ERASMUS-EDU-2022-PI-FORWARD (Partnerships for Innovation - Forward Looking Projects)

ERASMUS-EDU-2022-PI-FORWARD-LOT1 | ERASMUS-LS (ERASMUS Lump Sum Grants)

HECOF
Higher Education Classroom Of the Future

Higher Education Classroom Of the Future

D4.1 Integrated system first release

Work Package: 3	
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Status:	Final Version
Due Date:	31/10/2024
Version:	0.6
Submission Date:	27/2/25
Dissemination Level:	PU

Disclaimer:

Co-funded by the European Union

This project has received funding from the European Union's Erasmus+ Framework Programme under Grant Agreement No. 101086100.

HECOF Profile

Grant Agreement No.:	101086100
Acronym:	HECOF
Title:	Higher Education Classroom Of the Future
URL:	https://hecof.eu/
Start Date:	01/01/2023
Duration:	30 months

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Document History

Version	Date	Author (Partner)	Remarks/Changes
0.1	19/12/2024	Evangelos Rigas (KT)	Epameinondas Koutavelis (KT)
0.2	27/1/2025	Evangelos Rigas (KT)	Epameinondas Koutavelis (KT)
0.3	29/1/2025	Evangelos Rigas (KT)	Epameinondas Koutavelis (KT)
0.4	05/02/2025	Ioana Ghergulescu(ADAPTEMY) Jason Horn (NUROMEDIA) Evangelos Rigas (KT)	Ioana Ghergulescu(Adaptemy) Jason Horn (NUROMEDIA)
0.5	14/02/2025	Evangelos Rigas (KT)	
0.6	27/02/2025	Ioana Ghergulescu(ADAPTEMY) Jason Horn (NUROMEDIA) Evangelos Rigas (KT)	Ioana Ghergulescu(Adaptemy) Jason Horn (NUROMEDIA) Maria Karoglou (NTUA)

Abbreviations and acronyms

Abbreviation	Definition
HEI	Higher Education Institutions
AI	Artificial Intelligence
VR	Virtual Reality
VET	Vocational education and training
LLM	Large Language Model

Executive Summary

The HECOF initiative aims to revolutionize higher education teaching practices and education policies by creating a personalized and adaptive learning system that utilizes digital data from students' immersive learning experiences and leverages computational analysis from data science and AI. The project will focus on the field of Chemical Engineering and involve teachers and students from two pilot universities in its design and implementation.

This report is part of the deliverables from a project called "HECOF" which has received funding from the European Union's ERASMUS+ research and innovation program under grant agreement No 101086100.

The present document focuses on the first release of the HECOF integrated system. It outlines the progress made in developing the platform's key components and the initial implementation of its features, designed to create immersive, data-driven learning environments.

The document highlights the following key developments in the first release:

- VR-Capable Core: Tools for creating immersive learning exercises and escape room-like simulations tailored to chemical engineering education.
- AI-Based Adaptive Learning: Adaptive learning strategies and configurations to guide students through personalized learning paths.
- Data Analytics and Orchestration: Development of data lakes and APIs to aggregate, analyze, and present student performance metrics.
- Cross-Platform APIs and Dashboards: Initial implementations of interactive dashboards for data visualization and system interaction.

The deliverable also discusses the technical challenges encountered during this phase, including ensuring data security, streamlining system integration, and optimizing usability based on pilot testing feedback. Future steps involve completing the integration of subsystems, enhancing analytics capabilities, finalizing the dashboards, and improving feedback mechanisms for educators.

This report represents a significant milestone in the HECOF project, laying the groundwork for further iterations and broader deployment of the system in higher education settings. It emphasizes the project's commitment to fostering innovation, ethical AI use, and digital transformation in education.

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1. INTRODUCTION

1.1 About the project

Higher Education Classroom Of the Future (HECOF) project is implemented by a mixed partnership of organisations from different sectors that have the capacity to innovate in terms of digital tools and teaching and learning methods for the higher education systems, by leveraging the power of AI and machine learning for student assessment and adaptive learning based on individual learner's performance and behavior. The main goal of the HECOF initiative is to create systemic change in higher education teaching practice and national reforms in education by developing and testing an innovative personalised, adaptive way of teaching that exploit the digital data from students' learning activity in immersive environments and use computational analysis techniques from data science and AI. The project has a conceptual focus on "Chemical Engineering" academic discipline and will engage teaching staff and students from two pilot universities in its design and pilot testing. HECOF also wants to foster the development and uptake of safe and lawful AI that respects fundamental rights by providing insights on ethical and legal issues around the design of the system. It will drive the policy agenda by formulating recommendations on the role and use of AI for personalised, adaptive learning. HECOF technology has a clear potential to be mainstreamed in the vocational education and training sector for employees in the chemical engineering sector. Therefore, HECOF will support the first strategic priority of the Digital Education Action Plan (2021-2027), the development of a high-performing digital education ecosystem, by building capacity and critical understanding in all types of education and training institutions on how to exploit the opportunities offered by digital technologies for teaching and learning at all levels and for all sectors and to develop and implement digital transformation plans of educational institutions.

1.2 Overall Objective

The primary goal of the HECOF project is to drive systemic change in higher education by promoting innovation in teaching practices and national education reforms. This will be achieved by developing and testing an innovative, personalized, and adaptive approach to teaching that utilizes digital data from students' learning activities in immersive environments and incorporates computational analysis techniques from data science and AI.

1.3 Specific Objectives in WP4

The primary objectives of WP4 in the HECOF project are to develop and integrate the components of the HECOF platform, ensuring their deployment as a unified and functional solution. Specifically, WP4 aims to:

1. **Development of System Components**: Design and build the individual components of the HECOF platform, including the VR-capable core, AI-based adaptive learning modules, machine learning algorithms, data analytics modules, and interactive dashboards. Each component is tailored to provide immersive and personalized learning experiences.
2. **Integration of Components**: Establish seamless communication and interoperability between the developed components, ensuring they function cohesively within the unified HECOF system architecture.

3. **Deployment of the HECOF Solution**: Implement and deploy the integrated system in the pilot environments, facilitating its testing and validation in real-world educational scenarios.
4. **Support for Data-Driven Learning**: Develop robust data collection, synchronization, and analytics processes to support personalized learning paths, teacher feedback mechanisms, and performance tracking.
5. **Ensuring Scalability and Usability**: Focus on creating a system that is user-friendly, scalable, and adaptable to various higher education settings, emphasizing accessibility and ethical AI practices.
6. **Security and Compliance**: Incorporate secure data management practices and ensure compliance with GDPR and other relevant standards to protect user data and maintain system integrity.

These objectives align with the overarching goal of WP4 to deliver a functional, innovative, and impactful solution that supports the HECOF initiative's vision for transforming higher education through cutting-edge technology.

1.4 Purpose of the document

This deliverable regards the implementation of the first version of the HECOF platform. The deliverable consists of the developed software accompanied with a short description of the relevant implementation, as provided in the current document.

2. ARCHITECTURE

The HECOF platform consists of the following main components: the VR-capable Core, the AI-based Adaptive Learning component, the Machine Learning module, the Data Analytics module, the Classroom Orchestration data lake, the Cross-platform API and the Interactive Dashboards. Various tools and/or technologies have also been implemented/used to facilitate the development of these main components, as described in each component's section.

2.1 Flow of project and component interconnection

On a high level, the flow of procedures is the following:

Students log in to the platform and after choosing to start a lesson, they are directed to Adaptemy's Lesson Player that communicates with the AI Engine and ML components. The AI engine sends recommendations to the Lesson Player. The Lesson Player also communicates with Nuromedia's Player, in order to transmit information about student level and the lab that students will interact with. Then, the Nuromedia Player sends this information to the AI engine via XAPI. Data relative to students' performance are synchronized with KT's student data lake. Students and teachers can view the statistics and aggregated data through SIMAVI's frontend / interactive dashboards (Adaptemy's frontend during the first phase).

A basic overview of the intended high-level architecture of the HECOF platform and the connections between components is shown in the following diagram:

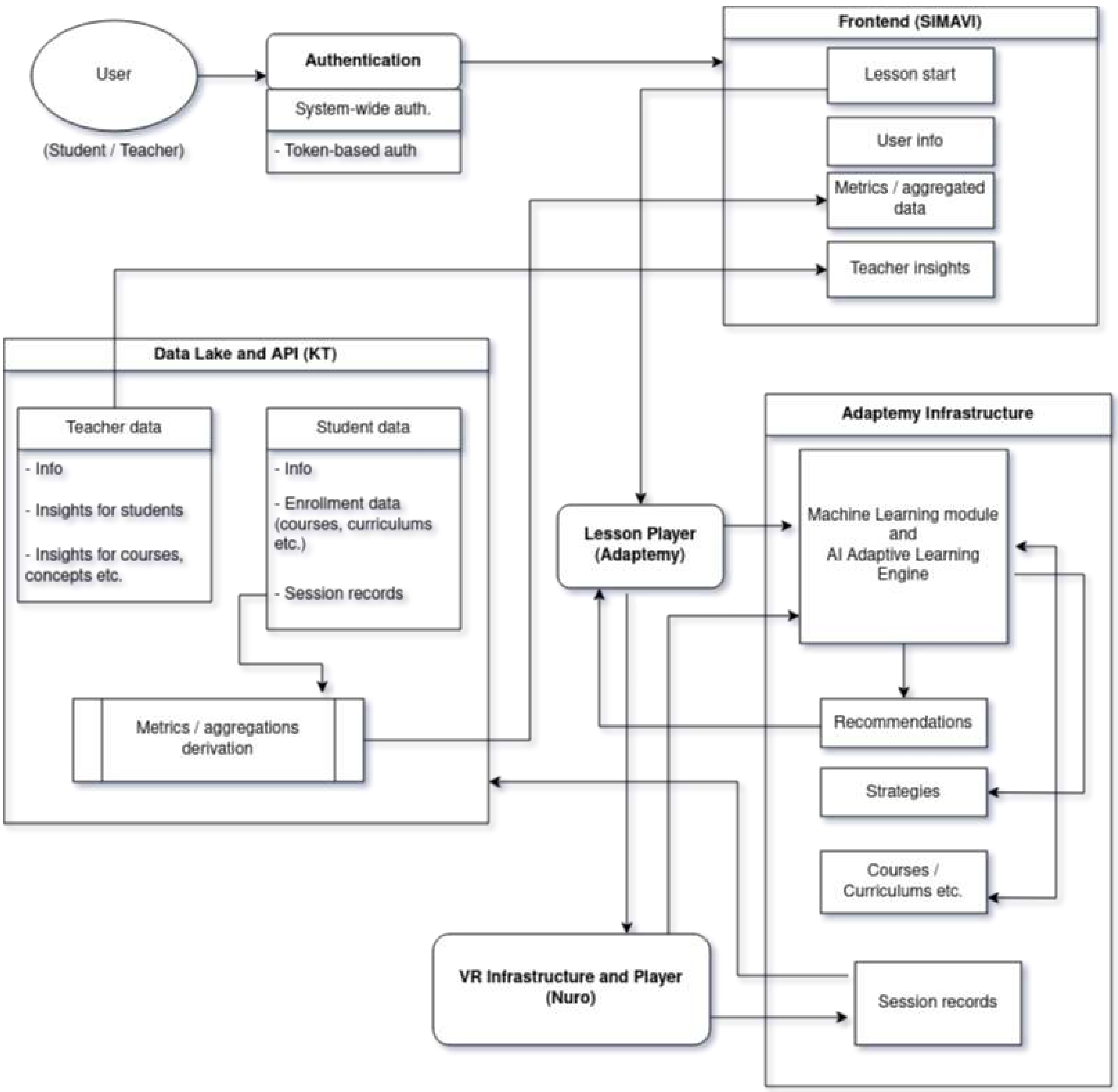

Figure 1. Intended high-level architecture of the HECOF platform in its final form

