HECOF
Higher Education Classroom Of the Future

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HECOF D5.3 Final Evaluation and Impact Assessment

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.

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EU classified —RESTREINT-UE/EU-RESTRICTED, CONFIDENTIEL-UE/EU-CONFIDENTIAL, SECRET-UE/EU-SECRET under Decision 2015/444

Co-funded by the European Union

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

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Status:	Final
Due Date:	M30
Version:	V1.0
Submission Date:	13/08/2025
Dissemination Level:	PU

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:	30M

Partners

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Document History

Version	Date	Author (Partner)	Remarks/Changes
0.1	28.03.2025	NURO	Draft – Structure
0.2	08.05.2025	NURO	Working Shared Document
0.3	09.07.2025	All Partners	Contributions to the shared document
1.0	12.08.2025	NURO and KT	Finalisation of the document

Executive Summary

This deliverable, **D5.3: Final Evaluation and Impact Assessment**, summarises the outcomes of the "Higher Education Classroom of the Future" (HECOF) pilot testing, evaluation, and impact assessment activities conducted in **Work Package 5 (WP5)**. It reports on the implementation, results, and analysis of two pilot cycles carried out at the **National Technical University of Athens (NTUA)** and **Politecnico di Milano (POLIMI)** in the field of chemical engineering, fulfilling **Milestone MS7**: *"Second round of pilot activities are implemented"*.

The HECOF project aims to advance the digital transformation of education by integrating **AI-driven adaptive learning** and **immersive VR laboratory simulations** into higher education teaching. Developed through a hybrid methodology combining Lean UX, learning design, and agile development, the HECOF system was iteratively refined between Evaluation #1 and Evaluation #2 based on direct user feedback. WP5 employed a **mixed-methods evaluation approach**, combining system performance analytics, learning analytics, and structured user feedback, to assess six key dimensions:

a) Technical functionality,
b) System performance and accuracy,
c) Pedagogical impact,
d) Satisfaction and perceived usefulness,
e) Usability, and
f) Social impact and presence.

Evaluation #1 (M22–M24) validated the initial Minimum Viable Product (MVP1), gathering feedback from students and educators on usability, technical performance, and pedagogical value. This feedback informed the agile co-development of the **final system release (MVP2)** in WP4.

Evaluation #2 (M27–M29) assessed MVP2's effectiveness in real classroom contexts, integrating the system into teaching activities at both pilot sites. At **NTUA**, the VR module supported the chemical extraction process from olive leaves, enabling students to practise and consolidate knowledge before entering the physical lab. At **POLIMI**, the VR bioreactor assembly and operation simulation offered a guided, focused training environment that complemented real lab practice. Across both pilots, adaptive learning features personalised study paths, reinforced complex concepts, and provided targeted self-assessment opportunities.

Findings show **high levels of student engagement**, improved conceptual understanding, and increased confidence in mastering complex topics. Educators highlighted HECOF's potential for enriching curricula, enhancing preparation for practical work, and enabling data-driven teaching. Feedback also generated actionable recommendations for future enhancement, including expanding AI-generated content, diversifying assessment formats, refining VR interactivity, and improving usability.

The **impact assessment** revealed value for multiple stakeholders: students gained digital and practical skills; educators explored innovative teaching strategies; institutions identified pathways for integrating immersive and adaptive technologies; and industry stakeholders recognised potential applications in technical training and upskilling.

With the successful completion of both evaluation cycles and the achievement of MS7, WP5 has validated the HECOF system's feasibility, effectiveness, and potential for broader adoption. The insights captured in this report will inform WP6 activities in communication, dissemination, and exploitation, supporting the project's long-term sustainability and scalability.

Abbreviations and acronyms

Abbreviation	Definition
AI	Artificial Intelligence
API	Application Programming Interface
HECOF	Higher Education Classroom of The Future
NTUA	NATIONAL TECHNICAL UNIVERSITY OF ATHENS: ETHNICON METSOVION POLYTECHNION
LPAD	Laboratory of Process Analysis & Design
M#	Project Month Number
MS#	Milestone Number
ML	Machine Learning
MVP	Minimum viable product
POLIMI	POLITECNICO DI MILANO
PH#. #	Phase Number
T#	Task Number
VR	Virtual Reality
W#	Week Number (ISO 8601)
WP#	Work package Number

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Introduction

1.1 Purpose of the Document and Follow-Up

This is the final report **D5.3 "Pilot testing, evaluation and impact assessment"** and summarises the outcome from HECOF Work Package 5 "Pilot testing, evaluation and impact assessment". It is the follow up document from D5.1 "Pilot monitoring and evaluation methodology" and D5.2 "First evaluation of pilot activities & user requirements refinement".

Pilot testing and evaluation activities were based on outcome from Work Package 2 "Requirement's analysis & privacy, social and ethical impact assessment", and Work Package 3 "Instructional strategies and assessment design." In strong collaboration with Work Package 4 "Agile development of HECOF system."

With this deliverable **milestone MS7 "Second round of pilot activities are implemented"** is achieved and results are given to task T6.4 "Sustainability and exploitation planning".

1.2 T5.5 description: Evaluation and Impact assessment

As described in the HECOF grant agreement: [1]

"T5.5 will carry out an overall assessment and evaluation of the system in terms of system performance issues and the social impact of using the system in HEIs including perspective of students and lecturers on the potential positive and negative effects of using it. The T5.5 will implement an impact assessment survey amongst the users of the system that will be applied at the end of the pilot activities. Based upon the participant feedback in T5.4 gathered by M24, T5.5 will provide recommendations for redesign the prototype for a further implementation iteration in T4.10."

1.3 About the Project

"Higher Education Classroom of the Future" (HECOF, ERASMUS+ GA No 101086100) initiative aims at revolutionising higher **education teaching practices and education policies** by creating systemic change. A multidisciplinary team develops and tests an innovative **personalised, adaptive** way of teaching, that exploits the digital data from students' **learning** activity **in immersive environments** and uses computational analysis techniques from data science and AI. This also necessitates 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. The project focuses on the field of **Chemical Engineering**, with involvement of **students and teaching staff**, from two pilot universities. 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 type 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.

HECOF follows a state-of-the-art **hybrid development methodology** [2] with Lean/UX in WP2, adaptive learning concepts [3], [4] in WP3, and SCRUM in WP4 in a phase frame defined in WP1, and refined in WP5, see D5.2.

[1] HECOF GA, Associated with document Ref. Ares (2022)8365788 - 02/12/2022

1.4 HECOF 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**.

HECOF has defined four specific objectives, while this document focuses on SO4:

- **SO1:** To design and develop instructional content and a personalized adaptive learning system in immersive learning environments with a conceptual focus on "Chemical Engineering" academic discipline
- **SO2**: To engage teaching staff and students in shaping and co-designing the learning system
- **SO3**: 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 and ethical educational deployment of AI-based technologies for teaching and learning.
- **SO4:** To pilot and assess the performance of the HECOF prototype system at the EU level, in a "Chemical Engineering" real classroom setting in two pilot studies, in terms of (i) effective and adequate learning experience (completeness), (ii) perceived benefits compared to traditional pedagogical model (quality), and (iii) user experience (acceptance).

1.5 Specific Objectives and Deliverables in WP5

WP5 addresses HECOF objective SO4 by six specific objectives:

1) Recruit students for the pilots and setup the pilot environment.
2) Train the teaching staff and students on how to use the HECOF solution.
3) Identify the starting level of knowledge, skills of students involved in pilot tests.
4) Fully operate and test the HECOF components and architecture on piloting experiments aimed to validate the HECOF prototype solution from a usability and end-user point of view.
5) Provide feedback and recommendations for HECOF system refinement in WP4.5) To validate the HECOF prototype solution from a usability and end-user point of view.
6) Evaluate the effectiveness of the HECOF prototype solution, the potential positive and negative effects of using AI in an immersive learning environment for personalized adaptive learning from the point of view of the pilot studies' participants

T5.4 "Pilot Running and Monitoring" implemented both evaluations based on T5.1 planning of WP5 to fulfil all these objectives as described in D5.1 as **guideline for HECOF Phase 3 "Monitoring and evaluation".** Outcome from the first evaluation was discussed with **D5.2 "First evaluation of pilot activities & user requirements refinement"** and given to "WP4 Agile development of HECOF system" to develop D4.2 the final version of the HECOF System. Based on that version the final evaluation was conducted. This report D5.3 is the final resume of WP5 "Pilot testing, evaluation and impact assessment".

2 WP5 Structure

WP5 handles the implementation of **Phase 3: "Monitoring and evaluation"** (Month 22-Month 29) - addressing **SO4 *"To pilot and assess the performance of the HECOF prototype system at the EU level, in a "Chemical Engineering" real classroom setting […]"***.

