a subject (Haleem et al., 2022; Papastergiou, 2008).

Other interactive initiatives, like the Hydrogen Games by Green Skills for Hydrogen (2024), also follow the Motivation Opportunity Ability Framework to provide students with a gamified learning experience. Adding a level of gamification to the intervention could help to develop interest and understanding about hydrogen within the energy transition.

3.2.2 Case Studies

To add insights on effective ways to create awareness and interest, various case studies of Dutch educational interventions and project cases were studied to find valuable insights and practices. These analysed programs are described in Appendix 13, and include programs such as Jouw Energie van Morgen, Waterstof in de Klas and Darel Education (Darel Education, 2023; Nikkiwp, 2024; Waterstof in de klas, 2023).

Throughout these projects and interventions, the use of hands-on activities, real-world problems and interactive experiences are a reoccurring method to increase students' interest and understanding. Aside from these Dutch programs, international programs like Hydrogen Horizon also demonstrate that hands-on activities, interactive lessons and real-world applications can effectively stimulate interest and create a better understanding (SRO, 2024).

These case studies each incorporate different aspects of the theories and frameworks that were analysed in the desk research. These aspects are outlined in Table 6, aligning the different projects to the theories and frameworks. Some projects have a stronger affiliation to certain theories. For instance, Darel Education’s masterclass demonstrates the importance of autonomy, competence, and relatedness of the Self-Determination Theory by allowing students to choose their own way to create solutions for energy transition challenges, and Jouw Energie van Morgen and Waterstof in de klas have a stronger tie to the Experiential Learning Theory, as they engage students though relatable and practical experiments.

Table 6: Case Study Analysis to Theories and Frameworks

Case Study	Experiential Learning Theory	Self-Determination Theory	Theory of Planned Behaviour	Motivation Opportunity Ability Framework
Darel Education	Hands-on masterclasses where students actively work on energy solutions.	Builds intrinsic motivation through teamwork and personal choices.	Changes behaviour by making students aware of their role in the energy transition.	Provides knowledge (Ability), a collaborative setting (Opportunity), and motivation through real-world influence.
Jouw Energie van Morgen	Science truck with practical experiments on energy solutions.	Autonomy from problem-solving and help from university students.	Changes attitudes through practical engagement.	Experience and knowledge (Ability), hands-on projects (Opportunity), and motivation through collaboration.
Waterstof in de klas	Guest lessons with real hydrogen uses and equipment.	Autonomy via hands-on learning and active participation.	Increases awareness of hydrogen’s role in the energy transition.	Direct experience (Ability), expert-led lessons (Opportunity), and motivation through real-life targets.
Scholen als Energie-ambassade	Project-based learning with students, teachers, and stakeholders.	Competence and autonomy through actual community projects.	Behaviour change by directly involving students in the energy transition.	Knowledge-sharing (Ability), community involvement (Opportunity), and motivation through visible impact.

Milieu-educatie Den Haag	Interactive lessons and sustainability projects.	Autonomy by allowing students to explore local sustainability solutions.	Building sustainable behaviours through environmental awareness.	Tools and learning targets (Ability), an interactive setting (Opportunity), and motivation through societal impact.
Energie(K) Onderwijs	Technical workshops and innovation projects.	Builds competence and autonomy with technical projects.	Shape career choices towards the energy sector.	Technical skills (Ability), access to professionals (Opportunity), and motivation through work relevance.
Hydrogen Horizon	International hands-on hydrogen STEM projects and competitions.	Autonomy and competence via practical hydrogen challenges.	Changes behaviour by allowing students to experience hydrogen first-hand.	Technical knowledge (Ability), global collaboration and competitions (Opportunity), and motivation through innovation.

This case study analysis shows that an intervention that combines experiential learning, autonomy, relatable real-world topics, and practical aspects could be most effective.

3.2.3 Interviews

The interviews with teachers and experts show that many of the findings from the desk research are also viable in practice. Yet they also show that implementing these theories and frameworks is not always as easy as it seems. The questions and answers of these interviews are added to Appendix 8 and Appendix 9.

The interviews show that not only do teachers and experts agree on the use of hands-on experiences, but even across different schools and expert fields, these insights are the same. Lessons where students get to interact with their personal interests to learn about a subject like hydrogen; for instance, in the Technasium lessons [redacted], students are highly motivated and even want to work on a hydrogen car project after school hours. Lessons with interactive kits also had a great effect on students, and in the interview with Tineke van der Meij, the use of hydrogen test kits from ENTRANCE was discussed as a possibility.

Teachers also indicated that the involvement of experts through guest lessons or interactive trips where they show what is currently being worked on in their field could be highly effective. The real-world context of field trips or guest lectures by experienced workers could create a lot of curiosity, and this could provide a line for students to grasp the concepts of hydrogen within the energy transition. In the interviews, the effect of an unfamiliar face, and also a person closer to the students' age, was also given as a good motivator and interest factor for students.

Apart from the notes on students working better and being more interested in projects where they get a challenging objective, teachers also noted that competitiveness among students often works as a motivating and captivating factor. It was also said that if a lesson is not structured, students will lose interest quicker, and using a follow-up assignment, or even just providing information for the students to look into after the intervention, is often very effective.

3.2.4 Surveys

As the students were set to answer a survey to assess their knowledge, awareness and interest in hydrogen and the energy transition, a question was added to get direct input from students on their preferred learning methods. The answers to the initial survey are shown in a table in Appendix 11. The question asking students about their preferred learning method was: What is your preferred way of learning (Op welke manier leer jij het liefst?).

Figure 4: Preferred learning methods HAVO students Montessori Lyceum Groningen

As can be seen in Figure 4 and Figure 5, the input from the participating students reflected what theory, teachers and experts state, showing that they prefer experimenting and hands-on activities. HAVO students of the Montessori Lyceum and the Hondsrug College prefer experimenting, hands-on activities, and videos on the subject. Guest speakers and/or excursions were, however, ranked the lowest, in contrast to what many teachers and experts indicated.

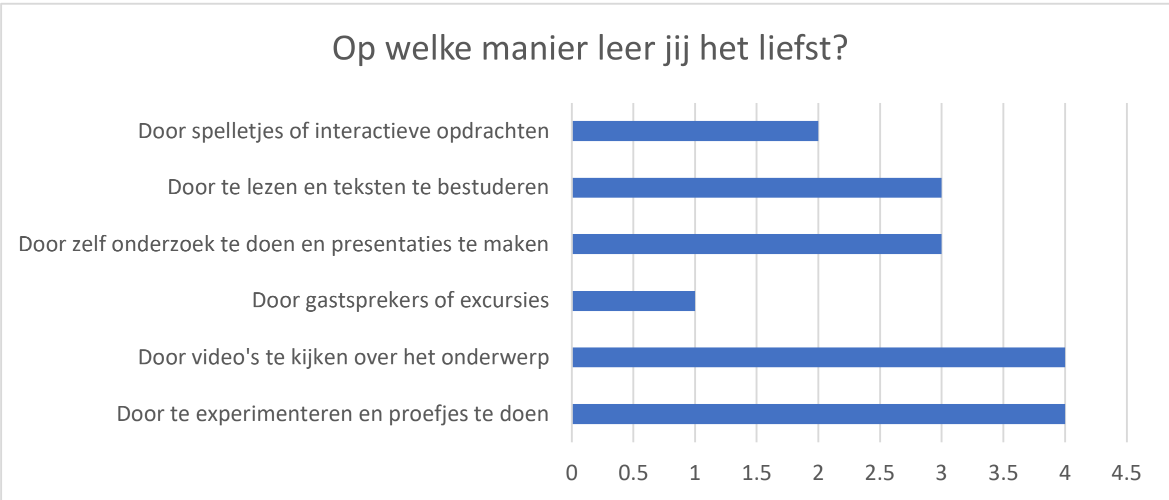


Figure 5: Preferred learning methods HAVO students Hondsrug College Emmen

Figure 6: Question if students would like to learn more about hydrogen in the energy transition, Montessori Lyceum HAVO

As can be seen in Figure 6 the surveys also showed that almost 75% of participants at the Montessori Lyceum would be interested in learning more about hydrogen in the energy transition if it is explained in a fun way. For HAVO students at the Hondsrug College, shown in Figure 7, 80% would be interested to learn more, with 20% also being interested if it is explained in a fun way. This once again indicated that making the intervention engaging and interesting is important to student participation.

Figure 7: Question if students would like to learn more about hydrogen in the energy transition, Hondsrug College HAVO

3.3 ENTRANCE’s role in hydrogen education

This section explores the third sub-question: “How do ENTRANCE’s current educational programs and expertise align with what is needed to engage HAVO students in hydrogen within the energy transition?”. This section uses desk research and interviews to find an answer to this question.

3.3.1 Desk Research

Education on hydrogen within the energy transition is largely new to the participating secondary schools, and this is where ENTRANCE can play an important role in shaping the development of this form of education.

Stakeholder theory

The framework of stakeholder theory can be useful to analyse how different stakeholders influence the implementation of an educational intervention on hydrogen within the energy transition. As described in Appendix 2, the stakeholder theory clarifies that collaboration between all relevant stakeholders is needed to align the educational information with that which is needed in society and possible industries (Nnadi & Mutyaba, 2023).

Studies show that a collaboration of multiple stakeholders for the development of educational programs often makes them more effective. Partnerships between schools, businesses, and research institutions are shown to create a higher interest among students and better learning results (Mitchell et al., 1997). ENTRANCE functions as a knowledge and learning centre in the Northern Netherlands, helping to bridge the gap between university education and practical efforts in the industry. On an international level, initiatives like the Hydrogen Education Foundation in the United States show the potential of collaboration between schools and industry (SRO, 2025b).

ENTRANCE’s Educational Position

ENTRANCE is a regional innovation hub for the northern Netherlands, with focus on sustainable energy, the energy transition and hydrogen innovations. ENTRANCE has a variety of educational opportunities for university students and professionals to develop a foothold in the world of hydrogen within the energy transition. These range from master's in renewable energy to a course on the role of hydrogen in the energy transition (ENTRANCE, 2023; ENTRANCE, 2025). Though there is a variety of choices for HBO, University, and masters students, there are currently no educational programs dedicated to teaching secondary students or teachers, especially HAVO students.

Research into partnerships between academic institutions and industry indicates that these partnerships can create a more effective education by adding real-world perspective into the theory that students have to learn (Perkmann et al., 2012). Another research shows that to make collaboration work well, it is important to create educational material that that fits in with the existing curriculum (Wals et al., 2014).

ENTRANCE’s role in secondary education

As shown in the Problem Analysis, ENTRACE currently has no direct role in secondary education, aside from small projects with, for instance, Technasium students. ENTRANCE could broaden its role in secondary education, connecting education to industrial application. ENTRANCE could provide hands-on workshops and real-world connections for students and combine this with education on hydrogen within the energy transition connected to their curriculum.

3.3.2 Interviews

Adding on to the findings of the desk research, the interviews with teachers and experts provide additional insights. The interviews give a practical insight into how ENTRANCE can align its goals of providing education on hydrogen in the energy transition with the needs and interests of students.

Through the interviews, it became clear that ENTRANCE has a large amount of potential resources and knowledge for secondary school hydrogen education. It also became clear that ENTRANCE is not widely known among students and that there is a lack of relatable material for secondary school students and teachers to work with. ENTRANCE is also seen as a great potential facilitator for connecting secondary education to industry and as a possible provider of hands-on learning opportunities like experiments and relatable real-world projects. A more thorough analysis of the insights and findings on ENTRANCE from the interviews is summarised in Table 7.

Table 7: Interview insights on how ENTRANCE's expertise and facilities align with student engagement

Category	Teacher Insights	Expert Insights
Need for educational materials	Teachers stated that ENTRANCE offers valuable knowledge, but it lacks prepared educational materials that can be easily integrated into their lesson plans. Time limitations also make integrating programs without outside help difficult.	Experts stated that the absence of hydrogen education resources limits access to energy transition and hydrogen knowledge. They suggested that ENTRANCE could work with teachers to create options for the curricula.
Limited awareness among students	Teachers noted that their students, and sometimes themselves, were unaware of ENTRANCE's existence and its role in energy transition and hydrogen innovation. Further collaborations, such as school visits and student-friendly materials, were suggested.	Experts acknowledged that ENTRANCE is not widely known among students. They recommended student awareness campaigns and adding ENTRANCE's activities into learning experiences.
Importance of hands-on learning	Teachers supported the idea of adding in-person experiments and real-world projects at ENTRANCE into hydrogen education. Some pointed to Technasium projects as a model for engaging students in active learning.	Experts confirmed that interactive, hands-on learning approaches, such as laboratory experiments and hydrogen technology demonstrations at ENTRANCE, could significantly enhance student engagement.
Connecting industry and education	Teachers see ENTRANCE as a potential connection between schools and industry but pointed out that this cooperation needs to be made more accessible for teachers and secondary school students.	Experts highlighted that ENTRANCE is in a good position to bridge the gap between industry developments and secondary education through guest lectures, site visits, and industry training.
Supporting teachers	Teachers expressed the need for training and resources to help teach hydrogen and energy transition-related topics. They thought that ENTRANCE could possibly create teacher development programs.	Experts agree that teacher training is essential for further hydrogen integration, as many educators lack familiarity with hydrogen and the energy transition. They stated possible (ENTRANCE) training sessions for teachers.
Aligning with the energy transition	Some teachers suggested that hydrogen education initiatives within the context of the energy transition should be created within a context that is relevant to students.	Experts agreed that hydrogen should be taught within a relatable context to the students to create a broad understanding of their role in the energy transition.

3.4 ENTRANCE's role in the development of an educational hydrogen intervention

In this section, the fourth sub-question is studied: "How can the facilities and expertise of ENTRANCE be used to create an engaging educational intervention?". This section analyses how ENTRANCE's facilities, expertise and network can be used to create an engaging educational intervention for hydrogen within the energy transition. This analysis is divided into desk research, including case studies, and data collection and analysis from the interviews with teachers and experts.

3.4.1 Desk Research and Case Studies

Desk research and case studies are analysed to find effective ways of creating an educational intervention. The desk research focuses on theories and educational methods found through the case studies.

Experiential Learning Theory

As described in Appendix 2, Experiential Learning Theory underlines that students learn better with direct hands-on experiences and engaging activities. Experiential learning is also shown to be especially effective for STEM educational subjects by helping to bridge the gap between the knowledge in theory and real-world applications (Alali & Wardat, 2018). Experiential learning can also help retain information better and help in the development of problem-solving skills to practical challenges (Moon, 2004).

For the intervention, this means that ENTRANCE could help through hands-on experience in the hydrogen labs at the ENTRANCE testing grounds or through the use of usable real-world experiments or equipment to help students understand difficult concepts. The intervention could also include interactive experiences, like group challenges or guided projects, to create a larger interest and engagement among students. These challenges or projects could be based on current real-world questions and problems at ENTRANCE to give a sense of importance and relatability.

As analysed in Appendix 13, similar approaches in case studies have been effectively using experiential hands-on learning to enhance the understanding and interest of students. This was found in Dutch educational interventions/programs like Darel Education, Jouw Energie van Morgen and Waterstof in de Klas, and international programs like Hydrogen Horizon (Darel Education, 2023; Nikkiwp, 2024; SRO, 2024b; Waterstof in de klas, 2023).

By designing the intervention with experiential learning in mind, students can have an active participation in the energy transition instead of a bland, passive information session, making the information more interesting and relevant for the students.

Stakeholder Theory

To create an effective educational intervention, collaboration between stakeholders is of great importance. As previously stated, the stakeholder theory also emphasises the importance of including all relevant stakeholders in the design and implementation of educational interventions or initiatives (Nnadi & Mutyaba, 2023).

ENTRANCE, as an energy transition and hydrogen hub, can play an important role in connecting stakeholders. ENTRANCE can help provide material for lessons or guest lectures and could eventually even help train teachers to integrate hydrogen within the energy transition into the lesson plans or curricula. ENTRANCE's network of companies and researchers can also help students gain insight into real-world applications and career possibilities. By using ENTRANCE's position as middle man, the intervention can be made practical, realistic and impactful, making sure it fits in a secondary school environment.

3.4.2 Interviews

Interviews with teachers and experts indicated a variety of ways in which ENTRANCE can help support the intervention design and implementation. One of the most notable came from the interview with Tineke van der Meij, where she indicated that ENTRANCE has a set of small battery-powered hydrogen kits available that are used for hydrogen education programs. Tineke indicated that these would be available and suitable for a HAVO level intervention, as it is intuitive and not complex to work with. These kits would let the students create a small amount of hydrogen with a double A battery, which then gets turned back into electricity through a fuel cell to power a tiny fan/windmill.

This hydrogen test kit would be a perfect hands-on experiment that can show the students how the hydrogen life cycle works in a small practical environment. This could even be made more interesting with gamification between groups of students to create the longest running windmill within a set time.

The interviews also indicated that the sharing of ENTRANCE projects and expertise could be very beneficial for the students, which would also be useful in combination with a visit to ENTREANCE facilities to see this first-hand. A big topic was also the inexperience of teachers when it comes to hydrogen and energy transition subjects, which both teachers and experts indicated ENTRANCE could play a role in in the future. Table 8 shows further insights from teachers and experts on ENTRANCE's possible supportive areas.

Table 8: Interview insights and findings: how ENTRANCE can support the intervention

Category	Teacher Insights	Expert Insights
Providing hands-on learning experiences	Teachers stress that (HAVO) students participate better with interactive assignments. ENTRANCE's labs, test settings and kits can provide valuable practical exposure to the energy transition and hydrogen.	Experts assert that hands-on learning improves knowledge retention. ENTRANCE's situation provides a good opportunity for students to interact with hydrogen and energy transition situations.
Facilitating guest lectures & industry insights	Guest lectures from ENTRANCE professionals would be beneficial, particularly for students struggling to see the relevance of hydrogen in their future careers.	Experts point out that interaction with professionals inspires students and could make career pathways clearer. ENTRANCE could connect students with industry professionals.
Supporting classroom-based learning	Teachers indicate that pre- and post-lesson materials would be beneficial to add education on hydrogen within the energy transition into lesson plans, but current lesson time is limited.	Experts suggest that digital resources and remote learning tools could be paired with ENTRANCE visits, making scalability beyond in-person workshops.
Training & supporting teachers	Some teachers feel underprepared to teach about hydrogen within the energy transition. Workshops or training from ENTRANCE could help them integrate hydrogen education into their lessons.	Experts note that teacher knowledge gaps can limit hydrogen education. ENTRANCE could help provide hydrogen teaching materials and could even create teacher certification programs.
Enhancing student motivation through real-world contexts	Teachers stress that students struggle to connect hydrogen to their daily lives. ENTRANCE's possibility to show real-world functions would increase motivation.	Experts indicate that students are more engaged when they see the relevance. ENTRANCE could provide project collaborations and even internship opportunities, and mentorships.
Organising structured excursions	For excursions, teachers prefer structured field trips with hands-on activities, as this creates effective engagement for HAVO students.	Experts suggest incorporating problem-based learning activities during visits, such as hydrogen system challenges, to enhance critical thinking.

3.5 Barriers to hydrogen education in secondary schools

This section addresses the fifth and final sub-question: *"What barriers or challenges could arise when implementing a successful educational intervention on the energy transition in secondary schools, and how can these be overcome?".* The analysis of this sub-question includes desk research, interview insights and survey findings.

3.5.1 Barriers and challenges

To create a clear overview of the possible barriers and challenges, Table 9 shows a variety of challenges found through the different research methods of desk research, interviews and surveys. Table 9 describes the barriers and shows the findings from the research methods.

Table 9: Overview of possible barriers to hydrogen intervention education

Barrier	Description	Findings from Desk Research	Findings from Interviews	Findings from Surveys
Curriculum constraints	The energy transition and hydrogen within it are not mandatory topics in the Dutch curriculum, making integration more difficult.	The national curriculum does not require energy transition or hydrogen education, leading to inconsistent coverage across schools (SLO, 2024).	Teachers report limited time in their lessons and a lack of structured lesson plans on the energy transition and hydrogen. Experts note similar situations.	Most students have never learned about hydrogen within the energy transition in class or only briefly heard about it in O&O or chemistry.
Teacher knowledge	Many teachers lack the necessary expertise to teach hydrogen-related topics confidently.	STEM educators often lack up-to-date training on hydrogen and the energy transition (Czako, 2022).	Teachers feel unqualified to teach hydrogen and would be open to following training workshops and receiving teaching resources.	Students notice that the energy transition and hydrogen are rarely discussed.
Limited hands-on learning opportunities	Schools often do not have the needed equipment or lab space for hands-on learning related to hydrogen within the energy transition.	Hands-on learning is critical for engagement, yet many schools do not have access to hydrogen-related lab activities (Alali & Wardat, 2018).	Teachers believe experiments and real-world applications would improve engagement, but mention budget and resource limitations.	Students prefer interactive and practical learning methods.
Student motivation & perceived complexity	Hydrogen is not always seen as relevant or understandable for secondary students.	The Theory of Planned Behaviour suggests that students are more engaged when they see real-world applications (Ajzen, 1991).	Teachers find that HAVO students struggle with complex scientific topics and need simplified explanations and relatable content.	Many students say they would like to learn more about hydrogen within the energy transition if it is taught in a fun and engaging way.
Lack of standardised teaching resources	Few secondary school resources exist on hydrogen education.	Most hydrogen education materials are designed for universities, making it hard for secondary schools to adapt them (Vivanco-Martín & Iranzo, 2023).	Teachers rely on external materials, with no standardised lesson plans for hydrogen within the energy transition.	Students report varying levels of learning experiences with hydrogen and the energy transition at different schools and levels.

3.5.2 Overcoming Barriers and Challenges

After analysing the possible barriers and challenges in Table 9, possible solutions were worked out to combat or prevent them. This is worked out in Table 10 through a set of proposed solutions, which are accompanied by a strategy to implement them and linked to theories that could support this solution and its implementation.

Table 10: Proposed solutions to barriers and challenges

Barrier	Proposed Solutions	Implementation Strategies	Supporting Theories
Curriculum constraints	Integrate hydrogen education into existing subjects.	Link hydrogen to chemistry, physics, geography, and technology lessons to fit within current teaching structures.	The Stakeholder Theory (Nnadi & Mutyaba, 2023) supports collaborating with teachers to create alignment with the curriculum.
Teacher knowledge	This could be solved with guest lessons or possible teacher training on hydrogen and energy transition topics.	Come in as a guest speaker in the name of ENTRANCE. See if workshops, online courses, or training materials could be developed to help teachers.	The Theory of Planned Behaviour (Ajzen, 1991) suggests that teacher knowledge and confidence in a subject can increase acceptance rates in education.
Limited hands-on learning opportunities	Increase access to practical experiments and real-world applications.	Use ENTRANCE to provide hydrogen-related activities, interactive demos and possible excursions.	The theory of experiential learning (Institute for Experiential Learning, 2023) emphasises that hands-on experience boosts student engagement and memory.
Student motivation & perceived complexity	Use interactive, problem-based learning to make hydrogen education more interesting.	Use real-world problem-solving activities that relate to their daily lives, with possible additions of gamified situations.	The motivation opportunity ability model (MacInnis et al., 1991) highlights that increasing relevance and accessibility boosts student motivation.
Lack of standardised teaching resources	Create an intervention to add on to the existing teaching materials and curriculum.	Work with experts, industry partners, and educators to develop age-appropriate, engaging educational content.	The Stakeholder Theory (Nnadi & Mutyaba, 2023) supports collaborating with teachers and experts to create alignment with the curriculum.

3.6 Design Requirements

This section formulates the requirements for the intervention design from the sub-chapters, and the way these requirements were clarified and prioritised is outlined.

MoSCoW Prioritisation

While collecting and analysing research data, various requirements for the intervention were found. These requirements vary in importance and priority, and to assess and clarify this priority, the MoSCoW prioritisation method was applied.

The MoSCoW method prioritises the requirements under four categories: Must, Should, Could and Won't (ProductPlan, 2024). The Must category requirements must be met to achieve the desired intervention. The Should category groups the requirements that should be included if the time and the design allow it, and the requirements in the Could category are to be included if the Must and Should requirements have been processed and finalised, and there is excess space and time to implement them. Finally, the Won't category includes requirements that could be beneficial but will not be implemented in this intervention.

Prioritised requirements

The Stakeholder Theory was utilised to analyse and prioritise the requirements for the intervention design. To create an effective and clear intervention, the input from teachers, experts, ENTRANCE, and students provides not just requirements, but also an insight into their importance. The insights from the interviews, surveys, meetings, and research led to the requirements and their prioritisation, as can be seen in Table 22 of Appendix 14.

These requirements are numbered, with related or sub-requirements numbered under the same number with an addition. The requirements are outlined with their description, followed by their priority on the MoSCoW prioritisation. Finally, this table also indicates the origin of the requirement.

For the clarity of the design, Table 11 contains these same requirements for the intervention, but sorted by priority to indicate the most important tasks first, creating a prioritised overview for the intervention design. The division of the table remains the same, with the requirement numbers, description, and origin. The only difference is that the MoSCoW priority is not the leading table factor.

Table 11: Requirements, sorted by priority according to MoSCoW

ID	Requirement Description	Priority	Origin
1	The intervention must align with HAVO students' current learning levels.	Must	Teachers, Experts
1.1	Covering the basics of hydrogen and its role in the energy transition, including different types of hydrogen and value chains.	Must	ENTRANCE, Teachers, Experts
1.2	Show that the energy transition, and hydrogen within it, is not just technical.	Must	ENTRANCE, Experts
2	The intervention must be engaging and interactive to maintain student interest.	Must	Students, Teachers
2.1	Include hands-on activities and/or experiments.	Must	Case Studies, Teachers, Students
3	The intervention must use motivational strategies to engage students.	Must	SDT, MOA Framework
3.2	Information is relatable and on the HAVO students' level.	Must	Teachers, TPB
4	The intervention must fit within school schedules and subjects.	Must	Teachers, Experts
4.1	Add minimal extra workload for teachers.	Must	Teachers, Experts
7	The effectiveness of the intervention must be measured.	Must	ENTRANCE, Hanze
7.1	Pre and post-intervention surveys with the students.	Must	Research Design
7.2	Observe and collect feedback from teachers and students.	Must	Research Design

2.2	Include relatable problem-solving tasks.	Should	Experts, Teachers, TPB
2.3	Utilize gamification or quizzes to enhance the interactivity of learning.	Should	Case Studies, SDT, MOA Framework
2.4	Enable students to work together in teams.	Should	Experts, Students
2.5	Allow students to make choices on learning directions (autonomy).	Should	SDT, Students
2.6	Use digital tools like videos and simulations.	Should	Experts, Students
3.1	Connect to students' daily lives and future career opportunities.	Should	TPB, Experts, Teachers
4.2	Fit in existing lesson blocks (or set times).	Should	Teachers
5	The intervention should also provide guidance and/or resources for teachers.	Should	Teachers, Experts
5.1	Allow flexibility for teachers to jump in/help.	Should	Teachers, Experts
5.4	Involve teachers directly in the lesson content.	Should	Teachers
6	The intervention should connect students to the industry and experts.	Should	ENTRANCE, Experts
7.3	Allow space for changes as the intervention progresses.	Should	Research Design
7.4	Space for improvements based on feedback.	Should	Research Design
8	The intervention should be designed to allow expansion and further use.	Should	ENTRANCE, Experts
8.1	Materials are reusable and stay relevant.	Should	ENTRANCE
8.2	The intervention is adaptable and scalable for other schools.	Should	Case Studies, Experts
8.3	There is a clear instruction and overview for the intervention.	Should	Teachers
1.3	Include real-world uses of hydrogen to make the topic relevant.	Could	Experts, ENTRANCE
1.4	Include a deeper dive into the science behind hydrogen production.	Could	Teachers, Experts
2.7	Include visits to ENTRANCE's testing grounds.	Could	ENTRANCE, Teachers, Experts
4.3	Fit within different secondary school levels.	Could	Teachers
5.2	Provide ready-to-use lesson plans with manuals.	Could	Teachers
5.3	Offer teacher training or workshops.	Could	Experts, Teachers
6.1	Involve guest speakers from the hydrogen sector.	Could	Experts, Case Studies
6.2	Include visits to hydrogen facilities/industry.	Could	Experts, Case Studies
9	The intervention will not require in-depth (technical) hydrogen knowledge.	Won't	ENTRANCE, Teachers
9.1	Mandatory lessons in the curriculum.	Won't	ENTRANCE, Teachers

4. Intervention Design

This chapter introduces the design of the intervention and the way it is created based on the data collection and analysis phase outcomes. The goal of the intervention is to enhance HAVO students' awareness, knowledge and interest in hydrogen within the energy transition, in an engaging, practical, hands-on and relatable way. This design triangulates the findings from desk research, case studies, interviews and surveys to develop an effective intervention that enhances awareness, knowledge and interest in hydrogen within the energy transition, and tackles identified barriers and challenges.

4.1 Design Framework

This section summarises the framework for the intervention design described throughout the data collection and analysis.

Intervention design objectives

The design objectives are to design the intervention to enhance HAVO students' understanding of the role of hydrogen in the energy transition and the potential contributions they could make, as well as to raise awareness and interest among students regarding the energy transition and hydrogen's place within it. The design objective of the intervention is also to achieve this by engaging students with interactive and relatable problem-solving activities.

Theoretical Foundation

The design of the intervention is developed with a foundation of theories and frameworks described in Appendix 2. Table 12 shows these frameworks and summarises their purpose in this research.

Table 12: Theoretical Foundation; Frameworks and Theories.

Theories and Frameworks	Purpose
Stakeholder Theory (ST) (Mitchell et al., 1997)	To make sure that the insights of different stakeholders are considered during intervention design.
Bloom's Taxonomy (BT) (Mcdaniel, 2010)	To structure the surveys, both before and after the intervention, using the learning levels from basic recall to higher-order critical thinking.
Experiential Learning Theory (ELT) (Institute for Experiential Learning, 2023)	To improve engagement and understanding by focusing on hands-on, interactive and practical activities.
Self-Determination Theory (SDT) (Ryan & Deci, 2000)	To intrinsically engage and motivate students through relatability, autonomy and competence.
Theory of Planned Behaviour (TPB) (Ajzen, 1991)	To understand and apply that student interest depends on the value they see in the topic, the importance others put on it, and the complexity of the information.
Motivation Opportunity Ability (MOA) Framework (MacInnis et al., 1991)	To ensure that the intervention creates motivation, opportunities, and abilities for students to engage with hydrogen within the energy transition.

The Stakeholder Theory is used throughout the interviews and for the analysis of all research methods to ensure that the insights of stakeholders are incorporated into the intervention design. The use of Bloom's Taxonomy is rooted in the surveys, as its learning levels were incorporated into the surveys for the students to build up the questions from basic recall to higher-order thinking, both for th01/05/2025e pre- and the post-intervention survey.

ELT, SDT, TPB, and the MOA Framework provide a foundation for the intervention design, particularly on how the intervention can be designed to effectively interest, motivate, and provide long-term awareness and knowledge for the students, as described in the data collection and analysis.

4.2 The Intervention Design

For this thesis, the intervention is represented in the form of an interactive educational lesson for fourth-year HAVO secondary school students. This intervention focuses on enhancing students' awareness, knowledge and interest in hydrogen within the energy transition through hands-on experiments, gamification in the form of problem-solving challenges and quiz elements, real-world relatability, and multimedia like videos and booklets.

4.2.1 Design Process

To illustrate the complete development of the intervention, the steps towards the final product are shown as a roadmap in Appendix 15. This roadmap helps improve reproducibility by visualising and clarifying the steps taken to develop, test, implement and receive feedback on the intervention. Figure 8 shows the process of the intervention design phase of this roadmap, with corresponding steps and their contents.

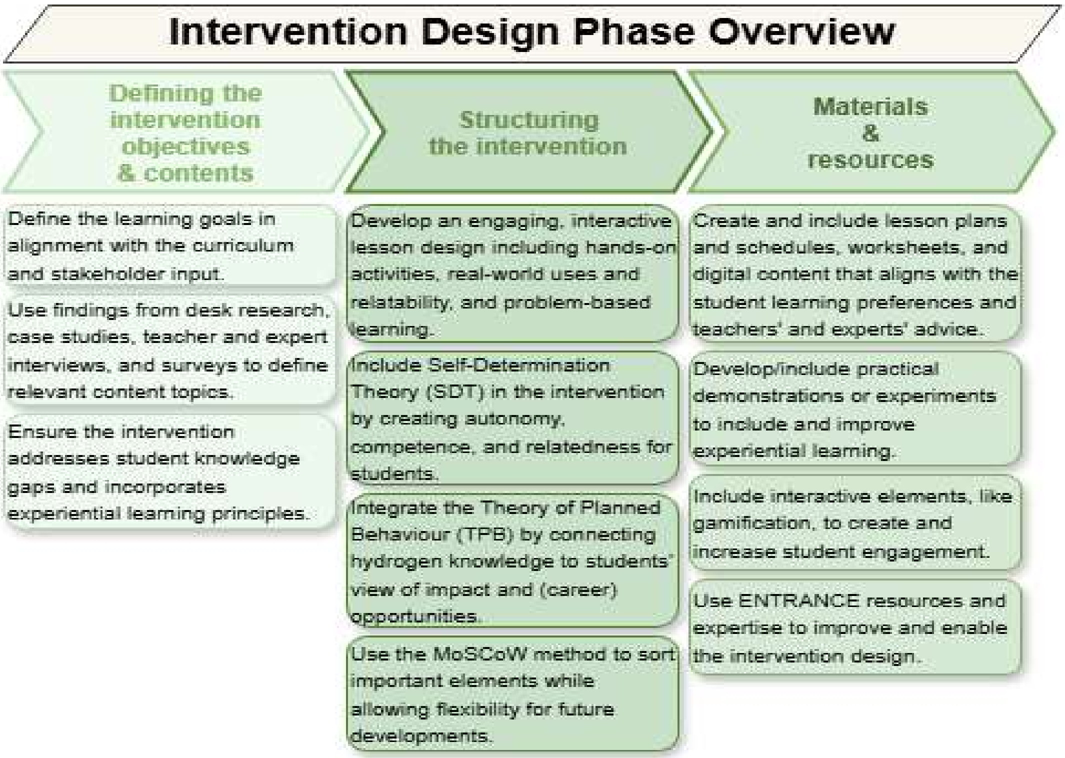


Figure 8: Intervention Design Phase Overview

4.2.2 Intervention Contents

This section provides an overview of the intervention contents and their design. Table 13 provides an overview of the timeline/lesson plan set out for the intervention, and the contents of those time periods. Table 13 also shows what methods are used to convey the information and engage the students, with theories and frameworks that support these methods and activities.

The contents were designed not only to convey the information within the available timeframe of the intervention, but to do this in a way that students stay engaged and focused as the different topics are introduced. For this reason, interactive questions and an assignment are placed within the presented informative sections. The timeline is not just to keep track of the time for intervention segments, but also to provide students with a structure and idea of the timeframe during the introduction.

Table 13: Intervention content and timeframe overview/lesson plan

Timeline	Activity	Description	Methods	Theories
0-5 min	Introduction & The Energy Transition	Introducing the lesson and asking students a relatable question about hydrogen. Then a basic explanation of the energy transition, and why it's important for the world and them.	Presentation, discussion, visuals	SDT, TPB, MOA Framework
5-15 min	Energy Transition Roles (group assignment)	A short, interactive energy transition assignment for the students to understand what jobs are connected to the energy transition.	Visuals, discussion, collaborative learning	ELT, SDT, TPB, MOA Framework
15-20 min	Hydrogen Basics	The basics of hydrogen, how it is produced, stored, and used. Including a question that includes them and the world around them.	Interactive Q&A, slides	TPB, MOA Framework
20-45 min	Hands-on Hydrogen Experiment (in groups)	A small group experiment with the Hydrogen Science Kit, creating hydrogen and turning it back into electricity to power a fan.	Experiment, collaborative learning	ELT, SDT, TPB, MOA Framework
45-50 min	Questions, Discussion & Reflection	Asking the students if there was anything unexpected they learned today. If they still have questions, allow for discussion.	Interactive, discussion, reflection	SDT, TPB, MOA Framework

Presentation

The course and content of the intervention rest on the support of a PowerPoint presentation, which can be found in Appendix 16. This presentation builds the foundation of energy transition and hydrogen knowledge, and introduces the activities and experiments.

The intervention presentation starts with a slide that introduces the students to recent news articles about climate change and its effects on the world. This slide will be open as the students walk into the room to show them recent changes and give them something to think about before the lesson starts. These articles show that last year once again broke the record for the warmest year, and the natural effects of this heat and change in climate globally (Europese Commissie, 2024; Goegebeur, 2025; KNMI, 2025).

Introduction

When the students enter the classroom, they all receive a playing card; there will be 3 of each card, with the fourth placed on the tables for the matching students to take a seat. This idea came forth in a stakeholder meeting with ENTRANCE, where the intervention was introduced and explained.

After the students are seated in their groups, the intervention will start with a quick introduction of the lesson and its contents. Here, the trick question about hydrogen being an energy source will be discussed in the form of a repeat of the question and a showing of the class's survey answer, waking them up to how easy misconceptions can be. This question was the 10th in the survey, as shown in Appendix 10.

The introduction of the lesson contents includes a time plan for the students to grasp how the lesson will look and how much time each section will take. This was recommended in the teacher interviews, as can be found in Appendix 8[redacted].

The Energy Transition

After the introductory slides, the basics of the energy transition are introduced with visuals. This includes the problem/need for the energy transition, what the transition is, and how it affects the world around the students. For many, these concepts are not new, as the students who filled in the survey also watched the "Morgenland" introductory energy transition video (Fields, n.d.).