For the timeframe that the current deliverable refers to, the architecture of the platform was concluded as follows:

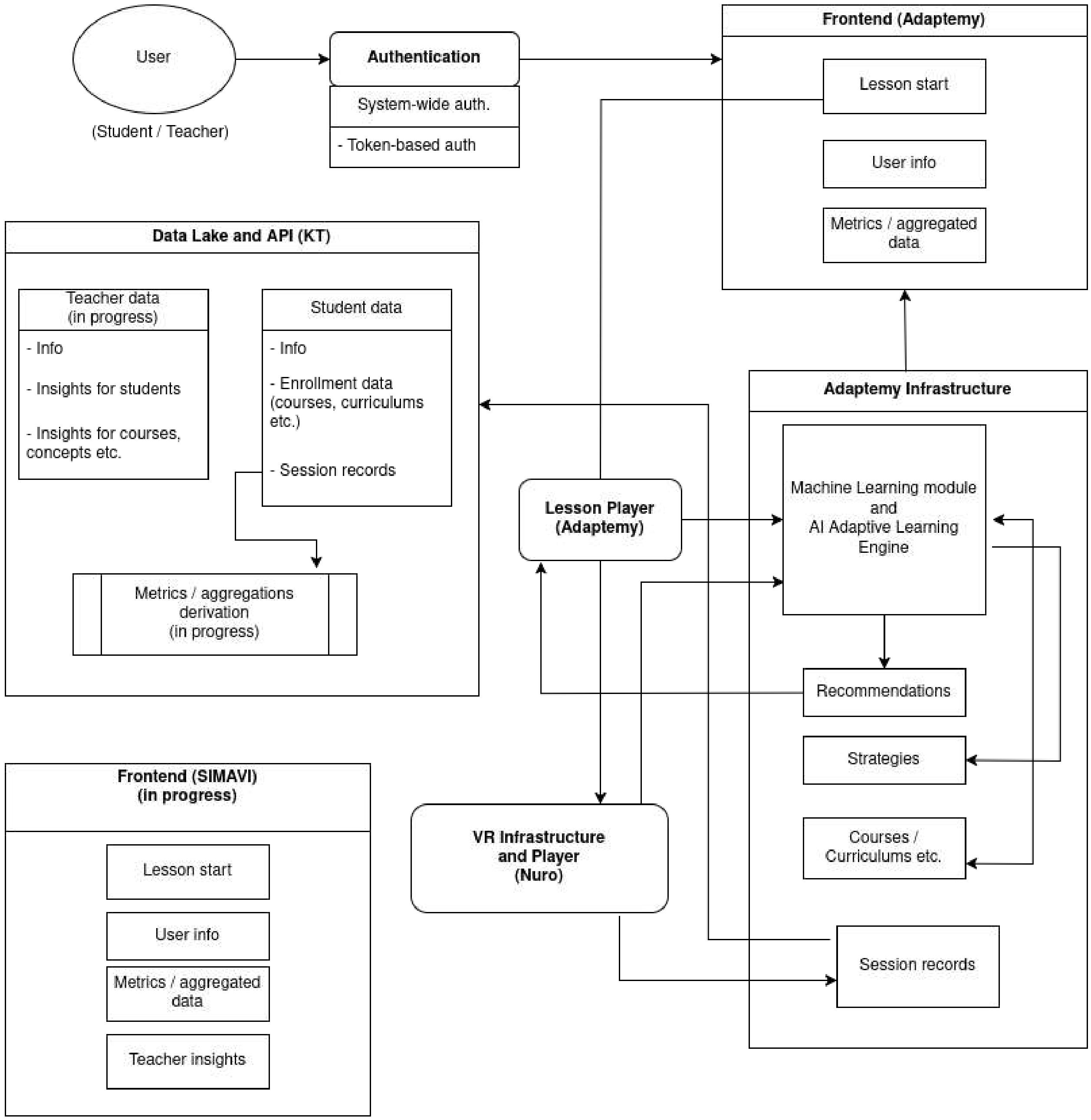

Figure 2. High-level architecture of the HECOF platform during the first phase

The goal is that by the next platform deliverable, all components will be deployed and communicating with each other, as described in the first diagram (Figure 1).

2.2 Tasks and Components

2.2.1 VR-capable core development (T4.1)

An authoring tool (World Builder) for creating/customising the VR Lab exercises that are designed like escape room serious games has been developed by NUROMEDIA. The result can be experienced by students through the Portal Hopper, a player app for content created and designed with the World Builder (rel. T4.1.2). Lab exercise task completion status updates and VR movement data are sent to Adaptemy's Adaptive learning backend (rel. T4.1.1). For GDPR purposes no data is stored locally. According to the requirement analysis results, students and teachers are not interested in a multi-user environment. Without the usage of a multi-user environment, there is no need to see another avatar, therefore the development of virtual humans is not necessary (rel. T4.1.3).

The creation of 3D-Environments has been implemented by NUROMEDIA in the World Builder and Portal Hopper tools. The requirement analysis resulted in a focus on immersion and realistic behaviours of the experiment simulations, not so much on photo-realistic graphics and 3D scanned environments. Furthermore, the hardware used by the universities resulted in focusing on reduced graphic fidelity. (rel. T4.1.4)

Pose information will be tracked and sent to Adaptemy for further analysis. Requirement analysis showed an interest for an easy to use setup. For that reason, additional hardware like Kinect sensors will not be used in this project. To widen the user group and improve accessibility, NUROMEDIA integrated optional mouse and keyboard control of Lab exercises as an alternative (rel T4.1.5).
As explained above, both students and teachers rejected the idea of a multiuser environment. Therefore, the shared VR Environment task (T4.1.6) has been cancelled.

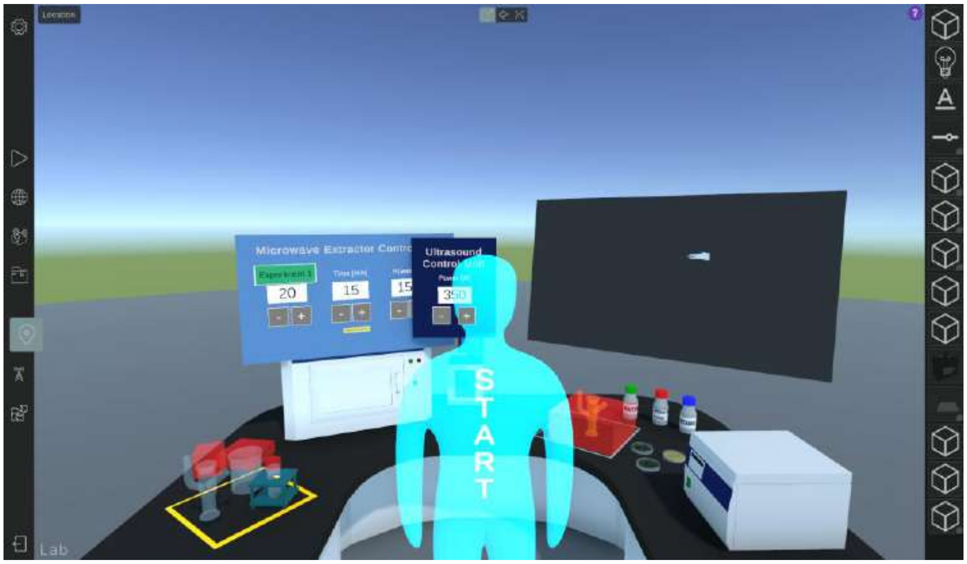

Figure 3. Pilot 1 (NTUA) - Lab exercise in location view of World Builder

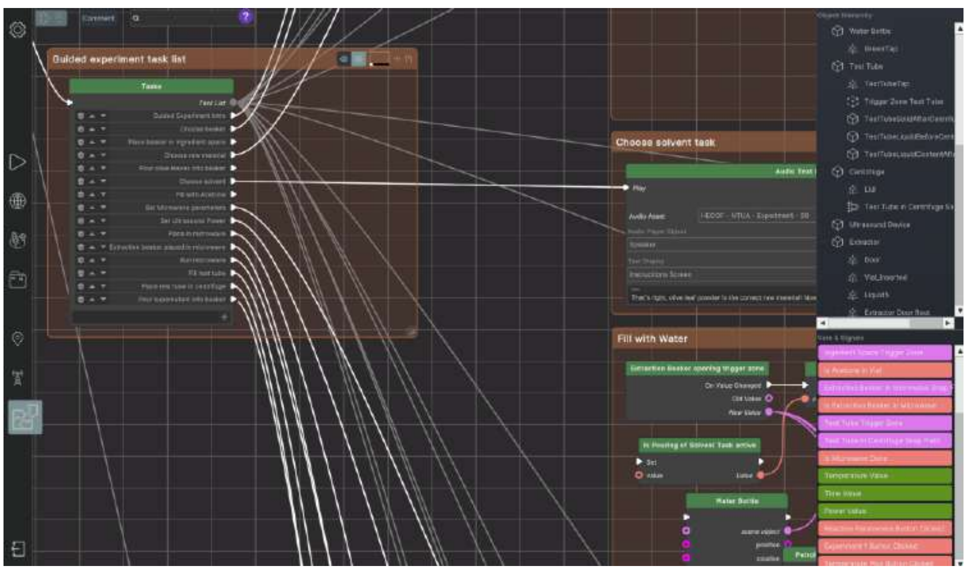

Figure 4. Pilot 1 (NTUA) - Snippet of the lab exercise logic file in logic editor of World Builder

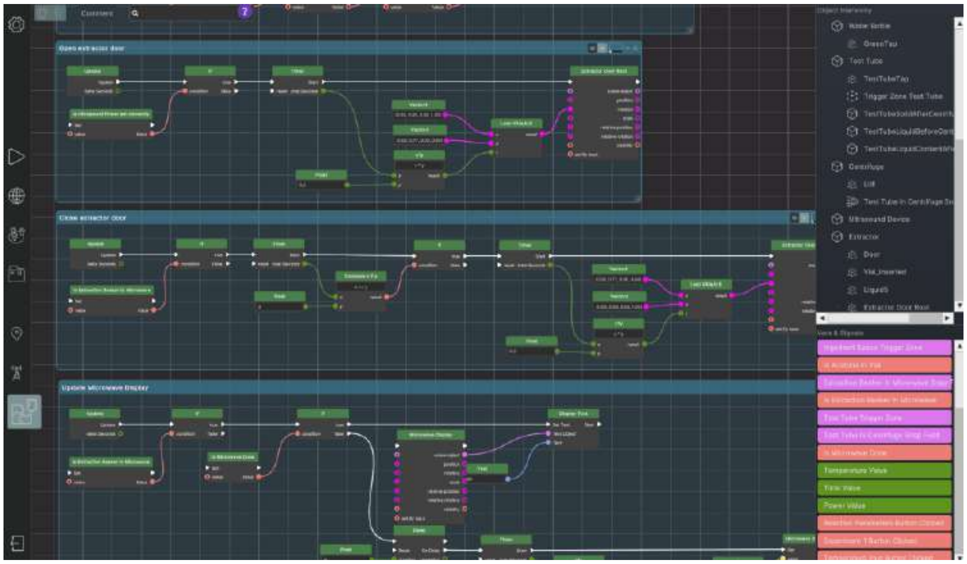

Figure 5. Pilot 1 (NTUA) - Snippet of the lab exercise logic file in logic editor of World Builder