Based on input from **WP2 "Requirements analysis & privacy, social and ethical impact assessment"**, **WP3 "Instructional strategies and assessment design"**, and **WP4 "Agile development of HECOF system"**. The agile co-development in WP4 and WP5 will continuously improve the HECOF system and training exercises.

Evaluation 1 was based on MVP1, released in M22 as D4.1. Outcome of the first evaluation will refine D2.1, and D5.1 by this document to adapt the development in WP4 and prepare the final evaluation. The co-development will be continued based on the first evaluation outcome to prepare MVP2 for the final evaluation 2.

Evaluation 2 will assess the D4.2 "HECOF Integrated system- Final release", delivered in M26. The outcome of pilot 1 and 2 will be analysed and compiled into D5.3 Final evaluation and impact assessment.

HECOF piloting will be implemented at two pilot universities in the field of chemical engineering.

- Pilot 1: NTUA, chemical extraction process
- Pilot 2: POLIMI, bioreactor

2.1 Phases in HECOF

HECOF is organized in four interrelated phases:

- Phase 1: Preparation (Month 1-Month 12) - Obj. addressed:SO1, SO2, SO3 (WP1,2,3)
- Phase 2: Implementation (Month 13-Month 26) - Obj. addressed:SO1 (WP4)
- Phase 3: Monitoring and evaluation (Month 22-Month 29) - Obj. addressed:SO4 (WP5)
- Phase 4: Dissemination and exploitation (Month 3-Month 30) - Obj. addressed: SO5, SO6

To enable WP5 fulfilling all these objectives, T5.1 performed the piloting planning as described in this document to initiate phase 3 of HECOF.

2.2 Phases of WP5

WP5 implements phase 3 "Monitoring and evaluation" and is structured in 8 sub phases:

1. PH3.0: Planning of methodology (WP5, T5.1 NURO) D5.1 M21
2. **PH3.1:** Preparation of pilot activities (WP5, T5.2, E5.1 & E5.2 SIMAVI)
3. **PH3.2:** Users Training (WP5, T5.3, E5.2 & E5.4 ADAPTEMY)
4. **PH3.3:** Evaluation 1 running and monitoring (WP5, T5.4 SIMAVI)
5. **PH3.4:** Analytics of the outcome and refinement of D2.1 & D5.1 by D5.2 M24 (WP5, T5.5 NURO)
6. PH3.5: Agile development of MVP2 (WP4, KT, all partners)
7. PH3.6: Evaluation 2 running and monitoring (WP5, T5.4 SIMAVI)
8. PH3.7: Analytics of the outcome and impact assessment by D5.3 M30 (WP5, T5.5 NURO)

Focus of this report are phases PH3.1 – PH3.4, PH3.0 was reported by D5.1, upcoming phases will be reported by D5.3.

Table 1 presents an overview of phase 3 as GANTT chart in week granulation, details of the sub phases are in section 5.1 of the Implementation.

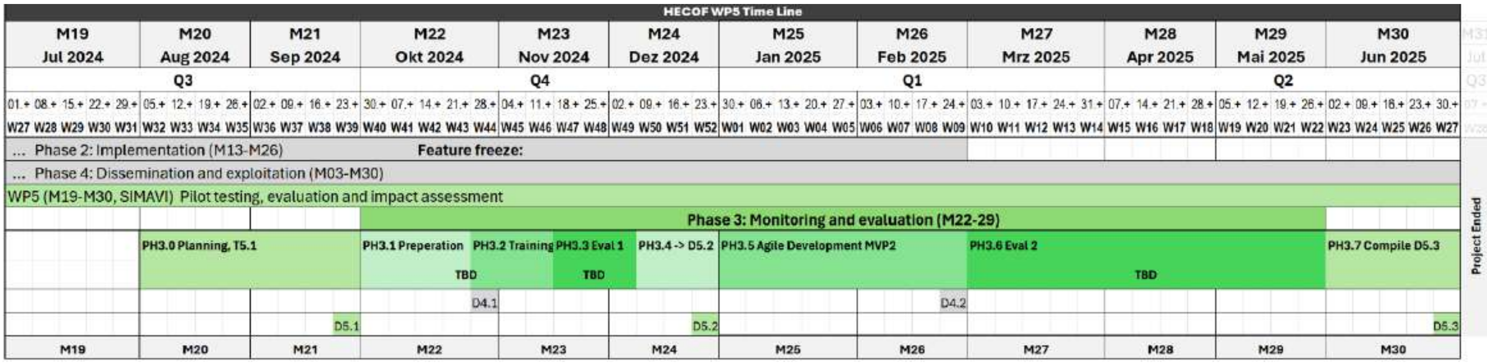


Table 1: HECOF Phases overview with a focus on WP5

2.3 Related HECOF Milestones

- MS6 (M24): evaluation #1 - pilot activities & user requirements refinement The milestone was reached in time, even when this document was submitted by a delay in M26. Findings were given to the agile development work package in advance.
- MS7 (M30): evaluation #2 - second round of pilot activities to assess,the effectiveness of the proposed learning environment and user satisfaction

2.4 Schedule of WP5 (Timetable)

Phase / Event	Month	Responsible	Step
PH3.0	M20-M21	NURO	T5.1 Planning, D5.1 M21
PH3.1	M22/M23	SIMAVI	T5.2 Preparation, E5.1 + E5.2
PH3.2	M22/M23	ADAPTEMY	T5.3 Training, E5.3 + E5.4
E5.1 + E5.3	M22	NTUA	Preparation and training event for Pilot 1
E5.2 + E5.4	M22	POLIMI	Preparation and training event for Pilot 2
PH3.3	M23/M24	SIMAVI	T5.3 Pilot Running and Monitoring, Evaluation 1
Eval 1.1	M24	NTUA	Evaluation 1 / Pilot 1
Eval 1.2	M24	POLIMI	Evaluation 1 / Pilot 2
PH3.4	M26	NURO	D5.2 "First evaluation of pilot activities & user requirements refinement"
PH3.5/ PH2	M25-M26	KT	WP4 agile development of MVP2
PH3.6	M27–M29	SIMAVI	T5.3 Pilot Running and Monitoring, Evaluation 2
Eval 2.1	M30	NTUA	Evaluation 2 / Pilot 1
Eval 2.2	M30	POLIMI	Evaluation 2 / Pilot 2
PH3.7	M30	NURO	T5.5 Evaluation and Impact assessment, D5.3

Table 2: Piloting and Evaluation Timetable

3 Partners Roles and Obligations in WP5

The HECOF partners' roles and obligations during the execution of the pilots are defined by this section, in order of beneficiary number.

3.1 KT – Coordinator, Technical Lead, Backend, Data Lake, and Deployment

The overall roles of KT are coordinator of HECOF (WP1, WP6) and technical lead (WP4).

KT delivers the first release of the HECOF system by D4.1 as input for the pilot 1. In WP5, T5.4 KT is the provider of the backend and data lake developed in WP4. (T4.3 – T4.7).

- Deployment of the HECOF infrastructure
- Support
- Maintenance and bug fixing
- Contribution to D5.1, D5.2 & D5.3

Findings of pilot 1 (D5.2) will be incorporated in the second development phase of WP4. KT delivers the final release of the HECOF system by D4.2 as input for the pilot 2.

3.2 NTUA – Use Case Partner 1, Chemical Extraction Process

Use case partner for pilot 1, chemical extraction process.

- Hosting E5.1 & E5.3
- Performing evaluation 1 & 2 by integration into the teaching.
- Provide feedback to D5.2 & D5.3
- Contribution to D5.1

3.3 POLIMI – Use Case Partner 2, Bioreactor

Use case partner for pilot 2, bioreactor.

- Hosting E5.2 & E5.4
- Performing evaluation 1 & 2 by integration into the teaching.
- Provide feedback to D5.2 & D5.3
- Contribution to D5.1

3.4 NURO – XR Lab Editor and Player, Pilot Planning and Reporting

The overall role of NURO is technical partner of HECOF responsible for user requirements (WP2, D2.1, D5.2), pilot planning and reporting (D5.1, D5.3). In WP4 NURO is responsible for the VR-LAB exercise experience and integration with Adaptemy AI, and adaptive learning (T4.1) and supports API development and integration (T4.8, T4.9).

In WP5 NURO is responsible for the pilot and evaluation planning (T5.1, D5.1), and reporting. Compiling pilot 1 outcome into D5.2 as feedback to WP4 (T5.4), and pilot 1 outcome into D5.3 as feedback to WP6 (T5.5). NURO delivers the outcome of T4.1 to the first release of the HECOF system by D4.1. In WP5, T5.4 NURO is the provider of the VR-LAB editor and exercise experience developed in WP4. (T4.1) in co-creation with the educators of the pilot sites.

- Delivery of editor and XR player software.
- Delivery of basic XR exercises.
- Support of the teaching staff to adapt the exercise.
- Technical support.
- Maintenance and bug fixing.
- Delivery of D5.1, D5.2 & D5.3.