Energy Transition Roles
After the basics of the energy transition are established, the students are introduced to a small interactive group exercise where they get to discuss within their group what jobs (out of a set of choices) are directly, indirectly, or not connected to the energy transition. They get 15 cards for various jobs that they can place on their paper under the three categories, discussing within the group which one is right. The job cards and explanations are added to Appendix 17. By discussing the results with the students, this exercise will show that they can be directly or indirectly connected to the energy transition, no matter what job they do, from an electrician to an athlete.

This exercise will allow students to actively work with the topic and provide students with autonomy, and stimulate collaborative learning in their group. It incorporates aspects from theories like the ELT through hands-on active learning, SDT through autonomy and competence and finding relatability of different work directions, and TBP through perceived behavioural control by showing students that no matter what job they want to do, they can be a part of the energy transition. This exercise also reflects these points as brought up by the teachers and experts in the interviews in Appendix 8, and Appendix 9.

Hydrogen Basics
After the energy transition roles exercise, the hydrogen basics come in. These slides start hydrogen electrolysis, showing the chemical reaction from water to hydrogen, relating it further to the HAVO chemistry curriculum. This slide also shows that electricity and water are generated by reversing this reaction inside a fuel cell. Visuals of an electrolyser and a fuel cell are added to show the applications.

Next, the difference between grey, blue and green hydrogen is visualised for the students, as seen in Figure 9. One of the main findings from students' answers in the pre-intervention survey, shown in Appendix 11, was that students supported the use of hydrogen "because it is green". In this slide, students are shown that hydrogen is not always green, especially the hydrogen currently used in the industry. This slide also shows how more hydrogen will be in demand in the future, causing the costs to rise, and what difference green hydrogen can make in that rising cost and why.

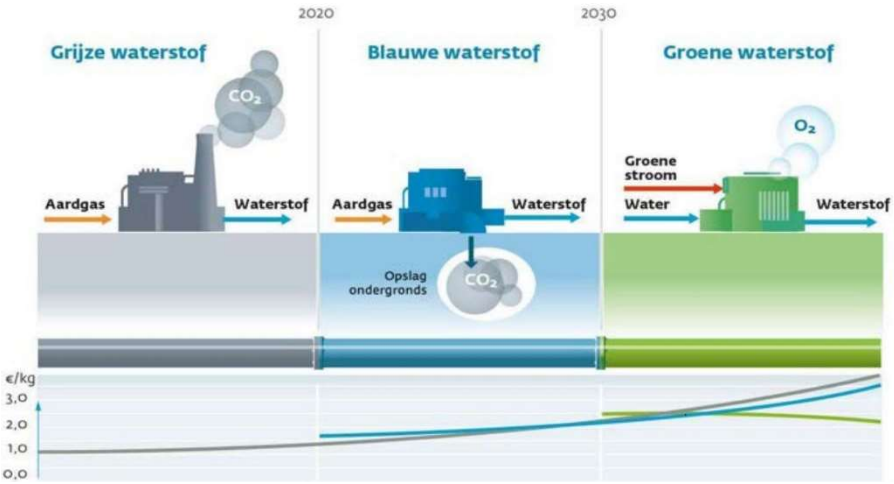


Figure 9: Gray, Blue and Green hydrogen production visualisation in Dutch. (Rob, n.d.)

This is followed by a slide showing the real-world application of hydrogen in cars, and how they work. Here, the students are asked to discuss within their group whether they think a Toyota Mirai hydrogen car can drive more or less than 5km on the amount of hydrogen in a 0.5 l bottle of water. An image of the Toyota Mirai is added here to show how a hydrogen car is just an average (or even better) looking car from the outside. After they all decide, the right answer is shown, together with the image of the car turning to an inside view of the car's hydrogen system. By involving the groups of students directly with a question about a car that they could one day even drive themselves, the hydrogen basics are not just a constant stream of information, but a relatable, collaborative and engaging experience.

Finally, the last slide on the hydrogen basics visualises hydrogen value chains, showing students what shape hydrogen production, distribution and use can take. This slide also clarifies how the hydrogen value chains connect to the energy transition. The opportunities of hydrogen use and transport methods are shown, with an added emphasis on hydrogen storage and transport compared to electricity transport and storage systems.

Hydrogen Experiment
After the students experience the basic concepts of hydrogen, they get the opportunity to work with hydrogen directly. The students will work in their groups of three and will each receive a Hydrogen Science Kit. This kit is designed by Horizon Educational and sourced from ENTRANCE (SRO, 2025a). Through the expert interviews, Tineke van der Meij introduced these kits as a part of ENTRANCE's resources, while also providing guidance and instruction on their use and arranging that the kits were available for the intervention.

With this hydrogen kit, the groups of students put together a small reversible fuel cell setup, first using this to create hydrogen with a battery, then using the hydrogen to produce electricity that spins a small fan. With this kit, students experience hydrogen in an interactive, collaborative, and active way, which was greatly supported by the desk research, case studies, interviews and student surveys. It could engage and motivate students by offering an exciting hands-on opportunity, create competence and enhance knowledge by putting theory into practice, and could create further interest by showing the students what they could already achieve in such a short time.

The interactive experience with this hydrogen kit will be the largest segment of the intervention, as it is important to provide the students with the interactive experience, and the research suggested that it would likely be the most effective way to enhance students' awareness, knowledge and interest in hydrogen within the energy transition.

Questions, Discussion and Reflection
The final segment of the intervention, and the presentation, is open for questions, discussion and reflection. This section is opened up by asking the students if they learned anything unexpected today, and letting a few students answer. If students have specific questions, other students are initially asked to try to answer them, if possible. This created discussion and could help retain the information they received during the intervention.

4.2.3 Additional Features
In addition to the presentation and its contents, the roles exercise, and the Hydrogen Science Kit, additional intervention features are described in this section.

Gamification
The first feature that overlaps the intervention contents is the use of gamification. Although not used directly, the groups of students who answer the question throughout the intervention correctly earn chocolate easter eggs, which are added to a cup with the group's number on the teacher's desk. Depending on their level of participation and engagement, groups can also earn or lose extra chocolate eggs throughout the intervention. An alternative is provided for students who can not eat chocolate eggs due to allergies. For students who participate in fasting activities, the chocolate eggs can be taken home to enjoy later.

Multimedia
As mentioned in the intervention contents, visualisations are used throughout the presentation to convey information in a more attractive and understandable way. Apart from this form of multimedia, interested students will receive a document with interesting websites, videos and even games for them to delve deeper into elements of the intervention they are most interested in. This document is added in Appendix 18.

4.3 Validation & Testing Plan

To design and implement an effective and suitable intervention, it is vital that all aspects are validated and tested thoroughly. This section clarifies how the iterations of the intervention are validated and tested with the target group and stakeholders. By testing the intervention with the target group, the alignment with the set goals improves, and barriers and challenges can be spotted and dealt with before full implementation.

4.3.1 Testing strategy

The testing strategy for this intervention consists of multiple segments, each of which contributes to perfecting the design. The testing will be done with the target audience of HAVO secondary school students, with input from stakeholders like ENTRANCE and teachers.

Initial feedback

The initial iterations of the intervention design are tested by introducing them to stakeholders and requesting feedback. The first stakeholder feedback came from ENTRANCE, where the first iteration of the intervention was presented. This design was made slightly overcomplicated, and feedback indicated that the amount of information would likely be too long and complicated for students to keep their attention on the presentation. The energy transition roles exercise was also initially designed as a game/competition between groups, but feedback rightly indicated that due to the nature of the exercise, the scoring system was doubtful. The jobs in this exercise were also initially partly job sectors, but this was confusing and overwhelming, so from that feedback, it was simplified. The game was also initially just before the hydrogen test kit experiment, but to create participation throughout the intervention, it was moved to an earlier section. It was also suggested to create a front page with current news clippings due to the relatability and importance it can create for the students, this suggestion was promptly implemented.

As a second test before the pilot, 2 secondary school students from Groningen, in close connection to the author, were asked to join a second test run of the intervention. One of these students studies at the Montessori Lyceum Groningen, the other at the Parcival College, which are both secondary schools. These students were very enthusiastic about the intervention, even without being able to participate in the interactive hydrogen experiment. They indicated that the information-to-interaction ratio is done well, but that in the roles exercise, there were too many roles and it took a very long time. They also advised using a water bottle during the question about the distance a hydrogen car could drive on the hydrogen from 0,5L water.

Pilot Testing

A pilot of the intervention will be conducted at the Montessori Lyceum Groningen. This pilot will be the first implementation of the designed intervention in a classroom and the first use of the hydrogen test kit experiment on the HAVO students. During the intervention, observations will be made to analyse the engagement of the students and the interest in the lesson materials.

Surveys

To measure changes in awareness and interest, participants of the intervention filled in a survey before the intervention was conducted to establish a baseline, with another survey to be conducted after the intervention, which can in turn be used to analyse changes, and the knowledge they retained. The second survey will also inquire what the students thought of the intervention.

5. Implementation Plan

This chapter provides a guide on how the intervention can be implemented effectively, focusing on usability, engagement and interest.

5.1 Implementation Strategy

For this research, the intervention will be piloted at the Montessori Lyceum Groningen. The presentation and activities are scalable and easily adaptable, with documentation on what is in the exercise and the experiment.

The intervention correlates with subjects in the current HAVO curricula, but as teachers are cramped for time, it is not feasible to expect teachers to use this intervention without outside help like from ENTRANCE.

In the future, this intervention could be further developed to include teacher training or specification to a specific subject, but in its current state, the intervention covers a variety of secondary school subjects.

5.2 Timing & Planning

The pilot of the intervention will be implemented on the 28th of March at the Montessori Lyceum in Groningen. In the week leading up to the intervention, the design is tested to acquire initial feedback from ENTRANCE and 2 students, as mentioned in the testing strategy. The pre-intervention surveys were conducted more than a month in advance, to implement the findings into the design, and the survey after the intervention will be conducted on the 8th of April.

The feedback and findings will then be analysed and worked out as recommendations for future development of the intervention.

5.3 Resources

The resources necessary for this intervention are low, but there are a few necessities. The hydrogen test kits need to be available to conduct this intervention, and the same goes for further materials needed for the experiments. For larger scales, the energy transition roles exercise needs expanding, which will mean the 2 sets of paper need to be printed, and the job cards need to be cut to size. Aside from that, the purchase of chocolate eggs or other rewards is a low but important cost.

Human resources

For the intervention to work effectively, the teacher should not be asked to perform it (alone). A guest speaker or expert who knows the intervention should be in charge to make sure it runs smoothly, with the teacher being able to help when needed.

5.4 Stakeholder Involvement & Engagement Strategy

To increase the chances of success for the intervention, stakeholder participation is key. ENTRANCE, Teachers, Students and Schools all have to work together for this intervention to be a success. If one of these stakeholders decides they will not participate, there is no way to move forward effectively.

To ensure that these stakeholders keep interest and stay engaged with the intervention, planning and communication are important. Schools often plan activities at the beginning of the year, and with ENTRANCE working with the schools and teachers to add activities into the year plan, the intervention could become a permanent success.

5.5 Monitoring, Evaluation & Continuous Improvement

During the intervention, the engagement and interest of the students are a constant point of interest. If the theory is no longer engaging the students, areas are dedicated that can be skipped to get to the interesting and engaging parts of the intervention.

The success of the intervention will be measured through observations of student participation and interest during the pilot, combined with feedback from the teacher and survey feedback from students. The survey feedback on the intervention will be combined with the analysed results of the changes in student awareness, interest and knowledge to form a conclusion.

The use of the intervention and its activities is documented for continuation and possible further development. The conclusions and results will be used to create further recommendations for future iterations and implementation.

6. Accountability Report

In this chapter, the research process, design process and the results are reflected upon from beginning to end, critically analysing each step and the choices that were made. It also includes the outcome of the intervention pilot and concludes whether the research question was answered and how. This is then followed by recommendations for the use and further development of this intervention.

6.1 Research Process

This section provides an overview of the research process, with critical reflection on the changes and choices that were made towards the final intervention design.

Problem statement

The problem statement for this research is:

“The lack of students interested in hydrogen within the energy transition hinders ENTRANCE's efforts to educate skilled workers.”

As described in the problem analysis, this problem statement arose from the gap between the current and the desired situation, in which ENTRANCE desires to educate more skilled workers for hydrogen works within the energy transition, and the lack of education in the HAVO curriculum focussed on hydrogen within the energy transition.

This problem statement underwent many changes throughout this thesis. Initially focusing on the broader aspects of the energy transition, including hydrogen technologies, it eventually narrowed down to an interest in hydrogen among HAVO students. The process of clarifying and refining the problem statement was one of the biggest challenges in the research, involving many iterations and a significant time investment.

Research Objectives

Throughout the thesis, the research objectives went through a variety of smaller and larger changes. Some of these changes were due to the clarity of the objectives, and others were because they were not research-oriented, but rather the clients’ goals, in this case, ENTRANCE.

The biggest and most important iterations in the objectives changed from the Preliminary Proposal to the initial submitted problem analysis. Table 14 shows how the objectives in the Preliminary Proposal were broad, with additions of financials, incorporation of hydrogen and career enthusiasm. While narrowing down the scope of the research, these objectives either fell outside the scope or were incorporated into clearer, more structured objectives, like what could be effective ways to create awareness, and interest HAVO students in hydrogen within the energy transition.

Through feedback received after the problem analysis that was handed in via OnStage, the final objectives were reworked to be even more consistent with academic research and with the envisioned outcomes of this project. These final research objective iterations are shown in the last column of Table 14.

Table 14: Research Objectives in different phases

To identify effective educational strategies for teaching high-school students about the energy transition, and changing their behaviour towards study choices.	Researching and analysing what is currently taught on the topic of hydrogen and the energy transition in Dutch secondary schools.	Analysing what is currently being taught at Dutch secondary schools, and evaluating HAVO students' knowledge, awareness, and interest in hydrogen within the energy transition.
To highlight the role of non-technical studies in contributing to the energy transition.	Analysing what affects the education of HAVO students on the topics of hydrogen within the energy transition.	Identifying what are effective ways to create awareness, and interest HAVO students for hydrogen within the energy transition.
To incorporate the significance of hydrogen technology within the broader context of the energy transition.	Analysing how ENTRANCE could influence the interest of HAVO secondary school students towards hydrogen within the energy transition.	Analysing how ENTRANCE's current educational programs and expertise align with what is needed to engage HAVO students in hydrogen within the energy transition
To design and implement an educational intervention aimed at increasing enthusiasm for energy transition careers among high-school students.	Designing an intervention that will allow ENTRANCE to actively work towards its goal of interesting HAVO students in hydrogen within the energy transition.	Designing and piloting an educational intervention that will allow ENTRANCE to bridge the gap between its current efforts and the needs of HAVO students, actively working towards its goal of interesting HAVO students in hydrogen within the energy transition.
To research where the financial backbone for an educational program like this could come from.	Conducting the designed intervention, in the name of ENTRANCE, for HAVO students.	Analysing if the intervention has influenced the awareness and interest of the participating HAVO students, taking into account ENTRANCE's goal of not only interesting HAVO students to work in the energy transition, but also to have a better understanding to collaborate better as informed citizens.
To evaluate the effectiveness of the intervention and gather feedback for future improvements.	Analysing if the intervention has influenced the awareness and interest of the participants, taking into account that ENTRANCE wants to not only interest HAVO students to work in the energy transition, but also to have a better understanding to collaborate better as citizens.	

6.1.1 Research Question

As the research objectives and scope changed throughout the process, the research question (RQ) and sub-questions (SQ) also changed. These changes ensured that the research questions remained focussed, aligned, and relevant to the research objectives and scope.

As shown in Table 15, the initial research question for this project was very broad, included only a small focus on hydrogen, and did not yet put the focus on HAVO students. As the scope and objectives were narrowed down, so was the research question.

The second column in *Table 22*Table 15 shows the initially submitted research question for this research. After receiving slight feedback, ENTRANCE's facilities and expertise were changed to not only be used, but also extended, as shown in the third column of *Table 22*Table 15. This small change impacted the impression of ENTRANCE's influence, from helping to develop new ideas to utilising existing possibilities.

Table 15: Research Question development

Preliminary Proposal RQ	Submitted V1 RQ	Final Research Question
"How can an educational intervention be designed and implemented to effectively create awareness and enthusiasm about the energy transition for high school students in their final years, demonstrating the significant roles of both technical and non-technical studies in this field, including demonstrations of emerging technologies like hydrogen at EnTranCe?"	"How can ENTRANCE's facilities and expertise be used to increase HAVO students' awareness of and interest in hydrogen for accelerating the energy transition?"	"How can ENTRANCE's facilities and expertise be used and extended to increase HAVO students' awareness of and interest in hydrogen for accelerating the energy transition?"

Sub-questions

As with the research question, the sub-questions also changed and evolved as the research progressed and the scope narrowed. The initial preliminary proposal sub-questions were closely related to the research objectives in the preliminary proposal. They were also broader and changed into more focused questions, relating to the new research objectives in the initial submission of the problem analysis. These iterations of the sub-question are shown in the first two columns of Table 16. The third column shows the final sub-questions for this research. Based on the changes in the research objectives and feedback specific to the sub-question, these final sub-questions are more directly connected to the research objectives, creating a strong base for the intervention design and main research question.

Table 16: Research Sub-question development

Nr.	Preliminary Proposal SQ	Submitted V1 SQ	Final Sub-questions
1	"What are the most effective educational strategies for teaching high-school students about the energy transition, and how can these strategies influence their behaviour towards study choices?"	"What is the current level of awareness and understanding of hydrogen within the energy transition among HAVO students at the participating schools?"	"What is currently being taught at participating secondary schools about hydrogen within the energy transition, and what is the HAVO student's level of knowledge, awareness, and interest?"
2	"How can the educational intervention highlight the importance and contributions of non-technical studies to the energy transition, and what impact does this have on students' perception of potential career paths?"	"What influences the educational attention on hydrogen within the energy transition, for HAVO students?"	"What are effective ways to create awareness and interest in hydrogen within the energy transition among HAVO students?"
3	"How can their significance of emerging technologies like hydrogen be effectively communicated to high-school students, with the use of the EnTranCe testing grounds?"	"What educational methods and activities are most useful to engage HAVO students and create interest in hydrogen within the energy transition?"	"How do ENTRANCE's current educational programs and expertise align with what is needed to engage HAVO students in hydrogen within the energy transition?"
4	"How should the educational intervention be designed and implemented to increase enthusiasm for careers in the energy transition among high-school students, and what are the measurable outcomes of this intervention?"	"How can the facilities and expertise of ENTRANCE be used to create an engaging educational intervention?"	"How can the facilities and expertise of ENTRANCE be used to create an engaging educational intervention?"
5	"What potential funding sources are available for developing and sustaining the educational intervention, and what requirements would need to be met?"	"What are potential barriers or challenges to implementing a successful educational intervention on the energy transition in secondary schools, and how can these be overcome?"	"What barriers or challenges could arise when implementing a successful educational intervention on the energy transition in secondary schools, and how can these be overcome?"

6	"How effective is the educational intervention in increasing awareness and enthusiasm for energy transition careers among high-school students, and what feedback mechanisms can be implemented to gather data for future improvements?"		

6.1.2 Theoretical Frameworks and Theories

The theoretical frameworks and theories created a foundation on which the intervention was designed. Created for the intervention design, Table 17 shows how they were utilised throughout the research and in the intervention design process. The ELT, SDT, TPB, and the MOA Framework provided insight on how the intervention is designed to effectively interest, motivate, and provide long-term awareness and knowledge for the students, as described in the data collection and analysis and the intervention design.

Table 17: Theoretical Foundation; Frameworks and Theories

Theories and Frameworks	Purpose
Stakeholder Theory (ST) (Mitchell et al., 1997)	To make sure that the insights of different stakeholders are considered during intervention design.
Bloom's Taxonomy (BT) (Mcdaniel, 2010)	To structure the surveys, both before and after the intervention, using the learning levels from basic recall to higher-order critical thinking.
Experiential Learning Theory (ELT) (Institute for Experiential Learning, 2023)	To improve engagement and understanding by focusing on hands-on, interactive and practical activities.
Self-Determination Theory (SDT) (Ryan & Deci, 2000)	To intrinsically engage and motivate students through relatability, autonomy and competence.
Theory of Planned Behaviour (TPB) (Ajzen, 1991)	To understand and apply that student interest depends on the value they see in the topic, the importance others put on it, and the complexity of the information.
Motivation Opportunity Ability (MOA) Framework (MacInnis et al., 1991)	To ensure that the intervention creates motivation, opportunities, and abilities for students to engage with hydrogen within the energy transition.

Though the core theories like SDT and TPB were established early on for the preliminary proposal, the use of Bloom's Taxonomy and Stakeholder Theory developed along with the research methods, as the research objectives were clarified and the scope narrowed. The data collection and analysis chapter thoroughly describes why and how BT and ST were used, which is summarised in Table 17. The use of BT helped build up the questions in a logical order for the students and was also found to make analysing the answers easier. The use of the ST helped focus on combined stakeholder interests throughout the research and in the intervention design. The ST also bound research methods together, improving survey development through interview analysis and analysing the similarities and conflicts in stakeholder views.

Some other theories noted in the preliminary proposal, like the Diffusion of Innovations Theory, were not used. This is because the research focussed on student motivation and engagement, and the DOI Theory focusses on how an innovation can be spread and implemented across many schools. The Value-Belief-Norm Theory was also left out, as this theory focusses more on measuring and influencing environmental norms, rather than increasing interest and awareness of hydrogen within the energy transition. The VBN model is more suited for analysing value-driven behaviour than engaging and motivating students. Even though aspects of these theories could be applied to this research, the focus on engagement, motivation, and learning of the ELT, SDT, TPB and MOA framework made their use more applicable than the DOI and VBN.

6.1.3 Methodology

The selected methodologies for this research were desk research, case studies, surveys, interviews and observations. Initially, in the preliminary proposal, focus groups, funding analysis, and evaluation were also selected as research methods. For the focus groups, the time constraint and scope of the research prevented an approach to this method, as for funding analysis, this was cut due to the scope of the research no longer including the financial analysis. Evaluation was not worked out as a separate methodology, but rather worked into the methods of observation and surveys to analyse results.

For the research leading up to the intervention design, the selected methodologies provided a broad overview of different aspects and insights that helped find answers to the research questions. As shown in Appendix 4, each sub-question was originally linked to at least two research methods. In the research process, it was found that desk research could improve the research in the first sub-question, and that the second sub-question could get information on student preferences through surveys.

The findings from the research methods were clarified and more thoroughly examined by triangulating the data gathered per sub-question. This led to a clearer overview of available information for the intervention design. Though its use and importance are clear, the triangulation research method was not initially included in the research approach, which it should have been.

Sample overview – Surveys
Students of both the Montessori Lyceum Groningen and the Hondsrug College Emmen participated in an initial and a follow-up survey. The Hondsrug College asked if their VWO students could participate in the survey, which was agreed upon to create a small overview of different levels of participation.

As shown in Table 18, the participation of HAVO students from the Hondsrug College in the initial survey was low, with no participation in the follow-up survey due to unavailability of students and conflicting schedules. For the Montessori Lyceum, all participants of the initial survey also filled in the follow-up survey after participating in the intervention lesson.

Table 18: Student survey sample

	Montessori Lyceum Groningen		Hondsrug College Emmen	
	HAVO	**VWO**	**HAVO**	**VWO**
Initial survey	11	0	5	25
Follow-up survey	11	0	0	16

The surveys also include questions on the participants' age and gender. These questions were included to gain insight into the division of genders in the participation classes, and the age of participants at the different educational levels and schools. Figure 10 shows the ages for the Montessori Lyceum, where 11 HAVO students of one class participated.

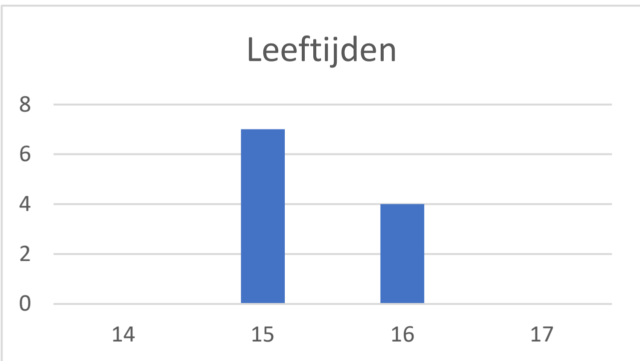


Figure 10: Survey participant, ages (Montessori Lyceum)

Figure 11 shows the complete overview of participants' ages for the initial survey, which includes HAVO and VWO students, the division of which is shown in Table 18. As only 16 VWO students participated in both surveys, Figure 12 shows the ages of only those students separately.

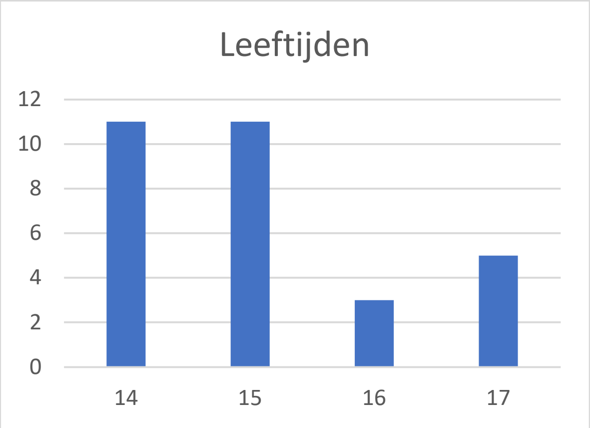


Figure 11: Hondsrug College first survey participants, ages

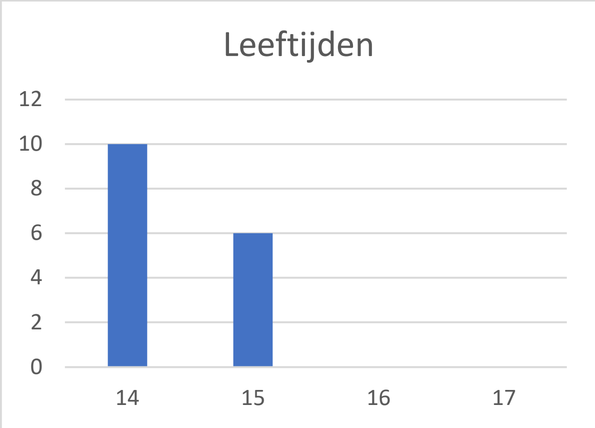


Figure 12: Hondsrug College participants of both surveys, ages

At the Montessori Lyceum, a slight majority of survey participants were female, as shown in Figure 13. Figure 14 shows that those who participated in both surveys for the Hondsrug College were overwhelmingly male, with less than 15% of students identifying as something else, and none as female. The overall participation in the initial survey at the Hondsrug College was also 80% male.

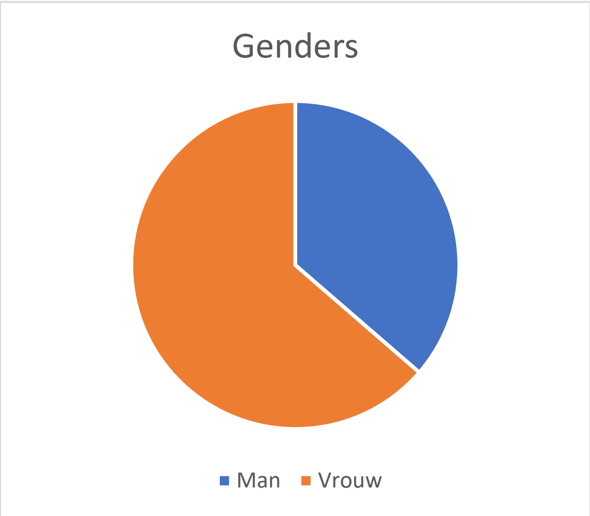


Figure 13: Montessori Lyceum survey participants, gender

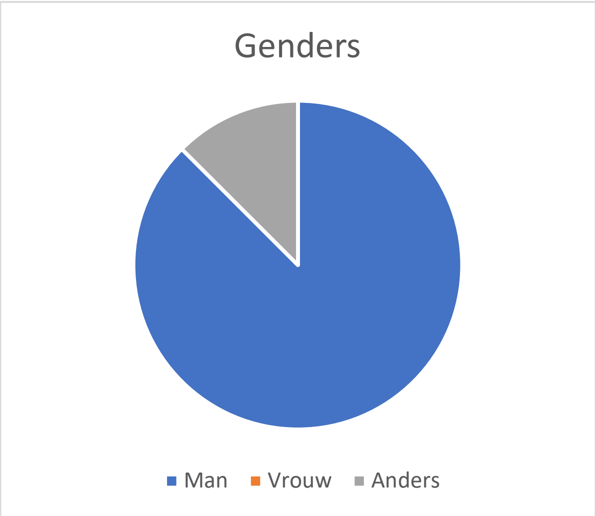


Figure 14: Hondsrug College participants of both surveys, gender

While an ideal representation would be close to a 50/50 split, the target of this survey was not to analyse gender based views, but rather to analyse initial insights and changes in awareness and interest. The survey answers did not indicate a clear bias towards aspects of the questions or the intervention based on their gender.

Sample overview – Interviews

For the interviews the sample was made up of four teachers, two from each participating school, and five experts, of which two worked at or with ENTRANCE, one at the RUG, one at the new energy coalition as head of the hydrogen project, and the last expert is the head of Technasium education of the Northern Netherlands. These samples of teachers and experts give a broad range of fields and offer distinct insights.

Ethical approach for data collection

The use of surveys and interviews as research methods brings direct contact with and information from students, teachers, and experts. The process involved collecting personal ideas, insights and experiences with education and hydrogen. For this reason, several precautions were taken to ensure the research was conducted ethically.

For the surveys, students were not asked to provide their names, making all information anonymous, yet usable. For the follow-up surveys, students were asked if they had participated in the first survey to ensure data integrity, while keeping student privacy.

For the interviews, the participants were informed about the intention of the research in advance and asked for consent to mention them by name. A follow-up email was sent to confirm agreement and acknowledgement. Interviews were also recorded; this was always done with the participants' consent, and only used for transcription and taking notes.

These measures ensured that the data collection process aligned with ethical research principles like informed consent, voluntary participation, transparency, and confidentiality.

6.1.4 Sub-question findings

This section gives a short overview of the main findings from the sub-questions and how these findings supported the development of the intervention design. A detailed analysis is included in Appendix 19.

Current state of hydrogen education

The research found that hydrogen and the energy transition are not structurally included in the national HAVO curriculum. Teachers and experts indicated that the basics of hydrogen are addressed in chemistry lessons, but not linked to the energy transition. The initial survey findings showed that students had limited understanding of the topic. However, the Hondsrug College surveys showed that some Technasium projects did discuss these topics. These findings provided the baseline for student knowledge before the intervention.

Engaging HAVO students in hydrogen

As further summarised and clarified in Appendix 19, the research found that theories like ELT, SDT, TPB, and the MOA framework could raise student awareness and interest. Case studies supported the importance of hands-on learning, real-world challenges, and group activities. The surveys and interviews also confirmed that HAVO students preferred interactive, practical assignments. These insights created the foundation for designing an engaging intervention.

ENTRANCE's role in hydrogen education

ENTRANCE offers many hydrogen programs related to hydrogen, but these are not specifically targeted at secondary school students. Awareness of ENTRANCE among students and teachers was also low. The research found promising hydrogen test kits, which allowed for practical hydrogen application in the intervention, linking ENTRANCE's resources to classroom activities.

ENTRANCE's role in the development of an educational hydrogen intervention

ENTRANCE's position between the education and work field practice makes it a possible middleman for student education through hands-on and in-person experiences. Visits to ENTRANCE could make a great impact on students by introducing them to real-world hydrogen projects and giving them hands-on experiences. The hydrogen test kits were chosen as an initial classroom implementation of ENTRANCE resources through collaboration with the expert they were then implemented into the intervention design.

Barriers to hydrogen education in secondary schools

The main points where both experts and teachers noted challenges that could arise were time constraints that schools and teachers face, fitting new information into the curriculum, and external support/extra work for teachers. These challenges were faced in the research and intervention design by ensuring clear communication for schools and teachers, linking the information to existing subjects and curricula, and providing an in-person guest lecture instead of pre-made lessons that the teachers had to figure out and provide themselves.

6.2 Intervention Design Justification

This section provides an overview of how the intervention design compares to the requirements, objectives, and what the results of the implementation show. The designed intervention was structured with a lesson time plan shown in Table 19, a presentation, and two experiments.

The first experiment asked the HAVO students to sort jobs into three columns: the first being directly involved in the energy transition, the second being indirectly involved in the energy transition, and the third being not involved. This allowed the students to work in groups and try to analyse possible future jobs they could have. After a few minutes, the answers would show that one way or another, all jobs have a relation to the energy transition and open up a short discussion. The second experiment lets the students create hydrogen with the hydrogen test kits provided by ENTRANCE, creating a hands-on learning experience.

Table 19: Intervention timeline

Timeline	*Activity*	*Description*	*Methods*	*Theories*
0-5 min	**Introduction & The Energy Transition**	Introducing the lesson and asking students a relatable question about hydrogen. Then a basic explanation of the energy transition, and why it's important for the world and them.	**Presentation, discussion, visuals**	**SDT, TPB, MOA Framework**
5-15 min	**Energy Transition Roles (group assignment)**	A short, interactive energy transition assignment for the students to understand what jobs are connected to the energy transition.	**Visuals, discussion, collaborative learning**	**ELT, SDT, TPB, MOA Framework**
15-20 min	**Hydrogen Basics**	The basics of hydrogen, how it is produced, stored, and used. Including a question that includes them and the world around them.	**Interactive Q&A, slides**	**TPB, MOA Framework**
20-45 min	**Hands-on Hydrogen Experiment (in groups)**	A small group experiment with the Hydrogen Science Kit, creating hydrogen and turning it back to electricity to power a fan.	**Experiment, collaborative learning**	**ELT, SDT, TPB, MOA Framework**
45-50 min	**Questions, Discussion & Reflection**	Asking the students if there was anything unexpected they learned today. If they still have questions, allow for discussion.	**Interactive, discussion, reflection**	**SDT, TPB, MOA Framework**

6.2.1 Intervention Implementation Insights

After designing the intervention and its implementation plan, the intervention was piloted among a class of Fourth-year HAVO students at the Montessori Lyceum in Groningen.

Observations

This section summarises the observations of the intervention pilot; the full observations can be found in Appendix 20.

Initially, students were notably not very excited that groups were assigned, but they eventually settled in. Though not all students were equally excited for the lesson, they got more enthusiastic when I explained the concept of receiving chocolate eggs for their participation and listened carefully. The reward seemed to help increase participation during the lesson, especially at the beginning. However, this seemed limited to creating initial engagement, and it did not seem to influence how students interacted with the content or their attitude during activities.

The first slide with headlines and the explanation that accompanied them drew in the attention, with engagement throughout the basics of the energy transition. The students got excited about the first exercise and participated well as groups to select what they thought were the answers, with one group getting a slight advantage due to a slip in the presentation. The students were very interested in the results of the exercise and were intrigued by it.

The basics of hydrogen kept their attention, with the question about hydrogen cars creating a good discussion within the groups. This was followed by them getting hands-on experience making hydrogen in their groups, which got the students very excited and actively participating.

The final discussion and questions were cut slightly short, but the students indicated that they enjoyed the lesson and then headed off for their lunch break.

Teacher feedback
The teacher noted that the students definitely seemed to enjoy the lesson and were all very actively engaged. As I had noticed, the teacher also implied that handing out the exercises/experiments beforehand would have been less time-consuming and less chaotic. She also noted that the addition of the chocolate eggs got a lot of students even more excited about participating in the lesson.

Survey results and student feedback
The participants of the intervention pilot at the Montessori Lyceum Groningen filled in a second, post-intervention survey, about a week after the pilot had been conducted. This survey once again asks students if they know what the energy transition is, what possible aspects of it are, and how important they find it, as can be seen in Appendix 21.

In this survey, the students were also asked if hydrogen is an energy source or carrier, as that was a trick question in the first survey that sadly no one noticed. This is followed by a question regarding the (possible) use of hydrogen within the energy transition. After this, the students are asked if they think their interested and their perceived importance of hydrogen and the energy transition has gone up since the first questionnaire, and how high they would rank that importance.

The students are also once again asked if they would want to do a job or study that focusses on the energy transition or hydrogen, but this time followed by a question if they think they will be in contact with the energy transition and hydrogen regardless. Finally, they are asked if they enjoyed the lesson and whether they found the lesson interesting.

Differences in the control group survey
The students at the Hondsrug College in Emmen also received a second survey, but without participating in the intervention pilot. This is to assess whether the survey itself has already affected the students. The differences in this survey for the Hondsrug College are that they do not get asked if they found the lesson fun and interesting, but if they found the surveys interesting. Other than that, they are the same, as the Hondsrug College survey can be seen in Appendix 22.

Due to scheduling issues at the Hondsrug College, the HAVO participants were not able to fill in the second survey, but the VWO students who also participated in the first survey were able to provide answers for analysis.

Results
After analysing the second survey answers from both participating secondary schools, the differences between the first (S1) and second (S2) surveys were laid out. For the participants at the Montessori Lyceum (ML), there is a clear difference between their awareness of what the energy transition is now (Figure 16), and in the first survey (Figure 15).

Figure 15: Do you know what the energy transition is? (S1, ML)

Figure 16: Do you know what the energy transition is? (S2, ML)

For the VWO students of the Hondsrug College (HC), the awareness of the energy transition also increased, but to a lower degree, as shown in Figure 17 and Figure 18. This is far from the big change seen from the students who participated in the intervention pilot.

Figure 17: Do you know what the energy transition is? (S1, HC)

Figure 18: Do you know what the energy transition is? (S2, HC)

Students of both schools were asked if they now viewed hydrogen as more important than before the first survey, to assess their awareness. The students who participated in the intervention (Figure 19) show a proportionally larger response that they do now think hydrogen is more important than the Hondsrug College student who did not partake in the intervention (Figure 20).