Figure 6. Locker Room before entering the Laboratory in Portal Hopper - Identical for Pilot 1 and 2

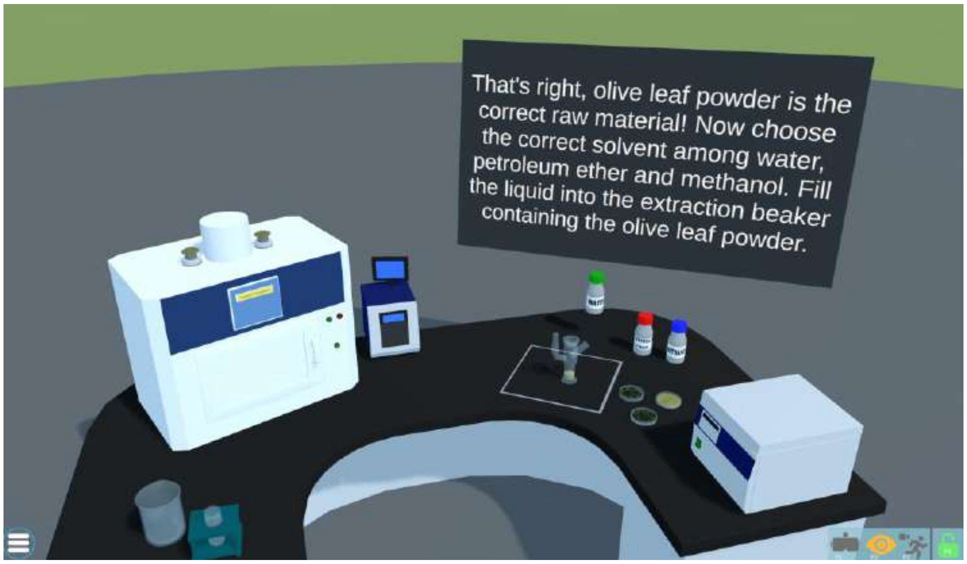

Figure 7. Pilot 1 (NTUA) - Preparation of extraction beaker in Portal Hopper

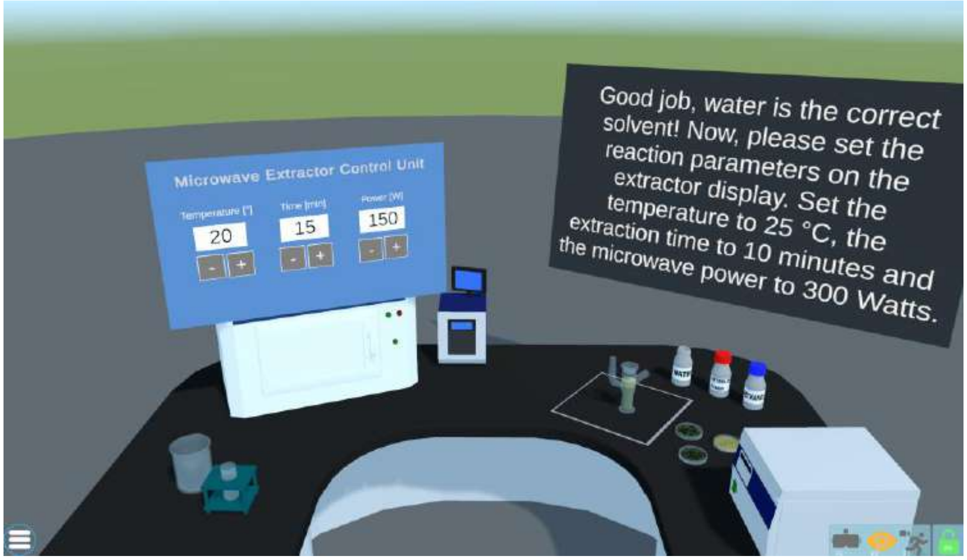

Figure 8. Pilot 1 (NTUA) - Setting of extraction parameters in Portal Hopper

Figure 9. Pilot 2 (POLIMI) - Introduction to apparatus in Portal Hopper

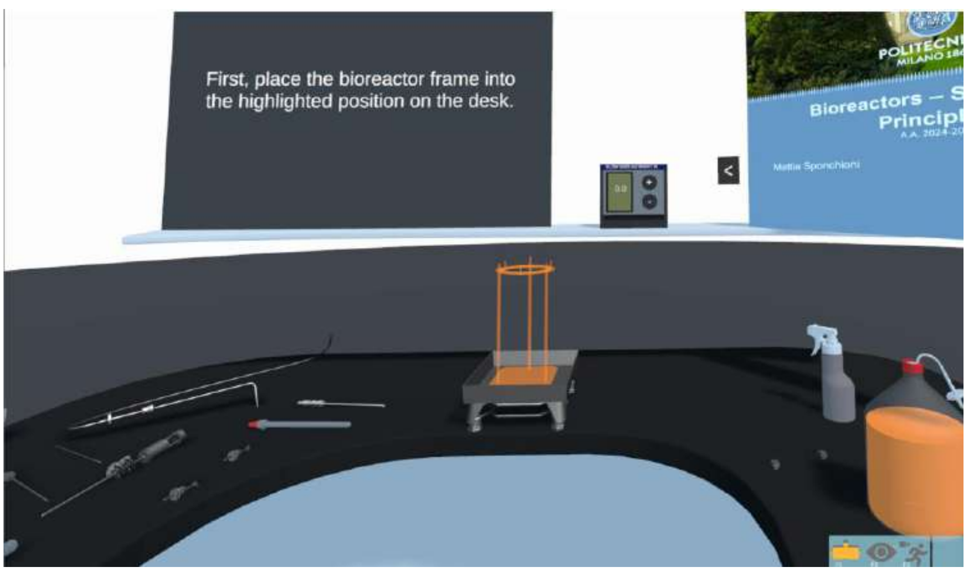

Figure 10. Pilot 2 (POLIMI) - Assembling of bioreactor in Portal Hopper

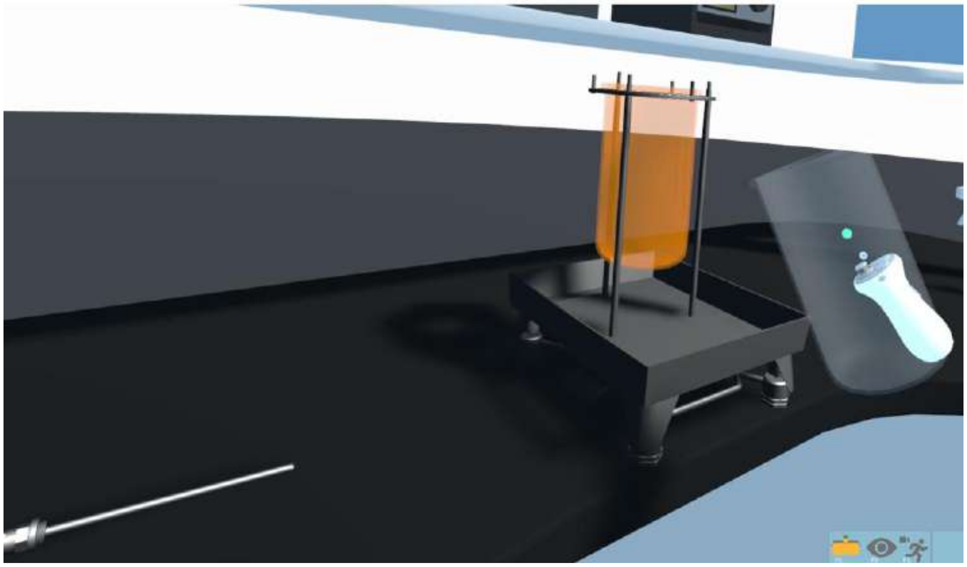

Figure 11. Pilot 2 (POLIMI) - Assembling of bioreactor in Portal Hopper

2.2.2 AI-based Adaptive Learning component (T4.2)

The learner model was configured by Adaptemy to model ability estimation, mastery level and several other related metrics on concepts from the given curriculums and to provide insights to modules that students will complete. Simulations were performed to identify specific threshold values for default question metrics and mastery estimation to match the required learning design specification and to overcome the cold start problem. Furthermore, specific threshold values for the learning experiences were configured based on simulations (i.e., the required low threshold values of probability to master when students should receive instructional/remedial or lower difficulty level for practise and the required high threshold values of probability to master when students should be recommended higher difficulty level practice quiz). Moreover, the engine was configured to listen to evidence from simulations and enable further modelling (i.e., based on the VR movement with headset).

The learning loops recommendations (i.e., Guided mastery/Knowledge acquisition, intake, practise, reinforcement, VR) were configured by Adaptemy. The configuration was informed by the learning design for: learning loop states, transition between states, content filter and content recommendation in a state (i.e., for instructional, remedial, assessment, examples). The AI Virtual Tutor was trained on the course materials. Furthermore, the recommendation of concepts and its explainability were configured. All the configuration details and the transition diagrams can be found in Thoth – Adaptemy's Authoring Tool – Adaptive Learning System section – Learning Strategies subsection and also presented in the following subsection.

2.2.2.1 HECOF Learning Loop Configuration in the Adaptemy AI Engine

Learning loops were configured for both POLIMI and NTUA in the Adaptemy AI Engine as per the Learning Design.

The following sections briefly presents the adaptivity on each loop and a print screen from the Thoth configuration tool showing the state flow diagram.

2.2.2.2 POLIMI Intake loop

The Intake Learning Loop is a learning experience designed to evaluate students' understanding of introductory concepts while identifying misconceptions and reinforcing prior knowledge. This structured loop ensures that learners engage with fundamental ideas through targeted quizzes, making the learning process more effective.

The loop dynamically adjusts based on student performance, offering remediation —instructional content — if a low probability of success is detected after the initial quiz. This ensures that students receive personalized learning experiences, progressing at their own pace while solidifying their foundational knowledge.

Figure 12 presents the Leaning loop configuration diagram for the POLIMI Intake Loop.