Findings of this document will be incorporated in the second development phase of WP4.

NURO delivers the final release of the HECOF XR components to D4.2 as input for the pilot 2.

3.5 SIMAVI – Dashboard and API, Pilot Preparation, Running and Monitoring

The overall role of SIMAVI is technical partner of HECOF responsible for piloting and evaluation implementation (WP5). In WP4 SIMAVI is responsible for the HECOF dashboard (T4.9) and integration with NURO's XR technology (T4.8, T4.9).

The dashboard will provide a way to visualise the personalised learning path including details about history and behaviour of their learning progress alongside with the roadmap for knowledge needed to plan and perform exams.

SIMAVI is WP5 lead and responsible for the pilot and evaluation preparation (T5.2, E5.1, E5.2) and running (T5.4). SIMAVI delivers the outcome of T4.1 to the first release of the HECOF system by D4.1. In WP5, T5.4, SIMAVI is provider of the dashboard and API developed and integrated in WP4 (T4.8. T4.9, T4.10).

- Preparation and implementation of E5.1, E5.2.
- Delivery of editor and XR player software.
- Delivery of basic XR exercises.
- Support of the teaching staff and students.
- SIMAVI collects the user feedback.
- Maintenance and bug fixing.
- Contribution to D5.1, D5.2 & D5.3.

The findings of pilot 1 (D5.2) will be incorporated in the second development phase of WP4.

SIMAVI delivers the final release of the HECOF dashboard and API to D4.2 as input for the pilot 2.

3.6 ADAPTEMY – Adaptive learning, AI, and User Training

The overall role of ADAPTEMY is technical partner of HECOF responsible for learning design for AI-based adaptive learning (WP3), and AI driven adaptive learning technologies (WP4). Moreover, in WP4, Adaptemy is responsible for HECOF's AI-based Adaptive Learning Component that will integrate and configure the Adaptemy AI Adaptive Learning Engine as per HECOF's Learning Design (T4.2), co-development with KT's of the HECOF ML and data analytics modules (T4.3, T4.4, T4.5) and the integration with NURO's XR technology.

In WP5, ADAPTEMY is responsible for the user training (T5.3, E5.2, E5.4). ADAPTEMY delivers the outcome of T4.2 to the first release of the HECOF system by D4.1. In WP5, T5.4 ADAPTEMY is the provider of the adaptive learning technology developed in WP4. (T4.1) based on the learning design (WP3).

- Preparation and implementation of E5.2, E5.4.
- Delivery of AI and adaptive learning components.
- Support of the teaching staff.
- Technical support.
- Maintenance and bug fixing.
- Contribution to D5.1, D5.2 & D5.3.

Findings of pilot 1 (D5.2) will be incorporated into the second development phase of WP4.

ADAPTEMY delivers the final release of the HECOF adaptive learning modules to D4.2 as input for the pilot 2.

4 Evaluation and Monitoring Methodology

4.1 Theoretical Approach

The approach for HECOF evaluation employs a mixed-methods approach, combining quantitative metrics from system performance and learning analytics with qualitative feedback from users. The evaluation methodology was developed in the Evaluation preparation phase and presented in D5.1. The methodology integrates current AI-adaptive learning and VR training research to assess the system's impact [3], [4], [5].

Evaluation dimensions:

- **Technical functionality**: system uptime, API success rate, response time, VR performance.
- **System performance**: system accuracy performance.
- **Pedagogical impact**: learning improvements and effectiveness.
- **Satisfaction and perceived usefulness**: student and teacher experience.
- **Usability Evaluation:** learning experience in learning loops, VR and overall system usability.
- **Social Impact and Presence**: evaluation through interviews and surveys.

4.1.1 Technical functionality

The technical functionality of the AI engine and VR experience play critical roles in ensuring smooth, uninterrupted learning experiences for students and educators. One of the key aspects is **system uptime**, which refers to the percentage of time the system is operational and accessible. Another crucial metric is the **API success rate**, which tracks the percentage of successful data requests made to the AI engine. In terms of **response times**, the goal is to keep a low latency (i.e., <1s), For the VR experience key metrics are **start time** for the VR exercise (i.e., < 3s) and **frame rate in VR** also the previous described response time of the AI API. VR start time and AI response time providing users with near-instant feedback and ensuring that adaptive learning paths adjust in real-time, maintaining optimal performance across various usage scenarios is essential to guarantee that **students experience seamless, personalised learning**. For the usage of head mounted VR devices a high frame rate (i.e., >60fps in VR, >30fps on desktop) is mandatory to have a **comfortable VR experience** and avoid the occurrence of VR sickness.

4.1.2 System Performance

The accuracy of the Adaptemy **AI engine** is a key measure of its effectiveness in delivering **personalised and adaptive learning** experiences. **System accuracy** refers to the AI's ability to correctly predict student outcome to assessment questions and further on to make predictions about learning needs. This is achieved by building a **learner model** based on evidence from the learner interactions.

To measure system accuracy effectively, we will focus on students who have provided sufficient **initial evidence**, such as completing early assessments. This approach helps mitigate the cold start problem, which occurs when the AI system lacks enough data **to make accurate predictions** or personalise learning paths effectively. By waiting for students to complete some initial work, we ensure that the AI has gathered enough meaningful data to make informed decisions. High accuracy directly impacts recommendations, **fostering a more personalised and efficient learning journey**.

4.1.3 Pedagogical Impact

The pedagogical impact of the HECOF AI and VR experience will be measured through key metrics that track learning improvements and overall effectiveness. One of the primary indicators of learning effectiveness will be the **learning gain per session per concept**, which measures how much students improve in their understanding of specific concepts after each learning session. This will be closely monitored through **learning analytics**, which provide insights into student progress and mastery of concepts, allowing us to track incremental improvements over time. Additionally, **pre- and post-tests** will be used to quantify learning outcomes, measuring the difference in student performance before and after engaging within the pilot. Other important metrics include the module **completion rate,** and **concept mastery rates**. These measures will provide a comprehensive view of the effectiveness of the AI-driven adaptive learning approach in enhancing student outcomes.

4.1.4 Satisfaction and Perceived Usefulness

The satisfaction and perceived usefulness of the HECOF system are essential for ensuring both students and teachers have a positive experience with the system. This dimension evaluates the **perceived usefulness**, where students and teachers evaluate how beneficial the AI-driven personalization and VR simulated exercises are in achieving their learning and teaching objectives. Lastly, the evaluation will focus on **overall user satisfaction**, evaluating how satisfied students and teachers are with the platform's ability to enhance their learning and teaching experiences without overwhelming them with complexity or technical difficulties. Furthermore, this dimension will evaluate the HECOF prototype solution through the lenses of the **potential positive and negative effects** of using AI in an immersive learning environment for personalised adaptive learning from the point of view of the pilot students' and teachers' participants.

4.1.5 Usability Evaluation

The usability evaluation of the HECOF system focuses on how effectively it supports seamless learning experiences through adaptive learning loops, the integration of **virtual reality (VR)**, and overall system usability. In the context of **learning loops**, the goal is for students to progress through these loops without disruptions. The inclusion of **VR** adds another dimension, offering immersive, interactive experiences that make learning more engaging. However, the usability of VR components will be evaluated based on their ease of use and whether they enhance, rather than complicate, the learning process. Another aspect for immersive training is the **well-being in VR** [5] and the usability of the flat 3D desktop version as fallback. Lastly, the system's **overall usability**—including navigation, and ease of use —will be assessed to ensure that both students and teachers can use the platform effectively without extensive training or technical issues. Furthermore, this dimension will test the HECOF AI, VR and data analytics components aiming to validate the HECOF prototype solution from a usability and end-user point of view. Students and teachers provided **feedback and recommendations** for HECOF **system refinement**.

4.1.6 Social Impact and Presence

In AI-adaptive learning systems without direct collaborative features, evaluating **social impact** and **social presence** focuses on how the system fosters interaction between students, teachers, and the platform itself. Metrics such as **teacher-student interaction frequency** and **peer engagement levels** can reveal the system's ability to promote social learning and connection. Surveys on **social presence** and **perceived isolation** provide insights into whether students feel supported or disconnected during their learning experience. Tracking these dimensions ensures that, even without built-in collaboration, the system encourages meaningful interaction and reduces feelings of isolation through its dashboards, human computer interfaces and Virtual Tutor. While the initial requirements analysis a **multi user experience in VR** was rejected by students and educators to avoid complex time coordination effort. After evaluation 1 this option for social interaction was reviewed and discussed. It was preferred to have the personal exchange beside the system in the learning groups.