Figure 19: Do you think hydrogen is more important now than before the first questionnaire? (ML)

Figure 20: Do you think hydrogen is more important now than before the first questionnaire? (HC)

The same goes for the interest students have for hydrogen compared to before the intervention. Students who participated in the intervention (Figure 21) indicate a larger increase of interest than students of the Hondsrug College who did not participate in the intervention (Figure 22). For this question, the reasoning of the Montessori Lyceum students who selected not more not less, was largely that they already found hydrogen interesting, compared to the Hondsrug College students, who often stated that they received no extra information.

Figure 21: Do you think hydrogen is more interesting now than before the first questionnaire? (ML)

Figure 22: Do you think hydrogen is more interesting now than before the first questionnaire? (HC)

A complete overview of the survey answers of the Montessori Lyceum students who also participated in the intervention pilot is available in Appendix 23. And likewise, the answers of the Hondsrug College students who filled in the second survey are added to Appendix 24.

Student feedback

The students who participated in the intervention pilot and filled in the second survey, 91% indicated that they enjoyed the lesson (Figure 23), and 82% indicated that they found it interesting (Figure 24). The students who did not enjoy the lesson or find it interesting noted they were not interested in hydrogen as a topic, and that made the lesson boring.

Figure 23: Did you enjoy the guest lesson? (ML)

Figure 24: Did you think the guest lesson was interesting? (ML)

For the students of the Hondsrug College in Emmen, those who filled in the second survey were asked if they found the surveys interesting. As shown in Figure 25 80% of the students did not think the surveys were interesting, many stated that it was a waste of their time.

Figure 25: Did you find the surveys interesting? (HC)

6.2.2 Research Basis Evaluation

In this section, the research objectives, outcomes, and requirements are evaluated to assess their effectiveness in creating a basis for the intervention design.

Research Objectives

The research objectives provided the basis for the research process, leading to a foundation for the intervention design. Through the division of data collection and analysis in the sub-questions, the research objectives progressed.

The first objective on the current knowledge and teachings helped understand and develop a baseline for the intervention design. The second objective focussed on creating awareness and interest among HAVO students, leading to the design of engaging and relatable hands-on activities that incorporate the students' learning preferences for the intervention. Appendix 25 further describes how the research objectives were linked to the research process and whether they were achieved.

The analysis of ENTRANCE's current educational programs and expertise for the third objective revealed elements, such as the hydrogen kits, that became central to the intervention. However, including less accessible programs and experts in the analysis could have provided a more thorough overview. Though this could have been a valuable addition to the research, the data gathered through the desk research, surveys, and interviews was reliable and enough to design the intervention.

Requirements

The research process led to requirements for the intervention, like the need for hands-on student activities, real-world relevance, and minimal extra workload for teachers. These requirements were based on the findings from the interviews, surveys, and frameworks like the ELT and SDT, and were categorised based on their importance through MoSCoW prioritisation.

All of the highest priority requirements, shown in Table 20, were achieved. A complete overview of the requirements, with an explanation on why the requirement was achieved or not, is added to Appendix 26.

Table 20: MoSCoW prioritised requirements status

ID	Requirement Description	Priority	Achieved
1	The intervention must align with HAVO students' current learning levels.	Must	Yes
1.1	Covering the basics of hydrogen and its role in the energy transition, including different types of hydrogen and value chains.	Must	Yes
1.2	Show that the energy transition, and hydrogen within it, is not just technical.	Must	Yes
2	The intervention must be engaging and interactive to maintain student interest.	Must	Yes
2.1	Include hands-on activities and/or experiments.	Must	Yes
3	The intervention must use motivational strategies to engage students.	Must	Yes
3.2	Information is relatable and on the HAVO students' level.	Must	Yes
4	The intervention must fit within school schedules and subjects.	Must	Yes
4.1	Add minimal extra workload for teachers.	Must	Yes
7	The effectiveness of the intervention must be measured.	Must	Yes
7.1	Pre and post-intervention surveys with the students.	Must	Yes
7.2	Observe and collect feedback from teachers and students.	Must	Yes

Critical research reflection

The research that led to the intervention design was logical and structured, and followed the research objectives. The triangulation of different data sources and theoretical frameworks created a strong foundation for the design. However, the research could have been improved with more validation, like larger or more pilot groups, or the use of ENTRANCE facilities outside of the classroom. Involving students more in the intervention design, for instance, through focus groups, also could have created a more suitable student-centred intervention.

6.3 Reflection

This chapter reflects on the thesis process as a whole, followed by the research integrity, and finally the moral and ethical considerations.

6.3.1 Process Evaluation

This section evaluates the intervention design process, reflecting on the introduction, methodologies and the results.

Research introduction

As described in section 6.1 Research Process, the initial problem statement was vague, broad, and connected to the energy transition as a whole, with an extensive research scope. The problem statement underwent many iterations, finally narrowing down to focus on awareness of and interest in hydrogen among HAVO students. This narrowed down the research scope, clarifying the research focus and boundaries.

After following these iterations, the final research objectives were aligned to the problem statement, analysing knowledge gaps, engagement strategies, and the potential of ENTRANCE's facilities and expertise. The final iteration of the main research question created a foundation for the research by being clear and researchable, and connecting to the final problem statement and research objectives.

Research methodologies

As stated in section 6.1.3 Methodology, the use of desk research, case studies, surveys, interviews and observations provided a broad overview of different aspects and insights. By using triangulation, findings were compared and validated. Where surveys and observations were especially useful to gain insight into student preferences and behaviour, the desk research and interviews were found to be most useful for finding theoretical frameworks and useful strategies.

Even though these research methods were effective, the small sample sizes, especially for the surveys, made the data less reproducible. And, though originally planned, the focus group research method was not used in this research due to time constraints and availability. This reduced student involvement in the research and intervention design process.

Results

The findings of the intervention pilot showed that students were engaged and actively participating in the group tasks and experiments. The survey results found an increase in both awareness and interest in the energy transition and hydrogen within it, following the research objectives. The observations during the intervention supported these results, with students showing enthusiasm and participation, especially in the hands-on activities.

The reliability of these results is limited due to the small sample size and the pilot only being conducted at one school. Even though the findings show a positive influence after the pilot, more and bigger pilot groups would be needed to create a better validation of the effectiveness of the intervention.

6.3.2 Research Integrity

The validity and reliability of this research stem from the combined use of various research methods supporting each other. The desk research findings were supported by insights from experts, teachers and students, making them more reliable and suitable for use in the design. The intervention design makes clear links to the research findings and the requirements.

To increase the reliability and replicability of the surveys, they were conducted at two secondary schools. Due to time constraints, the intervention pilot could not be conducted at both schools, but the research was conducted almost identically at both schools. Both the first and second surveys followed the same structure, with small differences for the school that did not receive the pilot. For the interviews, the teacher's questions were structured almost identically, with small changes in the structure of the expert interviews due to differences in their fields.

From both the surveys and the interviews, the data was reviewed and analysed multiple times to create a complete and accurate overview, and by using triangulation, the results were further validated. Even though the participation for the second survey was low, and the intervention was only piloted at one school, the methods used ensured the reliability of the results.

6.3.3 Moral Dilemmas and Ethical Considerations

Ethical research standards were met by asking for consent for the use of data, keeping the survey responses anonymous, and ensuring voluntary participation. Participants in the interviews were asked for their consent to use their names and data, with the clear indication that anonymity was possible, creating clarity and respecting their privacy.

Aside from these research ethics, the intervention design process found further moral dilemmas. As the intervention should not create a bias on hydrogen being the only or best solution for the energy transition, the intervention clarified different forms and roles of hydrogen, helping students form their own opinions.

The intervention should also not influence student choices, but focus on raising awareness. The students were introduced to different jobs related to the energy transition, instead of trying to persuade them to work in the energy transition. This was done to try and inspire students without leading them in one direction.

For the long term, is it important that the focus stays on creating awareness and collaborating with the students. This supports the development of their own ideas, instead of promoting specific technologies or industries.

6.4. Conclusion

This intervention design research was focused on using ENTRANCE's facilities and expertise to create an educational intervention that increases HAVO secondary school students' awareness of and interest in hydrogen within the energy transition. As the research progressed, the scope and focus of the project shifted from a wide approach towards the energy transition and promoting studies, to hydrogen within the energy transition in secondary HAVO education. By narrowing the scope of this research, the intervention became more relevant and increased its potential for success.

The research methods of desk research, case studies, interviews, surveys and observations provided a strong research setup and foundation for the intervention design. The selected theories and frameworks, like the self-determination theory, the experiential learning theory, and the MOA framework, helped relate the intervention to the students' learning preferences that were received through the surveys and the expert and teacher insights into effective learning methods.

The sub-questions found that hydrogen within the energy transition is currently not a part of the HAVO curriculum, and that students had limited knowledge on these topics. The sub-questions also showed that most students were interested in learning more about hydrogen within the energy transition if it was interestingly introduced to them, with their preferences leaning towards hands-on, real-world, relatable topics. The sub-questions also showed that ENTRANCE has great resources, facilities and expertise, but that it is currently not accessible to HAVO secondary school students and teachers. This provided the opportunity for ENTRANCE to use its resources in the educational intervention to create interest and awareness among students.

The designed intervention combines group work, hands-on experience and experiments, and relatability. This intervention was piloted at the Montessori Lyceum Groningen and was met with positive feedback from the teacher as well as the students. Even though the pilot was limited to a single HAVO class, the results were promising, and the intervention is adaptable and manageable for implementation in various settings.

The main research question, *"How can ENTRANCE's facilities and expertise be used and extended to increase HAVO students' awareness of and interest in hydrogen for accelerating the energy transition?"* was answered through the research, intervention design, and the intervention pilot. ENTRANCE's facilities and expertise can be extended and used to engage HAVO secondary school students and increase their awareness of and interest in hydrogen within the energy transition by providing hands-on resources, practical demonstrations and expert insights. The intervention design provides ENTRANCE with an adaptable tool to improve its educational outreach and increase student engagement with hydrogen within the energy transition.

6.5. Recommendations

The number one recommendation for the continuation of this research is to conduct a broader pilot at more schools, with the Hondsrug College in Emmen having already expressed further interest, and connections at the Parsival College Groningen indicating that they would be interested in the intervention lesson. Further pilots or implementations could also study the longer-term retention of knowledge among the students. For these pilots, it would be recommended to include at least 15 minutes of preparation time before the intervention starts, to set up the presentation, create a table layout, and divide the materials.

It would also be recommended to analyse the intervention contents with students' help, for instance, in a focus group setting. This would allow for direct student input and collaboration, resulting in an intervention that is more likely to be suitable for the pilots or further implementation.

For ENTRANCE, it is recommended that connections and collaboration between them and secondary schools stay strong, with possibly even providing training or materials for willing teachers, as that was an indicator in the teacher surveys. This intervention could also be further extended into specific subjects like O&O at Technasium schools and physics and chemistry classes; for this, modular components for the intervention would be a recommendation. With any further implementation of this intervention, it is highly recommended that teachers are supported in any form that the intervention is provided, as the present and time constraints are very high.

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Appendices

Appendix 1: Current Situation Analysis

The struggle against climate change has brought global attention to the importance of transitioning to sustainable energy systems. The European Union (EU) aims to reduce greenhouse gas emissions by 55% by 2030 (European Commission, 2024). Every EU nation develops a National Energy and Climate Plan (NECP) to accomplish this reduction. The NECP describes each nation's 10-year plan for achieving national and EU-wide binding targets. For the Netherlands, this NECP focuses on targets including: Renewable energy, Energy efficiency, Research, and Innovation (European Commission, 2021).

Though most of these plans focus on new technologies, they emphasise the need for skilled professionals who can assist in this transition and strive for advancements (Bulavskaya & Reynès, 2017). In key sectors relevant to the energy transition, such as energy supply, manufacturing, and technical and scientific activities, job vacancies across the EU have doubled between 2020 and 2023, with a similar rise in vacancies within the Netherlands (European Union, 2023). Across the Netherlands, almost 39% of job positions related to the energy transition remained unfilled. As seen in Figure 26, when looking at the northern Netherlands, these numbers are even higher, with 73% of positions unfilled in Groningen and 68% in Leeuwarden (ABN AMRO, 2023).

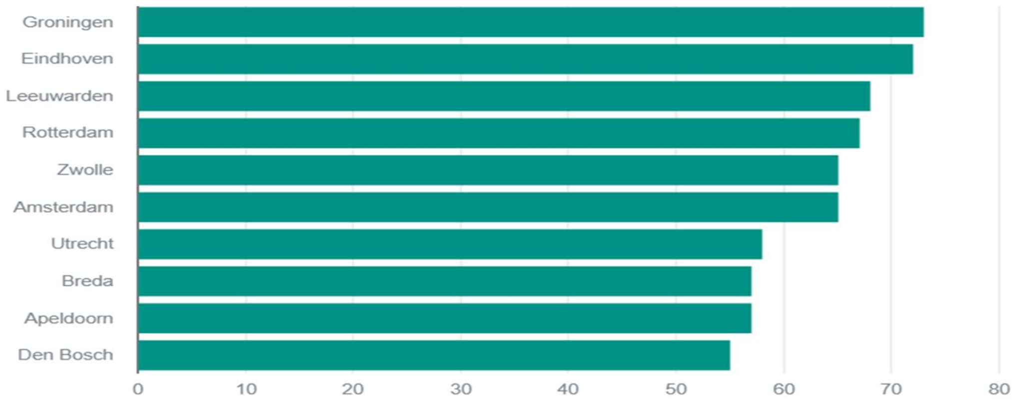


Figure 26: Percentage of unfilled vacancies for personnel in the energy transition (ABN AMRO,

The northern Netherlands is a leader in hydrogen and renewable energy innovation projects, with the HEAVENN project receiving the first ever 'Hydrogen Valley of the Year Award' from the European Clean Hydrogen Partnership, and being recognised by the European Commission as the first Hydrogen Valley of Europe (Clean Hydrogen Partnership, 2024). HEAVENN works towards a fully operational hydrogen economy in the northern Netherlands, involving 31 parties from 6 EU countries (HEAVENN, 2022). In the provincial development program of Groningen for 2024 until 2029, one of the province's main focuses is the energy transition and the need for skilled workers therein.

The provincial development program highlights the development of and investments in societally important projects, based within the province (Nationaal Programma Groningen, 2024). In the Groninger plans for 2024-2029, hydrogen, and schooling for knowledge and skills around hydrogen, are some of the main topics of focus within the energy transition plans in the region. The provincial plans aim to stimulate knowledge development and schooling, focusing on hydrogen education for MBO, universities (HBO and WO) and post-university students and workers (Provincie Groningen, 2023). The Waterstof Werkt: H2 Train and Learn Hub is one of the educational projects in the provincial program, focussing on boosting regional energy transition knowledge, with a focus on hydrogen. The H2 Train and Learn Hub is a collaboration between the following educational institutes at MBO, HBO and VO university levels: Alfa-college, Noorderpoort, DCTerra, Hanze, NHL Stenden, and Rijksuniversiteit Groningen (New Energy Coalition, 2024).

In the Netherlands, the national school curriculum describes what students in primary and secondary education need to be able to do and know at a nationwide level (Ministerie van Algemene Zaken, 2024). The national curriculum is formulated by Stichting Leerplan Ontwikkeling (SLO), together with teachers, scientists, experts and other organisations. The national curriculum includes core objectives or ‘Kerndoelen’ for lower secondary education, and final objectives or ‘eindtermen’ for upper secondary education (SLO, 2023).

Neither the core nor the final objectives of the national curriculum include topics with a focus on the energy transition. The core objectives for lower HAVO education only mention energy as a concept, with no set focus on hydrogen. Though the concepts of hydrogen and energy saving are mentioned in the final objectives for HAVO students, there is no mention of the energy transition or the relation to hydrogen (SLO, 2024).

Due to the global formulation of the core and final objectives, schools can create their own curriculum, as long as these objectives are covered. (SLO, 2024). Even though schools can choose to include energy transition-related topics in their curriculum. Research found that on a national level, 60% of teenagers indicated that the energy transition was never discussed in classes in any way. Only 11% of the questioned teenagers indicated that the energy transition was discussed regularly (Energie Beheer & PanelWizard). The choices for higher technical education for HAVO students have changed slightly over the last few years, with currently 23% of HAVO students choosing to pursue technical studies in the northern Netherlands, compared to a national average of 26% (Techniekpact, 2024).

Aside from the national curriculum and school-specific focus on the energy transition, in recent years independent projects have also started working to bring awareness of the energy transition to secondary schools. Projects by Darel Educational, Energie(K) Onderwijs, Milieueducatie Den Haag, and Waterstof in de Klas, aim to introduce secondary students to the energy transition. Though students and teachers indicate that the interventions provide a good introduction to the energy transition, there are no long-term results given about their effectiveness. (Darel Education, 2023; Interreg Vlaanderen-Nederland, 2023; Milieueducatie Den Haag, 2023; Alles over waterstof, 2022).

Appendix 2: Analysis of Theories, Models and Frameworks

This appendix provides a deeper analysis of the relevant theories, models, and frameworks, and explains how they are useful to analyse and address the research objectives and sub-questions.

Stakeholder Theory

Stakeholder Theory is concerned with taking the interests of all parties affected by, or interested in, a project into account. It can be used to identify stakeholders and their expectations, and then work with them to use this information. This theory is important for collaboration with stakeholders like schools, teachers, and ENTRANCE. It ensures that the intervention, the goals, and the concerns of all parties are addressed, making it more effective and acceptable by them (Mitchell et al., 1997).

Bloom's Taxonomy Theory

Bloom's Taxonomy groups learning objectives into six levels: recalling, discovering, utilising, exploring, assessing, and constructing. This structure provides a guide to designing educational activities to increase the level of learning. This model can help create the learning objectives of the intervention for students to not only gain knowledge on hydrogen within the energy transition but also apply and analyse this knowledge. This is especially useful for creating hands-on activities that create deeper thinking (Mcdaniel, 2010).

Theory of Experiential Learning

In Kolb's Experiential Learning Theory, experiential learning is seen as essential for learning, focusing on hands-on, and interactive education. The model has four stages: concrete experience, reflection, abstract conceptualization, and active experimentation. This model demonstrates how people learn better through, experiencing, reflecting, conceptualizing, and applying knowledge.

This theory can help design an engaging intervention, helping to excite and interest HAVO students with hands-on activities, aiming to create a better understanding of hydrogen within the energy transition. By using experiential learning, the intervention could be more interactive and memorable (Institute for Experiential Learning, 2023).

Theory of Self-Determination

The Self Determination Theory, created by Ryan and Deci, explores intrinsic and extrinsic motivation. Intrinsic motivation is driven by internal satisfaction and curiosity, while extrinsic motivation is driven by external rewards or pressures. The SDT outlines three basic psychological needs: autonomy, competence, and relatedness. Providing these will facilitate intrinsic motivation and engagement. This theory could help comprehend how to engage a HAVO student to participate in the intervention. By design, these activities can increase student interest in hydrogen and the energy transition by providing them with a sense of choice (autonomy), realising their abilities (competence) and linking to peers and mentors (relatedness) (Ryan & Deci, 2000).

Theory of Planned Behaviour

The Theory of Planned Behaviour, by Ajzen, suggests that behaviour is influenced by three factors: subjective norms, perceived behavioural control and attitudes toward the behaviour. Intention and external factors determine the likelihood of individuals engaging in specific behaviours. TPB could offer insight into how to get HAVO students to approach hydrogen and the energy transition. The intervention addresses subjective norms (peer and societal pressure) and perceived behavioural control (students' belief that they can perform the behaviour that they wish to do) (Ajzen, 1991).

Motivation Opportunity Ability Framework

According to the MOA Framework, individuals will be more likely to engage in behaviour if they are motivated, can carry it out, and have the opportunity to carry out the behaviour. This framework can work as a tool to see and solve threats to student engagement. If the intervention can be made motivating, understandable and accessible, it could help create student participation and interest (MacInnis et al., 1991).

Appendix 3: Analysis of Research Methodologies

This appendix provides a deeper analysis of the relevant theories, models, and frameworks, and explains how they are useful to analyse and address the research objectives and sub-questions.

Desk Research
Desk research, also known as secondary research, is a research method where existing scientific literature can be collected and analysed, without collecting primary data through surveys or fieldwork. In this research method, existing literature, like; books, studies, surveys, interviews, and other sources of data are analysed to find and extract information that can be used for this research. It can help identify gaps, understand past findings, and support other research methodologies (Moore, 2018).

Case Studies
The Case studies research methodology can be used in combination with desk research to analyse a single subject, such as existing educational programs and interventions involving hydrogen and renewable energy topics. Case studies are widely used in exploratory research to understand the subject well. Examples such as "Waterstof in de Klas" can be examined to extract lessons learned and best practices that can inform the design of this intervention (Alex, 2024).

Surveys
The survey research method collects information from a group of individuals by having them respond to questions. This method allows for the collection of data and is often used to explore human behaviour (Ponto, 2015). Surveys can be used to assess students' knowledge and views of hydrogen and the energy transition. Questions could be structured using Bloom’s Taxonomy, ranging from basic factual knowledge to more complex questions about the implications of hydrogen in society. These surveys can also be used before and after the intervention to evaluate its effectiveness.

Interviews
The research method of interviewing can be categorised as qualitative or quantitative, depending on the type of interview. If the interview is unstructured, the respondents can express themselves in their own way and pace, seen as qualitative research. If the interview is conducted in a structured, or semi-structured way, this is a form of qualitative research. Interviews are used to collect data through observation and response to questions, allowing information to be collected from participants as a direct source (Jamshed, 2014). Semi-structured interviews should be done with key stakeholders, including teachers, ENTRANCE workers, and experts. With these interviews, challenges, opportunities, and advice can be collected for the design of an educational intervention. A focus will be placed on understanding how to make hydrogen engaging and accessible for HAVO students.

Observations
The benefit of the observational research method is that it allows you to analyse people in their natural environment and to understand things from their perspective. This research method has been used to collect data first-hand since written observations began (Baker, 2006). During the pilot intervention, observations can be used to document student engagement, participation, and any challenges encountered. This data can then be used as recommendations for further development.

Triangulation
Triangulation collects and analyses data from different sources, like the different research methods, to cross-verify the information. This can reduce the chance of bias from one method and can strengthen the research credibility and findings. Triangulation could be very useful for this research because it can connect the insights from interviews and students with survey data and desk research results.

Appendix 4: Methodologies and Sub-questions

	Understanding Awareness & Engagement (research)			Intervention design	Barrier analysis
Research Sub-Questions	What is currently being taught at participating secondary schools about hydrogen within the energy transition, and what is the HAVO student's level of knowledge, awareness, and interest?	What are effective ways to create awareness and interest in hydrogen within the energy transition among HAVO students?	How do ENTRANCE's current educational programs and expertise align with what is needed to engage HAVO students in hydrogen within the energy transition?	How can the facilities and expertise of ENTRANCE be used to create an engaging educational intervention?	What barriers or challenges could arise when implementing a successful educational intervention on the energy transition in secondary schools, and how can these be overcome?
Research Methodologies	**Surveys** (students) To assess knowledge and views of hydrogen in energy transition	**Desk research/Case studies** Assess past interventions and programs to determine best practices and find what works	**Desk research** Analysing and comparing ENTRANCE's programs to the needs of the students	**Desk research/Case studies** Assessing similar interventions and ENTRANCE facilities, programs, equipment and possibilities	**Desk research** Assesment of common challanges
	Interviews (Teachers) To assess the current contact students get with hydrogen in energy transition	**Interviews** (Teachers/experts) Questioning teachers and experts on the best ways to interest and engage students	**Interviews** (Experts) Questioning ENTRANCE experts on current programs and their effectiveness	**Interviews** (Experts) Questioning ENTRANCE experts on suitable options for designing the intervention	**Interviews & surveys** Asses the experience and change in awarness and interest
					Observations Documenting barriers during the intervention pilot
Theories, Models & Frameworks	**Bloom's Taxonomy** Could be used to structure the questions for the student surveys and assess current learning levels **Stakeholder Theory** Could be used to analyse how teachers and schools put the focus on hydrogen in education	**Motivation Opportunity Ability** To analyze students' motivation and engagement **Theory of Planned Behaviour** To understand students' attitudes and willingness to engage **Theory of experm learning** To highlight hands-on, engaging, learning experiences	**Stakeholder Theory** Could be used to examine how ENTRANCE can collaborate effectively to meet the the interests and needs of schools and students	**Stakeholder Theory** Could be used to ensure that the intervention includes the interests and needs of schools, ENTRANCE, and students **Theory of experm learning** To design an intervention with hands-on experiences and real-world applications	**Stakeholder Theory** Could be used to find possible barriers and challanges and collaborate to find sollutions

Appendix 5: Project Planning

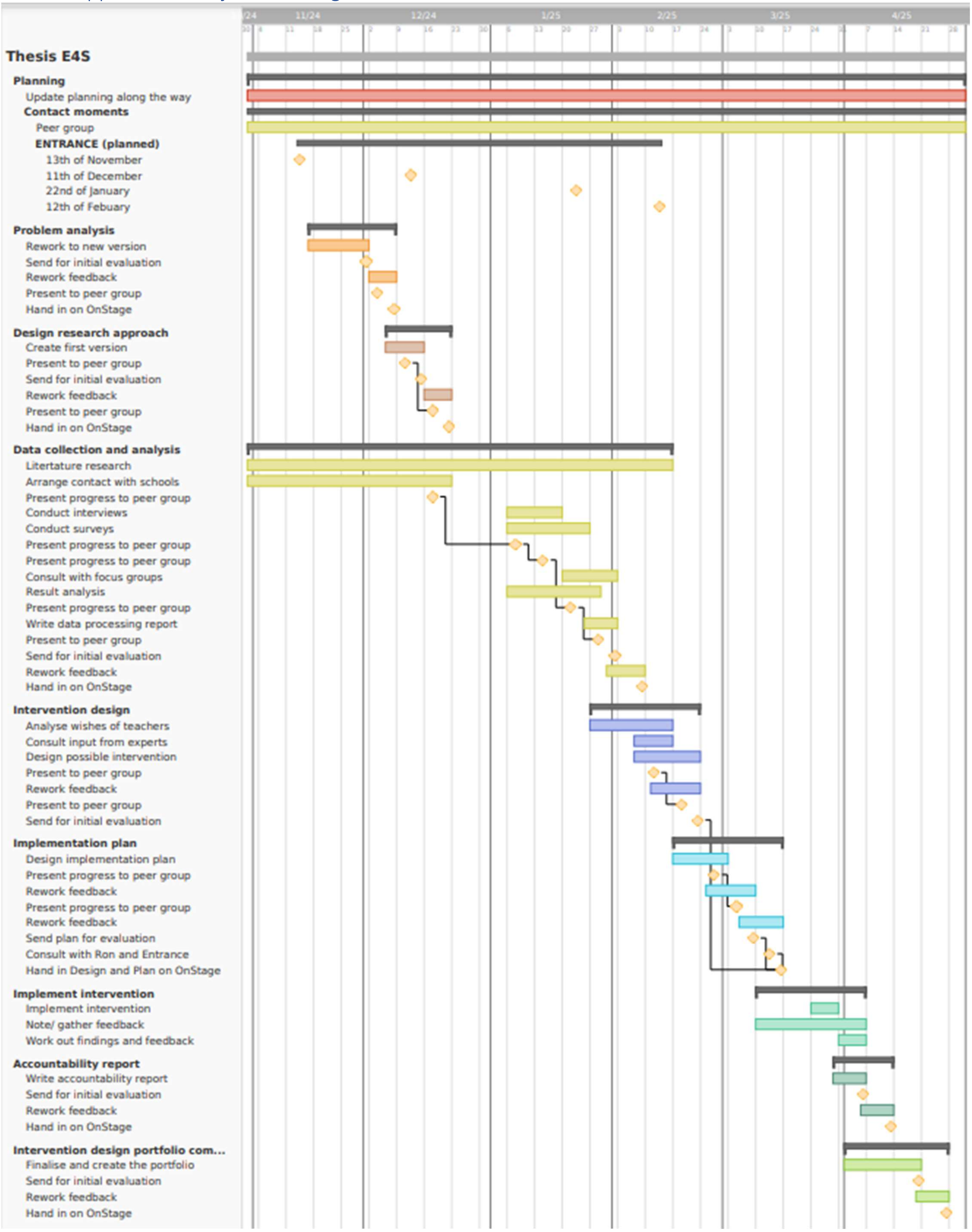


Figure 27: Planning table

Appendix 6: Base Teacher Interview Questions

Dutch version (as used for the interviews)**:**

Intro: Uitleg over dit project en de uitkijk op de interventie

Q1: Zou je kunnen omschrijven wat jouw rol is binnen het Montessori Lyceum?

Q2: Zijn er binnen het Montessori Lyceum al projecten of lessen (geweest) die betrekking hebben op de energietransitie of waterstof? Zo ja, wat zijn jouw ervaringen hiermee?

Q3: Hoe belangrijk vind je het dat leerlingen al tijdens hun middelbare schooltijd in aanraking komen met thema's zoals de energietransitie en waterstof?

Q4: Wat zie je als de grootste uitdagingen bij het betrekken van HAVO leerlingen bij technische of duurzame onderwerpen zoals waterstof?

Q5: Welke onderwerpen binnen waterstof en de energietransitie denk je dat het meest relevant en begrijpelijk zijn voor HAVO leerlingen?

Q6: Wat zou een interventie aantrekkelijk maken voor zowel leerlingen als docenten? Zijn er specifieke elementen of aanpakken die je zou aanbevelen?

Q7: Zijn er bepaalde activiteiten of methoden (zoals workshops, gastlessen of praktijkopdrachten) die je denkt dat het beste zouden werken voor jouw leerlingen?

Q8: Welke mogelijkheden zie je voor het integreren van de interventie binnen het huidige curriculum? Zijn er specifieke modules of vakken waar dit goed bij aansluit?

Q9: Hoe belangrijk is het voor jou dat een interventie meetbare resultaten oplevert, zoals een verhoogde interesse of bewustwording bij leerlingen?

Q10: Welke ondersteuning zou je nodig hebben om een interventie succesvol uit te voeren, zowel op docent- als op schoolniveau?

Q11: Hoe belangrijk vind je de samenwerking tussen scholen en organisaties zoals ENTRANCE?

Q12: Hoe kan ENTRANCE volgens jou een unieke bijdrage leveren aan het onderwijs op jouw school?

Q13: Wat zou je als docent het belangrijkste vinden dat leerlingen meenemen uit een project over waterstof en de energietransitie?

Q14: Zijn er specifieke barrières of obstakels die je voorziet bij het organiseren en uitvoeren van een interventie, en hoe zouden deze volgens jou overwonnen kunnen worden?

Q15: Heb je voorbeelden of ideeën uit eerdere projecten die kunnen dienen als inspiratie voor deze interventie?

Q16: Is er iets anders dat je belangrijk vindt om te delen over jouw visie op onderwijs of dit project?

English version (Translated by Joppe Ireland):

Q1: Could you describe your role at the Montessori Lyceum?

Q2: Are there, or have there already been projects or lessons at the Montessori Lyceum that focus on the energy transition or hydrogen?

Q3: How important do you think it is for students to encounter topics like the energy transition and hydrogen during their secondary education?

Q4: What do you see as the biggest challenges in engaging HAVO students with technical or sustainable topics like hydrogen?

Q5: Which topics within hydrogen and the energy transition do you think are most relevant and understandable for HAVO students?

Q6: What would make an intervention appealing to both students and teachers? Are there specific aspects or approaches you would recommend?

Q7: Are there specific activities or methods (such as workshops, guest lectures, or practical assignments) that you think would work best for your students?

Q8: What opportunities do you see for integrating the intervention into the current curriculum? Are there specific modules or subjects where this would fit well?

Q9: How important is it to you that an intervention delivers measurable results, such as increased interest or awareness among students?

Q10: What support would you need to successfully implement an intervention, both at the teacher and school levels?

Q11: How important do you consider the collaboration between schools and organizations like ENTRANCE, and why?

Q12: In your opinion, how can ENTRANCE make a unique contribution to education at your school?

Q13: What do you think is the most important takeaway for students from a project on hydrogen and the energy transition?

Q14: Are there specific barriers or challenges you foresee in organizing and executing an intervention, and how do you think these can be overcome?

Q15: Do you have examples or ideas from previous projects that could serve as inspiration for this intervention?

Q16: Is there anything else you think is important to share about your vision for education or this project?

Appendix 7: Example Expert Interview Questions

Dutch version (as used for the interviews)**:**

Intro: Uitleg over dit project en de uitkijk op de interventie

Q1: Zou je kunnen omschrijven wat voor rol speelt bij Stichting Technasium?

Q2: Welke ervaring heb je met het werken aan projecten bij ENTRANCE en hoe dragen deze bij aan de ontwikkeling van Technasium onderwijs?

Q3: Hoe zie je de samenwerking tussen Technasium scholen en ENTRANCE? Welke meerwaarde biedt deze samenwerking voor leerlingen?

Q4: Welke specifieke onderwerpen, zoals waterstof binnen de energietransitie, zijn het meest relevant voor Technasium projecten?

Q5: Hoe worden de projecten van Technasium afgestemd op de regionale arbeidsmarktbehoeften, zoals die in de energietransitie?

Q6: Wat zijn volgens jou de beste methoden om HAVO leerlingen enthousiast te maken voor technische vakken en onderwerpen zoals de energietransitie?

Q7: Welke rol speelt praktijkgericht onderwijs, zoals het Technasium, in het vergroten van interesse en kennis over waterstof en de energietransitie?

Q8: Zijn er specifieke projecten of activiteiten die volgens u het meest succesvol zijn geweest in het inspireren van leerlingen?

Q9: Wat denk je dat de grootste uitdagingen zijn bij het betrekken van HAVO leerlingen bij technologische onderwerpen zoals waterstof en de energietransitie?

Q10: Hoe kunnen mogelijke barrières, zoals weerstand van scholen of gebrek aan middelen, worden overwonnen?

Q11: Hoe wordt het succes van Technasium projecten gemeten, en zijn er specifieke meetbare resultaten die relevant zijn voor mijn onderzoek?

Q12: Welke feedback heb je ontvangen van leerlingen en docenten over projecten bij ENTRANCE en hoe is deze feedback gebruikt?

Q13: Wat zou jouw advies zijn voor het ontwerpen van een interventie die HAVO leerlingen meer bewust maakt van waterstof en de energietransitie?

Q14: Zijn er specifieke voorbeelden of initiatieven uit jou ervaring die ik kan gebruiken als inspiratie voor mijn interventie?

Q15: Wat zou in jou ogen een unieke bijdrage van ENTRANCE kunnen zijn aan de bewustwording over waterstof in het voortgezet onderwijs?

Q16: Is er iets anders wat je belangrijk vindt om te delen over uw werk bij Stichting Technasium of jou visie op onderwijs en de energietransitie?

English version (Translated by Joppe Ireland):

Q1: Could you describe the role you play at Stichting Technasium?

Q2: What experience do you have working on projects at ENTRANCE, and how do these contribute to the development of Technasium education?

Q3: How do you see the collaboration between Technasium schools and ENTRANCE? What added value does this collaboration offer to students?

Q4: What specific topics, such as hydrogen within the energy transition, are most relevant for Technasium projects?

Q5: How are Technasium projects aligned with regional labor market needs, such as those in the energy transition?

Q6: What do you think are the best methods to get HAVO students excited about technical subjects and topics like the energy transition?

Q7: What role does practice-oriented education, like Technasium, play in increasing interest and knowledge about hydrogen and the energy transition?

Q8: Are there specific projects or activities that you consider most successful in inspiring students?

Q9: What do you think are the biggest challenges in engaging HAVO students with technological topics like hydrogen and the energy transition?

Q10: How can barriers such as resistance from schools or a lack of resources be overcome?

Q11: How is the success of Technasium projects measured, and are there specific measurable results relevant to my research?

Q12: What feedback have you received from students and teachers about projects at ENTRANCE, and how has this feedback been used?

Q13: What would your advice be for designing an intervention to make HAVO students more aware of hydrogen and the energy transition?

Q14: Are there specific examples or initiatives from your experience that I can use as inspiration for my intervention?

Q15: What do you think would be a unique contribution from ENTRANCE to raising awareness about hydrogen in secondary education?

Q16: Is there anything else you find important to share about your work at Stichting Technasium or your vision on education and the energy transition?

Appendix 8: Teacher Interviews

Interview vragen: [redacted] Docent Montessori Lyceum Groningen

Intro: Uitleg over dit project en de uitkijk op de interventie

Q1: Zou je kunnen omschrijven wat jouw rol is binnen het Montessori Lyceum?
A1: Docent natuurkunde in de bovenbouw, voor 4 HAVO, 5 HAVO, 4 VWO, 5 VWO en 6 VWO.

Q2: Zijn er binnen het Montessori Lyceum al projecten of lessen (geweest) die betrekking hebben op de energietransitie of waterstof? Zo ja, wat zijn jouw ervaringen hiermee?
A2: Nee, eigenlijk niks. Lessen van buiten doen we eigenlijk niet. Warmtepompen worden heel kort benoemd in het curriculum, maar verder is er weinig aandacht voor. Soms doen leerlingen een profielwerkstuk (PWS) over energie, maar energie komt in 4 HAVO natuurkunde helemaal niet voor. In 5 HAVO zit energie in periode 1 en zou daar mogelijk bij natuurkunde kunnen aansluiten.