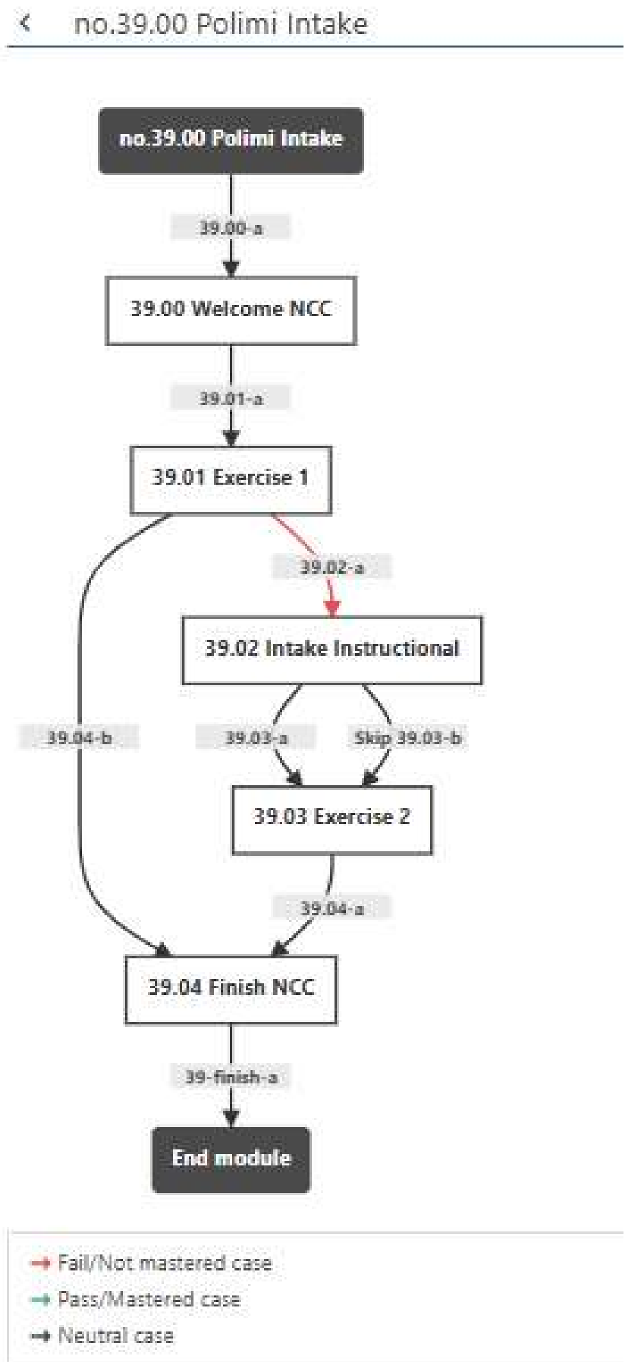

Figure 12. POLIMI Intake Loop - Configuration diagram

2.2.2.3 POLIMI Guided Mastery

The Guided Mastery Learning Loop is a learning experience designed to help students achieve mastery of a topic by progressing through concepts in a curriculum mapped sequence. This ensures that learners build their knowledge systematically, moving from the foundational concept to advanced concepts as well as moving at a concept level from easy to hard aspects, while maintaining awareness of their own progress. The loop integrates instructional content, quizzes, and assessments to reinforce learning, ensuring that students develop a comprehensive understanding of each concept before advancing.

The learning experience adjusts dynamically based on student performance, offering progressively challenging exercises —easy, medium, and hard— to assess comprehension. If a student demonstrates difficulty at any stage, remedial instructional content, such as alternative explanations, is provided before retesting. If challenges persist, further adaptations guide the learner through a different approach.

Figure 13 presents the Leaning loop configuration diagram for the POLIMI Guided Learning Loop.

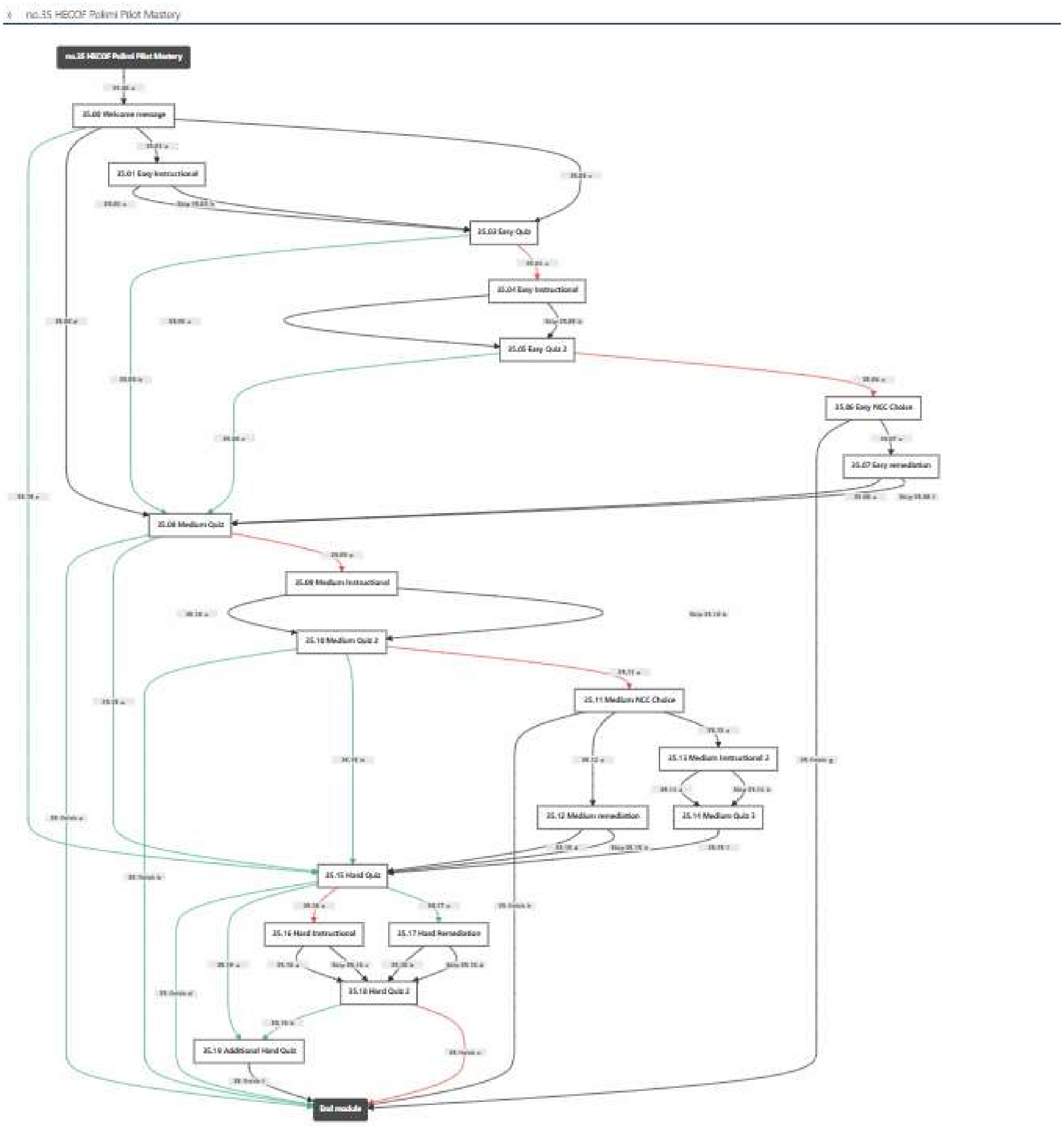

Figure 13. POLIMI Guided Mastery

2.2.2.4 POLIMI Practising Loop

The Practising Loop is a learning experience designed to reinforce practical concepts through structured exercises. It progresses in a mapped sequence, ensuring mastery by targeting sub-skills such as specific equation types. This loop enhances comprehension and helps students track their progress through focused practice.

Students' complete quizzes per sub-skill, with remediation provided if performance is low. If difficulties persist, additional instructional content is introduced before reattempting the exercise, ensuring personalized learning and mastery development.

Figure 14 presents the Leaning loop configuration diagram for POLIMI Practising Loop.

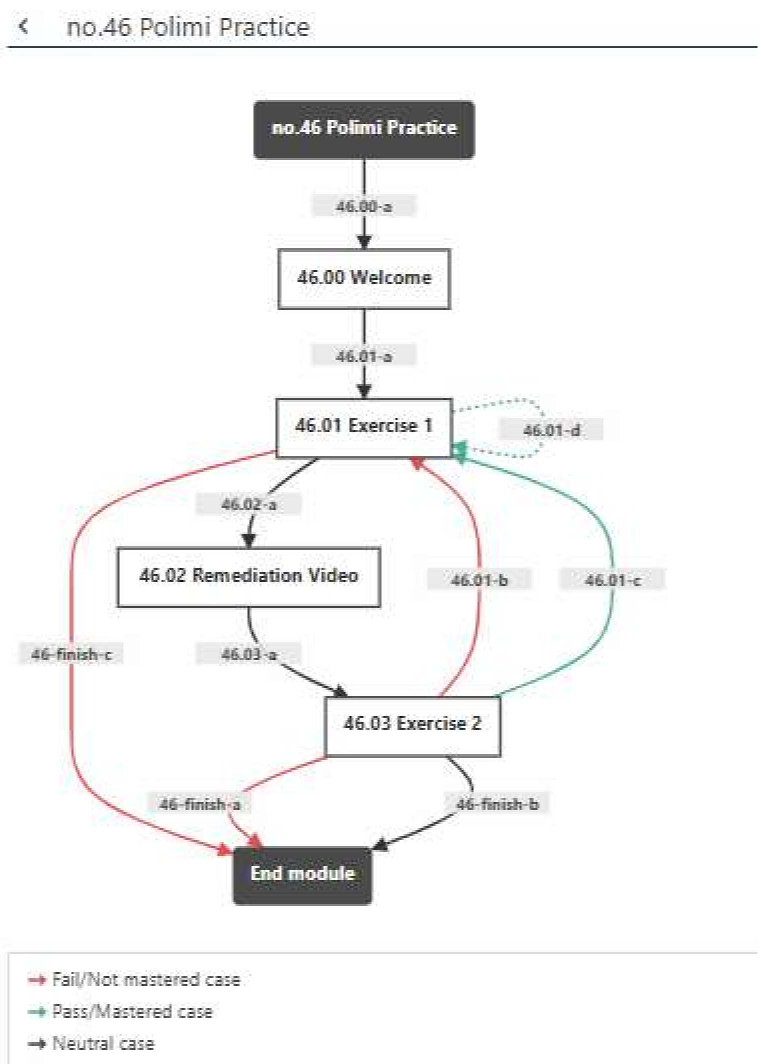

Figure 14. POLIMI Practising Learning Loop

2.2.2.5 POLIMI Reinforcement Learning Loop

The Reinforcement Learning Loop ensures long-term retention by using spaced repetition to review previously mastered concepts by interleaving assessment items. This loop helps consolidate knowledge, making it easier for students to retain and apply concepts over time.

In this learning experience, students choose their revision goals, then practise through assessment items that are selected through a spaced repetition approach.

Figure 15 presents the Leaning loop configuration diagram for POLIMI Reinforcement (Revision) loop.

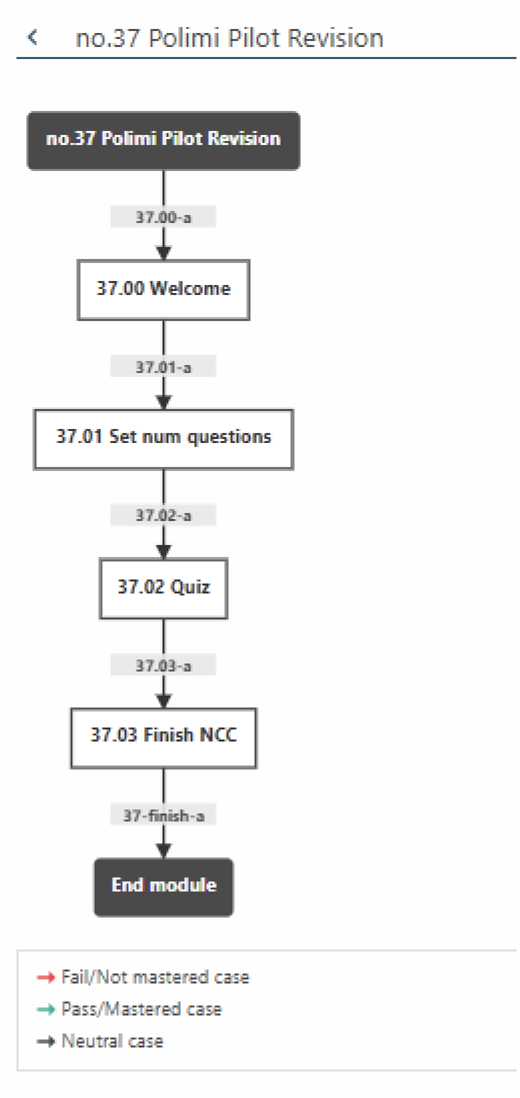

Figure 15. POLIMI Reinforcement (revision) Learning Loop

2.2.2.6 POLIMI VR Practice

The Practice (VR) Learning Loop provides an immersive VR experience, enabling students to engage with experiments in a simulated environment. This approach enhances practical understanding, making complex concepts more accessible and interactive while reinforcing hands-on learning.