5 Implementation

5.1 Phases of WP5

WP5 implements phase 3 "Monitoring and evaluation" in 8 sub phases:

- **PH3.0:** Planning of methodology (WP5, T5.1 NURO) D5.1 M21
- **PH3.1:** Preparation of pilot activities (WP5, T5.2, E5.1 & E5.2 SIMAVI)
- **PH3.2:** Users Training (WP5, T5.3, E5.2 & E5.4 ADAPTEMY)
- **PH3.3:** Evaluation 1 running and monitoring (WP5, T5.4 SIMAVI)
- **PH3.4:** Analytics of the outcome and refinement of D2.1 & D5.1 by D5.2 M24 (WP5, T5.5 NURO)
- **PH3.5:** Agile development of MVP2
- **PH3.6:** Evaluation 2 running and monitoring (WP5, T5.4 SIMAVI)
- **PH3.7:** Analytics of the outcome and impact assessment by D5.3 M30 (WP5, T5.5 NURO)

Details of these phases are described in D5.1 "Pilot monitoring and evaluation methodology" elaborated in **PH3.0**. This document focuses on implementation of PH3.1 - PH3.4 to prepare PH3.5 - PH3.7. 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. **PH3.1** has been integrated with PH3.2 by combining events for setup and training and the pilot sites of NTUA and POLIMI in a combination of online and onsite events. Outcome from **PH3.2** educators' feedback and **PH3.3** students' feedback was discussed, analysed, and compiled into the report **D5.2 "First evaluation of pilot activities & user requirements refinement"**. D5.2 is the refinement of "D2.1 User Requirements and Functional Specifications", and D5.1 to enable the agile development of MVP2 in **PH 3.5**. Based on this MVP2 the second and final evaluation was run in **PH3.6**.

The objective of this second evaluation phase was to collect feedback and data to enable the final phase PH3.7. SIMAVI implemented the second evaluation with the same approach of the first evaluation phase, with a more detailed and tailored approach during the second one, due to prior experience and also increased availability of the tools.

In **PH3.7** outcome from previous phases with educators' feedback and students' feedback was discussed, analysed, and compiled into this report. This **last phase of WP5** analysed and summarised the **piloting outcome**. At the end of the pilot activities. T5.5 applied an impact assessment survey amongst the users (students and educators) of the system. This report provides insights to technical aspects, pedagogical impact, satisfaction, perceived usefulness, usability, and social impact for the HECOF approach of a novel AI driven adaptive and immersive learning environment. **By this report WP5 is finalized and milestone MS7 "End of deployment and evaluation of pilots" is obtained.**

5.2 Combined Events for Deployment and User Training

The events for phases PH3.1 and PH3.2 had been organized as combined events to have synergy effects and reduce travelling. The **HECOF Training Course** was designed to introduce both students and teachers at pilot partner sites NTUA and POLIMI to the HECOF system, which integrates AI-adaptive learning, virtual reality (VR) exercises, and smart performance measurement and analytics. The training provided students with hands-on experience while helping teachers understand how to configure AI-driven learning loops, create VR content, and use analytics to enhance their teaching strategies.

For students, the training was structured into four modules. The first module introduced the HECOF system and AI-enhanced learning, explaining how the Adaptemy AI Engine personalised learning and how VR enhances engagement. The second module offered an interactive demo, allowing students to navigate the platform, experience adaptive learning loops, experience a VR exercise, and explore GenAI-powered learning activities like Think-Pair-Share. The third module focused on smart learning analytics, demonstrating how HECOF tracks performance, provides immediate feedback, and helps students identify learning gaps. The final module was a Q&A and feedback session, where students asked questions and shared their experiences using the system.

For teachers, the training also has four modules emphasizing the configuration of AI tools, VR content creation, and data-driven teaching strategies. The first module provided an overview of HECOF's pedagogical foundations, explaining how the Adaptemy AI Engine adapts learning paths and learning experiences through learning loops and how teachers can use VR for customized educational experiences. The second module focused on configuring the AI engine to align with learning goals and provided a walkthrough of the NURO XR Editor for creating VR-based exercises. The third module covered smart learning analytics, showing teachers how to interpret student performance data, adjust their instruction based on real-time insights, and ensure ethical data handling. The final module was a Q&A and feedback session, allowing teachers to discuss HECOF's applications in the classroom and to provide feedback on its implementation.

Overall, the HECOF Training Course ensured that students gain an understanding of the engaging **adaptive and VR learning experience**, while teachers learn to **personalize education** through AI and learning loops and VR tools. The structured training sessions helped both groups understand HECOF's capabilities, experience interactive demonstrations, and provide feedback, making the system more effective for modern education.

5.3 Integration Events for Adaptive AI and VR Lab

In parallel to the ongoing co-development, preparation, and training events, Adaptemy and NURO implemented technical **integration** meetings for setting up communication between NURO's VR Lab and Adaptemy's Backend (12.11.2024, 15.11.2024, 22.11.2024, 09.12.2024).

Topics:

- Establishing transmission of **user telemetry data** (left & right-hand position, orientation and point direction, head position, orientation and look direction).
- Establishing transmission of **step completion** data (lab exercises are divided in different steps, after each step a unique id is sent to the backend).
- Passing parameters to with the HOPPER link that is used in the Adaptemy platform to invoice the VR Lab. Information about **level** 1, 2 or 3 of the lab exercises is passed to Portal Hopper (level 1: introduction to the apparatus, level 2: guided experiment, level 3: challenge experiment - not implemented in evaluation 1 yet)

5.4 Pilot Evaluation Process and Implementation

Following the user training workshops, **students participating** in HECOF project were provided with credentials to access the system. This ensured that they had the necessary authentication to engage with the platform and its various learning experiences. Upon their initial login, students were redirected to a **pre-survey** designed to assess their perceptions and **expectations** regarding the system.

The pre-pilot survey **gathered comprehensive baseline information** about students' **demographics**, prior **experience** with technology, and their initial perceptions of AI-driven and VR-enhanced learning. It collected data on age, gender, education level, and field of study, providing insights into the diversity of the student group. Additionally, it assessed students' familiarity with virtual reality, adaptive learning, and AI-powered educational tools, using a scale to gauge their prior exposure and comfort levels. Another key aspect of the survey focused on students' current technology use for learning, including their primary **device preference** (desktop, laptop, tablet, smartphone, or VR headset). The survey also aimed to measure perceived usefulness of VR and AI-driven feedback, asking students how much they believed these tools would enhance their understanding of complex concepts and improve their learning experience. Furthermore, it explored **social presence** and interaction expectations, determining whether students anticipated meaningful engagement with teachers and peers after using the system. Lastly, the survey examined self-efficacy and engagement, evaluating students' confidence in mastering the subject, their engagement with traditional learning methods, and their biggest learning challenges. This data provided a foundational understanding of students' expectations and readiness for adaptive AI and VR-integrated learning, setting the stage for comparative analysis in the post-pilot phase.

The next phase involved **adaptive testing**, conducted based on insights from the pre-pilot study. This assessment aimed to tailor the learning experience by identifying each student's initial proficiency level and areas requiring further development. Once the adaptive testing was completed, students engaged with a range of interactive learning experiences within the system. These experiences included guided mastery, where they followed structured learning pathways, revision and reinforcement learning, where students revised previous learned concepts, and think-pair-share activities, facilitated by an AI agent to promote collaborative problem-solving. Additionally, a dedicated session was conducted for interacting and evaluating the Adaptive VR experience, enabling them to immerse themselves in an interactive, responsive learning environment tailored to their individual needs.

To conclude the pilot evaluation, students were directed to a **post-survey** link. The post-pilot survey assessed the impact of HECOF by evaluating students' perceived learning **gains**, engagement and **self-efficacy**, usability experiences, and **overall satisfaction** with the system. One of the primary areas of focus was **perceived learning gain**, where students rated how much their understanding of the subject had improved and how well the adaptive learning features helped them achieve their **educational goals**. They also rated the contribution of different learning experiences, including guided learning, reinforcement activities, think-pair-share interactions, and the VR learning loop, identifying **which components were most beneficial**. Another key component of the survey was **self-efficacy** and engagement, where students reflected on how their confidence in learning had changed and how **engaging** they found AI-driven feedback and VR simulations compared to traditional methods. The survey also captured insights on the AI's effectiveness in identifying positive aspects and challenges, **perceived usefulness**. In terms of usability, students provided feedback on the ease of navigating the system, the intuitiveness of the AI Virtual Tutor, and their comfort using VR tools, including any occurrences of VR sickness. Additionally, the **post-survey assessed social presence and interaction**, asking whether the system helped them feel connected to their instructors and peers. Finally, students shared their overall satisfaction, likelihood of recommending the system, and **suggestions for improvement**. Furthermore, a post-diagnostic assessment was conducted within the system to measure the learning progress and **compare** it against the initial adaptive testing results. For POLIMI pilot evaluation 1, challenges arose in obtaining sufficient responses to the post-survey, leading to an alternative qualitative approach that relied on interviews to gather student feedback as well as an additional survey for the VR experience. For NTUA pilot evaluation 1, the post-survey was complemented by short interviews with students regarding their perceived experience.