Q3: Hoe belangrijk vind je het dat leerlingen al tijdens hun middelbare schooltijd in aanraking komen met thema's zoals de energietransitie en waterstof?
A3: Het belangrijkste is dat ze de basisbegrippen van energie begrijpen, zoals de wet van behoud van energie. Ze moeten eerst de belangrijke concepten snappen voordat ze het bredere plaatje kunnen begrijpen. Maar als het eenmaal in de basis zit, dan is het zeker belangrijk dat ze ook de toepassingen en maatschappelijke relevantie leren kennen.

Q4: Wat zie je als de grootste uitdagingen bij het betrekken van HAVO leerlingen bij technische of duurzame onderwerpen zoals waterstof? Hoe los je dit op?
A4: De school zelf is voor veel leerlingen niet de belangrijkste prioriteit. Ze moeten een duidelijk doel voor ogen hebben en begrijpen waarom iets relevant voor hen is. Als ze niet snappen waarom een onderwerp belangrijk is, raken ze snel hun aandacht kwijt.

Q5: Hoe denkt u dat een interventie als deze zou passen in de bredere context van het onderwijs op het Montessori Lyceum?
A5: Donderdag middag practicum is flexibel, 2x 2 uur. Hier zou zo iets goed in kunnen passen. Een bezoek aan ENTRANCE zou ook in de eerste periode van 5 HAVO kunnen, omdat daar energie behandeld wordt in natuurkunde.

Q6: Welke onderwerpen binnen waterstof en de energietransitie denk je dat het meest relevant en begrijpelijk zijn voor HAVO leerlingen?
A6: Basis begrippen van natuurkunde, bijvoorbeeld de wet van behoud van energie. De maatschappelijke relevantie. Misschien zou het ook wel bij maatschappijleer passen.

Q7: Wat zou een interventie aantrekkelijk maken voor zowel leerlingen als docenten? Zijn er specifieke elementen of aanpakken die je zou aanbevelen?
A7: Toch op een donderdag middag doen, dan heb je tijd om mogelijk naar ENTRANCE te komen. Je zou het aan het begin van het schooljaar in kunnen plannen. Luisteren werkt maar 10 minuten, daarna moeten ze echt iets doen.

Q8: Zijn er bepaalde activiteiten of methoden (zoals workshops, gastlessen of praktijkopdrachten) die je denkt dat het beste zouden werken voor jouw leerlingen?
A8: Iemand anders voor de klas is altijd beter dan de eigen docent, dat maakt het interessanter. Actief bezig zijn is belangrijk; alleen luisteren werkt maar even (10 min).

Q9: Welke mogelijkheden zie je voor het integreren van de interventie binnen het huidige curriculum? Zijn er specifieke modules of vakken waar dit goed bij aansluit?
A9: Natuurkunde, scheikunde, economie en maatschappijleer wel.

Q10: Hoe belangrijk is het voor jou dat een interventie meetbare resultaten oplevert, zoals een verhoogde interesse of bewustwording bij leerlingen?
A10: Voor de leerlingen zelf zal het niet heel relevant zijn, maar ik zou het interessant vinden om te horen wat het effect is. Ik merk vanzelf in de lessen of ze er iets aan gehad hebben.

Q11: Welke ondersteuning zou je nodig hebben om een interventie succesvol uit te voeren, zowel op docent- als op schoolniveau?
A11: Meer stof dan tijd, dus de interventie zou het beste moeten passen in het geheel en ze iets van de stof leren. Het is leuker als iemand uit de praktijk komt, waar zijn we mee bezig, waar lopen we tegenaan. Als het bijvoorbeeld concepten zoals rendement kan koppelen aan de leerstof, zou het veel toegevoegde waarde hebben.

Q12: Hoe belangrijk vind je de samenwerking tussen scholen en organisaties zoals ENTRANCE?
A12: Belangrijk voor het concreet maken van de concepten die ze leren, leuk en dat ze weten wat er speelt en er up to date kennis is. Zeker toegevoegde waarde.

Q13: Hoe kan ENTRANCE volgens jou een unieke bijdrage leveren aan het onderwijs op jouw school?
A13: Uitjes met dingen laten zien en iets praktisch doen.

Q14: Wat zou je als docent het belangrijkste vinden dat leerlingen meenemen uit een project over waterstof en de energietransitie?
A14: Dat ze niet alleen de basiskennis hebben, maar ook begrijpen waar de kansen en uitdagingen liggen op het gebied van waterstof in de energietransitie.

Q15: Zijn er specifieke barrières of obstakels die je voorziet bij het organiseren en uitvoeren van een interventie, en hoe zouden deze volgens jou overwonnen kunnen worden?
A15: De grootste uitdaging is tijd. Een extra uur zou welkom zijn, maar het moet gekoppeld worden aan bestaande lesstof zodat het relevant blijft.

Q16: Heb je voorbeelden of ideeën uit eerdere projecten die kunnen dienen als inspiratie voor deze interventie?
A16: Nee

Q17: Is er iets anders dat je belangrijk vindt om te delen over jouw visie op onderwijs of dit project?
A17: Ik geloof dat de energietransitie nodig is en dat het belangrijk is om de jeugd hierin mee te nemen. Dit project kan daaraan bijdragen en ik ben benieuwd hoe het verder gaat.

English version: [redacted] (Translated by Joppe Ireland)

Q1: Could you describe your role at the Montessori Lyceum?
A1: I am a physics teacher in the upper years, teaching 4 HAVO, 5 HAVO, 4 VWO, 5 VWO, and 6 VWO.

Q2: Are there, or have there already been projects or lessons at the Montessori Lyceum that focus on the energy transition or hydrogen?
A2: No, not really. We don't usually do lessons from external sources. Heat pumps are briefly mentioned in the curriculum, but beyond that, there is little focus on the topic. Sometimes, students do a profile assignment (PWS) on energy, but energy is not covered at all in 4 HAVO physics. In 5 HAVO, energy is part of the curriculum in the first period, so it could be integrated into physics there.

Q3: How important do you think it is for students to encounter topics like the energy transition and hydrogen during their secondary education?
A3: The most important thing is that they understand the basic concepts of energy, such as the law of conservation of energy. They need to grasp these fundamental ideas before they can comprehend the bigger picture. But once they have that foundation, it's certainly valuable for them to learn about applications and societal relevance.

Q4: What do you see as the biggest challenges in engaging HAVO students with technical or sustainable topics like hydrogen?
A4: School is simply not a priority for many students. They need a clear purpose and an understanding of why something is relevant to them. If they don't see the importance, they lose focus quickly.

Q5: How do you think an intervention like this could fit into the broader context of education at the Montessori Lyceum?
A5: The Thursday afternoon practicum is flexible, with two sessions of two hours. This could be a good opportunity for such an intervention. A visit to ENTRANCE could also be scheduled in the first period of 5 HAVO, as energy is covered in physics at that time.

Q6: Which topics within hydrogen and the energy transition do you think are most relevant and understandable for HAVO students?
A6: The basic principles of physics, such as the law of conservation of energy. The societal relevance is also important. Perhaps it could even fit into social studies.

Q7: What would make an intervention appealing to both students and teachers? Are there specific aspects or approaches you would recommend?
A7: Scheduling it on a Thursday afternoon would work well, as there would be time to possibly visit ENTRANCE. You could plan it at the beginning of the school year. Listening works for about 10 minutes; after that, students really need to be actively engaged.

Q8: Are there specific activities or methods (such as workshops, guest lectures, or practical assignments) that you think would work best for your students?
A8: Having someone else in front of the class is always better than their regular teacher—it makes it more engaging. Being active is key; just listening only works for about 10 minutes.

Q9: What opportunities do you see for integrating the intervention into the current curriculum? Are there specific modules or subjects where this would fit well?
A9: It would fit well within physics, chemistry, economics, and social studies.

Q10: How important is it to you that an intervention delivers measurable results, such as increased interest or awareness among students?
A10: It won't be particularly relevant to the students themselves, but I would find it interesting to see what effect it has. I will naturally notice in lessons whether they have learned something from it.

Q11: What support would you need to successfully implement an intervention, both at the teacher and school levels?
A11: There's always more material than time, so the intervention should fit seamlessly into the curriculum and contribute to what they need to learn. It would be more engaging if someone from the field comes in to show real-world applications—what's happening now, what challenges are there. If it can integrate concepts like efficiency, it would add a lot of value.

Q12: How important do you consider the collaboration between schools and organizations like ENTRANCE, and why?
A12: It helps make the concepts students learn more tangible and gives them insight into real-world applications. It's also beneficial to ensure they have up-to-date knowledge about current developments.

Q13: In your opinion, how can ENTRANCE make a unique contribution to education at your school?
A13: Organizing excursions where students can see things in action and engage in hands-on activities.

Q14: What do you think is the most important takeaway for students from a project on hydrogen and the energy transition?
A14: Not just a basic understanding, but also awareness of the opportunities and challenges related to hydrogen in the energy transition.

Q15: Are there specific barriers or challenges you foresee in organizing and executing an intervention, and how do you think these can be overcome?
A15: The biggest challenge is time. An extra hour would be welcome, but it should be linked to existing lesson material to ensure its relevance.

Q16: Do you have examples or ideas from previous projects that could serve as inspiration for this intervention?
A16: No

Q17: Is there anything else you think is important to share about your vision for education or this project?
A17: I believe the energy transition is necessary and that it's important to involve young people in it. This project can contribute to that, and I'm curious to see how it develops.

Interview vragen: [redacted] Docent Montessori Lyceum Groningen
Intro: Uitleg over dit project en de uitkijk op de interventie

Vragen over leerlingen een survey laten doen en mogelijk andere docenten interviewen.

Q1: Zou je kunnen omschrijven wat jouw rol is binnen het Montessori Lyceum?
A1: Ik ben docent scheikunde en mentor in 3 vwo, daarnaast ben ik vertrouwenspersoon.

Q2: Zijn er binnen het Montessori Lyceum al projecten of lessen (geweest) die betrekking hebben op de energietransitie of waterstof? Zo ja, wat zijn jouw ervaringen hiermee?
A2: Het zit standaard in het programma (ook in de methode) aan het eind van havo 4 en vwo 5. Ik heb het over de lange en korte koolstofkringloop en het versterkt broeikaseffect en we hebben het over 'oplossingen' waar onder waterstof, al zitten aan die oplossingen natuurlijk ook haken en ogen.

Q3: Hoe belangrijk vind je het dat leerlingen al tijdens hun middelbare schooltijd in aanraking komen met thema's zoals de energietransitie en waterstof?
A3: Ik vind het heel belangrijk. Leerlingen komen in het dagelijks leven steeds vaker in aanraking met onderwerpen als de energietransitie en waterstof, bijvoorbeeld in nieuwsartikelen. Het is essentieel dat ze deze informatie kritisch kunnen beoordelen en niet zomaar aannemen wat er op sociale media of in discussies gezegd wordt.

Q4: Wat zie je als de grootste uitdagingen bij het betrekken van HAVO leerlingen bij technische of duurzame onderwerpen zoals waterstof?
A4: De beperkte interesse van de leerlingen is een grote uitdaging. Sommige leerlingen vinden het lastig om zich in het onderwerp te verdiepen, zeker als ze niet direct een link zien met hun eigen leefwereld.

Q5: Welke onderwerpen binnen waterstof en de energietransitie denk je dat het meest relevant en begrijpelijk zijn voor HAVO leerlingen?
A5: Lastig, allemaal wel begrijpelijk maar je moet vooral niet te veel willen want dan zitten de hoofden 'vol'.

Q6: Wat zou een interventie aantrekkelijk maken voor zowel leerlingen als docenten? Zijn er specifieke elementen of aanpakken die je zou aanbevelen?
A6: Actief, zorgen dat de leerlingen bezig zijn.

Q7: Zijn er bepaalde activiteiten of methoden (zoals workshops, gastlessen of praktijkopdrachten) die je denkt dat het beste zouden werken voor jouw leerlingen?
A7: Korte opdrachten met snelle feedback.

Q8: Welke mogelijkheden zie je voor het integreren van de interventie binnen het huidige curriculum? Zijn er specifieke modules of vakken waar dit goed bij aansluit?
A8: Ja zeker, het hoofdstuk over energie wordt vaak gezien als saai, dus als er een actieve manier is om er mee aan de slag te gaan zou ik dat zeker gebruiken.

Q9: Hoe belangrijk is het voor jou dat een interventie meetbare resultaten oplevert, zoals een verhoogde interesse of bewustwording bij leerlingen?
A9: Vooral informatie over of de leerlingen het begrepen hebben.

Q10: Welke ondersteuning zou je nodig hebben om een interventie succesvol uit te voeren, zowel op docent- als op schoolniveau?
A10: Het moet het goed passen binnen het lesprogramma zonder extra werkdruk te creëren.

Q11: Hoe belangrijk vind je de samenwerking tussen scholen en organisaties zoals ENTRANCE?
A11: Altijd goed om dingen buiten de school naar binnen te halen, dat is ook één van de pijlers van montessori onderwijs.

Q12: Hoe kan ENTRANCE volgens jou een unieke bijdrage leveren aan het onderwijs op jouw school?
A12: Leuke werkvormen/lessen die in 1 les kunnen worden uitgevoerd (of een paar losse lessen achter elkaar).

Q13: Wat zou je als docent het belangrijkste vinden dat leerlingen meenemen uit een project over waterstof en de energietransitie?
A13: Een goede basiskennis over hoe de energietransitie werkt en wat waterstof hierin betekent.

Q14: Zijn er specifieke barrières of obstakels die je voorziet bij het organiseren en uitvoeren van een interventie, en hoe zouden deze volgens jou overwonnen kunnen worden?
A14: Kan ik zo niet bedenken, misschien dat ze het saai vinden. Zoals ik ook al eerder zei, zorg dat het actief is.

Q15: Heb je voorbeelden of ideeën uit eerdere projecten die kunnen dienen als inspiratie voor deze interventie?
A15: Nee

Q16: Is er iets anders dat je belangrijk vindt om te delen over jouw visie op onderwijs of dit project?
A16: Niet dat ik zo weet.

English version: [redacted] (Translated by Joppe Ireland)

Q1: Could you describe your role at the Montessori Lyceum?
A1: Chemistry teacher and mentor for a 3 VWO class, next to that also the school confidant.

Q2: Are there, or have there already been projects or lessons at the Montessori Lyceum that focus on the energy transition or hydrogen?
A2: It is a standard part of the program (also in the modules) at the end of HAVO 4 and VWO 5. I cover the long and short carbon cycle and the enhanced greenhouse effect, and we discuss 'solutions,' including hydrogen. Of course, these solutions also come with challenges.

Q3: How important do you think it is for students to encounter topics like the energy transition and hydrogen during their secondary education?
A3: I think it is very important. Students increasingly encounter topics like the energy transition and hydrogen in everyday life, for example, in news articles. It is essential that they can critically assess this information and not just accept what is said on social media or in discussions.

Q4: What do you see as the biggest challenges in engaging HAVO students with technical or sustainable topics like hydrogen?
A4: The limited interest of students is a major challenge. Some students find it difficult to engage with the subject, especially if they do not see a direct connection to their own lives.

Q5: Which topics within hydrogen and the energy transition do you think are most relevant and understandable for HAVO students?
A5: It's difficult to say. In general, everything can be made understandable, but you shouldn't try to cover too much, as their minds can get 'overloaded.'

Q6: What would make an intervention appealing to both students and teachers? Are there specific aspects or approaches you would recommend?
A6: It should be active and ensure that students are engaged.

Q7: Are there specific activities or methods (such as workshops, guest lectures, or practical assignments) that you think would work best for your students?
A7: Short assignments with quick feedback.

Q8: What opportunities do you see for integrating the intervention into the current curriculum? Are there specific modules or subjects where this would fit well?
A8: Yes, definitely. The energy chapter is often seen as boring, so if there is an active way to work with it, I would certainly use it.

Q9: How important is it to you that an intervention delivers measurable results, such as increased interest or awareness among students?
A9: Mainly, I would like to know whether students understood the topic.

Q10: What support would you need to successfully implement an intervention, both at the teacher and school levels?
A10: It must fit well within the lesson plan without creating additional workload.

Q11: How important do you consider the collaboration between schools and organizations like ENTRANCE, and why?
A11: It is always good to bring external knowledge into the school. That is also one of the pillars of Montessori education.

Q12: In your opinion, how can ENTRANCE make a unique contribution to education at your school?
A12: Engaging lesson formats or activities that can be carried out within a single lesson (or a few consecutive lessons).

Q13: What do you think is the most important takeaway for students from a project on hydrogen and the energy transition?
A13: A solid basic understanding of how the energy transition works and what role hydrogen plays in it.

Q14: Are there specific barriers or challenges you foresee in organizing and executing an intervention, and how do you think these can be overcome?
A14: I can't think of any right away, but maybe students will find it boring. As I mentioned earlier, ensuring the intervention is interactive is crucial.

Q15: Do you have examples or ideas from previous projects that could serve as inspiration for this intervention?
A15: No.

Q16: Is there anything else you think is important to share about your vision for education or this project?
A16: Not that I can think of.

Interview vragen: [redacted] Docent Technasium Hondsrug College

Intro: Uitleg over dit project en de uitkijk op de interventie

Vragen over leerlingen een survey laten doen en mogelijk andere docenten interviewen.

Q1: Zou je kunnen omschrijven wat jou rol inhoud bij het Hondsrug College?
A1: [redacted] docent en coördinator Technasium, met focus op het enthousiasmeren van leerlingen voor techniek. Hij houdt zich bezig met het organiseren van contact tussen bedrijven en leerlingen, en richt zich op maatschappelijke uitdagingen zoals de energietransitie. Zijn rol omvat ook begeleiding van projecten en het zoeken naar oplossingen samen met de leerlingen.

Q2: Wat zijn volgens jou de belangrijkste doelen van het Technasium onderwijs?
A2: Om leerlingen beter voor te bereiden op de maatschappij door hen te leren zelfstandig te denken en buiten de kaders te opereren. Het gaat niet alleen om kennisoverdracht maar ook om het ontwikkelen van praktische vaardigheden en het begrijpen van maatschappelijke impact.

Q3: Hoe zie jij de samenwerking met bedrijven of organisaties (zoals ENTRANCE) binnen Technasium projecten?
A3: De samenwerking is essentieel en richt zich op relevante, uitdagende projecten die aansluiten bij de interesses van leerlingen. [redacted] zoekt vaak eerst naar wat leerlingen willen en past hier een probleemstelling bij aan, in plaats van andersom. Dit maakt de projecten aantrekkelijker voor zowel bedrijven als leerlingen.

Q4: Zijn er op het Hondsrug College projecten die over waterstof of de energietransitie gaan? Of heb je hier zelf ervaring mee?
A4: Ja, er is een project geweest waarbij VWO-3 leerlingen hebben gewerkt aan het gebruik van waterstof in vervoermiddelen.

Q5: Hoe belangrijk vind je het dat leerlingen al tijdens hun middelbare schooltijd in aanraking komen met thema's zoals waterstof en de energietransitie?
A5: Zeer belangrijk, omdat het hen bewust maakt van de maatschappelijke en technologische uitdagingen en kansen die de energietransitie biedt.

Q6: Wat denk je dat de grootste uitdagingen zijn om HAVO leerlingen enthousiast te maken voor waterstof en de energietransitie?
A6: HAVO leerlingen vinden abstracte onderwerpen zoals de energietransitie vaak ingewikkeld. Toepasbaarheid en directe relevantie voor hun eigen omgeving zijn essentieel om hun interesse te wekken.

Q7: Welke aanpak of activiteiten werken volgens jou het beste om HAVO leerlingen te betrekken bij technische onderwerpen zoals waterstof?
A7: Praktische, toepasbare opdrachten, zoals het ontwerpen van oplossingen voor boerderijen om zelf energie op te wekken met waterstof.

Q8: Hoe zorg jij ervoor dat projecten aansluiten bij de leerlingen?
A8: Door leerlingen zelf mee te laten denken over projecten en problemen, en projecten te koppelen aan hun interesses en toekomstplannen.

Q9: Zijn er bepaalde onderwerpen of thema's binnen waterstof die je denkt dat interessant of begrijpelijk/toepasselijk zijn voor HAVO leerlingen?
A9: Waterstof als brandstof voor auto's is een begrijpelijk en interessant onderwerp voor HAVO leerlingen.

Q10: Wat zijn volgens jou de grootste uitdagingen bij het organiseren van Technasium projecten, zoals logistiek of het vinden van geschikte opdrachtgevers?
A10: Logistieke uitdagingen zoals het verplaatsen van grote projecten binnen de school, en beperkte tijd en middelen binnen het rooster.

Q11: Hoe zouden docenten en leerlingen kunnen worden ondersteund bij complexe onderwerpen zoals waterstof en de energietransitie?
A11: Door toegang te bieden tot experts, duidelijke bronnen en concrete voorbeelden, en door leerkrachten te trainen in nieuwe technische onderwerpen.

Q12: Heb je tips of ideeën voor hoe ENTRANCE een meerwaarde kan bieden aan projecten voor middelbare scholen?
A12: Een locatie zoals ENTRANCE kan leerlingen inspireren door hen in een technische omgeving te laten werken en problemen op te lossen.

Q13: Wat voor feedback krijg je meestal van leerlingen en docenten over Technasium projecten?
A13: Leerlingen waarderen de praktische aanpak en zien vaak grote waarde in Technasium voor hun toekomst. Voor sommigen is het de reden geweest dat ze hun diploma hebben gehaald. 98% van zijn oud leerlingen doet iets in de techniek, gaat ook nog naar afstudeerprojecten. Heel veel contact met oud leerlingen, ook naar lessen en scholen. Veel feedback dat leerlingen heel veel baat hebben gehad bij Technasium.

Q14: Wat maakt een Technasium project volgens jou echt succesvol?
A14: Wanneer het een blijvende impact heeft op leerlingen en hen inspireert voor hun toekomst.

Q15: Zijn er bepaalde lessen of projecten die echt indruk hebben gemaakt op jou of de leerlingen?
A15: Het project met waterstof als brandstof voor voertuigen heeft indruk gemaakt door de betrokkenheid en enthousiasme van de leerlingen.

Q16: Wat zou je aanraden voor het ontwerpen van een interventie die HAVO leerlingen meer bewust maakt en interesseert over waterstof in de energietransitie?
A16: Prikkel ze om er echt over na te denken. Kijken of zij met een probleem zelf kunnen komen, dan daar op verder werken. Ontwerp interactieve en toepasselijke opdrachten die aansluiten bij de belevingswereld van de leerlingen. Laat hen zien hoe waterstof maatschappelijke impact heeft.

Q17: Zijn er specifieke voorbeelden of technieken die je hebt gebruikt en die ik kan toepassen in mijn eigen interventie?
A17: Werk met echte problemen en betrek experts. Zorg dat leerlingen zich serieus genomen voelen door hen actief mee te laten denken en te begeleiden.

Q18: Hoe zou ik ervoor kunnen zorgen dat een interventie blijvend impact heeft op de leerlingen?
A18: Door persoonlijke interesse en begeleiding te tonen, en door de interventie aan te laten sluiten op maatschappelijke uitdagingen.

Q19: Is er iets anders dat je belangrijk vindt om te delen over je werk of je visie op onderwijs en de energietransitie?
A19: Het doel van onderwijs zou meer moeten zijn dan alleen voorbereiding op examens; het zou leerlingen moeten voorbereiden op hun plek in de maatschappij.

English version: [redacted] (Translated by Joppe Ireland)

Q1: What is your role at the Hondsrug College?
A1: [redacted] is a teacher and Technasium coordinator, focusing on motivating students for technology. He organizes contact between companies and students and addresses societal challenges such as the energy transition. His role also includes guiding projects and finding solutions with students.

Q2: What do you consider the main goals of Technasium education?
A2: The goal is to better prepare students for society by teaching them to think independently and operate outside the box. It’s not just about transferring knowledge but also about developing practical skills and understanding societal impact.

Q3: How do you view the collaboration with companies or organizations (like ENTRANCE) within Technasium projects?
A3: Collaboration is essential and focuses on relevant, challenging projects that align with students' interests. [redacted] often first looks at what students want and tailors the problem statement accordingly, making the projects more appealing to both companies and students.

Q4: Are there projects at Hondsrug College related to hydrogen or the energy transition? Or do you have personal experience with them?
A4: Yes, there was a project where VWO students worked on using hydrogen in vehicles.

Q5: How important is it for students to be exposed to topics like hydrogen and the energy transition during their secondary education?
A5: It is very important because it raises awareness of the societal and technological challenges and opportunities presented by the energy transition.

Q6: What are the biggest challenges in getting HAVO students enthusiastic about hydrogen and the energy transition in your opinion?
A6: HAVO students often find abstract topics like the energy transition challenging. Making the subject applicable and directly relevant to their environment is crucial for generating interest.

Q7: Which approaches or activities would you think work best for involving HAVO students in technical topics like hydrogen?
A7: Practical and applicable assignments, such as designing solutions for farms to generate their energy using hydrogen.

Q8: How do you ensure that projects align with the student's needs?
A8: By involving students in thinking about the projects and problems and connecting projects to their interests and future plans.

Q9: Are there specific topics or themes within hydrogen that interest or apply to HAVO students?
A9: Hydrogen as a fuel for cars is a topic that is both understandable and interesting for HAVO students.

Q10: What are the biggest challenges in organizing Technasium projects, such as logistics or finding suitable clients?
A10: Logistical challenges, such as moving large projects within the school, and limited time and resources in the schedule. However, finding clients is not usually an issue.

Q11: How can teachers and students be supported with complex topics like hydrogen and the energy transition?
A11: By providing access to experts, clear resources, and concrete examples, and by training teachers in new technical subjects.

Q12: How can teachers and students be supported with complex topics like hydrogen and the energy transition?
A12: A location like ENTRANCE can inspire students by letting them work in a technical environment and solve real-world problems.

Q13: What feedback do you usually get from students and teachers about Technasium projects?
A13: Students appreciate the practical approach and often see significant value in Technasium for their future. For some, it has been the reason they managed to graduate.

Q14: What makes a Technasium project truly successful, in your opinion?
A14: When it has a lasting impact on students and inspires them for their future.

Q15: Are there specific lessons or projects that have significantly impacted you or the students?
A15: The project involving hydrogen as a fuel for vehicles left a strong impression due to the students' engagement and enthusiasm.

Q16: What would you recommend for designing an intervention to raise awareness and interest in hydrogen and the energy transition among HAVO students?
A16: Design interactive and relevant assignments that connect to the students' experiences. Show them the societal impact of hydrogen and let them explore how they can contribute to solutions.

Q17: Are there specific examples or techniques you've used that I could apply in my intervention?
A17: Work on real problems and involve experts. Ensure students feel taken seriously by actively engaging with them and guiding them.

Q18: How can I ensure that an intervention has a lasting impact on students?
A18: By showing genuine interest and offering guidance, and by linking the intervention to real-world challenges.

Q19: Is there anything else you find important to share about your work or your vision on education and the energy transition?
A19: Education should aim for more than just preparing students for exams; it should prepare them for their role in society.

Interview vragen: [redacted] Docent Hondsrug College

Intro: Uitleg over dit project en de uitkijk op de interventie

Q1: Zou je kunnen omschrijven wat jouw rol is binnen het Hondsrug College?
A1: Technasium docent en technisch onderwijsassistent. Mijn rol is zowel lesgeven als het leveren van verdiepende technische kennis aan de klas. Mijn achtergrond is in bouwkunde.

Q2: Zijn er binnen het Hondsrug College al projecten of lessen (geweest) die betrekking hebben op de energietransitie of waterstof? Zo ja, wat zijn jouw ervaringen hiermee?
A2: Ja, energietransitie komt eigenlijk wel in elk project terug. We kijken dan naar hoe je stroom en warmte zo duurzaam mogelijk kunt regelen. Persoonlijk een lezing in Delft bijgewoond over waterstof en de rol ervan in de energietransitie. Verder zijn er leerlingen bezig met waterstof, bijvoorbeeld in een waterstofauto, om meer inzicht te krijgen in hoe het werkt.

Q3: Hoe belangrijk vind je het dat leerlingen al tijdens hun middelbare schooltijd in aanraking komen met thema's zoals de energietransitie en waterstof?
A3: Het is een heel actueel en belangrijk onderwerp, maar leerlingen moeten al zoveel weten. Een basiskennis over waterstof en de energietransitie is belangrijk voor iedereen, maar niet iedereen hoeft diepere kennis te hebben. Bij technasium is diepte belangrijker, deze leerlingen zullen waarschijnlijk later met deze thema's te maken krijgen. Voor andere richtingen is een algemeen begrip voldoende.

Q4: Wat zie je als de grootste uitdagingen bij het betrekken van HAVO leerlingen bij technische of duurzame onderwerpen zoals waterstof? Hoe los je dit op?
A4: Interesse is erg lastig, zeker in de regio in Emmen. Duurzaamheid staat niet zo hoog. Bij HAVO leerlingen zie je dat meer dan VWO.

Q5: Hoe denkt u dat een interventie als deze zou passen in de bredere context van het onderwijs op het Hondsrug College?
A5: Zeker weten, gastdocenten werken altijd goed. Zorgen dat ze genoeg getriggerd worden en leuk opzet zou het erg goed passen.

Q6: Welke onderwerpen binnen waterstof en de energietransitie denk je dat het meest relevant en begrijpelijk zijn voor HAVO leerlingen?
A6: De gemiddelde jongen zullen veel hebben met transport, meiden over het algemeen iets lastiger, niet zeker hoe je die goed kan betrekken. De energiedichtheid laten zien, wat er allemaal mee kan.

Q7: Wat zou een interventie aantrekkelijk maken voor zowel leerlingen als docenten? Zijn er specifieke elementen of aanpakken die je zou aanbevelen?
A7: Zorg dat de interventie interessant en actief is. Meer gesettelde docenten kunnen het lastig vinden om hulp aan te nemen, dus een interventie zou moeten helpen zonder belerend over te komen. Bijvoorbeeld een soort handleiding, zodat ze leerlingen kunnen ondersteunen als die vragen hebben.

Q8: Zijn er bepaalde activiteiten of methoden (zoals workshops, gastlessen of praktijkopdrachten) die je denkt dat het beste zouden werken voor jouw leerlingen?
A8: Voorbeelden uit hun eigen praktijk werken goed. Laat ze zien hoe waterstof direct invloed heeft op dingen die ze kennen en doen. Zelf dingen doen werkt beter dan alleen luisteren.

Q9: Welke mogelijkheden zie je voor het integreren van de interventie binnen het huidige curriculum? Zijn er specifieke modules of vakken waar dit goed bij aansluit?
A9: Het kan op veel plekken passen: scheikunde, natuurkunde, maatschappijleer en aardrijkskunde. In het technasium zou het meer over toepassing gaan en minder over het maatschappelijke aspect.

Q10: Hoe belangrijk is het voor jou dat een interventie meetbare resultaten oplevert, zoals een verhoogde interesse of bewustwording bij leerlingen?
A10: Voor mij persoonlijk is dat niet heel belangrijk. Bij het technasium draait het vooral om ervaring en of de leerlingen iets geleerd hebben. In reguliere vakken kan meetbaarheid belangrijker zijn.

Q11: Welke ondersteuning zou je nodig hebben om een interventie succesvol uit te voeren, zowel op docent- als op schoolniveau?
A11: Het zou een onderdeel van het curriculum kunnen worden, vooral bij technasium. Gastlessen zijn waardevol en excursies naar ENTRANCE zouden een goede aanvulling zijn. Het koppelen van een opdracht voor en na de excursie kan ervoor zorgen dat de leerlingen er echt iets uit halen.

Q12: Hoe belangrijk vind je de samenwerking tussen scholen en organisaties zoals ENTRANCE?
A12: Heel belangrijk. Excursies zorgen vaak voor veel meer interesse, vooral als er een opdracht aan gekoppeld is. Dan blijft het beter hangen.

Q13: Hoe kan ENTRANCE volgens jou een unieke bijdrage leveren aan het onderwijs op jouw school?
A13: ENTRANCE is een waardevolle plek, met veel te zien en een prikkelende omgeving. Als er veel visuele en praktische demonstraties zijn, maakt dat veel indruk op de leerlingen.

Q14: Wat zou je als docent het belangrijkste vinden dat leerlingen meenemen uit een project over waterstof en de energietransitie?
A14: Bewustwording, ze hoeven geen diepgaande kennis te hebben, maar wel weten wat het is en mee kunnen praten en denken.

Q15: Zijn er specifieke barrières of obstakels die je voorziet bij het organiseren en uitvoeren van een interventie, en hoe zouden deze volgens jou overwonnen kunnen worden?
A15: Orde houden en structuur geven is belangrijk. HAVO leerlingen hebben duidelijke richtlijnen nodig, wat wordt er van hen verwacht, wat zijn de stappen, en wat doen ze als ze klaar zijn? Zonder duidelijke structuur raken ze afgeleid.

Q16: Heb je voorbeelden of ideeën uit eerdere projecten die kunnen dienen als inspiratie voor deze interventie?
A16: Het Esdal College heeft een proefopstelling waar een hometrainer stroom opwekt, die een waterstofinstallatie aandrijft en een racebaan laat werken. Dat laat het hele proces van energie opwekking tot gebruik zien.

Q17: Is er iets anders dat je belangrijk vindt om te delen over jouw visie op onderwijs of dit project?
A17: Bewustwording en interesse zijn het belangrijkst. Onderwerpen die ze echt niet leuk vinden, kun je ze niet door de strot duwen. Alles valt of staat met interesse en hoe je het koppelt aan hun leefwereld. Als je wilt, kan ik altijd feedback geven op je interventie.

English version: [redacted] (Translated by Joppe Ireland)

Q1: Could you describe your role at the Montessori Lyceum?

A1: Technasium teacher and technical education assistant. My role includes both teaching and providing in-depth technical knowledge to the class. My background is in construction engineering.

Q2: Are there, or have there already been projects or lessons at the Montessori Lyceum that focus on the energy transition or hydrogen?

A2: Yes, the energy transition comes up in almost every project. We look at how to manage electricity and heat as sustainably as possible. Personally attended a lecture in Delft on hydrogen and its role in the energy transition. Additionally, students have worked on hydrogen-related projects, such as a hydrogen-powered car, to gain more insight into how it works.

Q3: How important do you think it is for students to encounter topics like the energy transition and hydrogen during their secondary education?

A3: It is a very current and important topic, but students already have a lot to learn. A basic knowledge of hydrogen and the energy transition is essential for everyone, but not everyone needs an in-depth understanding. In Technasium, this depth is more relevant, as these students are more likely to work with these topics in the future. For other study paths, a general understanding is sufficient.

Q4: What do you see as the biggest challenges in engaging HAVO students with technical or sustainable topics like hydrogen?

A4: Generating interest is quite difficult, especially in the Emmen region. Sustainability is not a high priority for many students here. This is more apparent among HAVO students than VWO students.

Q5: How do you think an intervention like this could fit into the broader context of education at the Montessori Lyceum?

A5: Absolutely, guest lecturers always work well. If the students are engaged and the lesson is set up in an interesting way, it would fit very well.

Q6: Which topics within hydrogen and the energy transition do you think are most relevant and understandable for HAVO students?

A6: Most boys will be interested in transport-related applications, like hydrogen-powered cars. For girls, it might be a bit more difficult to find a direct connection, not sure how to engage them best. Showing the energy density of hydrogen and what can be done with it could be useful.

Q7: What would make an intervention appealing to both students and teachers? Are there specific aspects or approaches you would recommend?

A7: The intervention should be engaging and active. More experienced teachers might struggle with accepting external help, so the intervention should support them rather than come across as instructive. For example, providing a guide so teachers can support students if they have questions.

Q8: Are there specific activities or methods (such as workshops, guest lectures, or practical assignments) that you think would work best for your students?

A8: Real-world examples that connect to their own experiences work well. Showing them how hydrogen directly impacts things they know and do is important. Hands-on activities are much more effective than just listening.

Q9: What opportunities do you see for integrating the intervention into the current curriculum? Are there specific modules or subjects where this would fit well?

A9: It could fit into several subjects: chemistry, physics, social studies, and geography. In Technasium, the focus would be more on application rather than the societal aspects.

Q10: How important is it to you that an intervention delivers measurable results, such as increased interest or awareness among students?
A10: Personally, it's not very important. In Technasium, the main goal is experience and whether students have learned something. For regular subjects, measurable outcomes might be more relevant.

Q11: What support would you need to successfully implement an intervention, both at the teacher and school levels?
A11: It should ideally be part of the curriculum, especially in Technasium. Guest lectures are valuable, and excursions to ENTRANCE would be a great addition. Connecting the excursion to an assignment before and after could ensure that students take something meaningful from it.

Q12: How important do you consider the collaboration between schools and organizations like ENTRANCE, and why?
A12: Very important. Excursions often generate much more interest, especially when paired with an assignment. That way, the information sticks better.

Q13: In your opinion, how can ENTRANCE make a unique contribution to education at your school?
A13: ENTRANCE is a valuable place, with a lot to see and a stimulating environment. If there are many visual and practical demonstrations, it leaves a strong impression on students.

Q14: What do you think is the most important takeaway for students from a project on hydrogen and the energy transition?
A14: Awareness. They don't need deep technical knowledge, but they should understand what hydrogen is, what it can do, and how it fits into the energy transition.

Q15: Are there specific barriers or challenges you foresee in organizing and executing an intervention, and how do you think these can be overcome?
A15: Maintaining order and providing structure is key. HAVO students need clear guidelines: what is expected of them, what are the steps, and what should they do when they finish? Without a clear structure, they get distracted.

Q16: Do you have examples or ideas from previous projects that could serve as inspiration for this intervention?
A16: Esdal College has a setup where a stationary bike generates electricity, which then powers a hydrogen installation and a race track. This setup effectively demonstrates the full process from energy generation to practical application.

Q17: Is there anything else you think is important to share about your vision for education or this project?
A17: Awareness and interest are the most crucial aspects. You can't force students to engage with topics they don't find interesting. Everything depends on how well you connect it to their world. If you need feedback, feel free to ask, and I'll be happy to help.