In this learning experience, students progress through VR worlds, starting with an apparatus investigation to familiarize themselves with the tools. They then complete guided experiments, receiving step-by-step instructions to ensure comprehension. This personalized approach allows students to practice and refine their skills at their own pace.

Figure 16 presents the Leaning loop configuration diagram for POLIMI Practise (VR) loop.

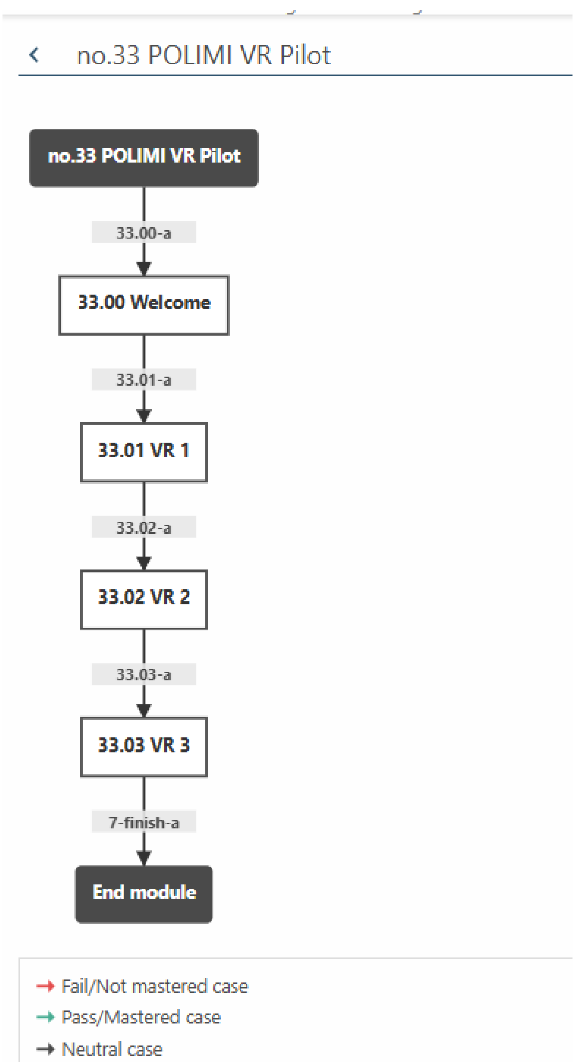

Figure 16. POLIMI Practice (VR) Loop

2.2.2.7 POLIMI Think Pair Share Loop

The Think-Pair-Share Learning Loop reinforces recent concepts through interactive explanations and study support. It leverages an AI-powered learning companion to guide students in reflecting on their understanding, sharing insights, and discussing key concepts.

The AI-agent presents students with their recent correct and incorrect answers, providing targeted explanations. It then facilitates a chat-based interaction as a Virtual Subject Expert, offering personalized responses and encouraging reflections to deepen understanding.

Figure 17 presents the Leaning loop configuration diagram for POLIMI Think-Pair-Share.

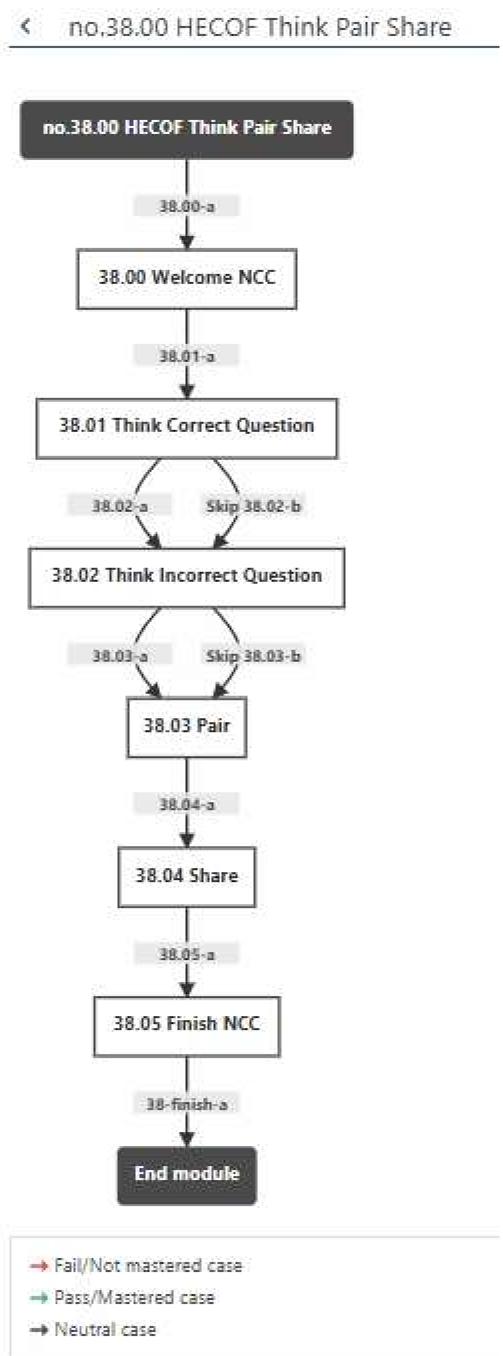

Figure 17. POLIMI Think-Pair-Share Learning Loop

2.2.2.8 POLIMI Diagnostics Loop

The Diagnostic Learning Loop was not initially planned in the learning design but was added at a later stage to serve as a pre-test to assess students' initial knowledge before starting the pilot. Using an adaptive assessment approach, it identifies strengths and gaps by dynamically selecting questions that provide the most informative insights into students' understanding.

As mentioned, during the learning experience, the assessment questions were chosen by the engine to tailor each student’s experience by recommending questions that maximize information gain. This ensures a precise diagnosis of knowledge level.

Figure 18 presents the Leaning loop configuration diagram for POLIMI Diagnostic loop.

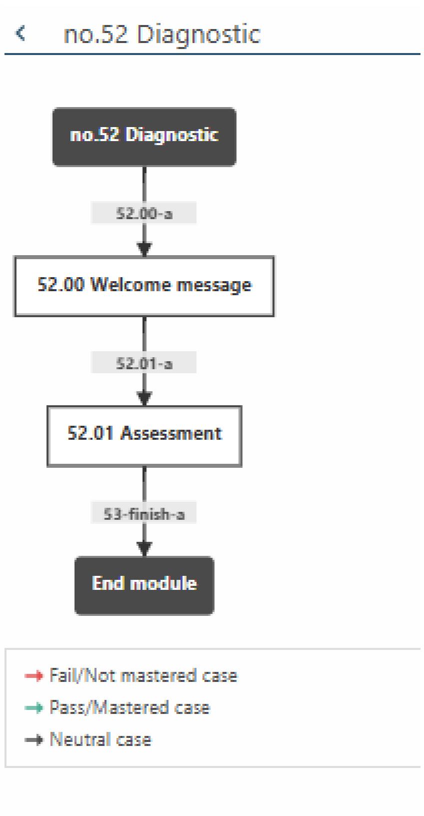

Figure 18. POLIMI Diagnostic Loop

2.2.2.9 POLIMI Post-assessment Loop

Like the Diagnostic Loop, this loop was not part of the initial learning design but was added to help with the evaluation, serving as a post-assessment (post-test). The Post-Assessment Learning Loop evaluates students' progress after completing the pilot by assessing the same concepts as the pretest but with different questions. This structured approach measures knowledge gains, reinforcing learning outcomes and identifying remaining gaps.

The loop selects questions that align with the pretest concepts while ensuring variation. This allows for a precise comparison of initial and acquired knowledge, providing valuable insights into student growth.

Figure 8 presents the Leaning loop configuration diagram for POLIMI Post-Assessment Loop.

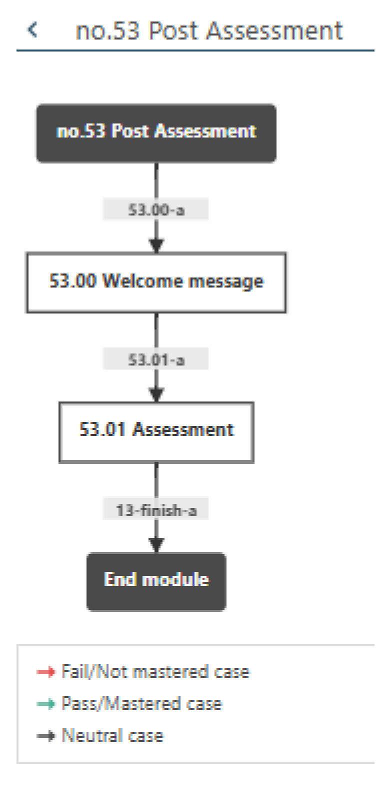

Figure 19. POLIMI Post- Assessment

2.2.2.10 NTUA Guided Mastery

The NTUA Guided Mastery Learning Loop is a structured learning experience which ensures that students achieve concept-level mastery by progressing through topics in a curriculum map sequence. Students will progress through easy, medium, and hard exercises. If performance is low, remedial content is introduced before reattempting. This personalized approach ensures mastery by dynamically adjusting learning paths based on individual success rates and comprehension levels.

The NTUA Guided Mastery is very similar to POLIMI Guided Mastery, the difference being in content type for initial instruction.

Figure 20 presents the Leaning loop configuration diagram for NTUA Guided Mastery Loop.