5.5 Monitoring

Throughout the pilot, response rates for both the **pre-survey and post-survey** were closely monitored, and reports on participation numbers were provided to the pilot implementation teams at POLIMI and NTUA. This ensured that **engagement levels and data collection were tracked effectively**. Additionally, initial learning analytics offered insights into user activity. For the main VR learning session, the implementation team was physically present on-site, ensuring smooth execution and immediate **support** for students. Simultaneously, teams from the implementation partners were available online, providing technical assistance and real-time troubleshooting to optimize the learning experience if needed. This coordinated approach allowed for **proactive monitoring**, technical support, and seamless adaptation to any challenges encountered during the pilot.

5.6 Evaluation 1

The objective of Evaluation 1 was to gather user **feedback for the agile development** to support the co-development of HECOF System version 2 (D4.2) that will be tested in evaluation 2, and collect performance data from the HECOF system. Evaluation 1 was based on D4.1 "HECOF first Minimum Viable Product (MVP)", released in M22 with customizations performed in the preparation and training phase. The detailed planning for evaluation 1 was elaborated in T5.2 preparation of pilot activities.

Evaluation 1 was **conducted at both pilot sites** with a focus on the usage of the HECOF system in the teaching activities by students and teachers.

At pilot 1, **NTUA** the evaluation was held in **December (17, and 19) of 2024** with a group of **17 students** participating. At pilot 2, **Polimi** the evaluation was held on **December 10, 2024** with a group of **14 students**.

Figure 1 Students performing exercises in the HECOF VR Laboratory

5.6.1 Pilot 1 NTUA

The **NTUA** use case is about the extraction of bioactive materials from olive leaves. In December (17, and 19) of 2024 a group of NTUA 17 students participated at the 1st evaluation of the HECOF system. The evaluation runtime was about 10 hrs in total. The students participated with enthusiasm in the whole process.

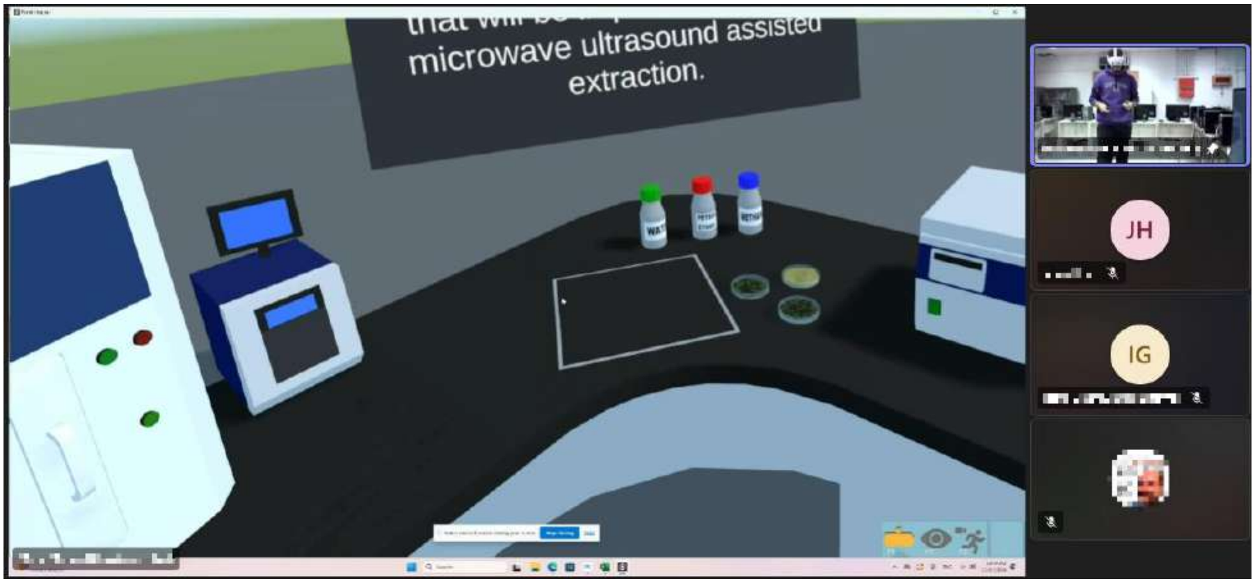


Figure 2 Evaluation 1 - XR Lab Testing by Students at Pilot 1 NTUA

Pilot 1 Events

- 5 Meetings: Co-Development / Preparation of Evaluation (25.10.2024, 01.11.2024, 08.11.2024, 12.11.2024, 19.11.2024)
    - Introduction to World Builder software
    - sharing of Lab Exercise World Builder project with teachers
    - refinement & co-development of the XR Lab Exercise
    - testing the Lab Exercise in VR and non-VR with the equipment at NTUA
- E5.1 + E5.3 Combined preparation and training event for Pilot 1 (30th Oct 2024)
- Test Runs for Evaluation 1 (05.12.2024 & 12.12.2024)
- Evaluation 1 (17.12.2024 & 19.12.2024)
    - students doing VR experience one by one with one headset (meta quest 3 ??)
    - runtime: about 2 hours & 2 hours

Here are some comments from them: "I really enjoyed the whole process; this is how future education should be! Or "It was a great experience, easy to use!", or "I enjoyed every moment and I've learned a lot about the exercise, before going to the laboratory"**.** Only one student has performed the real extraction experiment before entering the VR environment. Furthermore, few of them had previous experience in a VR environment. All students were easily and successfully navigated into the VR environment, followed the instructions and completed the test with success. The ones that were more familiar with such an environment pushed the system at its limits. Everyone expressed the interest to participate at the next stage of the evaluation and were very enthusiastic of how this AI-VR learning approach will change in the 2nd evaluation.

5.6.2 Pilot 2 POLIMI

The POLIMI use case is about bioreactor assembly and usage. On **December 10, 2024** a group of **14 students**. participated at the 1st evaluation of the HECOF system. The evaluation runtime was about 10 hrs in total.

E5.2 + E5.4 Combined preparation and training event for Pilot 2 (31st OCT 2024)

The event was implemented onsite at POLIMI and led by ADAPTEMY.

Co-development sessions POLIMI

2 Co-Development Sessions (13.11.2024, 14.11.2024) and a Test Run (06.12.2024) were held online.

Participants: reference teacher (instructor of the Biotechnology and Clinical Manufacturing course); instructor previously involved in the HECOF focus group (November 2023); 2 instructional designers from METID; 1 person from the technical support staff; Nuro (participating remotely)

Topics addressed:

- Nuro presented the World Builder software and the Lab Exercise World Builder to the instructor of the Biotechnology and Clinical Manufacturing course
- Collecting the instructor's remarks with respect to the state of progress of the implementation of the VR features agreed in November 2023 - remarks were collected here Remarks_November14th.docx

Outcomes:

Polimi team wrote to Nuro that, in terms of priorities, to perform evaluation 1 it is essential for the reference teacher to have in the VR:

- the assembly of the bioreactor divided into the 3 configurations (batch, fed-batch e perfusion, as agreed in November 2023)
- the locker rooms.

Pilot 2 evaluation was held in a VR facility called virtual lab, which is a classroom equipped with 15 desktop computers (Windows 10) equipped with Meta Quest 2 headsets and marked boundary areas. A test run was held in the same classroom on December 9 involving the instructor, METID, technical support staff and Nuro participating remotely.

People involved

- The pilot involved 14 students from the Biotechnology and Clinical Manufacturing course, both females and males.
- The course instructor took part in the pilot and actively led the session
- 2 instructional designers from METID participated to document the session along with students' remarks
- 1 person from the technical support staff was there to support users

Duration

1.5 hour

Tasks

Students were asked to operate simultaneously and individually:

- enter the Adaptemy platform
- wear the headset
- access the VR, enter the locker room and use the bioreactor with the hand grips
- fill in a questionnaire (before the post-survey questionnaire)

Remarks

Establishing a state-of-the-art, human-centric co-development approach based on LEAN UX and aligning roles according to agile principles for pilot 2 required significant effort and was time consuming. While differences in perspectives remained, a functional collaboration was ultimately achieved.

The remarks below were shared with Nuro by email.

- Due to the belated delivery of the prototype, it was not possible to identify possible issues related to the use scenarios of the VR: the differences among the configurations of the bioreactor were not clear as it was not possible to simulate variations of volume and growth of bacteria while starting the process
- Start button: how does it work depending on the bioreactor configuration? It should be clear to the user which parameters (volume variation, bacteria growth) he/she can verify and how they impact on the bioreactor – in other terms, the user should be able to experience in a realistic way that the system responds differently under different operational conditions, with targeted feedback depending on the error
- Improving the connection between the parts of the bioreactor that the student sees on the bench and content on the PC screen on the right
- Suggestions highlighted in orange to guide the assembling of the bioreactor should be configurable, so that they don't show/can be deactivated to nudge the user can retrieve content from memory, especially in case the student uses the VR application more than once
- Many users during the VR session found themselves too far down from VR application elements (e.g., too low to push the button to open the door) or "out of the scene", without the possibility to reach the proper height – please bear in mind that, following many tries, it does not seem to depend on the setting of the equipment

In addition to that, we observed that during the VR session some students had to move back and forth from the bench because otherwise they couldn't manage to reach the objects that in the real world might be within their reach on the bench.