Appendix 9: Expert Interviews

Interview vragen: [redacted] Scholierenacademie

Intro: Uitleg over het concept van interventies (naar aanleiding van mail), met hierbij ook een uitleg van mijn onderzoek.

Q1: Welke rol vervul je binnen de RUG en wat houd deze rol in?
A1: Verantwoordelijk voor profielwerkstukken bij de Scholieren Academie van de RUG. Ondersteunt leerlingen met hulp van studentenassistenten, die vragen beantwoorden en experimenten begeleiden. Daarnaast werk voor Science Linx, dat scholieren interesseert voor bèta en techniek. Een voorbeeld is de "Jouw Energie van Morgen" truck, die scholen bezoekt.

Q2: Wat voor ervaringen heb je met het werken met middelbare scholieren in (educatieve) interventies?
A2: Werk met middelbare scholieren aan profielwerkstukken, waarbij studentenassistenten scholieren begeleiden. Het werk met Studenten worden gewaardeerd vanwege hun leeftijd en praktische ervaring. Dit maakt de interactie toegankelijker en relevanter voor scholieren.

Q3: Wat waren de belangrijkste doelen van de interventies waaraan je hebt meegewerkt, en hoe werden de resultaten van deze doelen gemeten?
A3: Het primaire doel is leerlingen inzicht te geven in onderzoeksvaardigheden en interesse te wekken voor wetenschap. Er wordt geen uitgebreid onderzoek gedaan naar lange termijnresultaten, maar scholen vragen regelmatig om herhaling van de interventies. Ook word er wel om feedback gevraagd van docenten.

Q4: Hoe werd ervoor gezorgd dat de interventies boeiend en toegankelijk waren voor middelbare scholieren?
A4: Het is erg belangrijk dat de interventie relevant is. Het koppelen aan hun curriculum en het laten aansluiten bij hun huidige projectfase helpt de interesse te behouden. Praktische activiteiten gecombineerd met een verhaal maakt leerlingen meer betrokken.

Q5: Welke methoden of activiteiten (bijvoorbeeld workshops, praktische projecten) waren het meest effectief om de aandacht van leerlingen te trekken en houden?
A5: Een mix van uitleg en praktische opdrachten werkt het beste. Voorbeelden zijn het maken van zonnecellen en gebruik van interactieve les-vormen. Deze activiteiten moeten wel binnen een lesuur passen.

Q6: Hoe waren de interventies afgestemd op het schoolcurriculum en de verwachtingen van de docenten?
A6: Het liefst sluiten interventies aan op leerdoelen. Scholen plannen de sessies vaak zelf in, maar het is effectiever als ze op het juiste moment plaatsvinden, zoals wanneer leerlingen een project voorbereiden.

Q7: Wat waren de grootste uitdagingen bij de implementatie van de interventies?
A7: Uitdagingen zoals drukke roosters van scholen en planning zijn vaak een obstakel. Het succes van interventies hangt ook af van hoe goed ze aansluiten bij het curriculum en de meerwaarde die scholen erin zien. Ze vinden het soms als lastig om genoeg docenten voor de klas te hebben, moet passen en meerwaarde hebben.

Q8: Was er wel eens weerstand of een gebrek aan interesse van leerlingen of docenten?
A8: Soms hebben leerlingen of docenten weinig interesse als de interventie niet relevant lijkt. Het benadrukken van het belang van het onderwerp en een praktische aanpak kunnen dit verminderen.

Q9: Waren er logistieke uitdagingen, zoals planning of hulpmiddel problemen? Als wel, hoe waren deze aangepakt?
A9: Communicatie met scholen is soms lastig vanwege drukke docenten. Flexibiliteit en goede planning helpen hierbij. Studentenassistenten worden recentelijk goed voorbereid om eventuele problemen te minimaliseren. Niet iedereen is altijd even blij, kan lastig zijn met moeilijke klassen. Op de lange termijn is geld een grote uitdaging.

Q10: Wat voor meetbare resultaten zijn er gebruikt om het succes van interventies te beoordelen?
A10: Docenten geven feedback en nodigen vaak uit voor vervolginterventies. Langetermijneffecten worden niet onderzocht.

Q11: Heeft de interventie geleid tot veranderingen in de lange termijn, zoals een grotere interesse in (technische) vakken of een verbeterd begrip van de onderwerpen bij leerlingen? Zo ja, waaruit bleek dit?
A11: Dit wordt niet specifiek gemeten, maar positieve reacties en terugkerende verzoeken wijzen op succes. De Nederlandse stroom naar Béta opleidingen was erg klein in het verleden, is nu erg gegroeid, maar het verband is niet onderzocht. Er is persoonlijke ervaring met beïnvloede keuzen, maar geen onderzoek.

Q12: Hoe heeft feedback van leerlingen en docenten invloed gehad op toekomstige versies van interventies?
A12: Feedback wordt verwerkt in nieuwe versies van workshops, bijvoorbeeld kleine logistieke verbeteringen en aanpassingen in presentaties. Ook vanuit de Pabo opleidingen werden punten ontwikkelt.

Q13: Welk advies zou je geven voor het ontwerpen van een interventie om middelbare scholieren kennis te laten maken met onderwerpen zoals de energietransitie, en in het bijzonder waterstof in de energie transitie?
A13: Zorg voor een praktische activiteit en benadruk hoopvolle aspecten van de energietransitie. Combineer dit met uitleg over wat leerlingen zelf kunnen doen. Geef ze iets mee dat ze zelf zouden kunnen doen. Kijk of je zorgen op kan lossen, hou het praten kort en kijk of je aan kan sluiten op leerdoelen.

Q14: Wat zijn veelgemaakte fouten die vermeden kunnen worden bij het werken met deze leeftijdsgroep?
A14: Eerder besproken suggesties als het koppelen aan leerdoelen en flexibel plannen. [redacted] *gaat er nog even over na denken en er komt via de mail verder antwoord op.*

English version: [redacted] (Translated by Joppe Ireland)

Q1: What is your role at the University of Groningen (RUG), and what does it entail?
A1: [redacted] works at the Scholieren Academie, focusing on guiding high school students with their final school research projects (profielwerkstukken). She coordinates student assistants who help students with questions and experiments. She also works for Science Linx, which aims to inspire students in STEM fields, using tools like the "Jouw Energie van Morgen"-truck, a mobile education truck.

Q2: What experience do you have working with high school students in educational interventions?
A2: [redacted] collaborates with students on their final projects, supported by student assistants. These assistants are relatable to high school students due to their age and practical experience, making interactions engaging and effective.
Q3: What were the main goals of the interventions you participated in, and how were the outcomes measured?
A3: The main goal was to introduce students to scientific research skills and spark interest in STEM. Although long-term impact is not measured, frequent requests from schools for repeat interventions indicate their success. Teachers are also approached to receive some feedback.
Q4: How were the interventions made engaging and accessible for high school students?
A4: Interventions were closely aligned with the curriculum and current projects. Combining theoretical explanations with practical activities made the sessions engaging and relevant.

Q5: What methods or activities were most effective in maintaining student interest?
A5: Hands-on activities like building solar cells, combined with interactive teaching methods, were most effective. Activities should fit within a class lesson hour.

Q6: How were the interventions aligned with the school curriculum and teacher expectations?
A6: Schools were encouraged to integrate the interventions into their lesson plans. Sessions were most successful when timed to add on information during relevant phases in students' learning, such as project preparation.

Q7: What were the biggest challenges in implementing the interventions?
A7: Scheduling and logistical challenges, such as coordinating with schools' busy schedules, were common. Aligning the content with the curriculum was important for getting acceptance by teachers.

Q8: Did you encounter resistance or a lack of interest from students or teachers?
A8: Sometimes teachers or students had low interest, this was often due to the idea that it was irrelevant. Demonstrating the importance of the topic and making activities practical helped with this.

Q9: Were there logistical challenges, such as scheduling or resource problems? How were they addressed?
A9: Communication with busy teachers and schools was challenging. Flexibility and good preparation by student assistants were key to overcoming these issues.

Q10: What measurable results were used to assess the success of the interventions?
A10: Success was measured through teacher feedback and repeated invitations for future sessions. Long-term impact is not measured.

Q11: Did the intervention lead to long-term changes, such as increased interest in STEM fields?
A11: Long-term outcomes were not measured, but recurring requests from schools suggest a positive impact. There was personal experience with cases of influenced choices, but no research was done into this.

Q12: How did feedback from students and teachers influence future interventions?
A12: Feedback was incorporated into new workshops, such as improving logistical arrangements and refining teaching methods.

Q13: What advice would you give for designing an intervention to introduce high school students to topics like the energy transition, especially hydrogen technologies?
A13: Focus on practical activities and highlight optimistic aspects of the energy transition. Show students what they can do to make a difference. Combine this with explanations on what the students can do themselves and give them something they can do. If they have worries, see if you can solve them, don't talk too long and see if you can make it relatable.

Q14: What are common mistakes to avoid when working with this age group?
A14: Aligning activities with the curriculum and flexible planning, more to come though later mail contact.

Interview vragen: [redacted] ENTRANCE

Intro: Kort over progressie en ontwikkelingen praten

Q1: Wat is je rol binnen ENTRANCE en hoe zou je de inhoud/werking van deze rol beschrijven?
A1: Het strategisch en tactisch organiseren van leren binnen de energietransitie, waarbij studenten, onderzoekers, en het werkveld worden samengebracht. Dit gebeurt vooral binnen learning communities in de Innovatiewerkplaats ENTRANCE. [redacted] focust op de verbinding tussen onderwijs en het werkveld, aandacht voor leerinterventies die passen bij actuele kwesties in de energietransitie.

Q2: Wat voor ervaringen zijn er binnen ENTRANCE met het werken met middelbare scholieren in (educatieve) interventies?
A2: De focus ligt op het enthousiasmeren van scholieren voor de energietransitie door middel van multidisciplinaire projecten. Activiteiten variëren van spellen zoals de WE-Energy Game tot workshops, rondleidingen en begeleiding bij profielwerkstukken. Daarnaast worden hackathons georganiseerd in samenwerking met Technasium scholen in Groningen.

Q3: Wat waren de belangrijkste doelen van de interventies waaraan je hebt meegewerkt, en hoe werden de resultaten van deze doelen gemeten?
A3: Het hoofddoel is het bewustmaken van scholieren over de veelzijdigheid van de energietransitie. Metingen richten zich op hoe scholieren de energietransitie begrijpen en of ze inzien dat het verder reikt dan alleen technische aspecten. Systematische impactmetingen ontbreken echter door tijd- en resourcebeperkingen.

Q4: Hoe werd ervoor gezorgd dat de interventies boeiend en toegankelijk waren voor middelbare scholieren?
A4: Interventies worden gekoppeld aan schoolmodules zodat leerlingen er punten voor kunnen krijgen. Een combinatie van leuk, spannend en nuttig werkt het beste, samen met een wedstrijdelement. Projecten worden ingebed in de opleiding, wat zowel motivatie als structuur biedt.

Q5: Welke methoden of activiteiten (bijvoorbeeld workshops, praktische projecten) waren het meest effectief om de aandacht van leerlingen te trekken en houden?
A5: Effectieve methoden zijn projectmatige opdrachten waarbij leerlingen een probleem moeten oplossen. Workshops en lezingen worden gegeven als ondersteuning bij deze opdrachten. Experts worden ingezet om te begeleiden en te helpen bij de uitvoering.

Q6: Hoe waren de interventies afgestemd op de onderwijsdoelen en verwachtingen van scholen en docenten?
A6: Interventies worden afgestemd op bestaande curricula door samen te werken met middelbare scholen. Projecten worden vaak verwerkt in vakken of modules, vooral via samenwerking met Stichting Technasium.

Q7: Wat waren de grootste uitdagingen bij de implementatie van interventies en hoe zijn deze opgelost?
A7: Een grote uitdaging is het gebrek aan tijd bij docenten en scholen. Jaarplanningen zitten vaak vol, en docenten hebben weinig ruimte om nieuwe initiatieven op te nemen. Een mogelijke oplossing is samenwerking met schooldirecties om interventies vroegtijdig in de planning op te nemen.

Q8: Was er wel eens weerstand of een gebrek aan interesse van leerlingen, docenten of scholen en hoe werd hier mee omgegaan?
A8: Bij leerlingen is de belangstelling niet altijd groot, vooral als een interventie hen niets oplevert. Bij docenten is vaak sprake van een gebrek aan tijd en prioriteit. Actieve weerstand komt weinig voor, maar passieve desinteresse kan een obstakel zijn.

Q9: Welke logistieke of praktische obstakels komen vaak voor bij het plannen en uitvoeren van interventies?
A9: Gebrek aan communicatie vanuit leraren en scholen.

Q10: Wat voor meetbare resultaten zijn er gebruikt om het succes van interventies te beoordelen?
A10: Er zijn geen systematische meetbare resultaten, maar informele feedback van leerlingen en docenten wordt wel gebruikt.

Q11: Hoe heeft feedback van leerlingen en docenten invloed gehad op toekomstige versies van interventies?
A11: Geen specifieke feedback genoemd, maar informele input wordt gebruikt om interventies aan te passen.

Q12: Is er in eerdere projecten significante veranderingen in kennis of interesse van leerlingen waargenomen? Zo ja, hoe was dit zichtbaar?
A12: Geen structurele metingen gedaan, maar leerlingen die terugkomen voor vervolgactiviteiten worden wel gezien als een indicatie van succes

Q13: Waarom denk je dat waterstof een belangrijk onderwerp is voor middelbare scholieren om over te leren?
A13: Noord-Nederland is door Europa aangewezen als Hydrogen Valley, met een focus op waterstof als belangrijke energiedrager. Naar verwachting zullen in de toekomst veel banen ontstaan in de waterstofsector, wat van groot belang is voor de regionale economie.

Q14: Welke aspecten van waterstof in de energie transitie, vind je zelf het meest geschikt voor middelbare scholieren?
A14: Wat de toepassingsmogelijkheden zijn van waterstof. Mensen denken vaak dat je het in de brand moet steken, dat het gevaarlijk is en een probleem kan zijn. In de volle breedte dat mensen weten wat de mogelijkheden zijn en waarom we dit doen en wat het betekend. Bij voorkeur gekoppeld aan een deel van hun curriculum. Vervolgens een vraag stellen dat bij een project zou kunnen passen en in hun curriculum past. Hoe kunnen ze binnen waterstof en de energie transitie zelf waterstof toepassen. Ze die volle breedte laten zien, de rol van waterstof in de energie transitie.

Q15: Welk advies zou je geven voor het ontwerpen van een interventie die de bewustwording en interesse voor waterstof en de energietransitie vergroot voor middelbare scholieren?
A15: Als je focust op een project bvb waar ze samenwerken, zorg er voor naar de motivatietheorieën van Daisy en Ryan. De wat zachtere kant van leren. Ook motivatietheorieën in complexe contexten. Aansluiting op de belevingswereld van de leerlingen is heel belangrijk. Aansluiting op de doelgroep. Informatie die ze echt nodig hebben.

Q16: Wat zijn veelgemaakte fouten die vermeden kunnen worden bij het werken met deze leeftijdsgroep?
A16: Dat wij denken dat iedereen net zo enthousiast is als ons, kennis van de doelgroep, of niet hebben van die kennis is een valkuil. Een veelgemaakte fout is het gebruik van te complexe informatie. Het is belangrijk om onderwerpen simpel en overzichtelijk te houden. De spanningsboog van leerlingen is kort, dus informatie moet bondig en relevant zijn.

Q17: Zijn er bronnen, contacten of eerdere projecten die je verder nog aanbeveelt om als inspiratie voor deze interventie te gebruiken?
A17: Groen vermogen, H2 train and lern hub. Ontwikkeling mensen waterstofagenda

English version: [redacted] (Translated by Joppe Ireland)

Q1: What is your role within ENTRANCE, and how would you describe the content/function of this role?

A1: The role involves strategically and tactically organizing learning within the energy transition. Students, researchers, and the professional field are brought together, primarily within learning communities in the ENTRANCE Innovation Workshop. The focus is on connecting education with the professional field, emphasizing learning interventions that align with current challenges in the energy transition.

Q2: What experiences does ENTRANCE have with working with secondary school students in (educational) interventions?

A2: The focus is on engaging students in the energy transition through multidisciplinary projects. Activities range from games like the WE-Energy Game to workshops, tours, and guidance with profile assignments. Additionally, hackathons are organized in collaboration with Technasium schools in Groningen.

Q3: What were the primary goals of the interventions you have been involved with, and how were the results of these goals measured?

A3: The main goal is to raise awareness among students about the diverse nature of the energy transition. Measurements focus on how students perceive the energy transition and whether they understand it goes beyond just technical aspects. However, systematic impact measurements are lacking due to time and resource constraints.

Q4: How were the interventions made engaging and accessible for secondary school students?

A4: Interventions are integrated into school modules, allowing students to earn credits. A combination of fun, excitement, and practical value works best, alongside a competitive element. Embedding projects into their curriculum provides both motivation and structure.

Q5: What methods or activities (such as workshops, practical projects) were most effective in capturing and maintaining students' attention?

A5: Effective methods include project-based assignments where students solve a problem. Workshops and lectures are provided as support for these assignments. Experts are available to guide and assist students during the project.

Q6: How were the interventions aligned with the educational goals and expectations of schools and teachers?

A6: Interventions are tailored to existing curricula by collaborating with secondary schools. Projects are often integrated into subjects or modules, primarily through partnerships with Stichting Technasium.

Q7: What were the biggest challenges in implementing interventions, and how were these addressed?

A7: A significant challenge is the lack of time for teachers and schools. Annual schedules are often full, leaving little room for new initiatives. A potential solution is collaborating with school administrations to include interventions in their long-term planning.

Q8: Was there ever resistance or a lack of interest from students, teachers, or schools, and how was this handled?

A8: Students are often uninterested if an intervention offers them no tangible benefits. For teachers, lack of time and prioritization is a common issue. While there is rarely active resistance, passive disinterest can be an obstacle.

Q9: What logistical or practical obstacles often arise when planning and executing interventions?
A9: A significant obstacle is a lack of communication from schools and teachers.

Q10: What measurable results have been used to evaluate the success of interventions?
A10: There are no systematic measurable results, but informal feedback from students and teachers is considered.

Q11: How has feedback from students and teachers influenced future versions of interventions?
A11: No specific feedback was mentioned, but informal input is used to adjust interventions.

Q12: Have any significant changes in students' knowledge or interest been observed in previous projects? If so, how was this visible?
A12: No systematic measurements have been conducted, but students returning for follow-up activities are seen as an indicator of success.

Q13: Why is hydrogen an important topic for secondary school students to learn about?
A13: Northern Netherlands has been designated as a Hydrogen Valley by Europe, emphasizing hydrogen as a critical energy carrier. It is expected to create many future jobs in the hydrogen sector, making it essential for the regional economy.

Q14: Which aspects of hydrogen in the energy transition are most suitable for secondary school students?
A14: The applicability of hydrogen, such as industrial processes and energy storage, is relevant. The goal is to create awareness about the possibilities and significance of hydrogen in the energy transition.

Q15: What advice would you give for designing an intervention that increases awareness and interest in hydrogen and the energy transition for secondary school students?
A15: Focus on the students' perspectives and use motivational theories. Ensure interactive and relevant information connects to their daily lives.

Q16: What are common mistakes to avoid when working with this age group?
A16: A common mistake is assuming everyone is as enthusiastic about the topic. Simplicity and clarity are crucial to engage students effectively. The attention span of students is short, so information must be concise and relevant.

Q17: Are there resources, contacts, or previous projects you would recommend as inspiration for this intervention?
A17: Recommended resources include Groen Vermogen and the H2 Train and Learn Hub.

Interview vragen: [redacted] Technasium

Intro: Uitleg over dit project en de uitkijk op de interventie

Q1: Zou je kunnen omschrijven wat voor rol speelt bij bij Stichting Technasium?

A1: [redacted] netwerkregisseur voor de Technasium netwerken in Groningen, Friesland en Drenthe. Zijn taak is het onderhouden van de samenwerking tussen 18 scholen en het zogen voor kwaliteit van het Technasium onderwijs. Hij speeld als een soort spin in het web zonder directe macht en ondersteunt docenten en scholen door netwerken en verbindingen te leggen. Daarnaast organiseert hij projecten en stimuleert innovatie binnen het onderwijs.

Q2: Welke ervaring heb je met het werken aan projecten bij ENTRANCE en hoe dragen deze bij aan de ontwikkeling van Technasium onderwijs?

A2: Technasium heeft ENTRANCE als locatie gebruikt voor hackathons en andere challenges. Bijvoorbeeld, in samenwerking met het We Energy Game, hebben leerlingen gewerkt aan het toevoegen van waterstof als energiedrager aan het spel. Dit multidisciplinaire aspect en de inspirerende omgeving maken de samenwerking met ENTRANCE waardevol.

Q3: Hoe zie je de samenwerking tussen Technasium scholen en ENTRANCE? Welke meerwaarde biedt deze samenwerking voor leerlingen?

A3: De multidisciplinaire omgeving van ENTRANCE biedt meerwaarde, omdat het leerlingen uit verschillende richtingen samenbrengt. De locatie en techniek die zichtbaar is bij ENTRANCE inspireren leerlingen en laten hen zien hoe verschillende disciplines samenwerken.

Q4: Welke specifieke onderwerpen, zoals waterstof binnen de energietransitie, zijn het meest relevant voor Technasium projecten?

A4: Een fysiek bouwpakket dat leerlingen zelf kunnen samenstellen en waarmee ze iets concreets kunnen maken, zoals een waterstofvoertuig. Ook het toepassen van waterstof in mobiliteit en praktische projecten spreekt aan.

Q5: Hoe worden de projecten van Technasium afgestemd op de regionale arbeidsmarktbehoeften, zoals die in de energietransitie?

A5: Technasium bereidt leerlingen voor op actuele vraagstukken door hen wendbaarheid en zelfstandigheid te leren. Dit wordt gedaan door hen te koppelen aan experts en praktijkgerichte projecten die aansluiten op de arbeidsmarktbehoeften.

Q6: Wat zijn volgens jou de beste methoden om HAVO leerlingen enthousiast te maken voor technische vakken en onderwerpen zoals de energietransitie?

A6: Het laten zien dat hun werk impact heeft en betekenisvol is. HAVO leerlingen willen graag doen en ervaren in plaats van alleen te leren. Docenten spelen hierin een grote rol en moeten goed gecoacht worden om leerlingen te begeleiden.

Q7: Welke rol speelt praktijkgericht onderwijs, zoals het Technasium, in het vergroten van interesse en kennis over waterstof en de energietransitie?

A7: De kracht van praktijkgericht onderwijs ligt in het verbinden van leerlingen met actuele vraagstukken en opdrachtgevers. De maatschappelijke context en technische uitdagingen maken de projecten boeiend en relevant.

Q8: Zijn er specifieke projecten of activiteiten die volgens u het meest succesvol zijn geweest in het inspireren van leerlingen?

A8: Specifieke voorbeelden zijn niet genoemd, maar succes ligt in projecten met een sterke maatschappelijke context en betrokkenheid van echte opdrachtgevers.

Q9: Wat denk je dat de grootste uitdagingen zijn bij het betrekken van HAVO leerlingen bij technologische onderwerpen zoals waterstof en de energietransitie?
A9: Docenten hebben vaak onvoldoende technische kennis en zijn handelingsverlegen bij technische onderwerpen. Ook tijdsgebrek en weerstand binnen scholen maken het lastig om nieuwe projecten te introduceren.

Q10: Hoe kunnen mogelijke barrières, zoals weerstand van scholen of gebrek aan middelen, worden overwonnen?
A10: Ondersteun docenten door trainingen en kennis te bieden, zodat zij zelfverzekerd projecten kunnen begeleiden. Creëer een plek waar leerlingen en docenten terecht kunnen bij problemen.

Q11: Hoe wordt het succes van Technasium projecten gemeten, en zijn er specifieke meetbare resultaten die relevant zijn voor mijn onderzoek?
A11: Projecten worden geëvalueerd, maar meetbare resultaten ontbreken vaak. Wel blijkt uit data dat doorstroom naar technisch hoger onderwijs 19% hoger is bij Technasium dan bij reguliere scholen. (Techniekpact)

Q12: Welke feedback heb je ontvangen van leerlingen en docenten over projecten bij ENTRANCE en hoe is deze feedback gebruikt?
A12: Docenten waarderen de marktvormige structuur en de multidisciplinaire invulling bij ENTRANCE. Leerlingen vinden het inspirerend als projecten goed gestructureerd zijn en een duidelijke planning hebben.

Q13: Wat zou jouw advies zijn voor het ontwerpen van een interventie die HAVO leerlingen meer bewust maakt van waterstof en de energietransitie?
A13: Maak het project betekenisvol en relevant voor de leerlingen. Laat hen zien hoe ze een verschil kunnen maken op grote maatschappelijke vraagstukken, zonder hen het gevoel te geven dat alles op hun schouders rust.

Q14: Zijn er specifieke voorbeelden of initiatieven uit jou ervaring die ik kan gebruiken als inspiratie voor mijn interventie?
A14: Hive-mobility of iets als dat mogelijk als andere partijen te koppelen.

Q15: Wat zou in jou ogen een unieke bijdrage van ENTRANCE kunnen zijn aan de bewustwording over waterstof in het voortgezet onderwijs?
A15: ENTRANCE biedt een inspirerende plek waar leerlingen technieken kunnen zien en ervaren. Het tonen van echte projecten maakt een grote impact.

Q16: Is er iets anders wat je belangrijk vindt om te delen over uw werk bij Stichting Technasium of jou visie op onderwijs en de energietransitie?
A16: [redacted] benadrukt het belang van trainingen en ondersteuning voor docenten via de Technasium Academie. Goede training maakt het mogelijk om nieuwe onderwerpen effectief in te brengen.

English version: [redacted] (Translated by Joppe Ireland)

Q1: Could you describe the role you play at Stichting Technasium?

A1: [redacted] geography and biology teacher by training and has also taught ICT at MBO level. He has a master's degree in learning and innovation and is particularly interested in the innovative side of education. He has worked as a consultant and researcher at an agency in Groningen, focusing on how education and real-world work can intersect. [redacted] enjoys challenging students and introducing unpredictability to make education more dynamic. His title, "Netwerkregisseur," involves managing and coordinating the network of 18 Technasium schools in Groningen, Drenthe, and Friesland. While he does not hold direct authority, he builds connections and motivates teachers, who are the driving force behind the Technasium program.

Q2: What experience do you have working on projects at ENTRANCE, and how do these contribute to the development of Technasium education?

A2: ENTRANCE has occasionally been used as a meeting location and for challenges such as hackathons. For instance, students worked on the We Energy Game at ENTRANCE, exploring how hydrogen could be integrated into the game. The collaboration with ENTRANCE provides an inspiring environment and a multidisciplinary approach, allowing students to engage with real-world challenges.

Q3: How do you see the collaboration between Technasium schools and ENTRANCE? What added value does this collaboration offer to students?

A3: The multidisciplinary environment at ENTRANCE is highly beneficial as it allows students from different fields to collaborate. The location and visible technology at ENTRANCE inspire students and provide a hands-on learning experience.

Q4: What specific topics, such as hydrogen within the energy transition, are most relevant for Technasium projects?

A4: A physical hydrogen kit that students can assemble themselves and use to create something real, like a hydrogen-powered vehicle, would be highly relevant. Projects involving hydrogen in mobility, such as building and 3D-printing parts, are particularly engaging for students.

Q5: How are Technasium projects aligned with regional labor market needs, such as those in the energy transition?

A5: Technasium prepares students to be adaptable by teaching them to find solutions when faced with obstacles. Projects involve an expert from higher education and include career orientation to align with labor market demands.

Q6: What do you think are the best methods to get HAVO students excited about technical subjects and topics like the energy transition?

A6: HAVO students often choose Technasium because it offers hands-on learning rather than just absorbing material. Showing students that their work can make a real difference and has meaning is crucial. Teachers also play a vital role in guiding students effectively and making the projects engaging.

Q7: What role does practice-oriented education, like Technasium, play in increasing interest and knowledge about hydrogen and the energy transition?

A7: The strength of practice-oriented education lies in connecting students with current societal challenges and real-world clients. The combination of societal context and technical challenges makes these projects engaging and relevant.

Q8: Are there specific projects or activities that you consider most successful in inspiring students?
A8: While no specific examples were mentioned, successful projects generally have a strong societal context and involve real-world clients to make the work meaningful for students.

Q9: What do you think are the biggest challenges in engaging HAVO students with technological topics like hydrogen and the energy transition?
A9: Teachers often lack sufficient technical knowledge and are hesitant to tackle technical topics. Time constraints and resistance within schools also make it difficult to introduce new projects.

Q10: How can barriers such as resistance from schools or a lack of resources be overcome?
A10: Support teachers by providing training and knowledge so they can confidently guide students in these projects. Establish a place where students and teachers can seek help when they face challenges.

Q11: How is the success of Technasium projects measured, and are there specific measurable results relevant to my research?
A11: Projects are evaluated but not always measured quantitatively. However, data shows that Technasium students are 19% more likely to pursue technical higher education compared to regular students. (Techniekpact)

Q12: What feedback have you received from students and teachers about projects at ENTRANCE, and how has this feedback been used?
A12: Teachers appreciated a marketplace-like structure at ENTRANCE, where students could explore various topics and make choices. The multidisciplinary setup is inspiring, especially when projects have clear planning and structure.

Q13: What would your advice be for designing an intervention to make HAVO students more aware of hydrogen and the energy transition?
A13: Ensure the project is meaningful and shows students how the world around them is influenced by these topics. Avoid overwhelming students with complex terminology and make the connection to their own impact on societal challenges clear.

Q14: Are there specific examples or initiatives from your experience that I can use as inspiration for my intervention?
A14: Hive Mobility is mentioned as a potential partner or inspiration for collaborative projects.

Q15: What do you think would be a unique contribution from ENTRANCE to raising awareness about hydrogen in secondary education?
A15: ENTRANCE provides an inspiring location where students can see and experience technology firsthand. Showing real projects creates a lasting impact on students.

Q16: Is there anything else you find important to share about your work at Stichting Technasium or your vision on education and the energy transition?
A16: [redacted] emphasizes the importance of teacher training and support through the Technasium Academy. Good training enables teachers to effectively introduce new topics to students.

Interview vragen: [redacted] Waterstof Werkt: train and learn hub

Intro: Uitleg over dit project en de uitkijk op de interventie

Q1: Wat voor rol speel je binnen Waterstof Werkt en hoe zou je zelf omschrijven wat dit inhoud?
A1: Projectmanager, programmamanager, coördineert het programma over het geheel. Het project bestaat uit zeven werkpakketten, waarvan sommige gaan over PO en VO, communicatie en disseminatie. Elk pakket heeft een eigen leider. [redacted] rol is om alles bij elkaar te brengen en het overzicht te behouden. Elke maand is er overleg met de werkpakketleiders om de voortgang te bespreken.

Q2: Wat zie je als de belangrijkste doelen van Waterstof Werkt op het gebied van onderwijs en de arbeidsmarkt in de regio?
A2: De regio staat bekend om gaswinning, wat heeft geleid tot veel banenverlies door de transitie van gas. Met ongeveer 9 miljard euro aan investeringen in duurzame energie willen we ervoor zorgen dat dit geld goed wordt besteed. Het doel is om een goed opgeleide beroepsbevolking te ontwikkelen in samenwerking met scholen en bedrijven. Tijdens het project willen we meer dan 1.000 mensen opleiden.
Q3: Waarom is het volgens jou belangrijk om waterstof en de energietransitie op te nemen in het voortgezet onderwijs?
A3: Het gaat vooral om bewustwording. MBO docenten ontwikkelen al lespakketten voor PO en VO. Door jonge scholieren vroeg te introduceren met waterstof en de energietransitie kunnen ze dit meenemen in hun latere studiekeuzes.

Q4: Welke aspecten van waterstof in de energietransitie denk je meest geschikt te zijn om voor HAVO leerlingen te introduceren?
A4: Interactieve ervaringen zoals een waterstofroute kunnen effectief zijn. Leerlingen uitleggen wat waterstof is, hoe het wordt gemaakt, en welke rol het speelt als energiedrager. Het laten zien van toepassingen zoals in mobiliteit en de waterstofwijk in Hoogeveen kan interesse wekken.

Q5: Hoe draagt Waterstof Werkt bij aan het vergroten van de interesse voor technische en energietransitie-gerelateerde studies onder middelbare scholieren?
A5: Door het ontwikkelen van lespakketten over waterstof voor basis- en middelbare scholen. Dit benadrukt niet alleen de technische kant, maar ook andere aspecten van de energietransitie.

Q6: Welke methoden of activiteiten heeft Waterstof Werkt gebruikt om jongeren te betrekken bij waterstof? Welke waren het meest succesvol?
A6: Nog geen projecten geweest, zijn nog in ontwikkeling. Po is in concept klaar, maar VO is nog in ontwikkeling.

Q7: Waterstof Werkt richt zich op een gecoördineerde aanpak tussen onderwijsinstellingen en bedrijven. Hoe belangrijk is deze samenwerking, en wat zijn de grootste uitdagingen?
A7: Samenwerking is erg belangrijk. Bedrijven moeten aangeven welke vaardigheden zij nodig hebben, zodat het onderwijs hierop kan inspelen. Een uitdaging is dat bedrijven soms zelf initiatieven opzetten of wachten totdat de noodzaak hoger is.

Q8: Hoe wordt ervoor gezorgd dat de onderwijsactiviteiten van Waterstof Werkt aansluiten op de behoeften van scholen en bedrijven?
A8: Dit gebeurt door nauw overleg en samenwerking met zowel scholen als bedrijven. Er wordt geluisterd naar de behoeften en verwachtingen van beide partijen bij het ontwikkelen van de lespakketten.

Q9: Welke/wat voor meetbare resultaten gebruikt Waterstof Werkt om de impact van het programma te beoordelen?
A9: Vragen aan MBO docenten

Q10: Zie je al tekens van blijvende veranderingen in het onderwijs of de regio dankzij Waterstof Werkt?
A10: Nog geen gerealiseerde projecten

Q11: Welke obstakels komt Waterstof Werkt tegen bij het ontwerpen en implementeren van een doorlopende leerlijn?
A11: Over het algemeen staat het curriculum redelijk vast, lastig om dingen toe te voegen. Je moet net enthousiaste docenten hebben die er tijd voor maken. Jaarprogramma's staan vast, urgentie is voor scholen niet zo groot vaak, je moet leeraren zo ver krijgen om een deel van zijn les er voor open te maken. Capaciteit is ook lastig, tekort aan leeraren dus vaak is het lastig om iets extra toe te voegen.

Challanged based leurning, studiepunten krijgen om mee te doen aan projecten bij bvb ENTRANCE.

Q12: Heeft u suggesties of aanbevelingen voor het ontwerpen van een interventie om HAVO leerlingen meer bewust te maken van waterstof en de energietransitie?
A12: Maak het interactief en relevant voor hun bestaande lessen. Denk aan een korte, duidelijke uitleg door een expert uit het bedrijfsleven of onderwijs.

Q13: Zijn er specifieke projecten of benaderingen binnen Waterstof Werkt die als voorbeeld kunnen dienen voor mijn onderzoek en interventie?
A13: Voor deze specifieke opdracht is er geen direct voorbeeld, maar projecten zoals Techlab en De Magneet kunnen inspirerend zijn, mail van MBO docent.

Q14: Wat zou in jou ogen een unieke bijdrage van ENTRANCE kunnen zijn aan de bewustwording over waterstof in het voortgezet onderwijs?
A14: Het tonen van de faciliteiten en lopende projecten bij ENTRANCE heeft veel toegevoegde waarde.

Q15: Is er iets anders dat je belangrijk vindt om te delen over Waterstof Werkt en het onderwijs in waterstof en de energietransitie?
A15: Eigenlijk alles wel besproken

Q16: Zijn er bronnen, contacten of eerdere projecten die je verder nog aanbeveelt om als inspiratie voor deze interventie te gebruiken?
A16: De Magneet, Techlab en rapporten over de waterstofeconomie in Noord-Nederland. Ook VR-brillen die Waterstof Werkt gebruikt, kunnen een interessante toevoeging zijn

English version: [redacted] (Translated by Joppe Ireland)

Q1: What is your role within Waterstof Werkt, and how would you describe it?
A1: As a project manager, I coordinate the entire program. The project consists of seven work packages, each with its leader. My role is to bring everything together and monitor overall progress, holding monthly meetings with the work package leaders.

Q2: What are the main goals of Waterstof Werkt regarding education and the regional labor market?
A2: The northern Netherlands is known for gas extraction, which has led to significant job losses with the switch away from gas. With around €9 billion in sustainable energy investments, we aim to use these funds effectively to develop a skilled workforce in collaboration with schools and companies, training over 1,000 people within three years.

Q3: Why is it important to include hydrogen and the energy transition in secondary education?
A3: Awareness is key. By introducing hydrogen and the energy transition early, students can incorporate this knowledge into their study and career decisions later.

Q4: Which aspects of hydrogen in the energy transition are most suitable to introduce to HAVO students?
A4: Interactive experiences such as explaining hydrogen as an energy carrier and showing its applications, like in mobility and the hydrogen neighbourhood in Hoogeveen, can spark interest.

Q5: How does Waterstof Werkt increase interest in technical and energy-transition-related studies among secondary students?
A5: By developing educational packages about hydrogen for primary and secondary schools, highlighting technical aspects and other fields.

Q6: What methods or activities has Waterstof Werkt used to engage youth in hydrogen? Which have been most successful?
A6: No specific projects have been conducted for secondary education yet; these are still in development. For primary education, a concept is already prepared.