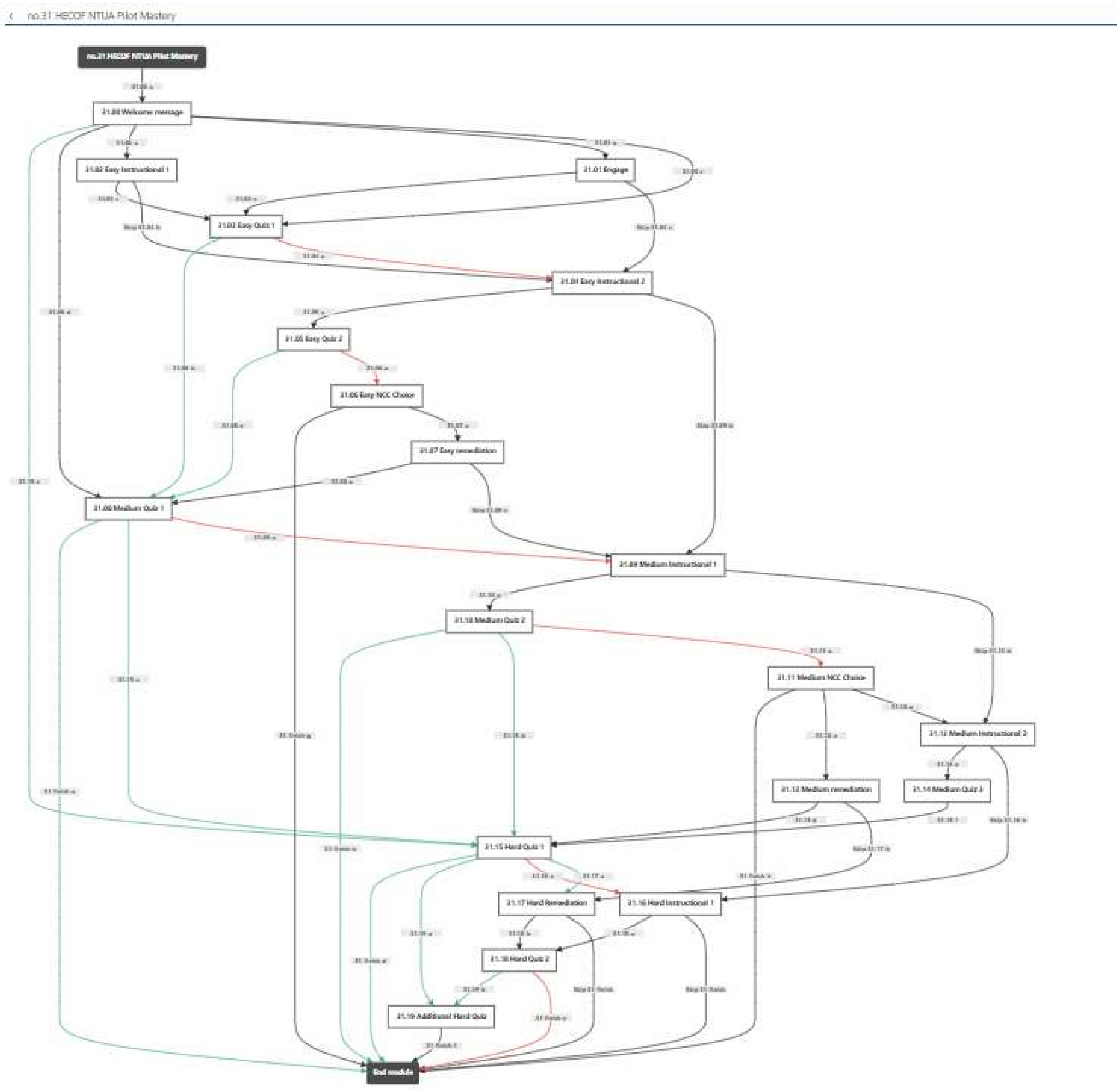

Figure 20. NTUA Guided Mastery Learning

2.2.2.11 NTUA Reinforcement (Revision) Loop

Similar to POLIMI Reinforcement Loop, the NTUA Reinforcement Learning Loop strengthens retention by using spaced repetition to revisit recently mastered concepts. It consolidates learning through interleaved assessment questions, ensuring long-term knowledge retention and deeper understanding. Students set their revision goals in terms of number of questions, and answer questions selected by the AI engine through a spaced repetition approach.

Figure 21 presents the leaning loop configuration diagram for NTUA Reinforcement (Revision) Loop.

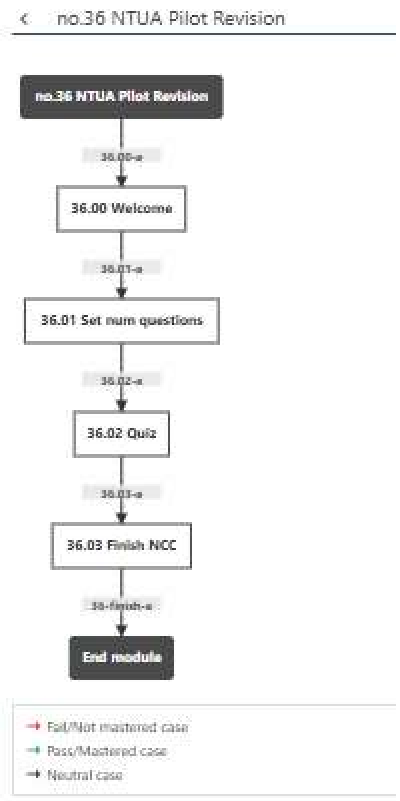

Figure 21. NTUA Reinforcement (Revision) Loop

2.2.2.12 NTUA Practice VR Loop

The adaptivity in the NTUA Practice VR Loop is very similar to the adaptivity in the POLIMI Practice VR Loop. Similar to POLIMI Practice VR Loop, the NTUA Practice (VR) Learning Loop provides an immersive virtual reality experience, allowing students to engage in hands-on experiments in a simulated environment in order to enhance practical understanding, making complex experiments more accessible and interactive, regardless of physical lab constraints.

Students will start with an apparatus investigation to familiarize themselves with the tools. They then progress to guided experiments, where step-by-step instructions ensure comprehension, allowing students to practice and refine their skills at their own pace. Furthermore, the NTUA VR Loop included several questions to assess the VR experience.

Figure 22 presents the leaning loop configuration diagram for NTUA Reinforcement (Revision) Loop.

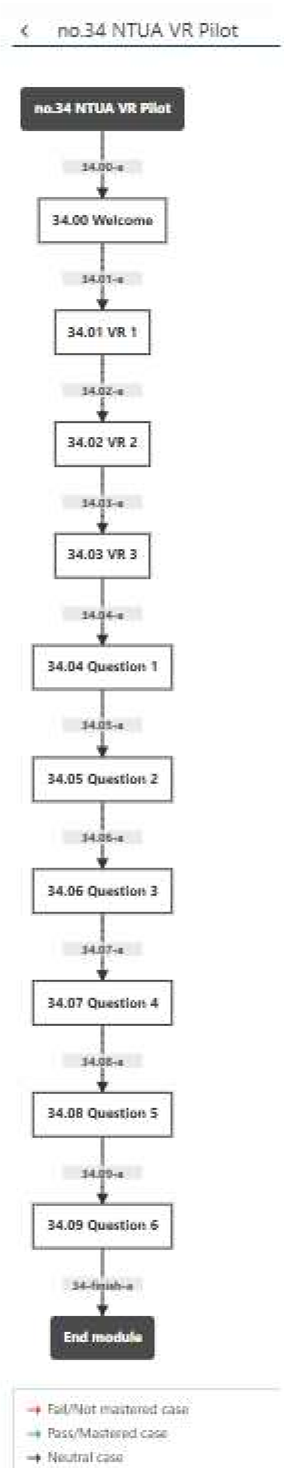

Figure 22. NTUA Practice VR Loop

2.2.2.13 NTUA Think Pair Share

The NTUA Think-Pair-Share Learning Loop, similar to the POLIMI Think-Pair-Share, strengthens comprehension by offering interactive explanations and study support. It utilizes an AI-driven learning companion to help students reflect on their understanding, exchange insights, and engage in discussions about key concepts.

The AI-agent presents students with their recent correct and incorrect answers, providing targeted explanations. It then facilitates a chat-based interaction as a Virtual Subject Expert, offering personalized responses and encouraging reflections to deepen understanding.

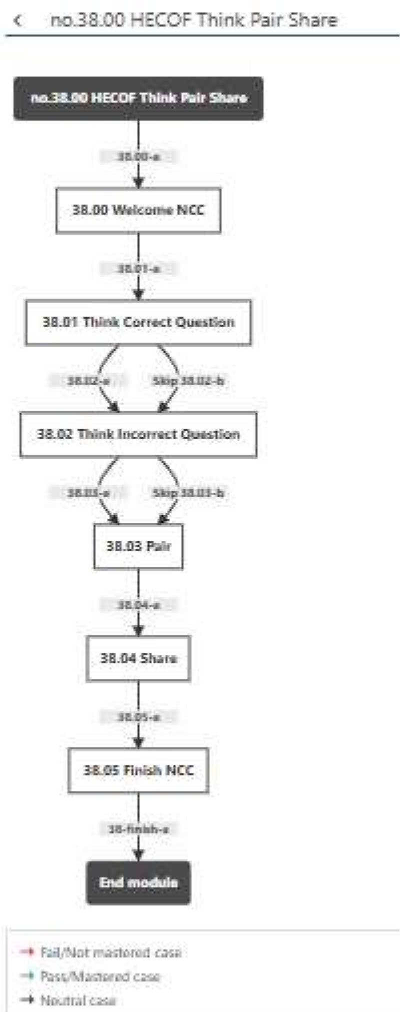

Figure 23. HECOF (NTUA) Think Pair Share

2.2.2.14 NTUA Diagnostic Loop

Similar to the POLIMI Diagnostic Loop, The NTUA Diagnostic Loop was not originally part of the initial learning design but was later integrated as a pre-test to evaluate students' prior knowledge before the pilot began. By leveraging an adaptive assessment approach, it dynamically selects questions that offer the most valuable insights into students' strengths and areas for improvement.

Throughout the learning process, the assessment engine tailored each student's experience by selecting questions that maximized information gain. This ensured an accurate diagnosis of their knowledge level.

Figure 24 presents the leaning loop configuration diagram for NTUA Reinforcement (Revision) Loop.

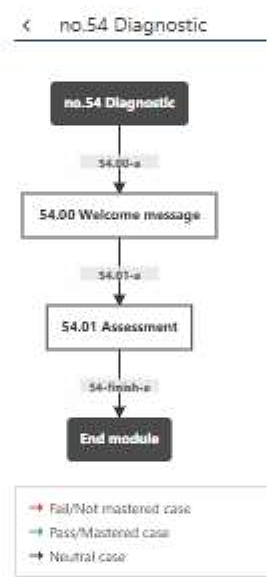

Figure 24. NTUA Diagnostic Loop

2.2.2.15 NTUA Post-Assessment Loop

Like the Diagnostic Loop, this loop was not part of the initial learning design but was added to help with the evaluation, serving as a post-assessment (post-test). The Post-Assessment Learning Loop evaluates students' progress after completing the pilot by assessing the same concepts as the pretest but with different questions. This structured approach measures knowledge gains, reinforcing learning outcomes and identifying remaining gaps.

Similar to the POLIMI Post-Assessment Loop, the NTUA Post-Assessment loop selects questions that align with the pretest concepts while ensuring variation. This allows for a precise comparison of initial and acquired knowledge, providing valuable insights into student growth.

Figure 25 presents the Leaning loop configuration diagram for POLIMI Post-Assessment Loop.

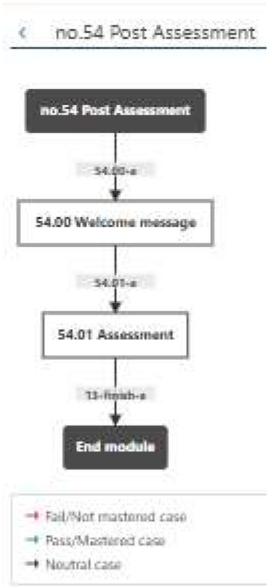

Figure 25. NTUA Post-Assessment Loop

2.2.3 Machine learning module (T4.3)

Initial work by Adaptemy has been done, while the collection data from the pilot to improve, test and evaluate the model is underway.

2.2.4 Data analytics module development (T4.4)

In this first iteration of platform development, simplified analytics and a comprehensive API (XAPI standard, REST) for getting report-specific data (i.e., information about students in the class regarding their performance, progress and effort) have been implemented by Adaptemy. Research into what type of analytics and reports needed was also performed.