Reference documents

- questionnaire https://forms.office.com/Pages/DesignPageV2.aspx?subpage=design&FormId=K3EXCvNtXUKAjjCd8ope6_e9-9cnsqRAh54OdehtK69UQVBXV0g1U1JUWTY2N1AwWVRaREMwQlZWVC4u&Token=a2f09d7736f04afcbabb7f9dbf9acae5
- Remarks we collected during the co-development session Remarks_November14th.docx

5.7 Evaluation 2

The objective of evaluation 2 was to assess the outcome of HECOF and collect performance data from the HECOF system. Evaluation 2 was based on D4.2 "HECOF final Minimum Viable Product (MVP)", released in M26.

Evaluation 2 - POLIMI

The 2nd Polimi pilot explored how adaptive learning and VR can enhance understanding and engagement in complex scientific topics. Users were asked to perform a series of tasks basically by:

- answering questions to identify and reinforce weak areas and refine understanding through AI
- assembling the bioreactor, changing the parameters and seeing the different results

Evaluation 2 - NTUA

At pilot 1, **NTUA** the evaluation was held between **12-20 June 2025** with a group of **17 in total** 7 female, 10 male. 8 were in the age group 18-24, 4 were in the age group 25-34, 4 were in the age group 45-54, 1 was 55+

The students were mainly undergraduate students belonging to the semester in which the selected process (extraction) is taught. Three PhD candidates also tested the system, which had already tested the real experiment, so they could make a comparison between the actual experiment and the virtual one. Additionally, professors and laboratory teachers tested the system.

Evaluation 2 of the HECOF system was carried out using the final MVP (D4.2) between May and June 2025 at the two pilot universities, NTUA and POLIMI. The process followed the same structured methodology as in Evaluation 1, but benefitted from a more tailored approach thanks to lessons learned in the first phase and the full integration of the final technical components. At both sites, students first completed the pre-survey and adaptive testing to establish baseline skills and configure personalised learning paths. They then engaged in AI-driven guided mastery, reinforcement activities, and think-pair-share exercises, followed by immersive VR laboratory sessions. These VR tasks were directly linked to the pilot use cases: bioreactor assembly and operation at POLIMI, and chemical extraction from olive leaves at NTUA. The VR activities were designed to respond dynamically to user actions, allowing learners to manipulate parameters, observe process changes, and receive AI-driven feedback on their performance.

The evaluation combined quantitative data collection (system logs, performance analytics, survey responses) with qualitative observations from instructors and implementation staff. SIMAVI coordinated the implementation, ensuring smooth technical operation and supporting on-site facilitation. At NTUA, participation included both undergraduate students and a small number of PhD candidates and faculty members, enabling comparative feedback between users with and without prior real-lab experience. At POLIMI, the VR sessions took place in a dedicated virtual lab classroom, enabling simultaneous individual participation. Across both pilots, monitoring teams provided immediate technical assistance, ensuring continuous engagement and accurate data capture. The post-survey measured perceived learning gains, usability, satisfaction, and social presence, while system analytics assessed task completion rates, AI accuracy, and VR interaction quality, thus fulfilling the milestone MS7 and completing WP5's evaluation cycle.

6 Results and Impact Assessment

6.1 Pre-Survey

The pre-survey for Evaluation 2 was designed to capture baseline information on participants' backgrounds, prior exposure to AI-driven and VR-based learning, and their expectations for using the HECOF system. It included questions on demographics, education level, and field of study, as well as familiarity with virtual reality tools and adaptive learning technologies. Students were also asked to assess their current learning methods, device preferences, and perceived challenges in mastering complex topics. In addition, the survey gauged initial attitudes towards the usefulness of VR simulations, AI-generated feedback, and personalised recommendations, along with anticipated levels of engagement and social interaction. This data provided a reference point for comparing changes in perceptions, skills, and confidence after the pilot activities.

6.1.1 Demographics

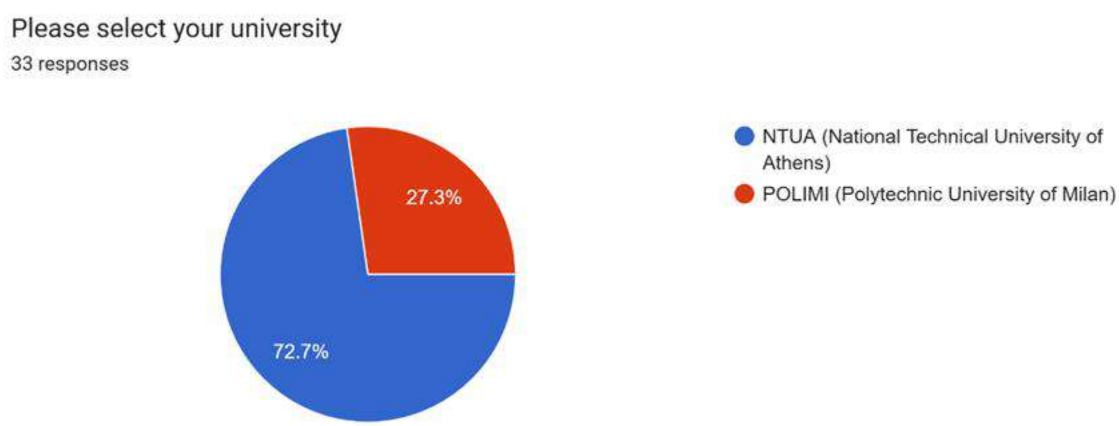


Figure 3 Evaluation 2 - Pre-survey - University Distribution of Participants

In Evaluation 1, student participation was distributed between two universities, with the National Technical University of Athens (NTUA) contributing 72.7% of the responses and the Polytechnic University of Milan (POLIMI) contributing 27.3%. A total of 33 responses were collected, providing a diverse sample for evaluating the pilot's implementation and effectiveness across different academic environments.

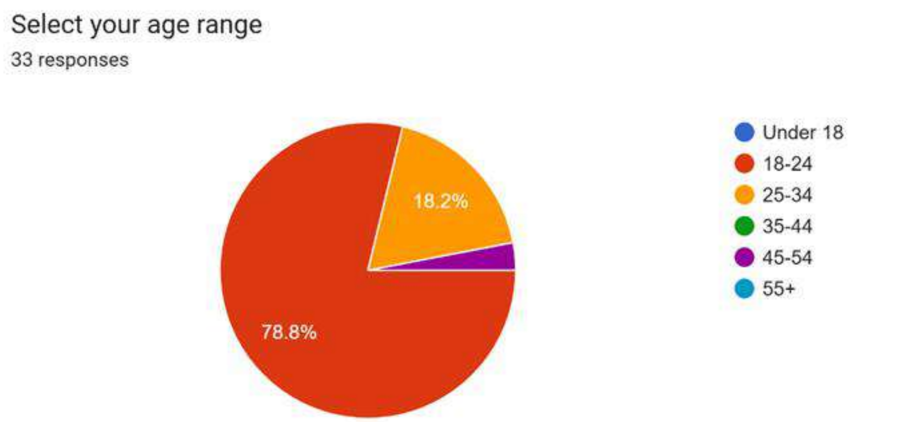


Figure 4 : Evaluation 2 - Pre-survey - Age Range of Participants

Most participants were 18-24 years old (78.8%), followed by 25-34 (18.2%), with minimal representation from older groups. This aligns with the typical university student demographic.

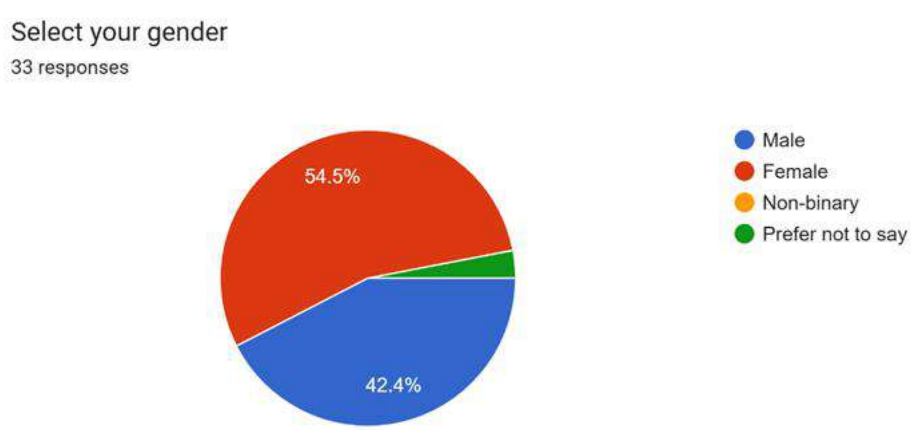


Figure 5 Evaluation 2 - Pre-survey - Gender Distribution of Participants

The gender distribution showed 54.5% female participants, 42.4% male, and a small percentage choosing non-binary or prefer not to say. This indicates a relatively balanced representation with a slight female majority.