Q7: How important is collaboration between educational institutions and companies, and what are the biggest challenges?
A7: Collaboration is crucial, as companies must communicate their needs so education can adapt. Challenges include companies waiting until there's a clear necessity to act.

Q8: How are educational activities aligned with the needs of schools and companies?
A8: Through close collaboration and discussions, ensuring alignment with their expectations while developing the lesson packages. Ask MBO teacher for more.

Q9: What measurable results does Waterstof Werkt use to evaluate its impact?
A9: Ask MBO teacher what the package will include

Q10: Are there lasting changes in education or the region due to Waterstof Werkt?
A10:

Q11: What obstacles does Waterstof Werkt face in creating a continuous learning pathway?
A11: Fixed curricula make adding new topics difficult. Teacher shortages also limit capacity.

Q12: Do you have suggestions for designing an intervention to raise HAVO students' awareness of hydrogen and the energy transition?
A12: Make it interactive and connect it to existing lessons. Consider easy and short explanations from experts in the field.

Q13: Are there specific projects within Waterstof Werkt that could serve as examples for my research and intervention?
A13: No direct examples for this task, but projects like Techlab and De Magneet can offer inspiration.

Q14: What unique contribution could ENTRANCE make to hydrogen awareness in secondary education?
A14: ENTRANCE's facilities and ongoing projects provide a valuable opportunity for hands-on learning.

Q15: Do you want to add anything else about Waterstof Werkt and hydrogen education in the energy transition?
A15: Everything has been discussed.

Q16: Are there resources, contacts, or past projects you recommend for inspiration?
A16: De Magneet, Techlab, and reports on the hydrogen economy in the northern Netherlands. Additionally, VR modules used by Waterstof Werkt could be a useful tool.

Interview vragen: Tineke van der Meij, ENTRANCE

Intro: Uitleg over dit project en de uitkijk op de interventie

Q1: Zou je jou rol binnen ENTRANCE kunnen omschrijven en hoe sluit deze aan bij jouw ervaringen?
A1: Natuurkundige, gestudeerd en gepromoveerd in Utrecht, en heeft bijna 30 jaar gewerkt bij Gasunie, waar ze begon als onderzoeker. Ze raakte de laatste 2 jaar betrokken bij ENTRANCE via strategie en innovatie en richt zich nu vooral op waterstofprojecten. Haar taken omvatten netwerkactiviteiten, publieksactiviteiten en niet-regulier onderwijs. Ze geeft gastlessen, colleges over energietransitie en waterstof, en organiseert workshops zoals "Waterstof in een uur." Haar rol draait om het verbinden van kennisinstellingen, bedrijven en studenten.

Q2: Welke ervaringen heb je met waterstofprojecten en hoe hebben deze je inzicht gegeven op de rol van waterstof in de energietransitie?
A2: Ze werkt met praktische experimenten, zoals het gebruik van waterstofkits, waarmee mensen waterstof kunnen maken en een molentje kunnen laten draaien. Deze hands-on aanpak laat zien hoe waterstof een rol speelt in een toekomstig energiesysteem. Ze benadrukt dat waterstof niet alleen technisch interessant is, maar ook essentieel voor systeemintegratie, vooral in industrie en opslag.

Q3: Hoe zie je de samenwerking tussen bedrijven, scholen en organisaties zoals ENTRANCE? Wat werkt goed en wat kan beter?
A3: De samenwerking tussen ENTRANCE en middelbare scholen is beperkt. Technasium projecten zijn een uitzondering, maar de focus ligt op oudere studenten. Bedrijven investeren vaak in eenmalige projecten of materialen, maar docenten hebben niet de tijd of middelen om deze zelfstandig te gebruiken/inzetten. Voor succesvolle samenwerking zou nodig zijn dat projecten aansluiten bij bestaande curricula en docenten ontzorgen.

Q4: Zijn er voorbeelden van samenwerkingen waarbij onderwijs en praktijk goed samenkwamen?
A4: Projecten zoals "Waterstof in een uur" en Technasium opdrachten, waarbij studenten worden betrokken bij praktische uitdagingen. Succesvolle projecten hebben een duidelijke koppeling tussen theorie en praktijk en bieden zowel leerlingen als docenten ondersteuning.

Q5: Hoe belangrijk is het dat jongeren al vroeg leren over waterstof en de energietransitie?
A5: Het is erg belangrijk dat jongeren begrijpen hoe waterstof past binnen de energietransitie. Dit helpt om bewustzijn te creëren en interesse te wekken voor vervolgstudies en carrières in de sector. Vroege exposure kan leerlingen inspireren om technische richtingen te verkennen.

Q6: Wat zijn volgens jou de belangrijkste onderwerpen binnen waterstof voor HAVO leerlingen?
A6: Het belangrijkste is de praktische toepassing van waterstof, zoals het gebruik ervan als brandstof en de voordelen voor een duurzaam energiesysteem. Het is belangrijk om misverstanden, zoals het idee dat waterstof gevaarlijk is, weg te nemen en een breed beeld van de mogelijkheden te schetsen.

Q7: Welke activiteiten of projecten hebben volgens jou goed gewerkt om jongeren enthousiast te maken over waterstof en de energietransitie?
A7: Praktische workshops zoals "Waterstof in een uur" zijn erg succesvol. Door hands-on activiteiten zoals het bouwen van waterstofkits en het creëren van een competitief element, raken leerlingen enthousiast en betrokken. Een ander voorbeeld is het "Morgenland" filmpje, dat energietransitie op een toegankelijke manier uitlegt.

Q8: Welke uitdagingen zie je bij het betrekken van middelbare scholen bij waterstofprojecten? Hoe kunnen deze worden overwonnen?
A8: De grootste uitdaging is dat docenten en scholen weinig tijd en middelen hebben. Het is essentieel om projecten te laten aansluiten bij bestaande leerdoelen en modules, zodat docenten worden ontzorgd. Enthousiaste docenten zijn vaak de sleutel tot succes.

Q9: Hoe kunnen docenten en leerlingen het beste worden ondersteund bij het leren over complexe onderwerpen zoals waterstof?
A9: Docenten zouden getraind moeten worden om het onderwerp goed te kunnen overbrengen. Het aanbieden van kant-en-klare lesmodules die aansluiten bij bestaande curricula is belangrijk. Extra ondersteuning, zoals workshops en hulpmaterialen, kan ook docenten en leerlingen helpen.

Q10: Welke unieke rol kan ENTRANCE spelen in het verbinden van scholen met de waterstofsector?
A10: ENTRANCE kan fungeren als brug tussen het onderwijs en de praktijk. Door studenten en scholen toegang te bieden tot faciliteiten en expertise, kan het moeilijke ideeën concreet maken. De locatie en beschikbare middelen zijn ideaal voor het organiseren van demonstraties en workshops.

Q11: Heb je aanbevelingen of voorbeelden van projecten die als inspiratie kunnen dienen voor mijn interventie?
A11: "Waterstof in een uur" workshop en het gebruik van waterstofkits. Ook het gebruik van het "Morgenland" filmpje als introductie tot de energietransitie, mogelijk gevolgd door praktische opdrachten. Met (nep) certificaat dat ze waterstof hebben gemaakt. Mogelijk een medestudent vragen.

Q12: Is er iets anders dat je belangrijk vindt om te delen over jouw werk of ideeën die ik mee kan nemen in mijn onderzoek?
A12: Ze benadrukt het belang van het ontzorgen van docenten en het integreren van waterstof onderwijs binnen bestaande modules. Daarnaast wijst ze op de waarde van visuele hulpmiddelen en hands-on activiteiten om abstracte concepten toegankelijk te maken.

English version: Tineke van der Meij (Translated by Joppe Ireland)

Q1: Could you describe your role within ENTRANCE and how it aligns with your experiences?
A1: A physicist by training, with a Ph.D. from Utrecht. She worked at Gasunie in Groningen for almost 30 years, starting as a researcher. She became involved with ENTRANCE in the past two years through her work in strategy and innovation and now focuses primarily on hydrogen projects. Her tasks include networking, organizing public activities, and providing non-standard education. She gives guest lectures, delivers talks about the energy transition and hydrogen, and organizes workshops like "Hydrogen in an Hour." Her role revolves around connecting knowledge institutions, companies, and students.

Q2: What experience do you have with hydrogen projects, and how has this given you insight into the role of hydrogen in the energy transition?
A2: Tineke works with practical experiments, such as using hydrogen kits to produce hydrogen and power small devices like a fan. This hands-on approach demonstrates how hydrogen can function within a future energy system. She emphasizes that hydrogen is not just a technical innovation but also crucial for system integration, particularly in industry and energy storage.

Q3: How do you view the collaboration between companies, schools, and organizations like ENTRANCE? What works well, and what could be improved?
A3: Collaboration between ENTRANCE and secondary schools is limited. Technasium projects are an exception, but the focus is mainly on older students. Companies often invest in one time projects or materials, but teachers often lack the time and resources to use these effectively. For successful collaboration, projects shoudl align with existing curricula and reduce the burden on teachers.

Q4: Are there examples of collaborations where education and practice came together successfully?
A4: Projects like "Hydrogen in an Hour" and Technasium assignments have effectively combined theory with practice. Successful projects link academic learning with real-world applications, providing support for both students and teachers.

Q5: Do you think it's important for young people to learn about hydrogen and the energy transition at an early age?
A5: Young people should understand how hydrogen fits into the energy transition. This awareness can inspire them to pursue studies and careers in the sector. Early exposure can motivate students to explore technical fields.

Q6: In your opinion, what are the most important topics related to hydrogen for HAVO students?
A6: The focus should be on the practical applications of hydrogen, such as its use as fuel and its benefits for a sustainable energy system. It's also important to help disprove misconceptions, like the idea that hydrogen is dangerous, and to provide a broad overview of its potential.

Q7: Which activities or projects have effectively excited young people about hydrogen and the energy transition?
A7: Practical workshops, like "Hydrogen in an Hour," have been very successful. By engaging students in hands-on activities, such as building hydrogen kits, and adding a competitive element, students become enthusiastic and engaged. The "Morgenland" video is also effective, showing a clear explanation of the energy transition.

Q8: What challenges do you see in involving secondary schools in hydrogen projects, and how can these be overcome?

A8: The biggest challenge is that teachers and schools often lack time and resources. Projects must align with existing learning objectives and modules to reduce the workload for teachers. Enthusiastic teachers are often the key to success.

Q9: How can teachers and students best be supported in learning about complex topics such as hydrogen?
A9: Teachers should be trained to effectively convey these topics. Providing ready-made lesson modules that integrate with the existing curriculum is important. Additional support, such as workshops and educational materials, can help both teachers and students.

Q10: What unique role can ENTRANCE play in connecting schools with the hydrogen sector?
A10: ENTRANCE can serve as a bridge between education and practice. By offering schools and students access to facilities and expertise, it can help make difficult concepts more real. The location and available resources are ideal for organizing demonstrations and workshops.

Q11: Do you have any recommendations or examples of projects that could serve as inspiration for my intervention?
A11: "Hydrogen in an Hour" workshop and hydrogen kits are excellent examples. Also the use of the "Morgenland" video as an introduction to the energy transition, followed by practical assignments.

Q12: Is there anything else you think is important to share about your work or ideas that I can take into my research?
A12: She highlights the importance of reducing the load on teachers and integrating hydrogen education within existing modules. She also stresses the value of visual tools and hands-on activities to make abstract concepts accessible

Appendix 10: Initial Survey Questions

Vragenlijst waterstof in de energietransitie

1. Hoe oud ben je?

[ ]

In jaren

2. Wat is je gender? *(Vink één optie aan)*

- Vrouw ○
- Man ○
- Anders ○
- Zeg ik liever niet ○

3. Welk niveau doe je? *(Vink alles aan wat van toepassing is)*

- ☐ VMBO
- ☐ HAVO
- ☐ VWO

4. Welk profiel heb je gekozen? *(Vink één optie aan)*

- Cultuur en Maatschappij ○
- Economie en Maatschappij ○
- Natuur en Gezondheid ○
- Natuur en Techniek ○

5. Weet je wat de 'energietransitie' is? *(Vink één optie aan)*

- Ja ○
- Wel van gehoord, maar niet zeker wat het is ○
- Nee ○

6. Kun je kort beschrijven wat je denkt dat de energietransitie betekent, of zou kunnen betekenen? *(Vink alles aan wat van toepassing is)*

- Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken ☐
- Het verbeteren van energie-efficiëntie in huizen en bedrijven ☐
- Minder gebruik maken van fossiele brandstoffen zoals olie en gas ☐
- Overstappen op duurzamere energiebronnen zoals zon en wind ☐
- Ik weet het niet ☐

De energietransitie in "Morgenland"

Kijk nu met de klas het filmpje "Morgenland" en kijk of je bij de vorige vraag de goede antwoorden hebt. (verander niet je antwoorden)

7. Vind jij de energietransitie belangrijk? *(Vink één optie aan)*

Ja, het is belangrijk voor de toekomst ○
Ja, maar ik weet niet waarom ○
Nee, ik denk niet dat het belangrijk is ○
Weet ik niet ○

8. Is de energietransitie ooit besproken in een van je lessen? *(Vink één optie aan)*

Ja ○
Nee ○
Weet ik niet (meer) ○

9. Zo ja, in welke les of lessen?

10. Heb je ooit gehoord van waterstof als energiebron? *(Vink één optie aan)*

Ja ○
Nee ○
Weet ik niet zeker ○

11. Is waterstof ooit besproken in een van je lessen? *(Vink één optie aan)*

Ja ○
Nee ○
Weet ik niet (meer) ○

12. Zo ja, in welke les of lessen?

13. Waar denk je dat waterstof voor gebruikt wordt in de energietransitie? *(Vink alles aan wat van toepassing is)*

☐ Als brandstof voor auto's
☐ Als opslag van energie
☐ In de industrie
☐ Voor de productie van elektriciteit
☐ Voor het verwarmen van huizen en gebouwen
☐ Weet ik niet

14. Denk je dat waterstof belangrijk kan zijn in de energietransitie? *(Vink één optie aan)*

Ja ○
Nee ○
Weet ik niet ○

15. Waarom denk je dat waterstof wel of niet belangrijk kan zijn?

16. Hoe interessant vind je energie-gerelateerde onderwerpen?

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Op een schaal van 1 tot 10

17. Zou je meer willen leren over waterstof en de rol ervan in de energietransitie? *(Vink alles aan wat van toepassing is)*

- Ja, lijkt me interessant ☐
- Misschien, als het op een leuke manier wordt uitgelegd ☐
- Nee, lijkt me niet interessant ☐

18. Op welke manier leer jij het liefst? *(Vink alles aan wat van toepassing is)*

- Door te experimenteren en proefjes te doen ☐
- Door video's te kijken over het onderwerp ☐
- Door gastsprekers of excursies ☐
- Door zelf onderzoek te doen en presentaties te maken ☐
- Door te lezen en teksten te bestuderen ☐
- Door spelletjes of interactieve opdrachten ☐

19. Zou je later willen studeren of werken met energie of waterstof? *(Vink één optie aan)*

- Ja ○
- Nee ○
- Weet ik niet ○

20. Zo ja, wat zou je willen doen? Zo nee, waarom niet?

Appendix 11: Initial Survey Answers

Answers Montessori Lyceum

Vraag:	Leerling 1	Leerling 2	Leerling 3	Leerling 4	Leerling 5	Leerling 6	Leerling 7	Leerling 8	Leerling 9	Leerling 10	Leerling 11
1: Hoe oud ben je? (in jaren)	15	16	16	15	16	15	15	15	16	15	15
2: Wat is je gender?	Man	Man	Man	Man	Man	Vrouw	Vrouw	Vrouw	Vrouw	Vrouw	Vrouw
3: Welk niveau doe je?	HAVO	HAVO	HAVO	HAVO	HAVO	HAVO	HAVO	HAVO	HAVO	HAVO	HAVO
4: Welk profiel heb je gekozen?	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Gezondheid/ Natuur en Techniek	Natuur en Gezondheid/ Natuur en Techniek	Natuur en Gezondheid	Natuur en Techniek
5: Weet je wat de 'energietransitie' is?	Wel van gehoord, maar niet zeker wat het is	Nee	Wel van gehoord, maar niet zeker wat het is	Wel van gehoord, maar niet zeker wat het is	Wel van gehoord, maar niet zeker wat het is	Nee	Wel van gehoord, maar niet zeker wat het is	Wel van gehoord, maar niet zeker wat het is	Nee	Wel van gehoord, maar niet zeker wat het is	Wel van gehoord, maar niet zeker wat het is
6: Wat denk je dat de energietransitie betekend, of zou kunnen betekenen?	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Minder gebruik maken van fossiele brandstoffen zoals olie en gas	Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken	Overstappen op duurzamere energiebronnen zoals zon en wind	Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas	Overstappen op duurzamere energiebronnen zoals zon en wind	Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas	Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Overstappen op duurzamere energiebronnen zoals zon en wind
7: Vind jij de energietransitie belangrijk?	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Nee, ik denk niet dat het belangrijk is	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, maar ik weet niet waarom	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst
8: Is de energietransitie ooit besproken in een van je lessen?	Weet ik niet (meer)	Ja	Ja	Ja	Nee	Ja	Ja	Weet ik niet (meer)	Weet ik niet (meer)	Ja	Ja
9: Is waterstof ooit besproken in een van je lessen?	Ja	Weet ik niet (meer)	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Weet ik niet (meer)
10: Zo ja, in welke les of lessen zijn waterstof en/of de energietransitie besproken?	Biologie en scheikunde	-	Scheikunde en Bio	Biologie en Scheikunde	Waterstof in Scheikunde en Bio	Scheikunde / Aardrijkskunde	Scheikunde en Aardrijkskunde	Weet ik niet meer (ik denk natuurkunde)	Aardrijkskunde	Aardrijkskunde, scheikunde	-
11: Heb je ooit gehoord van waterstof als energiebron?	Ja	Ja	Ja	Ja	Weet ik niet (meer)	Ja	Ja	Nee	Ja	Ja	Weet ik niet (meer)
12: Waar denk je dat waterstof voor gebruikt wordt in de energietransitie?	Als brandstof voor auto's, In de industrie, Voor de productie van elektriciteit, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, In de industrie, Voor de productie van elektriciteit	Voor de productie van elektriciteit	Voor de productie van elektriciteit	Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, Als opslag van energie, In de industrie	Weet ik niet	Als brandstof voor auto's, In de industrie, Voor het verwarmen van huizen en gebouwen	Voor het verwarmen van huizen en gebouwen, Weet ik niet	Als brandstof voor auto's, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, Voor het verwarmen van huizen en gebouwen

13: Denk je dat waterstof belangrijk kan zijn in de energietransitie?	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja
14: Waarom denk je dat waterstof wel of niet belangrijk kan zijn? Bijvoorbeeld: Wel, omdat het hernieuwbaar en groen is? Of niet omdat het duur is?	-	De auto's	Wel, omdat het hernieuwbaar en groen is	Wel, omdat je zonder uitstoting energie krijgt	Beter voor de natuur als we meer waterstof gebruiken	Wel, omdat het groen is	Het is beter voor het milieu	Ik weet het echt niet, maar ik denk van wel	Zorgt niet voor CO2 uitstoot	Omdat het groen is	Omdat het alleen waterdamp uitstoot in plaats van CO2
15: Hoe interessant vind je energie-gerelateerde onderwerpen?	7	5	6	6	4	6.5	2	7	7	7	5
16: Zou je meer willen leren over waterstof in de energietransitie?	Misschien, als het op een leuke manier wordt uitgelegd	Nee, lijkt me niet interessant	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Ja, lijkt me interessant	Nee, lijkt me niet interessant	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd
17: Waarom zou je hier wel of niet meer over willen leren?	Omdat het wel belangrijk is	Omdat ik het saai vind	Niet persee want het lijkt me niet heel interessant	Wel, omdat ik om de wereld geef en ik zou willen weten wat ik er aan zou kunnen doen	Het onderwerp vind ik wel belangrijk, maar niet heel interessant	Ik vind het klimaat heel belangrijk	Het maakt me niet heel veel uit	Omdat het belangrijk kan zijn voor de toekomst	Omdat ik wil weten hoe ze het gebruiken en of ze t voor veel dingen kunnen gebruiken	Omdat het belangrijk is voor de toekomst	Als het een goede vervanger is voor CO2 uitstoot zou ik er wel meer over willen weten
18: Op welke manier leer jij het liefst?	Door te experimenteren en proefjes te doen, Door te lezen en teksten te bestuderen	Door te experimenteren en proefjes te doen, Door video's te kijken over het onderwerp, Door gastsprekers of excursies	Door te experimenteren en proefjes te doen, Door spelletjes of interactieve opdrachten	Door te lezen en teksten te bestuderen	Door video's te kijken over het onderwerp, Door te lezen en teksten te bestuderen, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door video's te kijken over het onderwerp, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door zelf onderzoek te doen en presentaties te maken, Door spelletjes of interactieve opdrachten	Door video's te kijken over het onderwerp, Door te lezen en teksten te bestuderen	Door te experimenteren en proefjes te doen, Door video's te kijken over het onderwerp, Door te lezen en teksten te bestuderen	Door video's te kijken over het onderwerp, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen
19: Waarom vind je deze manier van leren fijn?	Omdat ik het zelf doen makkelijker kan doen	Dan is het leuker dan naar letters kijken	Actief leren, zelf wat doe (i.p.v. boek lezen)	Omdat ik dan rustig de tijd kan nemen	Dan neem ik de stof het best in me op voor de volgende keer	Niet zo saai	Omdat je er echt mee bezig bent en mn focus houd	Door eerst filmpjes te kijken snap ik het beter. Door de tekst te lezen kan je er de belangrijkste stof eruit halen	Dan onthoudt ik het beter	Dan moet ik zelf ook eerst iets doen	Omdat je zelf bezig bent
20: Zou je later willen studeren of werken met energie of waterstof?	Weet ik niet	Weet ik niet	Nee	Weet ik niet	Nee	Weet ik niet	Nee	Nee	Weet ik niet	Weet ik niet	Nee
21: Zo ja, wat zou je willen doen? Zo nee, waarom niet?	Weet ik niet	-	Nee, want het is niet mijn hobbie	Weet niet	Niet interresant genoeg voor een hele studie	Nee, lijkt me niet interresant genoeg	Ik ben meer van de sociaal kunstzinige kant	Omdat ik dat niet interessant vind als werk	No idea	Geen idee	Wil naar het conservatorium en daar leer je niet over energie

Answers Hondsrug College

	Antwoorden: Hondsrug College HAVO 4				
Vraag:	Leerling 1	Leerling 2	Leerling 3	Leerling 4	Leerling 5
1: Hoe oud ben je? (in jaren)	17	15	16	15	15
2: Wat is je gender?	Vrouw	Man	Man	Man	Man
3: Welk niveau doe je?	HAVO	HAVO	HAVO	HAVO	HAVO
4: Welk profiel heb je gekozen?	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Techniek	Natuur en Techniek	Natuur en Techniek
5: Weet je wat de 'energietransitie' is?	Ja	Ja	Wel van gehoord, maar niet zeker wat het is	Wel van gehoord, maar niet zeker wat het is	Ja
6: Wat denk je dat de energietransitie betekend, of zou kunnen betekenen?	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Minder gebruik maken van fossiele brandstoffen zoals olie en gas	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Overstappen op duurzamere energiebronnen zoals zon en wind	Minder gebruik maken van fossiele brandstoffen zoals olie en gas	Overstappen op duurzamere energiebronnen zoals zon en wind
7: Vind jij de energietransitie belangrijk?	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Nee, ik denk niet dat het belangrijk is	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst
8: Is de energietransitie ooit besproken in een van je lessen?	Weet ik niet (meer)	Nee	Nee	Weet ik niet (meer)	Ja
9: Is waterstof ooit besproken in een van je lessen?	Weet ik niet (meer)	Nee	Nee	Ja	Ja
10: Zo ja, in welke les of lessen zijn waterstof en/of de energietransitie besproken?	Aardrijkskunde volgensmij of Natuurkunde	-	-	Scheikunde met waterstof	-
11: Heb je ooit gehoord van waterstof als energiebron?	Ja	Ja	Ja	Weet ik niet (meer)	Ja
12: Waar denk je dat waterstof voor gebruikt wordt in de energietransitie?	Als brandstof voor auto's, In de industrie, Voor de productie van elektriciteit, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, In de industrie, Voor de productie van elektriciteit	Als brandstof voor auto's, In de industrie	In de industrie, Voor het verwarmen van huizen en gebouwen	Als opslag van energie, In de industrie, Voor het verwarmen van huizen en gebouwen

13: Denk je dat waterstof belangrijk kan zijn in de energietransitie?	Ja	Ja	Ja	Ja	Ja
14: Waarom denk je dat waterstof wel of niet belangrijk kan zijn? Bijvoorbeeld: Wel, omdat het hernieuwbaar en groen is? Of niet omdat het duur is?	Er is genoeg water en niet zo schadelijk	Wel, omdat het beter is dan fossiele brandstof	Omdat het nieuw is en daardoor nog veel te ontwikkelen is	Wel, omdat we hebben dan niet een hele grote voorraad nodig, als het herniewbaar is	Omdat het een grote energiedichtheid heeft voor opslag
15: Hoe interessant vind je energie-gerelateerde onderwerpen?	7	5	6	8	8
16: Zou je meer willen leren over waterstof in de energietransitie?	Ja, lijkt me interessant	Misschien, als het op een leuke manier wordt uitgelegd	Ja, lijkt me interessant	Ja, lijkt me interessant	Ja, lijkt me interessant
17: Waarom zou je hier wel of niet meer over willen leren?	Omdat je daar wel wat aan hebt in het echte leven en het me heel interessant lijkt	Omdat het belangrijk is in de toekomst	Omdat het interresant is	Wel, want energie spreekt mij sowieso wel aan	Het is een interresant onderwerp waar we nog veel over hebben te leren
18: Op welke manier leer jij het liefst?	Door te experimenteren en proefjes te doen, Door video's te kijken over het onderwerp, Door gastsprekers of excursies, Door zelf onderzoek te doen en presentaties te maken, Door te lezen en teksten te bestuderen,	Door te experimenteren en proefjes te doen, Door zelf onderzoek te doen en presentaties te maken, Door spelletjes of interactieve opdrachten	Door video's te kijken over het onderwerp	Door te experimenteren en proefjes te doen, Door video's te kijken over het onderwerp, Door zelf onderzoek te doen en presentaties te maken, Door te lezen en teksten te bestuderen	Door te experimenteren en proefjes te doen, Door video's te kijken over het onderwerp, Door te lezen en teksten te bestuderen
19: Waarom vind je deze manier van leren fijn?	Is niet zo saai en als iets leuk is onthoud je het ook makkelijker	Het is niet alleen maar lezen	Dan heb ik er beeld bij	-	Je bent dan echt zelf bezig
20: Zou je later willen studeren of werken met energie of waterstof?	Nee	Weet ik niet	Weet ik niet	Weet ik niet	Weet ik niet
21: Zo ja, wat zou je willen doen? Zo nee, waarom niet?	Nee, ik wil graag de zorg in later	Ik weet niet wat voor studies er zijn	-	Zo ja dan omdat het wel interessant lijkt voor mij	Enerige opslag en efficientie

	Antwoorden: Hondsrug College VWO 3																		
Vraag:	Leerling 6	Leerling 7	Leerling 8	Leerling 9	Leerling 10	Leerling 11	Leerling 12	Leerling 13	Leerling 14	Leerling 15	Leerling 16	Leerling 17	Leerling 18	Leerling 19	Leerling 20	Leerling 21	Leerling 22	Leerling 23	Leerling 24
1: Hoe oud ben je? (in jaren)	14	14	14	14	14	14	15	15	14	14	15	15	14	15	14	15	15	15	14
2: Wat is je gender?	Man	Man	Man	Man	Man	Man	Man	Man	Man	Man	Vrouw	Man	Man	Man	Man	Man	Man	Zeg ik liever niet	Man
3: Welk niveau doe je?	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO
4: Welk profiel heb je gekozen?	Economie en Maatschappij	Natuur en Techniek	Natuur en Techniek	Natuur en Gezondheid	Natuur en Techniek	Natuur en Techniek	Natuur en Techniek	Natuur en Techniek	Natuur en Techniek	Natuur en Techniek	Natuur en Techniek	Natuur en Techniek	Natuur en Techniek	Natuur en Gezondheid	Natuur en Techniek	Natuur en Gezondheid	Natuur en Techniek	Natuur en Gezondheid	Natuur en Gezondheid
5: Weet je wat de 'energietransitie' is?	Wel van gehoord, maar niet zeker wat het is	Ja	Wel van gehoord, maar niet zeker wat het is	Ja	Wel van gehoord, maar niet zeker wat het is	Ja	Ja	Wel van gehoord, maar niet zeker wat het is	Ja	Wel van gehoord, maar niet zeker wat het is	Ja	Nee	Ja	Wel van gehoord, maar niet zeker wat het is	Ja	Ja	Ja	Ja	Ja
6: Wat denk je dat de energietransitie betekend, of zou kunnen betekenen?	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Minder gebruik maken van fossiele brandstoffen zoals olie en gas	Overstappen op duurzamere energiebronnen zoals zon en wind, Minder gebruik maken van fossiele brandstoffen zoals olie en gas	Overstappen op duurzamere energiebronnen zoals zon en wind	Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Overstappen op duurzamere energiebronnen zoals zon en wind	Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Minder gebruik maken van fossiele brandstoffen zoals olie en gas	Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Ik weet het niet	Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind
7: Vind jij de energietransitie belangrijk?	Nee, ik denk niet dat het belangrijk is	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, maar ik weet niet waarom	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, maar ik weet niet waarom	Ja, het is belangrijk voor de toekomst	Ja, maar ik weet niet waarom	Ja, het is belangrijk voor de toekomst	Weet ik niet	Ja, het is belangrijk voor de toekomst	Weet ik niet	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst
8: Is de energietransitie ooit besproken in een van je lessen?	Weet ik niet (meer)	Ja	Ja	Ja	Weet ik niet (meer)	Ja	Ja	Ja	Ja	Weet ik niet (meer)	Ja	Weet ik niet (meer)	Ja	Nee	Ja	Ja	Ja	Ja	Ja
9: Is waterstof ooit besproken in een van je lessen?	Ja	Weet ik niet (meer)	Ja	Ja	Nee	Ja	Ja	Ja	Ja	Ja	Ja	Nee	Ja	Weet ik niet (meer)	Ja	Ja	Ja	Weet ik niet (meer)	Ja
10: Zo ja, in welke les of lessen zijn waterstof en/of de energietransitie besproken?	Met O en O	Aardrijkskunde en O en O	O en O en Scheikunde	Aardrijkskunde	Aardrijkskunde	Toen we een project moesten maken om duurzamer te werk te gaan	In bijna elke omdat wij daar op het moment onderzoek naar doen	In techniek lessen	O en O	O en O	Waterstof : nu / Energietransitie : Klas 2	-	Toen we opdracht haden over het veen gebied met huizen	-	O en O	Scheikunde	Natuurkunde en Scheikunde	Scheikunde exact anders	O en O
11: Heb je ooit gehoord van waterstof als energiebron?	Ja	Ja	Ja	Weet ik niet (meer)	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja
12: Waar denk je dat waterstof voor gebruikt wordt in de energietransitie?	Als brandstof voor auto's, In de industrie, Voor de productie van elektriciteit, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, In de industrie, Voor de productie van elektriciteit, Weet ik niet	Als brandstof voor auto's, Als opslag van energie, Voor de productie van elektriciteit, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, In de industrie, Voor de productie van elektriciteit	Als brandstof voor auto's, Voor de productie van elektriciteit	Als brandstof voor auto's, Voor de productie van elektriciteit, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, In de industrie, Voor het verwarmen van huizen en gebouwen	Weet ik niet	Als brandstof voor auto's, Als opslag van energie, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, In de industrie, Voor de productie van elektriciteit	Als brandstof voor auto's, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, Voor de productie van elektriciteit, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, Als opslag van energie, Voor de productie van elektriciteit	Als brandstof voor auto's, Als opslag van energie, In de industrie, Voor de productie van elektriciteit	Als brandstof voor auto's, Als opslag van energie, Voor de productie van elektriciteit, In de industrie	Als brandstof voor auto's, Als opslag van energie, In de industrie, Voor de productie van elektriciteit, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, In de industrie, Voor de productie van elektriciteit, Voor het verwarmen van huizen en gebouwen
13: Denk je dat waterstof belangrijk kan zijn in de energietransitie?	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja

14: Waarom denk je dat waterstof wel of niet belangrijk kan zijn? Bijvoorbeeld: Wel, omdat het hernieuwbaar en groen is? Of niet omdat het duur is?	Water is er genoeg	Omdat het groen is	Wel, want het eigenlijk gewoon water en dat gaat minder snel op dan fossiele brandstoffen	Wel, omdat het hernieuwbaar is	Wel omdat het niet uit de aarde komt	Het is namelijk duurzaam	Wel, omdat het groen is	Wel omdat het hernieuwbare energie is	Electrisch is een tussenfase, waterstof is de toekomst	Voor auto's	Wel belangrijk maar erg duur	Wel, omdat het goed is voor het milieu	Wel, het is hernieuwbaar en het kan een vervanger van bij voorbeeld diezel	Wel, het stoot weinig uit	Wel, omdat het groen is	Omdat het als opslag voor energie kan zijn	Het is groen, hernieuwbaar, het kan niet duur zijn en levert geen broeikasgassen	Omdat het vanzelf goedkoper wordt met de populariteit	Het is groen
15: Hoe interessant vind je energie-gerelateerde onderwerpen?	4	7	8	8	7	7	5	7	8	7	7	4	7	8	7	5	7	3	8
16: Zou je meer willen leren over waterstof in de energietransitie?	Nee, lijkt me niet interessant	Misschien, als het op een leuke manier wordt uitgelegd	Ja, lijkt me interessant	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Ja, lijkt me interessant	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Nee, lijkt me niet interessant
17: Waarom zou je hier wel of niet meer over willen leren?	Weet ik niet, lijkt me beetje saai	Omdat het iets is wat ze in de toekomst willen grebuiken en dus is het interresant om te weten wat het is	Het is wel een leuk onderwerp	Als het niet leuk is wil ik het ook niet hebben	Als het niet leuk word uitgelegd hoeft het van mij niet	Omdat het voor de toekomst belangrijk is	Het is soms moeilijk te begrijpen	Het lijkt me intressant om over te leren	Wij zijn bezig met een motor die op waterstof loopt	Het lijkt me wel interesant	Weet ik niet, lijkt me wel grappig	Ik wil het wel weten, maar het interesseert mij niet zodanig dat ik er mee aan de gang wil gaan	Omdat het belangrijk is voor de toekomst	Ja, lijkt me wel grappis	Ik vind het opzich wel interessant	Er wordt hier al veel over gepraat	Docent maakt uit	Wel - het is belangrijk voor de toekomst, Niet - het is best saai	Auto's moeten niet elektrisch of op waterstof rijden
18: Op welke manier leer jij het liefst?	Door te experimenteren en proefjes te doen, Door video's te kijken over het onderwerp, Door gastsprekers of excursies, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door gastsprekers of excursies, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door spelletjes of interactieve opdrachten, Door video's te kijken over het onderwerp	Door te experimenteren en proefjes te doen, Door gastsprekers of excursies, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door gastsprekers of excursies, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door gastsprekers of excursies, Door zelf onderzoek te doen en presentaties te maken, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door video's te kijken over het onderwerp, Door zelf onderzoek te doen en presentaties te maken, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door gastsprekers of excursies	Door te experimenteren en proefjes te doen, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen	Door te experimenteren en proefjes te doen, Door video's te kijken over het onderwerp	Door te experimenteren en proefjes te doen, Door gastsprekers of excursies, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door gastsprekers of excursies	Door te experimenteren en proefjes te doen, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door video's te kijken over het onderwerp, Door te lezen en teksten te bestuderen, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door gastsprekers of excursies	Door spelletjes of interactieve opdrachten
19: Waarom vind je deze manier van leren fijn?	Is leuker	Ik vind het cool als er iets gebeurt en dingen te ontdekken	Dan ben je actiever bezig	Omdat het leuk is	Dan doe je wat	Omdat ik liever zelf iets wil doen	Ik houd van dingen doen en daar leer ik het meest uit	Het is interactief en ik leer beter vaak door het te doen	Excurdies zijn leuk en een beetje dingen ontdekken ook.	Dat is leuk	Met de handen	Omdat het de beste manier van leren is voor mij	Omdat op deze manier hoef je niet stom uit schoolboeken te lezen	Dan let ik op	Je leert er ook echt dingen	Omdat dit leuk is	Het houdt mijn aandacht er bij	Het is machtig interessant	Daarom
20: Zou je later willen studeren of werken met energie of waterstof?	Nee	Weet ik niet	Ja	Weet ik niet	Weet ik niet	Weet ik niet	Nee	Weet ik niet	Nee	Weet ik niet	Weet ik niet	Nee	Weet ik niet	Ja	Weet ik niet	Nee	Ja	Nee	Nee
21: Zo ja, wat zou je willen doen? Zo nee, waarom niet?	Weet ik niet	Ik heb niet zo veel interresse	Nog geen idee	Weet ik nog niet	Ik weet niet of ik het wil kiezen	Ik weet nog niet wat ik wil	Nee, mijn interesses liggen anders	Het lijkt me wel intressant maar niet voor werk	Nee ik ga toch liever naar de veehouderij toe	Lijkt me geen leuk werk	Misschien	Omdat ik andere plannen heb voor studies	Ik wil graag iets met werktuigbouwkunde willen doen	Ja, elektricien	Ik weet het niet	Omdat ik iets nuttigs met mijn leven wil doen	Scheikunde studeren	Zie vraag 15	Zie vraag 17

	Antwoorden: Hondsrug College VWO 5					
Vraag:	Leerling 25	Leerling 26	Leerling 27	Leerling 28	Leerling 29	Leerling 6
1: Hoe oud ben je? (in jaren)	17	17	16	17	17	16
2: Wat is je gender?	Vrouw	Vrouw	Vrouw	Man	Man	Man
3: Welk niveau doe je?	VWO	VWO	VWO	VWO	VWO	VWO
4: Welk profiel heb je gekozen?	Natuur en Techniek	Natuur en Gezondheid	Natuur en Techniek	Natuur en Gezondheid/ Natuur en	Natuur en Gezondheid/ Natuur en	Cultuur en Maatschappij
5: Weet je wat de 'energietransitie' is?	Wel van gehoord, maar niet zeker wat het is	Wel van gehoord, maar niet zeker wat het is	Wel van gehoord, maar niet zeker wat het is	Ja	Ja	Ja
6: Wat denk je dat de energietransitie betekend, of zou kunnen betekenen?	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele	Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind
7: Vind jij de energietransitie belangrijk?	Weet ik niet	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst	Ja, het is belangrijk voor de toekomst
8: Is de energietransitie ooit besproken in een van je lessen?	Weet ik niet (meer)	Ja	Weet ik niet (meer)	Ja	Ja	Ja
9: Is waterstof ooit besproken in een van je lessen?	Ja	Weet ik niet (meer)	Ja	Ja	Ja	Weet ik niet (meer)
10: Zo ja, in welke les of lessen zijn waterstof en/of de energietransitie besproken?	Scheikunde	Aardrijkskunde	Scheikunde	O en O, Nederlands, Maatschappijleer, Natuurkunde, Engels	Scheikunde en Natuurkunde	Aardrijkskunde
11: Heb je ooit gehoord van waterstof als energiebron?	Nee	Ja	Ja	Ja	Ja	Ja
12: Waar denk je dat waterstof voor gebruikt wordt in de energietransitie?	Als brandstof voor auto's	Als brandstof voor auto's, In de industrie	Voor de productie van elektriciteit, Voor het verwarmen van huizen en gebouwen	Als brandstof voor auto's, Als opslag van energie, In de industrie, Voor de productie van elektriciteit, Voor het verwarmen van huizen en	Als brandstof voor auto's, Voor de productie van elektriciteit	Als brandstof voor auto's, In de industrie

13: Denk je dat waterstof belangrijk kan zijn in de waarom...?	Ja	Ja	Ja	Ja	Ja	Ja
14: Waarom denk je dat waterstof wel of niet belangrijk kan zijn? Bijvoorbeeld: Wel, omdat het hernieuwbaar en groen is? Of niet omdat het ...?	Wel, omdat het duurzaam is	Het is geen fossiele brandstof volgensmij dus duurzaam?	Eigenlijk beide bovenstaande redenen	Wel, omdat indien het groen geproduceerd is er veverder geen broeikasgasse...	Wel, omdat het groen is en veel aanwezig	Het is groen
15: Hoe interessant vind je energie-gerelateerde ...?	4	3	7	6	6	4
16: Zou je meer willen leren over waterstof in de energietransitie?	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd	Misschien, als het op een leuke manier wordt uitgelegd
17: Waarom zou je hier wel of niet meer over willen leren?	Omdat het wel belangrijk is voor je toekomst	Het interesseert me niet echt	Omdat het een belangrijke factor is voor (waarschijnlijk) het klimaat	Het is wel interessant, maar het is een (te) veel besproken onderwerp waardoor het door de herhaling saai wordt	Ik vind het een belangrijk onderwerp waar over nagedacht moet worden	Ik vind het een belangrijk onderwerp, maar heel interessant vind ik niet
18: Op welke manier leer jij het liefst?	Door te lezen en teksten te bestuderen	Door video's te kijken over het onderwerp, Door te lezen en teksten te bestuderen	Door te experimenteren en proefjes te doen, Door video's te kijken over het onderwerp, Door gastsprekers of excursies, Door spelletjes of interactieve opdrachten	Door te experimenteren en proefjes te doen, Door video's te kijken over het onderwerp, Door te lezen en teksten te bestuderen	Door te experimenteren en proefjes te doen, Door gastsprekers of excursies, Door zelf onderzoek te doen en presentaties te maken, Door spelletjes of interactieve opdrachten	Door video's te kijken over het onderwerp, Door gastsprekers of excursies, Door te lezen en teksten te bestuderen
19: Waarom vind je deze manier van leren fijn?	Omdat dit het meest praktisch is	Werkt het beste, kan ik motivatie voor vinden	Het houdt mijn aandacht er bij	Weinis contact waardoor je op eigen tempo kan doen. Ook zijn het vrij low-effort manieren om dingen te leren	Praktisch gericht en afwisseling met gebruikelijke lesprocedure	Ik lees of luister liever dan dat ik zelf actief aan het werk moet
20: Zou je later willen studeren of werken met energie of waterstof?	Nee	Nee	Weet ik niet	Nee	Nee	Nee, lijkt me niet interresant genoeg
21: Zo ja, wat zou je willen doen? Zo nee, waarom niet?	Nee, lijkt me niet leuk, klinkt te ingewikkeld	Saai, interresseert me niet, klinkt ingewikkeld	Weet nog niet goed wat ik ga doen	Nee, want mijn intresse ligt niet bij waterstof of iets anders technisch	Gewoon niet een intresse gebied waar ik een carriere in zou willen	Omdat het voor mij geen boeiend vakgebied is

Appendix 12: Initial Survey Answers – Analysis and Visualisations

This appendix visualises and provides a descriptive analysis of the answers to the main survey questions.