A separate data lake to store the students' data needed for presenting the student profile and measuring statistics and aggregates for student progress has been developed by Konnektable. This data lake is used to store all synchronized relevant data from Adaptemy's data pool. An API has also been implemented to retrieve said data from the data lake, with the option of enhancing it with endpoints to manipulate the data as desired by requirements. The whole infrastructure has been developed using the Django REST Framework and a PostgreSQL relational database model.

At the time of the first pilot, the data lake had been deployed, but not used during pilot tests, since the aggregating functionalities were not yet in place. It was decided that Adaptemy's data lake was to be used instead for that particular timeframe, in order to achieve a seamless experience for pilot sessions. Future updates will be incorporating this data lake as well. During that time, Adaptemy and Konnektable have been collaborating to identify the necessary metrics and aggregations and implement as desired, so that user experience and decision-making is further enhanced. Data is visually presented through a frontend solution and interactive dashboards (see 2.2.9 below).

The synchronization process was done manually, with the plan being to transition to automatic synchronization and the usage of snapshots, i.e. student progress data at the time of synchronization. This will help to better identify student progress and needs at various points in time.

2.2.5 Classroom orchestration data lake (T4.5)

Part of the data lake described in T2.4 facilitates the functionalities described in T4.5, i.e. the data lake relative to student data and teaching observations is a unified solution implemented by Konnektable. This helps minimizing interconnection between components and having the necessary access to the same data needed for both tasks. Teaching staff is also planned to have access to metrics discussed in T4.4, in order to extract better conclusions regarding the learning process. The development of API endpoints for posting/retrieving teacher observations is in progress and will be completed in the next product version.

2.2.6 Data Security module (T4.6)

Up until the first phase of development and first pilot, organizations were responsible for maintaining security on respective individual components. There is ongoing research on how to unify the security aspect, using a single-sign-on technology. All communications utilize the HTTPS protocol, to ensure data safety through encryption.

2.2.7 Resource orchestration component (T4.7)

As per T4.6, permissions are being managed by organizations through logging in. Endpoints and various operations are being secured by login mechanisms. Single-sign-on technology will result in users being able to access the individual components by using a single login mechanism. This will be finalized in the next version.

2.2.8 Cross platform API (T4.8)

At the time of the first pilot, the VR-LAB by Nuromedia was directly connected to Adaptemy's infrastructure via REST API. The VR-LAB is invoked by the learner platform via HTTP/GET request with learner id and difficulty level as parameters. While in a VR session, the VR application sends progress and performance data to the AI module. Difficulty adaptation was implemented for the first version by utilizing the difficulty level parameter for level 1 & 2. Nuromedia's development is based on Unity's OpenXR implementation and is tested on Quest 2 & 3.

2.2.9 Interactive Dashboards (T4.9)

At the time of the first release, two frontend development cycles were occurring concurrently: An interactive dashboard development by Adaptemy, developed to facilitate the implementation and testing of their components (a web page-based solution) and an interactive dashboard development by SIMAVI (an application-based solution, developed in Unity), which will be the end product regarding the platform dashboard aspect. Since SIMAVI's solution was still under development during the first pilot phase, it was decided that only Adaptemy's web interactive dashboards were to be used for that phase. The final version will deal with this task by having the application-based interactive dashboards connecting to the data lakes in order to retrieve all relevant data.

Figure 26 presents the "Topics by Students" view of the dashboard. It presents two key visualizations: Diagnostic status distribution Topic(s) (Processes-Extraction). Diagnostic status shows students who have undergone diagnostic versus those who have not. Topic(s) status indicates the progress in the specific status.

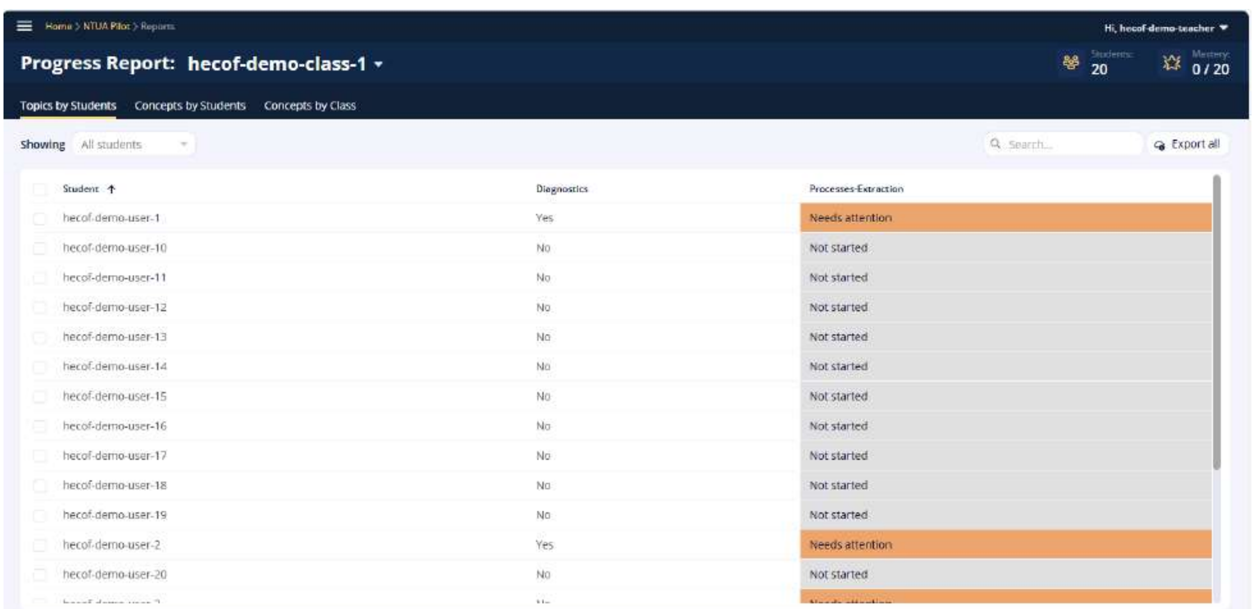

Figure 26. Dashboard - Topics by Students View

Figure 27 presents the "Concepts by Students" view of the dashboard. It provides insights into individual student progress across the concepts within the course. Once a student is selected, the view presents concept performance breakdown in terms of *mastery level* (a measure of mastery level that ranges from "Needs Attention" to "Progressing", "Expert", and "Mastered", *attempts* (number of attempts the students has made), *questions* (the total number of questions attempted), *ability score* (a numerical representation of a student's ability in the topic), *precision* (a measure of how much precision the engine has in the estimating student ability), *learning time* (the time spent learning the concept). The dashboard enables lecturers to identify struggling students, track individual progress, and plan targeted interventions for better mastery outcomes.

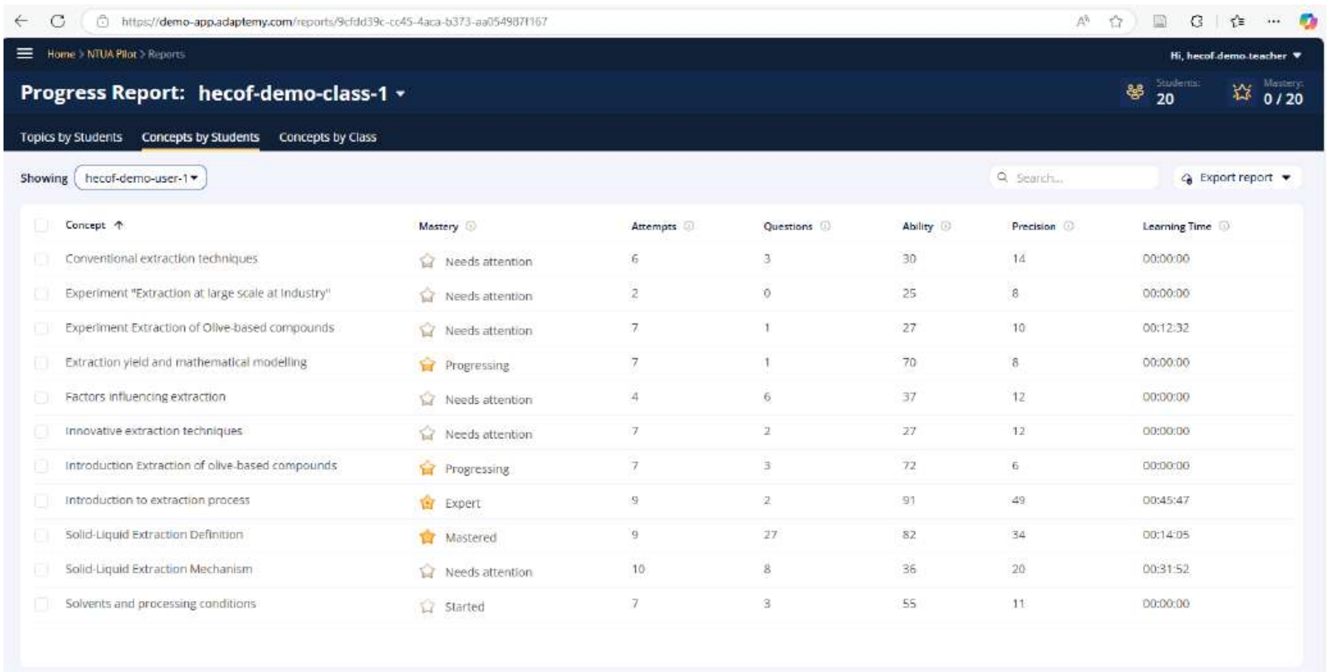

Figure 27. Dashboard - Concepts by Students View

Figure 28 presents the "Concepts by Class" view of the dashboard. It shows student mastery distribution across different mastery level: Expert (number of students with are at expert level - the higher level of proficiency), *mastered* (number of students why have fully mastered the concepts), *progressing* (number of students who have begun working on the topic and are making progress but haven't mastered it yet), *needs attention* (number of students who who are struggling), *started* (students who have begun working on the topic), *not started* (students who haven't engaged with the concept yet). This dashboard view enables lecturers to track class-wide progress, pinpoint learning gaps, and plan targeted interventions to enhance student understanding.