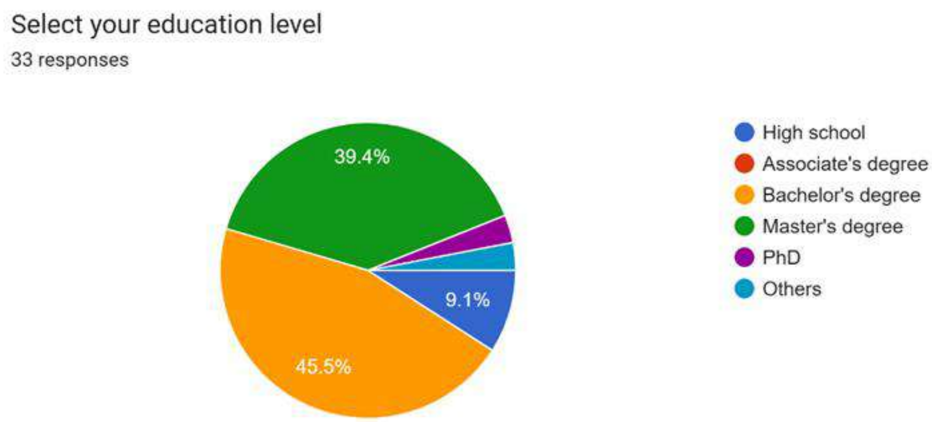


Figure 6 Evaluation 2 - Pre-survey - Education Level of Participants

Most participants were pursuing a Bachelor's degree (45.5%) or a Master's degree (39.4%), with smaller representation from high school, PhD, and other categories. This reflects a primarily higher education student demographic.

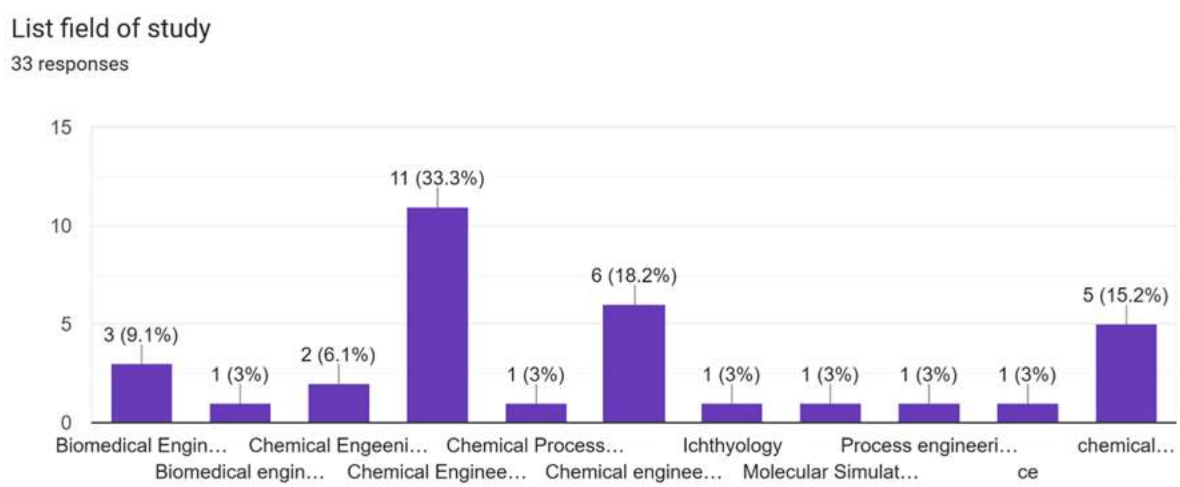


Figure 7 Evaluation 2 - Pre-survey - Field of Study Distribution

The most common field of study among participants was Chemical Engineering (33.3%), followed by Chemical Process Engineering (18.2%) and Chemical Sciences (15.2%). Other represented fields included Biomedical Engineering (9.1%), along with smaller percentages in Ichthyology, Process Engineering, and Molecular Simulation. This distribution indicates a strong alignment between students' profile and profile of the piloted courses.

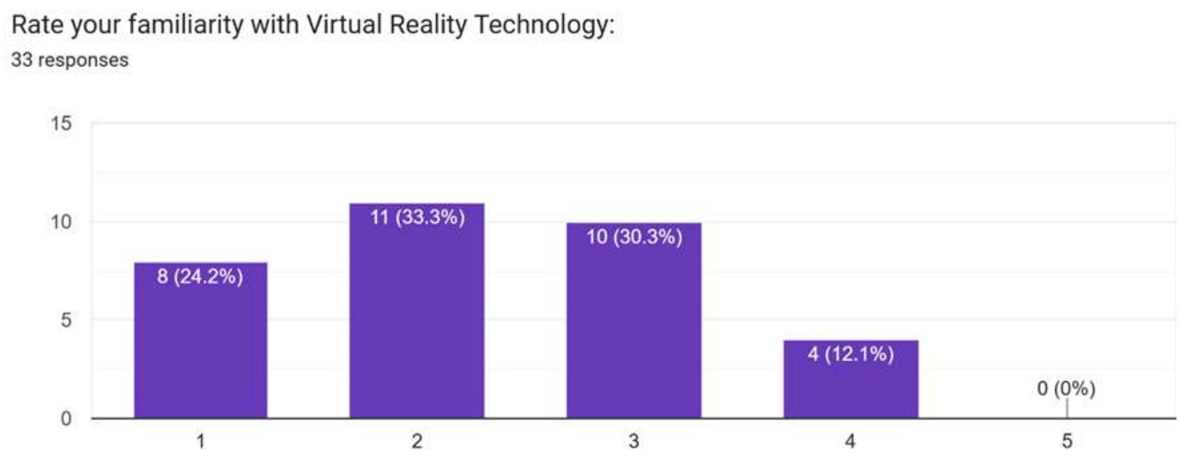


Figure 8 Evaluation 2 - Pre-survey - Familiarity with Virtual Reality Technology

Most participants had limited familiarity with Virtual Reality (VR) technology. The majority rated their familiarity as 2 (slightly familiar, 33.3%) or 3 (somewhat familiar, 30.3%), while 24.2% reported no familiarity (1). Only 12.1% considered themselves very familiar (4), and no participants rated themselves as experts (5). This suggests that most students had minimal prior exposure to VR.

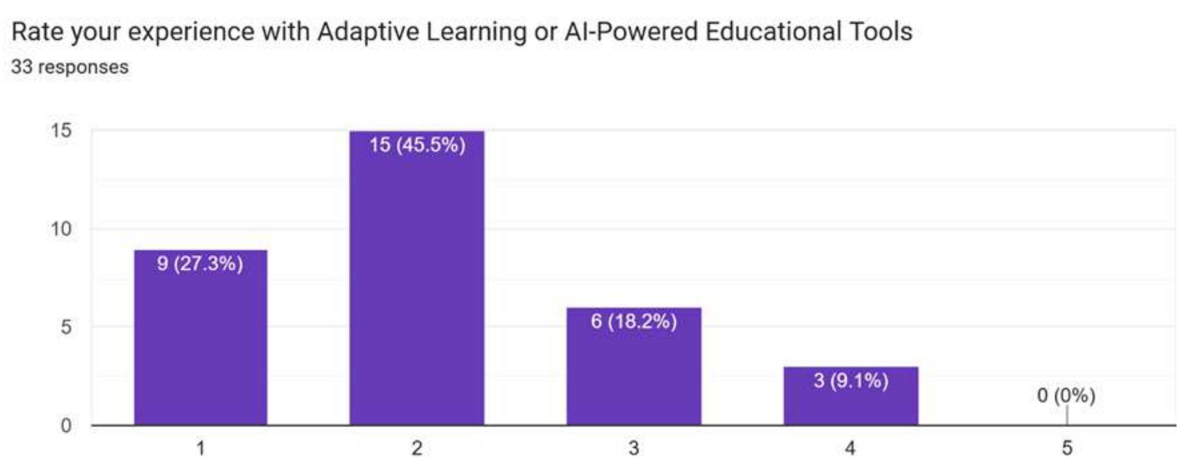


Figure 9 Evaluation 2 - Pre-survey - Experience with Adaptive Learning or AI-Powered Educational Tools

Most participants had limited experience with adaptive learning or AI-powered educational tools. The largest group (45.5%) rated their experience as 2 (limited experience), while 27.3% had no prior experience (1). Only 18.2% had some experience (3), and 9.1% reported extensive experience (4), with no participants identifying as experts (5). These results indicate that many students were relatively new to AI-driven learning environments.