The visualisation of the answers from the Montessori Lyceum and Hondsrug College HAVO and VWO students to the question asking if they know what the energy transition entails is visualised in a pie chart. As shown in Figure 28, at the Montessori Lyceum, more than a quarter of students did not know what the energy transition is, with the remaining students indicating that they have heard of it, but they are not sure what it is.

Figure 28: Question if students know what the energy transition is, HAVO Montessori

Figure 29 and Figure 30 show that at the Hondsrug College, the awareness of the energy transition as a concept is a lot higher, with 60% of both HAVO and VWO students noting that they know what it is, and 40% of HAVO and 37% of all participants having hear of it but not being sure what it is. There was only one participant at the VWO level who did not know what the energy transition is.

Figure 29: Question if students know what the energy transition is, HAVO Hondsrug College

Figure 30: Question if students know what the energy transition is, HAVO+VWO Hondsrug College

The question after this one, show in Appendix 10: Initial Survey Questions, asked the participating students what they thought the energy transition could mean. Originally, this question was an open question, but after feedback from teachers, this was changed to a multiple-choice question, with only the right answers and an option that they don't know. Out of all 41 participating students, 10 selected all the right answers, as seen in Appendix 11: Initial Survey Answers. After this, the students watched a video explanation of the energy transition called ”Morgenland” up until the point that the video started explaining hydrogen (Fields, n.d.). This short film was recommended by Tineke van der Meij during the interview and provided a short, entertaining and detailed explanation of the energy transition for the students to continue the questionnaire. After this, the students were asked to look back at their answers to the question above but not to change them.

In the survey, a large majority of the participants of both the HAVO of the Montessori Lyceum and the VWO of the Hondsrug College indicated that both the energy transition and hydrogen had at some point been discussed in their lessons. For the HAVO students at the Hondsrug College, this was lower, with only 20% indicating that the energy transition was discussed and 40% indicating that both the energy transition and hydrogen were never discussed in lessons. For the Montessori Lyceum, the lessons where hydrogen and/or the energy transition are/were discussed are shown in Figure 31, with chemistry being the main contributor, which is not unusual, as hydrogen atoms and bonds are also a part of the chemistry curricula.

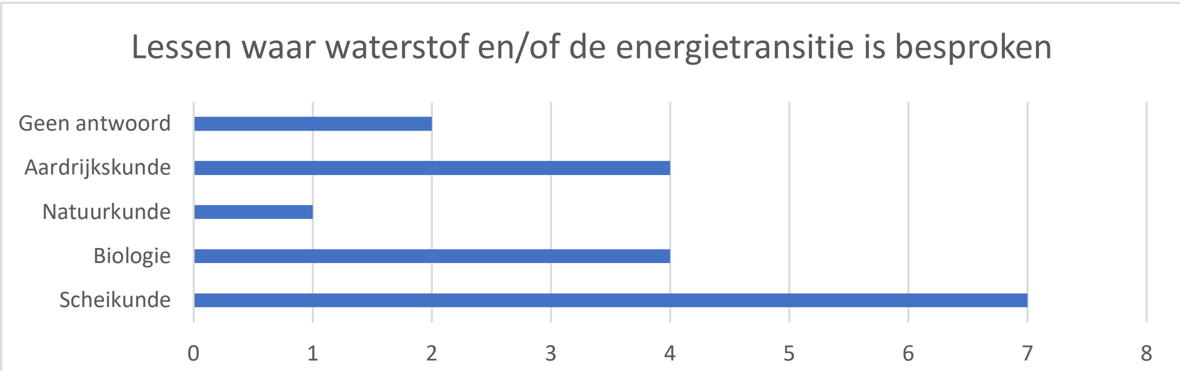


Figure 31: Lessons where energy transition or hydrogen were discussed, HAVO Montessori Lyceum

For the Hondsrug College, the HAVO participants noted that hydrogen and the energy transition were not discussed as much as the VWO participants did. As Figure 32 shows, chemistry, physics and geography were noted as lessons that included the subjects. For the VWO participants, Figure 33 shows the main answer was once again chemistry, with onderzoeken en ontwerpen (O&O), the Technasium subject, noted as a close second. O&O is not provided as a subject at the Montessori Lyceum, as they are a school without Technasium.

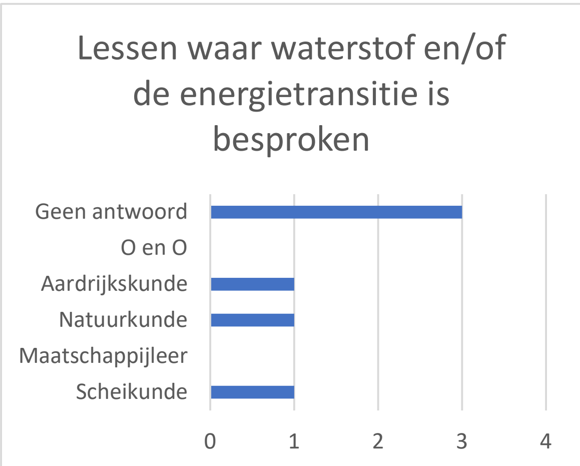


Figure 32: Lessons where energy transition or hydrogen were discussed, HAVO Hondsrug College

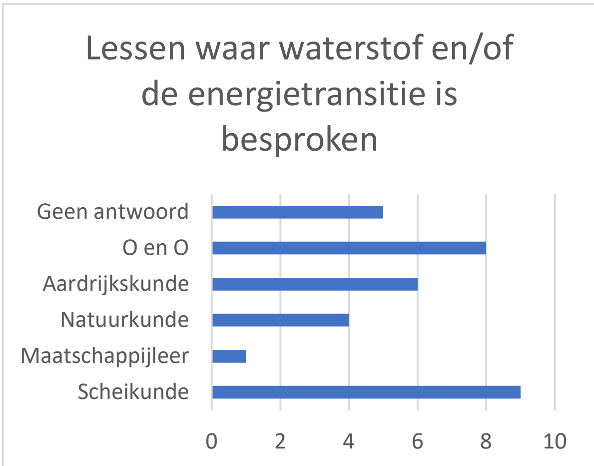


Figure 33: Lessons where energy transition or hydrogen were discussed, HAVO+VWO Hondsrug College

Appendix 13: Case studies into Related Interventions/Projects

This appendix shows an insight into a variety of interventions/projects for secondary schools for educational topics related to this intervention. The following educational projects in the Netherlands focus on the energy transition:

- **Energie(K) Onderwijs:** This project was created to prevent the energy transition from slowing down due to a lack of skilled workers in the energy sector. The 'Energie(K) Onderwijs' project is a project that is not just within the Netherlands, but a collaboration between the southern Netherlands and the Flemish region of Belgium, working together as one to prevent shortcomings in the energy transition. This project focuses on clarifying the need for skilled workers, designing educational projects, and interesting and inspiring students for a future in the energy transition. This project also reflects a strong case for the Motivation-Opportunity-Ability framework by motivating through career relevance, opportunity through access to professional and ability by teaching (technical) skills (Interreg Vlaanderen-Nederland, 2023; MacInnis et al., 1991).

- **Milieueducatie Den Haag:** An organisation aiming to help people under 16 make conscious choices for a sustainable society, doing this by supporting teachers with practical and lively lessons (Milieueducatie Den Haag, 2022). One of their focuses is the energy transition, in which they offer a learning trajectory for secondary schools. This trajectory contains learning targets for each year of secondary school, for both HAVO and VWO levels, aiming to make the students see why the energy transition is needed and what it means for their surroundings (Milieueducatie Den Haag, 2023).

- **Darel Education Masterclass Energietransitie:** Since 2018, Derel Education has provided free energy transition masterclasses to secondary school and MBO students. This non-profit organisation is backed by Gasunie, EBN, TenneT and the Amsterdam & Rotterdam harbour companies to provide attention to the energy transition in secondary and MBO education (Darel Education, 2023). For HAVO students the masterclasses provide interactive ways to work together and create possible solutions and applications for the energy transition. This also follows the lines of the Self-Determination Theory through the autonomy, competence and relatedness students get by working on personal ideas of solutions. They offer information about the forms of energy and the societal role of the energy transition, with a view into the students' behaviour and their role in the future (Darel Education, n.d.).

  Darel Education has now provided 866 masterclasses to more than 22.000 students, with students finding that the problems are bigger and more urgent than expected. Schools indicated that the classes were inspiring and valuable for the students (Darel Education, 2024).

- **Jouw Energie van Morgen:** The Rijksuniversiteit Groningen's science truck travels across the Netherlands to inspire students in secondary education with current issues in the sciences and technical fields. Under the banner of 'Jouw Energie van Morgen', secondary students are challenged to help think about usable energy solutions for the future (Nikkiwp, 2024). Through an interview with [redacted] from the RUG, the experience and outcomes of working with the science truck and other initiatives of the RUG like the 'Scholieren Academie' were discussed. The questions and answers to this interview can be found in Appendix 9: Expert Interviews.

  [redacted] now works at the Scholieren Academie (RUG, 2024b), which focuses on introducing secondary school students to scientific research skills and sparking interest in STEM subjects. This is done with the help of university students as teachers. There is no long-term research on the effects of this project, effectiveness is measured by a checkup with teachers on how it went, and the success is also measured through reoccurring invites from schools.

Before working at the Scholieren Academie, [redacted] worked together [redacted] in the 'Jouw Energie van Morgen' truck. Here, she travelled around the Netherlands with the truck's expandable classroom. The addressed subjects changed regularly, but the energy transition and secondary students' vision on energy and sustainability was often a big subject, with interactive activities and hands-on lessons that look at current situations. [redacted] noted that the 'Jouw Energie van Morgen' truck was often a great success with exited feedback from both teachers and students (Nikkiwp, 2024).

To get a better insight into the effectiveness and goals of the 'Jouw Energie van Morgen' truck, a subsequent interview would have been arranged with Theo Jurriens. This interview was, however, never conducted as Theo did not agree to an online interview and scheduling conflicts prohibited an in-person interview.

Scholen als Energieambassade in de wijk: This multi-stakeholder action research by the TU Delft, Technotrend and Energie-U investigated the role (secondary) schools could play in the energy transition. Together with students, teachers and stakeholders of the participating schools, a variety of interventions were created to research the effect that these schools can have on the social progression of the energy transition. This project also takes the Theory of Planned Behaviour under its wing by involving the students in existing (local) community energy projects.

The results of this research showed a significant positive development in the knowledge of the energy transition among students, and the students showed a very positive attitude towards sustainability and the energy transition. Schools indicate that the initiatives improved the quality of education, and they did not just create interest in the energy transition and sustainability among students, but also the teachers, parents and school direction. Some schools even began centralising sustainability in their curriculum (De Caluwé et al., 2020).

- **Waterstof in de klas:** This energy transition project focuses on hydrogen, and how hydrogen can be of importance in the energy transition. Started by the 'Alles over waterstof' foundation, this project brings understanding and experiencing hydrogen together for students in a guest lesson (Alles over waterstof, 2022). In this guest lesson, students learn what hydrogen is, how it is made, the uses of hydrogen and its future, and how safe hydrogen is. These lessons include many hands-on and practical parts. Schools indicated that the lessons are inspiring, not just for the students but also for the teachers (Waterstof in de klas, 2023).

  To get a better understanding of these guest lessons and their results, an inquiry for contact was made. After the initial phases of the research had passed, a late reply indicated that the attempted contact had ended up in the spam folder, but after once again inquiring about a possible contact moment, no reply was received.

Theory and framework analysis

Table 21 analyses the case studies in line with the Theories and Frameworks that were found and analysed in the desk research.

Table 21: Case Study Analysis to Theories and Frameworks

Case Study	**Experiential Learning Theory**	**Self-Determination Theory**	**Theory of Planned Behaviour**	**Motivation Opportunity Ability Framework**
Darel Education	Hands-on masterclasses where students actively work on energy solutions.	Builds intrinsic motivation through teamwork and creative freedom.	Shifts behaviour by making students aware of their role in the energy transition.	Provides knowledge (Ability), collaborative setting (Opportunity), and motivation through real-world impact.
Jouw Energie van Morgen	Science truck with practical experiments on energy solutions.	Autonomy in problem-solving and guidance from university students.	Changes attitudes towards sustainability through practical engagement.	Tools and knowledge (Ability), hands-on experience (Opportunity), and motivation through collaboration.
Waterstof in de Klas	Guest lessons with real hydrogen applications and technology.	Autonomy through hands-on learning and active participation.	Increases awareness of hydrogen's role in the energy transition.	Direct experience (Ability), expert-led lessons (Opportunity), and motivation through real-life applications.
Scholen als Energieambassade	Collaborative project-based learning with students, teachers, and stakeholders.	Builds competence and autonomy through real-life community projects.	Changes behaviour by directly involving students in the energy transition.	Knowledge-sharing (Ability), community involvement (Opportunity), and motivation through visible impact.
Milieueducatie Den Haag	Interactive lessons and sustainability projects.	Encourages autonomy by allowing students to explore local sustainability solutions.	Builds sustainable habits through environmental awareness.	Tools and learning targets (Ability), interactive setting (Opportunity), and motivation through societal impact.
Energie(K) Onderwijs	Technical workshops and innovation projects.	Builds competence and autonomy through technical projects.	Influences career choices towards the energy sector.	Technical skills (Ability), access to professionals (Opportunity), and motivation through career relevance.
Hydrogen Horizon	International hands-on hydrogen STEM projects and competitions.	Builds student autonomy and competence through practical hydrogen technology challenges.	Changes behaviour by allowing students to experience the future of hydrogen first-hand.	Technical knowledge (Ability), global collaboration and competitions (Opportunity), and motivation through innovation.

Appendix 14: MoSCoW Prioritised Requirements

Table 22 shows the intervention requirements sourced from the data collection and analysis, sorted into corresponding groups, with MoSCoW prioritisation and the origin of the requirement.

Table 22: Sorted requirements with MoSCoW Prioritisation

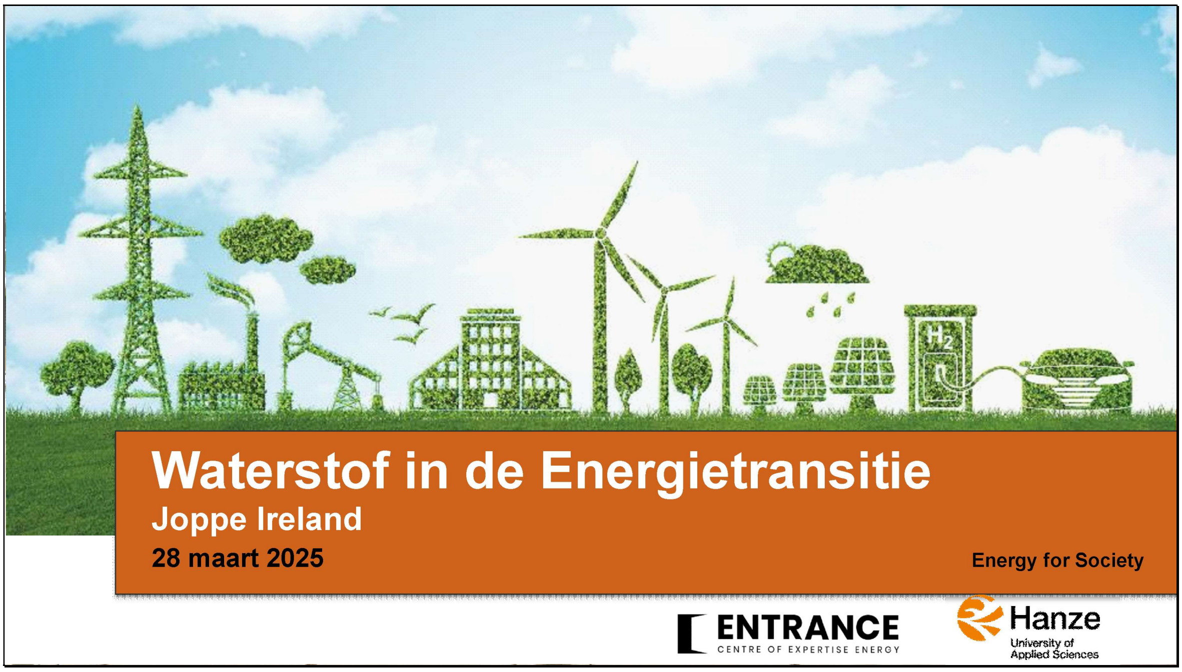
ID	Requirement Description	Priority	Origin
1	The intervention must align with HAVO students' current learning levels.	Must	Teachers, Experts
1.1	Covering the basics of hydrogen and its role in the energy transition. Including different types of hydrogen and value chains.	Must	ENTRANCE, Teachers, Experts
1.2	Show that the energy transition, and hydrogen within it is not just technical.	Must	ENTRANCE, Experts
1.3	Include real-world uses of hydrogen to make the topic relevant.	Should	Experts, ENTRANCE
1.4	Include a deeper dive into the science behind hydrogen production.	Could	Teachers, Experts
2	The intervention must be engaging and interactive to maintain student interest.	Must	Students, Teachers
2.1	Include hands-on activities and/or experiments.	Must	Case Studies, ELT, Teachers, Students
2.2	Include relatable problem-solving tasks.	Should	Experts, Teachers, TPB
2.3	Utilize gamification or quizzes to enhance the interactivity of learning.	Should	Case Studies, SDT, MOA Framework
2.4	Enable students to work together in teams.	Should	Experts, Students
2.5	Allow students to choose learning directions that interest them (autonomy).	Should	SDT, Students
2.6	Use digital tools like videos and simulations.	Should	Experts, Students
2.7	Include visits to ENTRANCE's testing grounds.	Could	ENTRANCE, Teachers, Experts
3	The intervention must use motivational strategies to engage students.	Must	SDT, MOA Framework
3.1	Connect to students' daily lives and future career opportunities.	Should	TPB, Experts, Teachers
3.2	Information is relatable and on the HAVO students' level.	Must	Teachers, TPB
4	The intervention must fit within school schedules and subjects.	Must	Teachers, Experts
4.1	Add minimal extra workload for teachers.	Must	Teachers, Experts
4.2	Fit in existing lesson blocks (or set times).	Should	Teachers
4.3	Fit within different secondary school levels.	Could	Teachers
5	The intervention should also provide guidance and/or resources for teachers.	Should	Teachers, Experts
5.1	Allow flexibility for teachers to jump in/help.	Should	Teachers, Experts
5.2	Provide ready-to-use lesson plans with manuals.	Could	Teachers
5.3	Offer teacher training or workshops.	Could	Experts, Teachers
5.4	Involve teachers directly in the lesson content.	Should	Teachers
6	The intervention should connect students to the industry and experts.	Should	ENTRANCE, Experts
6.1	Involve guest speakers from the hydrogen sector	Could	Experts, Case Studies
6.2	Include visits to hydrogen facilities/industry.	Could	Experts, Case Studies
7	The effectiveness of the intervention must be measured.	Must	ENTRANCE, Hanze
7.1	Pre and post-intervention surveys with the students.	Must	Research Design
7.2	Observe and collect feedback from teachers and students.	Must	Research Design
7.3	Allow space for changes as the intervention progresses.	Should	Research Design
7.4	Space for improvements based on feedback.	Should	Research Design
8	The intervention should be designed to allow expansion and further use.	Should	ENTRANCE, Experts

8.1	Materials are reusable and stay relevant.	Should	ENTRANCE
8.2	The intervention is adaptable and scalable for other schools.	Should	Case Studies, Experts
8.3	There is a clear instruction and overview for the intervention.	Should	Teachers
9	The intervention will not require in-depth (technical) hydrogen knowledge.	Won’t	ENTRANCE, Teachers
9.1	Mandatory lessons in the curriculum.	Won’t	ENTRANCE, Teachers

Appendix 15: Intervention Development Roadmap

Figure 34: Hydrogen Education Intervention Roadmap

Appendix 16: Intervention Presentation



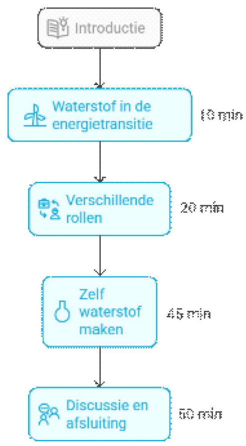
Waterstof als energiebron

Heb wel eens gehoord van waterstof als energiebron.
- Ja
- Nee

Is waterstof een energiebron?
- Ja
- Nee

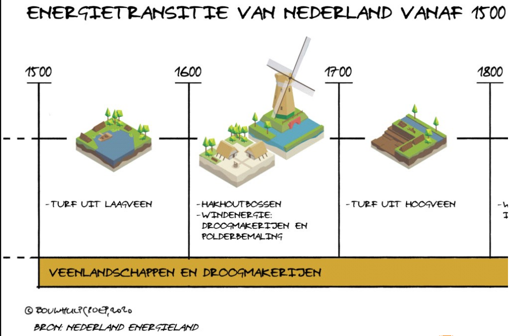
Wat gaan we doen?

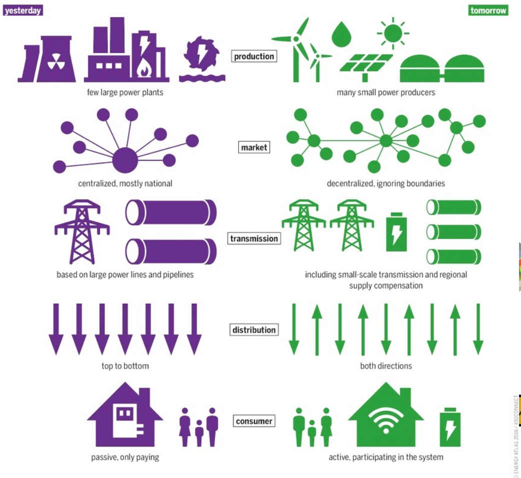
1. De energietransitie
   - Basistheorie
   - Verschillende rollen
   - Waterstof
     - Basistheorie
     - Soorten
     - Mogelijkheden
     - In het dagelijks level
2. Zelf waterstof maken
3. Vragen en discussie

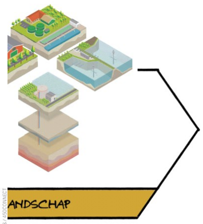


De energietransitie

- Het probleem
- De transitie
- De wereld om je heen







ENTRANCE CENTRE OF EXPERTISE ENERGY

Hanze University of Applied Sciences

Verschillende rollen: Opdrachtje

Bekijk de verschillende beroepen en overleg met je groepje bij welke categorie ze passen:

- **Direct betrokken bij de energietransitie**
- **Indirect betrokken bij de energietransitie**
- **Niet betrokken bij de energietransitie**

Lijst met beroepen:

Advocaten
Architecten
Atleten
Automonteurs
Docenten
Electromonteurs
Financieel adviseurs
Game designer

(Huis) Artsen
Mode ontwerpers
Muzikanten
Politici
Psychologen
Reclame makers
Verplegers

ENTRANCE CENTRE OF EXPERTISE ENERGY

Hanze University of Applied Sciences

Verschillende rollen: Antwoorden

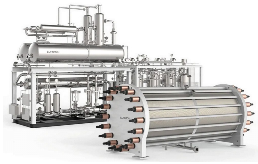
Bekijk de antwoorden van je groepje, wat valt je op?

Direct betrokken bij de energietransitie
Advocaten
Architecten
Automonteurs
Docenten
Electromonteurs
Financieel adviseurs
Reclame makers
Mode ontwerpers
Politici
Psychologen

Indirect betrokken bij de energietransitie
Atleten
Game designer
(Huis) Artsen
Muzikanten
Verplegers

Niet betrokken bij de energietransitie

Waterstof: Basis



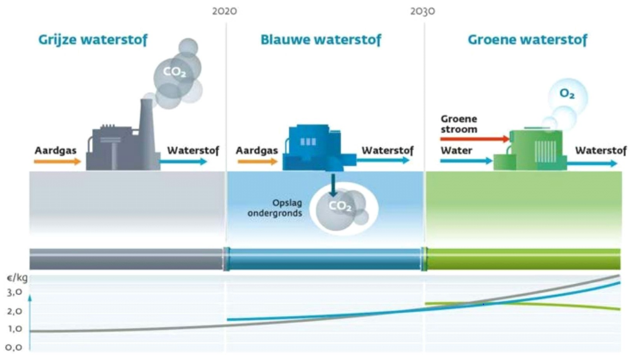
Electrolyse → Electrolyser

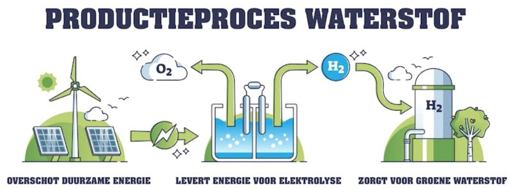
$$2\ H_2O + Energy = 2H_2 + O_2$$

Vloeibaar, Electriciteit, Gas, Gas

Oxidatie ← Brandstofcel

Waterstof: Soorten





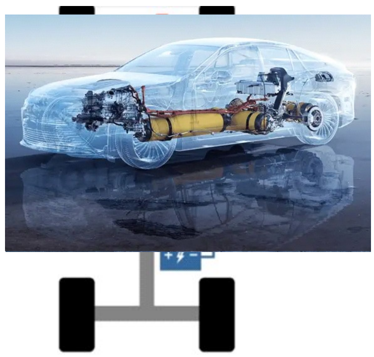
ENTRANCE CENTRE OF EXPERTISE ENERGY
Hanze University of Applied Sciences

Waterstof: In het dagelijks leven

Een Toyota Mirai waterstof auto gebruikt 1kg waterstof per 100km
Als je de waterstof uit een 0,5l flesje water zou halen,
zou de Mirai daar meer of minder dan 5km op kunnen rijden?

- Meer
- Minder

Een Toyota Mirai kan 5,5km rijden op de waterstof uit een 0,5l flesje water!



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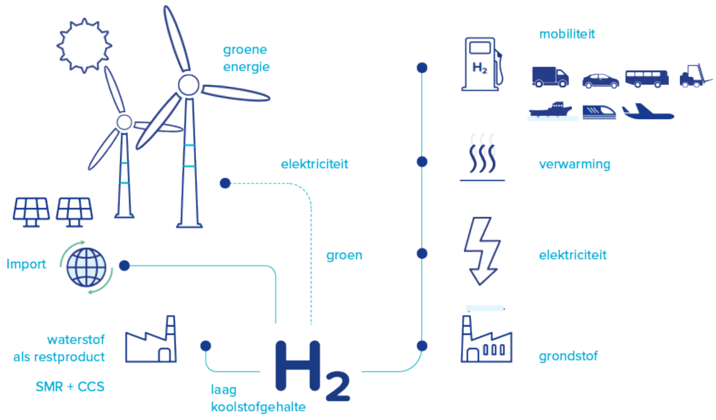
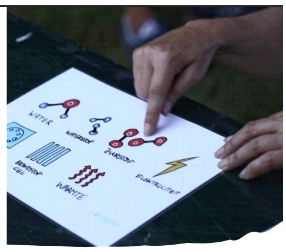
Waterstof: Mogelijkheden



Zelf waterstof maken

Bekijk de uitleg op het bord!



Vragen en discussie

ENTRANCE CENTRE OF EXPERTISE ENERGY
Hanze University of Applied Sciences

Appendix 17: Energy Transition Roles Exercise

Rollen in de energietransitie

Bekijk de verschillende beroepen en overleg met je groepje bij welke categorie ze passen:

- **Direct betrokken bij de energietransitie**
- **Indirect betrokken bij de energietransitie**
- **Niet betrokken bij de energietransitie**

Leg dan de kaartjes bij de categorie waar jullie denken dat ze horen:

Direct betrokken bij de energietransitie	Indirect betrokken bij de energietransitie	Niet betrokken bij de energietransitie

Kaartjes:

Advocaten	Atleten	Mode ontwerpers
Architecten	Game designers	Reclame makers
Automonteurs	(Huis) Artsen	Politici
Docenten	Verplegers	Psychologen
Electromonteurs	Muzikanten	Financieel adviseurs

Appendix 18: Link Sheet

Leuke filmpjes, websites en spelletjes over waterstof en de energietransitie

Deze links leiden naar filmpjes met meer informatie leuke en belangrijke energietransitie en waterstof onderwerpen:

- **Morgenland: https://www.youtube.com/watch?v=B39OUrjtgzg**
- **Waterstof in de energietransitie: https://www.youtube.com/watch?v=FyLeD8J82dw**
- **Hoe werkt de waterstof auto: https://youtu.be/w8tFxbrXWi0?si=8zSbT3_cmFZ-E0s3**
- **Nos, rijden op waterstof: https://youtu.be/L9mo1pRURWM?si=DBlRuxtdAxIED4yF**
- **Waterstof recept: https://vimeo.com/561483302**
- **Waterstof in duurzame wereld: https://youtu.be/n3l_q7ROd30?si=Ow7w2p8bv8N9SACX**

Deze links leiden naar websites waar je meer informatie kan vinden over leuke en belangrijke energietransitie en waterstof onderwerpen:

- **Kaart van waterstofprojecten in Nederland: https://waterstofkaart.missieh2.nl/nl/Indirect betrokken bij de energietransitie**
- **Leuke informatie over waterstof: https://unitedhydrogenlimited.com/information-hub/ (Engels)**
- **15 dingen die je moet weten over waterstof:** https://www.tno.nl/nl/duurzaam/industrie/co2neutrale-industrie/schone-waterstofproductie/15-dingen-die-je-moet-weten-waterstof/
- **Hoe kunnen scholen helpen met de energietransitie:** https://stichtingtechnotrend.nl/scholen-kunnen-helpen-bij-energietransitie-wijken
- **Dit doet de EU: https://european-union.europa.eu/priorities-and-actions/actions-topic/energy_nl**

Deze links leiden naar spelletjes of interactieve websites waar je spellen kan doen met de energietransitie en waterstof:

- **Waterstof op zee spel: https://h2mare.info/ (Duits)**
- **Energie transitie in de buurt regelen: https://web.jrc.ec.europa.eu/visitors-centre-tools/recxploration/ (Engels)**
- **Stop de disaster game: https://www.stopdisastersgame.org/game/ (Engels)**
- **Stroomnetwerk balanceren: https://www.neso.energy/energy-101/balancing-grid-interactive-game (Engels)**

Appendix 19: Sub-question Findings

This appendix shows a more detailed overview of the main findings from the sub-questions and how these findings helped to develop the intervention design.

Current state of hydrogen education

This sub-question reads: "What is currently being taught at participating secondary schools about hydrogen within the energy transition, and what is the HAVO student's level of knowledge, awareness, and interest?".

By conducting desk research, surveys with the students and interviews with teachers and experts, an overall and school-specific answer was found to this sub-question. In the national HAVO educational curricula, the energy transition, and hydrogen within it, are not structurally included for students. Experts and teachers also reflected that these subjects are not generally a focus in HAVO education, except for certain projects from, for instance, Technasium.

Teachers at the participating school indicated that hydrogen is covered as an element in chemistry lessons, but not as a part of the energy transition, or the energy transition itself. Students who participated in the surveys also indicated that the concept of hydrogen as an element, or its general chemical use, was discussed sparsely in lessons, but not in the context of the energy transition. The participants at the Hondsrug College in Emmen were overall better informed, likely due to their participation in Technasium projects that included these subjects.

This sub-question provided a base level of understanding and knowledge of hydrogen and how it is approached in schools, to be used for the design of the intervention.

Engaging HAVO students in hydrogen

This sub-question reads: "What are effective ways to create awareness and interest in hydrogen within the energy transition among HAVO students?". For this sub-question, desk research, case studies, interviews and surveys came together to create a clear picture of possibilities and insights on how the intervention could effectively create awareness and interest.

Desk research found that the use of the ELT, SDT, TPB, and the MOA framework could raise awareness and interest among HAVO students. ELT encourages hands-on, interactive, and practical learning, which can engage students through practical experiments. SDT focusses on engaging and motivating students through relatability, autonomy and competence, for instance, through group activities. TPB stresses that student interest depends on the value they and others put on a topic, and its complexity. Lastly, the MOA Framework states that the intervention should provide motivation, opportunity and ability to create engagement.