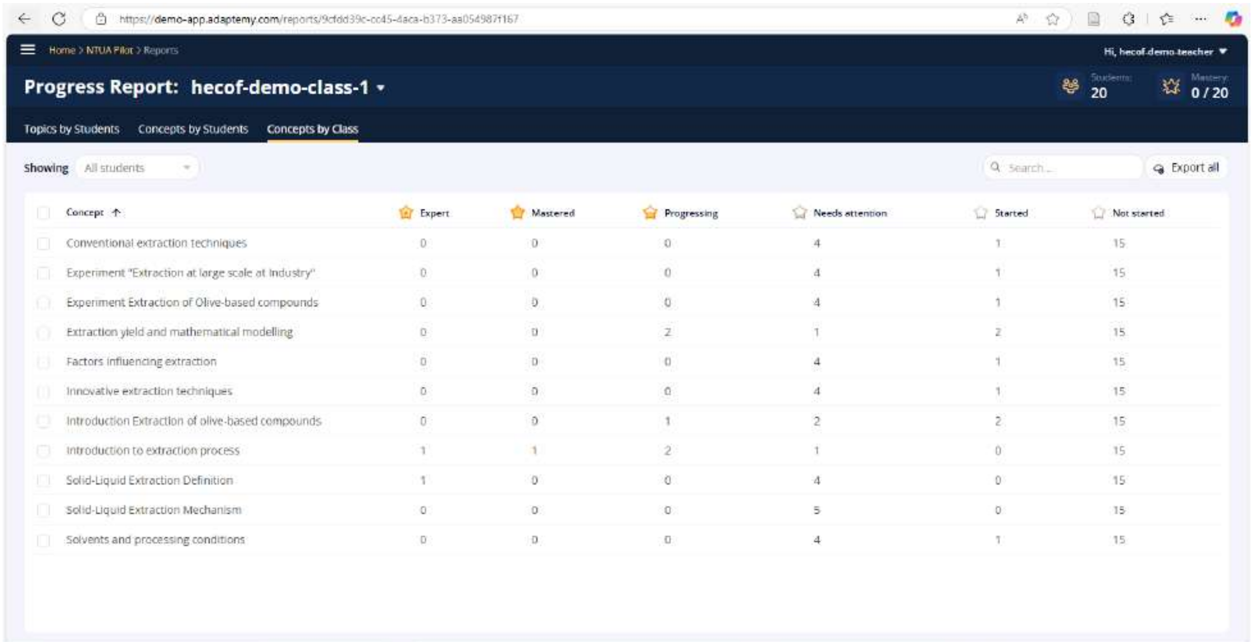

Figure 28. Dashboard - Concepts by Class View

The SIMAVI dashboard will use a connectivity module based on REST API calls which will read and display metrics about the courses and topics that are relevant for the students and for the teachers. The first step for the user when opening the dashboard will be to authenticate by using a username and password. Figure 29 presents the login page for SIMAVI's solution , while Figure 30 shows the current version of the proposed metrics integrated into the dashboard.

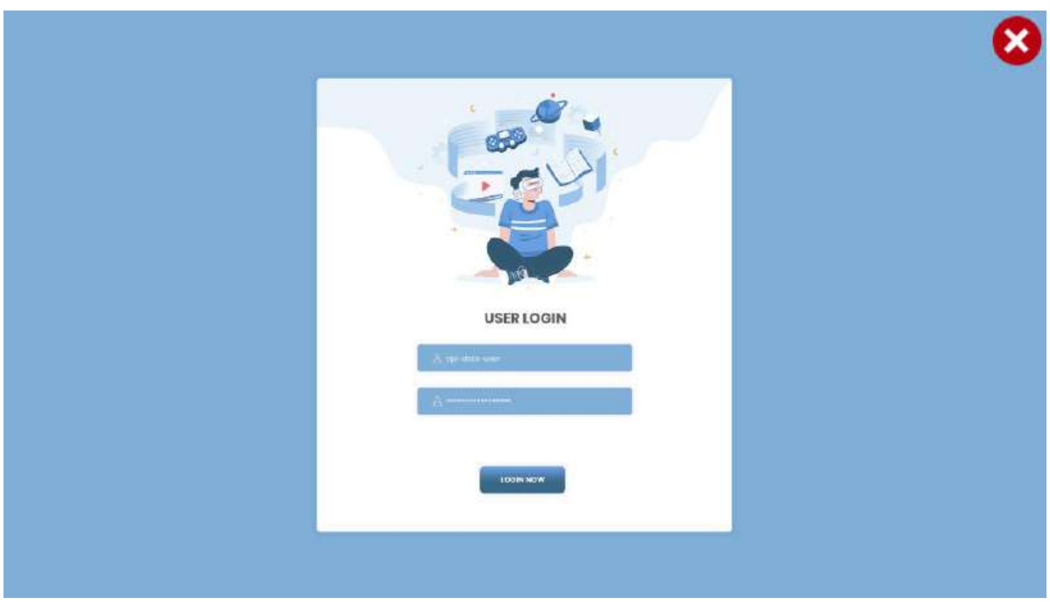

Figure 29. Simavi dashboard - Login

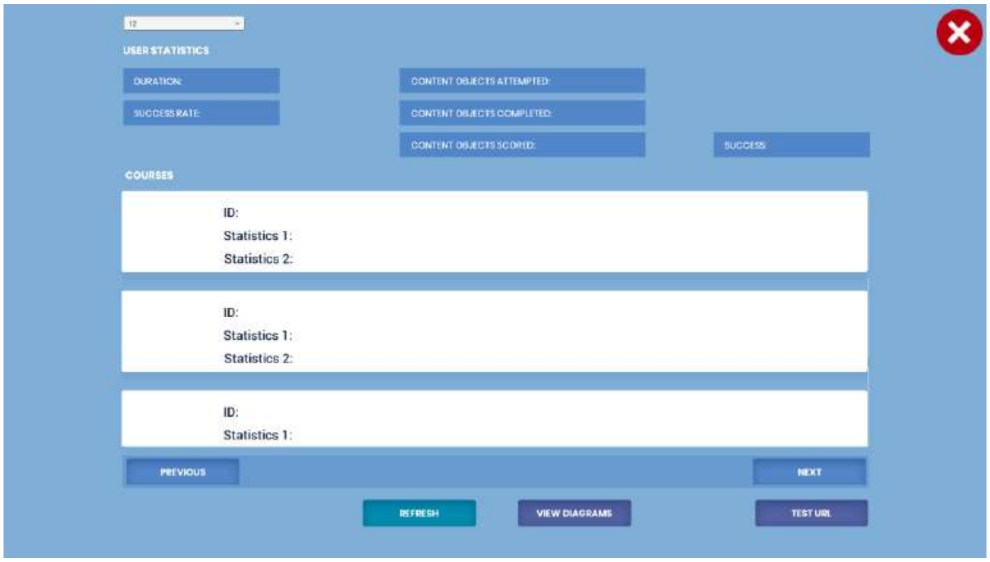

Figure 30. Simavi dashboard - draft version of metrics

2.2.10 Technical testing and refinement (T4.10)

Testing and Co-Design Sessions were held with teachers of both NTUA and POLIMI to constantly improve and optimize the Lab exercise for first pilot evaluation. Five Co-Design Sessions and two test runs took place before Evaluation 1 of Pilot 1 at NTUA, whereas two Co-Design Sessions and one test run took place before Evaluation 1 of Pilot 2 at POLIMI.

The HECOF VR Lab application could be downloaded and installed from a dedicated homepage (see figure 31).

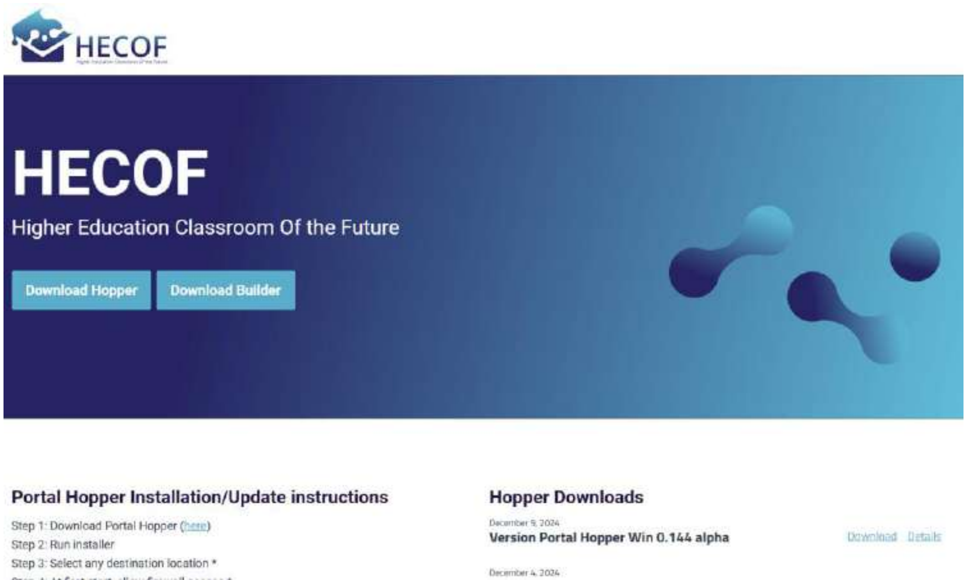

Figure 31. Download portal for HECOF VR Lab applications

Details regarding the first pilot phase are shown in the tables below:

Pilot 1 NTUA:

Objective	Date	Details
Co-Development & Preparation for Evaluation	25/10/2024	- Introduction to World Builder software - Sharing of Lab Exercise World Builder project with teachers - Refinement & co-development of the VR Lab Exercise - Testing of the Lab Exercise in VR and non-VR with the equipment at NTUA
	01/11/2024	
	08/11/2024	
	12/11/2024	
	19/11/2024	
Test Runs for Evaluation 1	05/12/2024	
	12/12/2024	
Evaluation 1	17/12/2024	- Students doing VR experience one by one with one headset - Runtime: about 7 hours for the first day and 3 hours for the second day
	19/12/2024	

Table 1. Details of first pilot phase sessions (NTUA)

Objective	Date	Details
Co-Development Sessions	13/11/2024	- Introduction to World Builder software - Sharing of Lab Exercise World Builder project with teachers - Refinement & co-development of the VR Lab Exercise
	14/11/2024	
Test Runs for Evaluation 1	06/12/2024	
Evaluation 1	10/12/2024	- Students doing VR experience simultaneously on a number of computers/headsets in 2 groups - Runtime: about 1.5 hours

Table 2. Details of first pilot phase sessions (POLIMI)

3. CONCLUSIONS

This deliverable, D4.1, marks a pivotal step in the development and deployment of the HECOF platform, laying the groundwork for transforming higher education through innovative technologies. The progress achieved in WP4 demonstrates the project's commitment to creating a robust, personalized, and adaptive learning ecosystem that leverages the power of VR, AI, and data analytics.

The document outlines the design, development, and integration of key system components, including the VR-capable core, AI-based adaptive learning modules, data analytics framework, and interactive dashboards. These components work cohesively to deliver immersive and personalized learning experiences while enabling educators to access actionable insights to enhance teaching practices.

The development process faced several challenges, including ensuring seamless component integration, optimizing system usability, and addressing security and compliance requirements. By adopting a user-centered approach and gathering feedback from pilot tests, the HECOF team has made significant strides in refining the platform's functionality and user experience.

Key achievements of WP4 include:

1. Development of immersive VR-based educational tools and simulations tailored for chemical engineering.
2. Implementation of AI-driven adaptive learning models and learning loops to provide personalized learning pathways and experiences.
3. Establishment of data lakes and APIs for real-time data synchronization and analytics.
4. Initial deployment of interactive dashboards for visualizing student performance and progress.

5. Advancement in security mechanisms to ensure data protection and system integrity.

Looking forward, WP4 will focus on:

- Completing the integration of all subsystems and finalizing inter-component communication.
- Enhancing analytics capabilities to provide more comprehensive insights into student learning outcomes.
- Delivering the final version of the interactive dashboards, ensuring accessibility and usability for both students and educators.
- Expanding teacher feedback mechanisms to support continuous improvement of the learning process.
- Ensuring scalability and adaptability for diverse educational contexts and user groups.

This deliverable reflects the HECOF project's vision of creating a future-ready higher education ecosystem. The achievements of WP4 serve as a foundation for further iterations and advancements, paving the way for broader adoption of the HECOF solution in higher education institutions. By aligning with the strategic goals of the Digital Education Action Plan (2021–2027), HECOF is positioned to drive meaningful change in teaching practices and education policies, fostering innovation, inclusivity, and ethical AI integration in education.

This document is issued within the frame and for the purpose of the Higher Education Classroom Of the Future project. This project has received funding from the European Union's Erasmus+ Framework Programme under Grant Agreement No. 101086100.

Co-funded by the European Union

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