The case studies, both national and international, supported the use of these theories by showing that hands-on learning is often combined with real-world challenges to engage students. This included group work, experiments, and tasks that aligned with the theoretical frameworks and were found to be promising methods to increase student engagement.
Not just the case studies and desk research indicated the effectiveness of the theory behind these different theories and frameworks, but the insights from teachers and experts also heavily supported the use of hands-on experiences, but also competitiveness, autonomy and structure. This reflects these theories and frameworks and strengthened their possible importance in the intervention design further. The students themselves were also asked about their preferred learning methods through the surveys, with high favourability of experiments and interactive assignments.

These results created a clear path forward for the design of the intervention, and what could be effective for the intervention to create awareness and interest in hydrogen within the energy transition among HAVO students.

ENTRANCE's role in hydrogen education

This sub-question reads: "How do ENTRANCE's current educational programs and expertise align with what is needed to engage HAVO students in hydrogen within the energy transition?". For this sub-question, desk research and interviews were used to analyse ENTRANCE's existing programs, expertise and resources, to implement the identified theories and frameworks into practice through the design and implementation of the intervention.

The research into this sub-question found that though ENTRANCE has many programs focussed on hydrogen and hydrogen education, secondary school students, in particular HAVO students, are not specifically targeted with these programs. Students and teachers also lack awareness of ENTRANCE, and what ENTRANCE does and stands for.

Though not focussed on HAVO students, the interviews revealed a promising resource of hydrogen test kits that could be used to create a small amount of hydrogen in a hands-on experiment. These kits allow for the practical application of hydrogen in a classroom, and these sets were noted as a promising opportunity for the intervention design.

ENTRANCE's role in the development of an educational hydrogen intervention

This sub-question reads: "How can the facilities and expertise of ENTRANCE be used to create an engaging educational intervention?". This sub-question continues on the information gathered through the earlier sub-questions, combining the promising resources, expertise and research through desk research and interview analysis.

ENTRANCE's position between the education and work field practice makes it a possible middleman for student education through hands-on and in-person experiences. Visits to ENTRANCE could make a great impact on students by introducing them to real-world hydrogen projects and giving them hands-on experiences. The hydrogen test kits were chosen as an initial classroom implementation of ENTRANCE resources through collaboration with the expert they were then implemented into the intervention design.

Barriers to hydrogen education in secondary schools

This sub-question reads: *"What barriers or challenges could arise when implementing a successful educational intervention on the energy transition in secondary schools, and how can these be overcome?"*. For this sub-question, the knowledge acquired through the other sub-questions was analysed, and with the use of interview questions, common barriers were identified.

The main points where both experts and teachers noted challenges that could arise were time constraints that schools and teachers face, fitting new information into the curriculum and external support/extra work for teachers. These challenges were faced in the research and intervention design by ensuring clear communication for schools and teachers, linking the information to existing subjects and curricula, and providing an in-person guest lecture instead of pre-made lessons that the teachers had to figure out and provide themselves.

Appendix 20: Intervention Pilot and Observations

As the day of the intervention pilot neared, preparations were made, and the intervention was showcased to the ENTRANCE representatives for early feedback from the client. This feedback and showcase session brought many important insights, and gave room for personal reflection and practice of the intervention. The biggest changes in the intervention came in the form of switching the order of tasks or information given through the presentation, with small adjustments to the showcased information itself.

After this showcase, the intervention was tested by conducting it (online) with two secondary school students who gave feedback on the experience, points of interest and possible feedback on improvements. This intervention test brought no major changes as the students enjoyed the activities that were possible, and understood and liked the information that was provided. The only recommendations were a shorter list of possible jobs related to the energy transition, as it took up a lot of time to do that exercise, which was then implemented.

On the day of the intervention pilot, the cards and sheets for the energy transition jobs exercise were forgotten at home after binding them before the intervention. Luckily, there was just enough time to spare to retrieve them, but this left little time to prepare in the classroom.

Observations during the pilot

As the class came in, they received cards representing their group for the lesson; they were notably not very excited to not choose their own groups, but after a few minutes, they settled in. The teacher sat at the back of the classroom to observe and help if needed. I explained to the students that they all got one colour (see-through) plastic cup, in which they would receive chocolate eggs if their group participated well; the better the participation, the more eggs.

It was clear that not all students were very excited about the lesson and the topic, and in the background, the school band was rehearsing loudly outside, which was a big distraction for some students. When the presentation started, the first slide of current headlines pulled in a lot of the attention, with the relatability of the explanation seemingly drawing them in further.

The basics of the energy transition seemed to keep the students engaged while they were explained, after which they were very excited that there was an exercise they could do in their groups. I called one person from each group forward to collect the paper and cards, after which all students actively participated and discussed in groups. The collection of the papers did not go smoothly, and it would have been better for the papers to be situated on the groups' tables already.

During the time the groups were discussing, the slide was accidentally switched to the answers, with one group getting a small glance at them. When all groups were done, the answers were shown, and many students were surprised that all jobs were related to the energy transition in some way. This prompted a discussion on why and how some jobs were, and the students actively participated.

After this, the hydrogen basics were shown and explained, with a question on the distance a hydrogen car can travel grabbing a lot of the attention, somehow all the groups got the question right. The participation up to this point was very high.

The students then finally got to make hydrogen themselves, once again, one group member came to collect the test kits, which turned into slight chaos, and would have been avoided by placing the kits on the table beforehand. The students were very enthusiastic about this hands-on experiment and participation was very high all around.

As the students were slowly following the steps, the lesson end became near, so as the first groups finished the experiments and packed them back in the box, others were only just halfway. In the end, the final discussion was cut short to allow all groups to finish the experiment. In the final few minutes, the students were asked if they had any questions, but there were no big ones. The students were then asked if they enjoyed the lesson, and many heads nodded and many yesses were heard. After this, the students got to leave and enjoy their break.

Teacher feedback/observation

The teacher noted that the students definitely seemed to enjoy the lesson and were all very actively engaged. As I had noticed, the teacher also implied that handing out the exercises/experiments beforehand would have been less time-consuming and less chaotic. She also noted that the addition of the chocolate eggs got a lot of students even more excited about participating in the lesson.

Appendix 21: Post-intervention Survey, Montessori Lyceum Groningen

Vragenlijst waterstof in de energietransitie Deel 2

0. Heb je de eerste vragenlijst over waterstof ingevuld? *(Vink één optie aan)*

- ◯ Ja
- ◯ Nee

1. Hoe oud ben je? [ ] *In jaren*

2. Wat is je gender? *(Vink één optie aan)*

- ◯ Vrouw
- ◯ Man
- ◯ Anders
- ◯ Zeg ik liever niet

3. Welk niveau doe je? *(Vink alles aan wat van toepassing is)*

- VMBO ☐
- HAVO ☐
- VWO ☐

4. Welk profiel heb je gekozen? *(Vink alles aan wat van toepassing is)*

- ☐ Cultuur en Maatschappij
- ☐ Economie en Maatschappij
- ☐ Natuur en Gezondheid
- ☐ Natuur en Techniek

5. Weet je wat de 'energietransitie' is? *(Vink één optie aan)*

- Ja ◯
- Nee ◯
- Wel van gehoord, maar niet zeker wat het is ◯

6. Wat denk je dat de energietransitie betekent, of zou kunnen betekenen? *(Vink alles aan wat van toepassing is)*

- ☐ Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken
- ☐ Het verbeteren van energie-efficiëntie in huizen en bedrijven
- ☐ Minder gebruik maken van fossiele brandstoffen zoals olie en gas
- ☐ Overstappen op duurzamere energiebronnen zoals zon en wind
- ☐ Ik weet het niet

JOP_1 *Reageren* ☒ *en* ● papersurvey.io JZJL0001

7. Is waterstof een energiebron of een energiedrager? *(Vink één optie aan)*

- ◯ Een energiebron
- ◯ Een energiedrager
- ◯ Weet ik niet

8. Wat weet je over waterstof in de energietransitie? *(Vink alles aan wat van toepassing is)*

- ☐ Waterstof kan worden gebruikt als vervanger voor fossiele brandstof
- ☐ Waterstof is altijd groen
- ☐ Waterstof kan worden gemaakt van water of aardgas
- ☐ Waterstof is beter om kort energie op te slaan dan een batterij
- ☐ Waterstof is beter om lang energie op te slaan dan een batterij
- ☐ Ik weet er weinig tot niks over

9. Wat was het meest verrassende of interessante dat je hebt geleerd tijdens de gastles?

10. Hoe belangrijk vind je de energietransitie?

1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ 10 ◯

Op een schaal van 1 tot 10

11. Denk je nu dat de energietransitie belangrijker is dan *VOOR* de eerste vragenlijst over waterstof? Waarom wel of niet? *(Vink één optie aan)*

- Ja ◯
- Nee ◯
- Niet meer niet minder ◯

Waarom:

12. Vind je de energietransitie nu interessanter dan *VOOR* de eerste vragenlijst over waterstof? Waarom wel of niet? *(Vink één optie aan)*

- Ja ◯
- Nee ◯
- Niet meer niet minder ◯

Waarom:

13. Hoe belangrijk denk je dat waterstof is/kan zijn in de energietransitie?

1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ 10 ◯

Op een schaal van 1 tot 10

JOP_1 *Reageren* ⊠ *en* ● papersurvey.io JZJL 0002

14. Denk je nu dat waterstof belangrijker is dan *VOOR* de eerste vragenlijst over waterstof? Waarom wel of niet? *(Vink één optie aan)*

Ja ◯
Nee ◯
Niet meer niet minder ◯

Waarom: [ ]

15. Hoe interessant vind je het onderwerp waterstof?

0	1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

Op een schaal van 1 tot 10

16. Vind je waterstof nu interessanter dan *VOOR* de eerste vragenlijst over waterstof? Waarom wel of niet? *(Vink één optie aan)*

Ja ◯
Nee ◯
Niet meer niet minder ◯

Waarom: [ ]

17. Zou je later een beroep of studie willen doen die te maken heeft met waterstof of de energietransitie? Waarom wel of niet? *(Vink één optie aan)*

Ja ◯
Nee ◯
Weet ik niet ◯

Waarom: [ ]

18. Denk je dat als je niet er voor kiest om een beroep of studie te doen die te maken heeft met waterstof of de energietransitie, je toch te maken zal hebben met deze onderwerpen? Waarom wel of niet? *(Vink één optie aan)*

Ja ◯
Nee ◯
Weet ik niet ◯

Waarom: [ ]

19. Vond je de gastles over waterstof leuk? Waarom wel of niet? *(Vink één optie aan)*

◯ Ja
◯ Nee

Waarom: [ ]

JOP_1 *Reagerен ⊠ en ●* papersurvey.io JZJL 0003

20. Vond je de gastles over waterstof interessant? Waarom wel of niet? *(Vink één optie aan)*

- ◯ Ja
- ◯ Nee

Waarom:

21. Zijn er nog vragen of onderwerpen die je verder zou willen onderzoeken over waterstof of de energietransitie?

JOP_1 *Reageren* ⊠ *en* ● papersurvey.io JZJL 0004

Appendix 22: Second Survey, Hondsrug College Emmen

Vragenlijst waterstof in de energietransitie Deel 2

0. Heb je de eerste vragenlijst over waterstof ingevuld? *(Vink één optie aan)*

- ◯ Ja
- ◯ Nee

1. Hoe oud ben je? [ ] *In jaren*

2. Wat is je gender? *(Vink één optie aan)*

- ◯ Vrouw
- ◯ Man
- ◯ Anders
- ◯ Zeg ik liever niet

3. Welk niveau doe je? *(Vink alles aan wat van toepassing is)*

- VMBO ☐
- HAVO ☐
- VWO ☐

4. Welk profiel heb je gekozen? *(Vink alles aan wat van toepassing is)*

- ☐ Cultuur en Maatschappij
- ☐ Economie en Maatschappij
- ☐ Natuur en Gezondheid
- ☐ Natuur en Techniek

5. Weet je wat de 'energietransitie' is? *(Vink één optie aan)*

- Ja ◯
- Nee ◯
- Wel van gehoord, maar niet zeker wat het is ◯

6. Wat denk je dat de energietransitie betekent, of zou kunnen betekenen? *(Vink alles aan wat van toepassing is)*

- ☐ Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken
- ☐ Het verbeteren van energie-efficiëntie in huizen en bedrijven
- ☐ Minder gebruik maken van fossiele brandstoffen zoals olie en gas
- ☐ Overstappen op duurzamere energiebronnen zoals zon en wind
- ☐ Ik weet het niet

JQP2_1 *Reageren ☒ en ●* papersurvey.io DONO 0001

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7. Is waterstof een energiebron of een energiedrager? *(Vink één optie aan)*

- ◯ Een energiebron
- ◯ Een energiedrager
- ◯ Allebei
- ◯ Geen van beide
- ◯ Weet ik niet

8. Wat weet je over waterstof in de energietransitie? *(Vink alles aan wat van toepassing is)*

- ☐ Waterstof kan worden gebruikt als vervanger voor fossiele brandstof
- ☐ Waterstof is altijd groen
- ☐ Waterstof kan worden gemaakt van water of aardgas
- ☐ Waterstof is beter om kort energie op te slaan dan een batterij
- ☐ Waterstof is beter om lang energie op te slaan dan een batterij
- ☐ Ik weet er weinig tot niks over

9. Denk je dat je meer over waterstof hebt geleerd sinds de vorige keer dat je deze vragenlijst hebt ingevuld? Waarom wel of niet? *(Vink één optie aan)*

Ja ◯
Nee ◯
Niet meer niet minder ◯

Waarom: ____

10. Hoe belangrijk vind je de energietransitie?

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

Op een schaal van 1 tot 10

11. Denk je nu dat de energietransitie belangrijker is dan *VOOR* de eerste vragenlijst over waterstof? Waarom wel of niet? *(Vink één optie aan)*

Ja ◯
Nee ◯
Niet meer niet minder ◯

Waarom: ____

12. Vind je de energietransitie nu interessanter dan *VOOR* de eerste vragenlijst over waterstof? Waarom wel of niet? *(Vink één optie aan)*

Ja ◯
Nee ◯
Niet meer niet minder ◯

Waarom: ____

JOP2_1 *Reageren* ⊠ *en* ● papersurvey.io D0N0 0002

13. Hoe belangrijk denk je dat waterstof is/kan zijn in de energietransitie?

1 2 3 4 5 6 7 8 9 10

○ ○ ○ ○ ○ ○ ○ ○ ○ ○

Op een schaal van 1 tot 10

14. Denk je nu dat waterstof belangrijker is dan *VOOR* de eerste vragenlijst over waterstof? Waarom wel of niet? *(Vink één optie aan)*

Ja ○
Nee ○
Niet meer niet minder ○

Waarom:

15. Hoe interessant vind je het onderwerp waterstof?

0 1 2 3 4 5 6 7 8 9 10

○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○

Op een schaal van 1 tot 10

16. Vind je waterstof nu interessanter dan *VOOR* de eerste vragenlijst over waterstof? Waarom wel of niet? *(Vink één optie aan)*

Ja ○
Nee ○
Niet meer niet minder ○

Waarom:

17. Zou je later een beroep of studie willen doen die te maken heeft met waterstof of de energietransitie? Waarom wel of niet? *(Vink één optie aan)*

Ja ○
Nee ○
Weet ik niet ○

Waarom:

18. Denk je dat als je niet er voor kiest om een beroep of studie te doen die te maken heeft met waterstof of de energietransitie, je toch te maken zal hebben met deze onderwerpen? Waarom wel of niet? *(Vink één optie aan)*

Ja ○
Nee ○
Weet ik niet ○

Waarom:

JOP2_1

Reageren ☒ *en* ●

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DOND 0003

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19. Vond je deze vragenlijsten interessant? Waarom wel of niet? *(Vink één optie aan)*

- ◯ Ja
- ◯ Nee

Waarom: ________________

20. Zijn er nog vragen of onderwerpen die je verder zou willen onderzoeken over waterstof of de energietransitie?

JOP2_1

Reageren ⊠ *en* ●

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DOND 0004

Appendix 23: Second Survey Answers Montessori Lyceum Groningen

Vraag:	Leerling 1	Leerling 2	Leerling 3	Leerling 4	Leerling 5	Leerling 6	Leerling 7	Leerling 8	Leerling 9	Leerling 10	Leerling 11
1: Hoe oud ben je? (in jaren)	15	16	16	15	17	15	15	15	16	15	15
2: Wat is je gender?	Man	Man	Man	Vrouw	Vrouw	Vrouw	Vrouw	Vrouw	Vrouw	Vrouw	Vrouw
3: Welk niveau doe je?	HAVO	HAVO	HAVO	HAVO	HAVO	HAVO	HAVO	HAVO	HAVO	HAVO	HAVO
4: Welk profiel heb je gekozen?	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Gezondheid	Natuur en Gezondheid/ Natuur en Techniek	Natuur en Gezondheid/ Natuur en Techniek	Natuur en Gezondheid	Natuur en Techniek
5: Weet je wat de 'energietransitie' is?	Ja	Ja	Ja	Ja	Wel van gehoord, maar niet zeker wat het is	Ja	Wel van gehoord, maar niet zeker wat het is	Ja	Wel van gehoord, maar niet zeker wat het is	Ja	Wel van gehoord, maar niet zeker wat het is
6: Wat denk je dat de energietransitie betekend, of zou kunnen betekenen?	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Overstappen op duurzamere energiebronnen zoals zon en wind	Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken	Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind
7: Is waterstof een energiebron of energiedrager?	Een energiedrager	Een energiedrager	Een energiedrager	Een energiedrager	Een energiedrager	Een energiedrager	Een energiedrager	Een energiedrager	Een energiedrager	Een energiedrager	Een energiebron
8: Wat weet je over waterstof in de energietransitie?	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof, Waterstof kan worden gemaakt van water of aardgas, Waterstof is beter om lang energie op te slaan dan een batterij	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof, Waterstof is beter om lang energie op te slaan dan een batterij	Waterstof is beter om kort energie op te slaan dan een batterij, Waterstof kan worden gebruikt als vervanger voor fossiele brandstof	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof, Waterstof is beter om kort energie op te slaan dan een batterij	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof, Waterstof kan worden gemaakt van water of aardgas	Waterstof kan worden gemaakt van water of aardgas, Waterstof is beter om lang energie op te slaan dan een batterij	Waterstof is altijd groen	Waterstof kan worden gemaakt van water of aardgas	Waterstof is altijd groen	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof, Ik weet er weinig tot niks over	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof, Waterstof is beter om lang energie op te slaan dan een batterij
9: Wat was het meest verrassende of interresante dat je hebt geleerd tijdens de gastles?	Hoe het systeem in elkaar zit van de werking van waterstof in de energie-transitie	Hoe ver je met 1 flesje water kan rijden	Dat je het zelf kan maken	Dat heel veel beroepen hier mee werken	Dat alle beroepen er wat mee te maken hebben	Dat we waterstof gingen maken	Energie uit watersgtof hoe te maken	Zelf waterstof maken	Hoe je energie krijgt uit waterstof (hoe je dat kan doen)	Dat proefje, dat de propellor ging draaien bijv.	Dat een auto zo 5,5km kan rijden op een flesje water
10: Hoe belangrijk vind je de energietransitie?	9	8	6.5	9	8	10	7	8	8	9	7
11: Denk je nu dat de energietransitie belangrijker is dan voor de 1e vragenlijst?	-	Ja	Niet meer niet minder	Nee	Ja	Niet meer niet minder	Niet meer niet minder	Ja	Ja	Ja	Niet meer niet minder

12: Vind je de energietransitie nu interessanter dan voor de 1e vragenlijst?	-	Ja	Niet meer niet minder	Nee	Nee	Ja	Niet meer niet minder	Nee	Niet meer niet minder	Ja	Ja
13: Hoe belangrijk denk je dat waterstof is/kan zijn in de energietransitie?	7	10	5	8	8	7	9	8	8	10	9
14: Denk je nu dat waterstof belangrijker is dan voor de 1e vragenlijst?	-	Ja	Niet meer niet minder	Ja	Ja	Ja	Niet meer niet minder	Ja	Niet meer niet minder	Ja	Ja
15:Hoe interresant vind je het onderwerp waterstof?	7	7	5	2	5	7	-	6	6	8	6
16: Vind je waterstof nu interessanter dan voor de 1e vragenlijst?	-	Ja	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Ja	Niet meer niet minder	Nee	Ja	Ja	Niet meer niet minder
17: Zou je later een beroep of studie willen doen die te maken heeft met waterstof of de energietransitie?	Nee	Weet ik niet	Nee	Nee	Nee	Weet ik niet	Nee	Nee	Nee	Ja	Nee
18: Denk je dat als je niet er voor kiest om een beroep of studie te doen die te maken heeft met waterstof of de energietransitie, je toch te maken zal hebben met deze onderwerpen?	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Weet ik niet	Ja	Ja
19: Vond je de gastles over waterstof leuk?	Nee	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja
20: Vond je de gastles over waterstof interessant?	Ja	Ja	Nee	Nee	Ja	Ja	Ja	Ja	Ja	Ja	Ja
21: Zijn er nog vragen of onderwerpen die je verder zou willen onderzoeken over waterstof of de energietransitie?	Nee	-	-	Nee	Nee	Nee	-	-	Nope	Niet persee	-

Hanze University of Applied Sciences

ENTRANCE CENTRE OF EXPERTISE ENERGY

Appendix 24: Second Survey Answers Hondsrug College Emmen

Vraag:	Leerling 6	Leerling 7	Leerling 8	Leerling 9	Leerling 10	Leerling 11	Leerling 12	Leerling 13
1: Hoe oud ben je? (in jaren)	15	15	15	15	15	14	13	14
2: Wat is je gender?	Man	Man	Man	Man	Man	Man	Anders	Man
3: Welk niveau doe je?	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO
4: Welk profiel heb je gekozen?	Economie en Maatschappij	Natuur en Techniek	Natuur en Techniek	Natuur en Gezondheid	Natuur en Techniek	Natuur en Techniek	Economie en Maatschappij	Natuur en Techniek
5: Weet je wat de 'energietransitie' is?	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Ja
6: Wat denk je dat de energietransitie beteke of zou kunnen beteken	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Minder gebruik maken van fossiele brandstoffen zoals olie en gas	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Overstappen op duurzamere energiebronnen zoals zon en wind	Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind
7: Is waterstof een energiebron of energiedrager?	Een energiebron	Een energiebron	Een energiebron	Een energiebron	Weet ik niet	Een energiebron	Allebei	Een energiedrager
8: Wat weet je over waterstof in de energietransitie?	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof, Waterstof kan worden gemaakt van water of aardgas, Waterstof is beter om kort energie op te slaan dan een batterij, Waterstof is beter om lang energie op te slaan dan een batterij	Waterstof is altijd groen	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof, Waterstof kan worden gemaakt van water of aardgas, Waterstof is beter om kort energie op te slaan dan een batterij, Waterstof is beter om lang energie op te slaan dan een batterij	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof, Waterstof kan worden gemaakt van water of aardgas, Waterstof is beter om kort energie op te slaan dan een batterij, Waterstof is beter om lang energie op te slaan dan een batterij	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof, Waterstof is altijd groen, Waterstof kan worden gemaakt van water of aardgas, Waterstof is beter om kort energie op te slaan dan een batterij, Waterstof is beter om lang energie op te slaan dan een batterij, Ik weet er weinig tot niks over	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof, Waterstof is beter om lang energie op te slaan dan een batterij
9: Denk je dat je meer over waterstof hebt geleerd sinds de vorige keer dat je deze vragenlijst hebt ingevuld?	Niet meer niet minder	Ja	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Nee	Ja
10: Hoe belangrijk vind j de energietransitie?	6,5	7	6	7,5	7	6	7	8
11: Denk je nu dat de energietransitie belangrijker is dan voor 1e vragenlijst?	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Nee	Nee

Vraag:	Leerling 14	Leerling 15	Leerling 16	Leerling 17	Leerling 18	Leerling 19	Leerling 20	Leerling 21
1: Hoe oud ben je? (in jaren)	14	15	14	14	14	14	14	14
2: Wat is je gender?	Man	Anders	Man	Man	Man	Man	Man	Man
3: Welk niveau doe je?	VWO	VWO	VWO	VWO	VWO	VWO	VWO	VWO
4: Welk profiel heb je gekozen?	Natuur en Gezondheid	Natuur en Techniek	Natuur en Techniek	Natuur en Gezondheid	Natuur en Techniek	Natuur en Techniek	Natuur en Gezondheid	Economie en Maatschappij
5: Weet je wat de 'energietransitie' is?	Ja	Wel van gehoord, maar niet zeker wat het is	Ja	Ja	Wel van gehoord, maar niet zeker wat het is	Wel van gehoord, maar niet zeker wat het is	Ja	Wel van gehoord, maar niet zeker wat het is
6: Wat denk je dat de energietransitie beteke of zou kunnen beteken	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Het verbeteren van energie-efficiëntie in huizen en bedrijven, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Het ontwikkelen van nieuwe technologieën om energie duurzamer te maken, Minder gebruik maken van fossiele brandstoffen zoals olie en gas, Overstappen op duurzamere energiebronnen zoals zon en wind	Overstappen op duurzamere energiebronnen zoals zon en wind	Overstappen op duurzamere energiebronnen zoals zon en wind, Minder gebruik maken van fossiele brandstoffen zoals olie en gas	Overstappen op duurzamere energiebronnen zoals zon en wind, Minder gebruik maken van fossiele brandstoffen zoals olie en gas	Het verbeteren van energie-efficiëntie in huizen en bedrijven
7: Is waterstof een energiebron of energiedrager?	Een energiebron	Een energiebron	Een energiebron	Een energiebron	Allebei	Een energiebron	Een energiebron	Weet ik niet
8: Wat weet je over waterstof in de energietransitie?	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof, Waterstof is altijd groen	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof	Ik weet er weinig tot niks over	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof	Waterstof kan worden gebruikt als vervanger voor fossiele brandstof	Ik weet er weinig tot niks over
9: Denk je dat je meer over waterstof hebt geleerd sinds de vorige keer dat je deze vragenlijst hebt ingevuld?	Niet meer niet minder	Nee	Nee	Nee	Nee	Nee	Nee	Nee
10: Hoe belangrijk vind j de energietransitie?	7	8	-	4	7	7	8	3
11: Denk je nu dat de energietransitie belangrijker is dan voor 1e vragenlijst?	Niet meer niet minder	Ja	Nee	Nee	Nee	Nee	Nee	nee

10: Hoe belangrijk vind je de energietransitie?	6,5	7	6	7,5	7	6	7	8	7	8	-	4	7	7	8	3
11: Denk je nu dat de energietransitie belangrijker is dan voor de 1e vragenlijst?	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Nee	Nee	Niet meer niet minder	Ja	Nee	Nee	Nee	Nee	Nee	nee
12: Vind je de energietransitie nu interessanter dan voor de 1e vragenlijst?	Niet meer niet minder	Niet meer niet minder	Nee	Niet meer niet minder	Ja	Ja	Ja	Niet meer niet minder	Ja	Nee	Nee	Nee	Nee	Nee	Nee	Nee
13: Hoe belangrijk denk je dat waterstof is/kan zijn in de energietransitie?	7	9	8	7	6	9	9	8	7	9	8	4	8	8	7	8
14: Denk je nu dat waterstof belangrijker is dan voor de 1e vragenlijst?	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Niet meer niet minder	Ja	Niet meer niet minder	Ja	Niet meer niet minder	Nee	Niet meer niet minder	Nee	Nee	Nee	Nee	Nee	Ja
15:Hoe interresant vind je het onderwerp waterstof?	6,5	6	8	5	7	6,5	9	9	7	5	6	0	7	7	8	4
16: Vind je waterstof nu interessanter dan voor de 1e vragenlijst?	Niet meer niet minder	Niet meer niet minder	Nee	Niet meer niet minder	Ja	Niet meer niet minder	Ja	Niet meer niet minder	Ja	Niet meer niet minder	Nee	Nee	Nee	Nee	Nee	Ja
17: Zou je later een beroep of studie willen doen die te maken heeft met waterstof of de energietransitie?	Nee	Nee	Nee	Nee	Nee	Weet ik niet	Ja	Weet ik niet	Nee	Nee	Weet ik niet	Nee	Nee	Nee	Nee	Nee
18: Denk je dat als je niet er voor kiest om een beroep of studie te doen die te maken heeft met waterstof of de energietransitie, je toch te maken zal hebben met deze onderwerpen?	Ja	Ja	Ja	Nee	Ja	Ja	Ja	Ja	Ja	Ja	Ja	Nee	Ja	Ja	Ja	Ja
19: Vond je deze vragenlijsten interresant?	Nee	-	Nee	Nee	Nee	Ja	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee	Nee
20: Zijn er nog vragen of onderwerpen die je verder zou willen onderzoeken over waterstof of de energietransitie?	Te veel	-	Nee	Nee	Nee	Nee	Nee	Nee	Niet echt	-	Waterstof	Nee	Nee	Nee	Nee	Nee hoor

Appendix 25: Objective Evaluation Overview

This appendix shows whether the research objectives were achieved, how the process was and how they turned out. Table 23 shows the final research objectives, with a column evaluating the objective and whether it was achieved.

Table 23: Research Objective Evaluation

Final Objective	Objective Evaluation
Analysing what is currently being taught at Dutch secondary schools, and evaluating HAVO students' knowledge, awareness, and interest in hydrogen within the energy transition.	This objective was achieved through the analysis conducted for the first sub-question. Surveys, interviews and desk research were conducted to provide insight into the current state of hydrogen education and students' knowledge and interest.
Identifying what are effective ways to create awareness, and interest HAVO students for hydrogen within the energy transition.	This objective was achieved through the analysis conducted for the second sub-question. Here, the combination of desk research, case studies, interviews and surveys found that methods like hands-on activities, autonomy, and relatability could be effective. The results of the intervention pilot observations and the following survey supported this.
Analysing how ENTRANCE's current educational programs and expertise align with what is needed to engage HAVO students in hydrogen within the energy transition	This objective was largely achieved. Though ENTRANCE's expertise and resources were analysed, a more thorough analysis into less accessible programs could have provided more possibilities for the intervention.
Designing and piloting an educational intervention that will allow ENTRANCE to bridge the gap between its current efforts and the needs of HAVO students, actively working towards its goal of interesting HAVO students in hydrogen within the energy transition.	This objective takes the research process and findings for the development of the intervention, and was only partly achieved. Though the pilot showed how the interactive, hands-on intervention showed positive results, the intervention pilot was on a small scale and needs further development for ENTRANCE to bridge the gap.
Analysing if the intervention has influenced the awareness and interest of the participating HAVO students, taking into account ENTRANCE's goal of not only interesting HAVO students to work in the energy transition, but also to have a better understanding to collaborate better as informed citizens.	This objective was largely achieved based on the intervention and survey results. Even though 75% of the participating students indicated they would not want to work directly with hydrogen or the energy transition (Figure 35), 88% of them were aware that they would likely still come into contact with it (Figure 36). It was, however, not possible to analyse the long-term impact of this intervention in the pilot, which would help further achieve this goal.

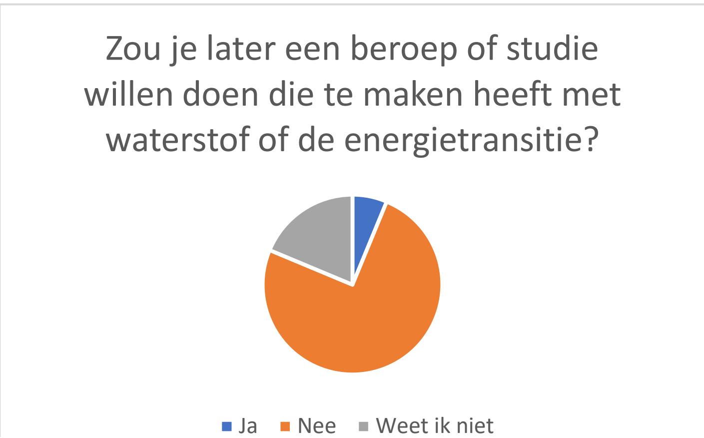

Figure 35: Would you want to work or study with the energy transition or hydrogen? (ML)

Figure 36: Do you think you would be involved with the energy transition or hydrogen either way? (ML)

Appendix 26: Requirement Results

This appendix shows the requirements that were then prioritised based on their importance through MoSCoW prioritisation. These requirements are shown below, along with a column showing whether they were achieved or not, and an explanation on why the requirement was or was not achieved.

All Must requirements were entirely achieved, as well as about 75% of the Should requirements. 20% of the Should requirements were partially achieved, and one was not addressed during the pilot phase. About one-third of the Could requirements were achieved, showing their lower priority within the scope. All Won't requirements were followed.

Table 24: Requirement evaluation

ID	Requirement Description	Priority	Achieved	Reason
1	The intervention must align with HAVO students' current learning levels.	Must	Yes	The intervention was designed in collaboration with the teacher and with input from experts.
1.1	Covering the basics of hydrogen and its role in the energy transition, including different types of hydrogen and value chains.	Must	Yes	The roles hydrogen can play, and its sorts and value chains, are visualised and explained.
1.2	Show that the energy transition, and hydrogen within it, is not just technical.	Must	Yes	It shows and clarifies a variety of jobs within the energy transition and hydrogen.
2	The intervention must be engaging and interactive to maintain student interest.	Must	Yes	The effective theories and frameworks, together with expert, teacher and student input, were used.
2.1	Include hands-on activities and/or experiments.	Must	Yes	Includes experiments and exercises
3	The intervention must use motivational strategies to engage students.	Must	Yes	The research motivational strategies were implemented in the design
3.2	Information is relatable and on the HAVO students' level.	Must	Yes	Relates to their interests and adds things from their environment
4	The intervention must fit within school schedules and subjects.	Must	Yes	The intervention was designed to fit within a standard lesson block and linked to existing curriculum themes like science and sustainability.
4.1	Add minimal extra workload for teachers.	Must	Yes	The lesson structure, materials, and experiments were prepared and conducted without the need for teacher assistance.
7	The effectiveness of the intervention must be measured.	Must	Yes	Effectiveness was measured through pre- and post-intervention surveys and observations with feedback from teachers and students.
7.1	Pre and post-intervention surveys with the students.	Must	Yes	Students completed surveys before and after the intervention to assess changes in awareness and interest.
7.2	Observe and collect feedback from teachers and students.	Must	Yes	Observations during the lesson and feedback from the teacher provided insight in the intervention's reception.
2.2	Include relatable problem-solving tasks.	Should	Yes	Students worked on problem-solving group tasks related to energy transition jobs and hydrogen use.

2.3	Utilize gamification or quizzes to enhance the interactivity of learning.	Should	Yes	Gamified elements like competitive group activities were integrated into the tasks to stimulate engagement.
2.4	Enable students to work together in teams.	Should	Yes	Group work was a central element of the intervention's experiments and assignments.
2.5	Allow students to make choices on learning directions (autonomy).	Should	Yes/No	Students had some autonomy during group discussions, but the overall lesson structure and tasks were pre-set.
2.6	Use digital tools like videos and simulations.	Should	Yes	A supporting PowerPoint presentation included visual materials and real-world examples.
3.1	Connect to students' daily lives and future career opportunities.	Should	Yes	The intervention related hydrogen to familiar topics and introduced various career possibilities connected to the energy transition.
4.2	Fit in existing lesson blocks (or set times).	Should	Yes	The intervention was designed to fit into one standard class period.
5	The intervention should also provide guidance and/or resources for teachers.	Should	Yes/No	Some guidance was provided through the presentation and materials, but full lesson manuals were not developed.
5.1	Allow flexibility for teachers to jump in/help.	Should	Yes	The teacher could easily participate and assist students during the hands-on activities.
5.4	Involve teachers directly in the lesson content.	Should	Yes	Teachers were encouraged to join group discussions and help students during experiments.
6	The intervention should connect students to the industry and experts.	Should	No	No direct industry connection or external expert involvement was included during the pilot phase.
7.3	Allow space for changes as the intervention progresses.	Should	Yes	The structure allowed for adjustments based on student responses and teacher feedback.
7.4	Space for improvements based on feedback.	Should	Yes	Feedback from the pilot was used to suggest improvements for future use.
8	The intervention should be designed to allow expansion and further use.	Should	Yes/No	The intervention is adaptable but would require some additional development for wider use.
8.1	Materials are reusable and stay relevant.	Should	Yes	The experiments and presentation materials can be reused without needing regular updates.
8.2	The intervention is adaptable and scalable for other schools.	Should	Yes/No	The main content is adaptable, but logistics for resources and guidance could need changes for different schools.
8.3	There is a clear instruction and overview for the intervention.	Should	Yes	Clear time planning, activities, and structure were provided to guide the intervention.

1.3	Include real-world uses of hydrogen to make the topic relevant.	Could	Yes	Real-world examples of hydrogen applications were added to the lesson content.
1.4	Include a deeper dive into the science behind hydrogen production.	Could	No	The intervention focused on practical awareness and did not explore detailed chemical processes.
2.7	Include visits to ENTRANCE's testing grounds.	Could	No	Due to time constraints and logistics, no visits were included during the pilot phase.
4.3	Fit within different secondary school levels.	Could	Yes/No	The content was designed for HAVO level but could be adapted for other levels with modifications.
5.2	Provide ready-to-use lesson plans with manuals.	Could	No	The PowerPoint and experiment materials could be used, but no teacher manual was developed.
5.3	Offer teacher training or workshops.	Could	No	Teacher training or workshops did not fit within the project scope.
6.1	Involve guest speakers from the hydrogen sector.	Could	No	Guest speakers were not involved in the pilot intervention.
6.2	Include visits to hydrogen facilities/industry.	Could	No	No external visits were included within the scope of the pilot project.
9	The intervention will not require in-depth (technical) hydrogen knowledge.	Won't	Yes	Students were introduced to basic hydrogen concepts without needing deep technical knowledge.
9.1	Mandatory lessons in the curriculum.	Won't	Yes	The intervention was designed as an additional educational opportunity, not a mandatory part of the HAVO curriculum.