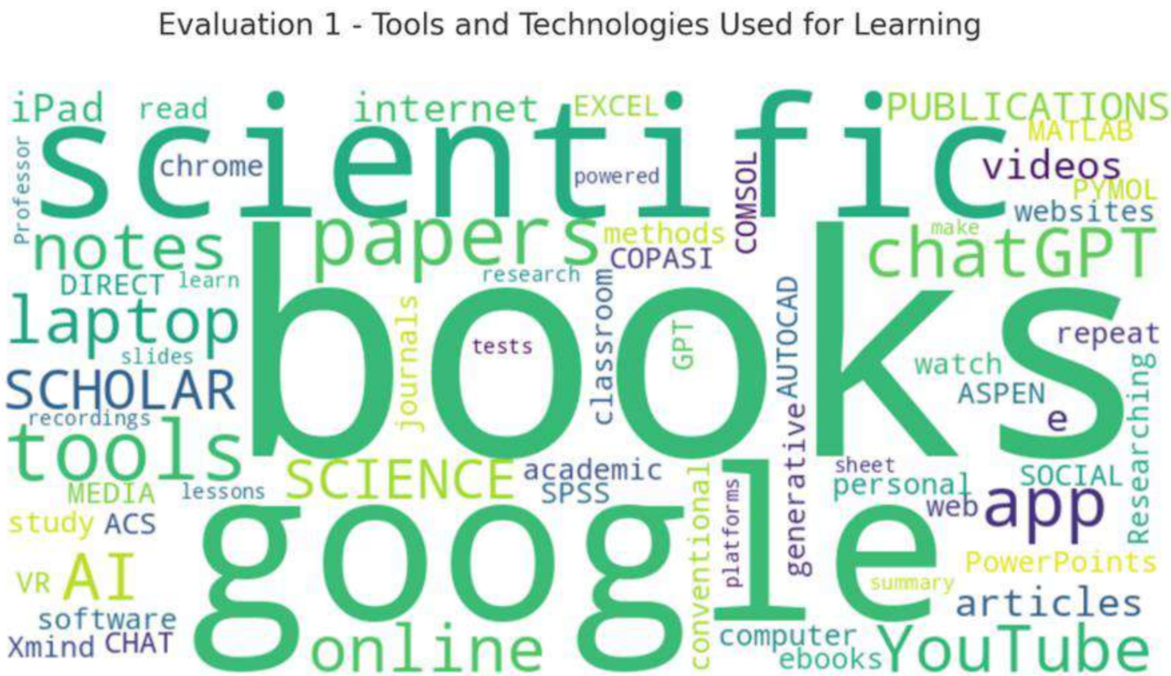


Figure 10: Evaluation 2 - Pre-survey - Word-cloud of Tools and Technologies Used for Learning

Participants reported using a mix of traditional and digital learning tools, including search engines (Google, Google Scholar), AI-powered tools (ChatGPT, Perplexity), and scientific resources (ScienceDirect, ACS Publications). Many relied on books, handwritten notes, YouTube videos, and online platforms for their studies. Additionally, specialized software like MATLAB, COMSOL, AutoCAD, and SPSS was used for problem-solving and research. The responses highlight a blended approach to learning, integrating both interactive digital tools and conventional study methods.

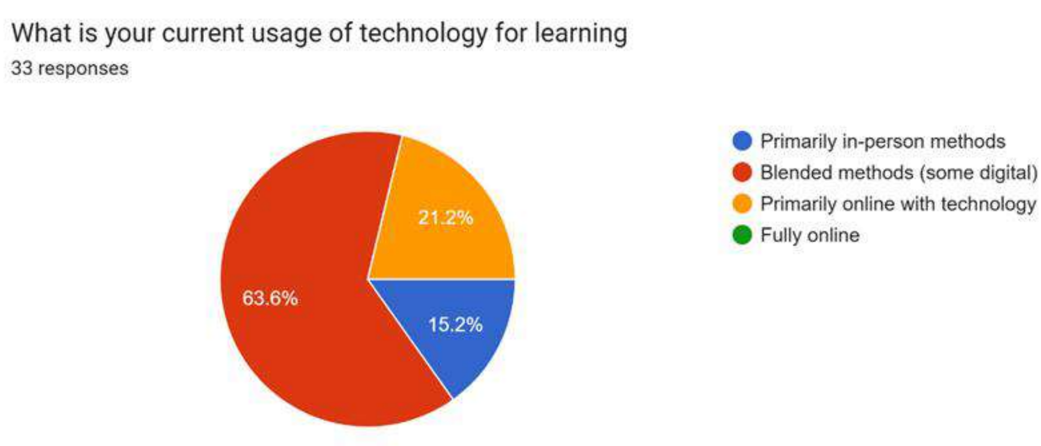


Figure 11 : Evaluation 2 - Pre-survey - Current Usage of Technology for Learning

Most participants (63.6%) reported using a blended learning approach, combining in-person and digital methods. 21.2% relied primarily on online learning with technology, while 15.2% used in-person methods exclusively. No participants reported being fully online, indicating a strong preference for mixed or hybrid learning environments.

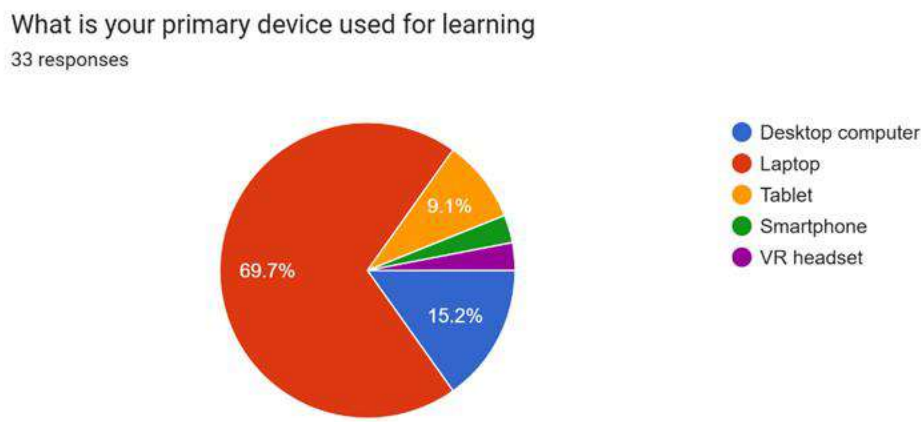


Figure 12: Evaluation 2 - Pre-survey - Primary Device Used for Learning

The majority of participants (69.7%) used a laptop as their primary learning device, followed by desktop computers (15.2%). Tablets (9.1%), smartphones, and VR headsets had minimal representation, indicating a strong usage of traditional computing devices for educational purposes.

6.1.2 Perceived usefulness

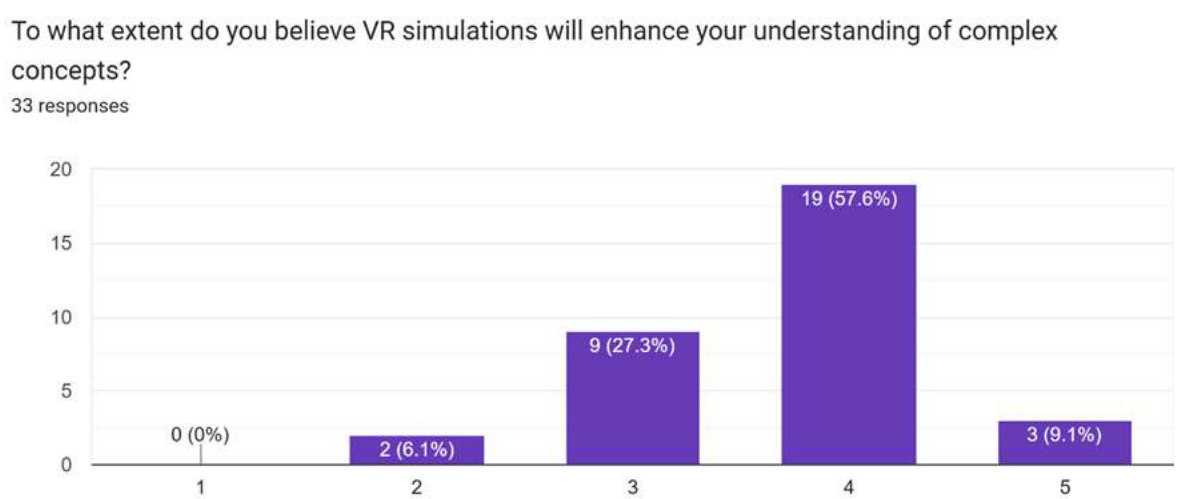


Figure 13: Evaluation 2 - Pre-Survey - Expected Usefulness of VR Simulations for Learning Complex Concepts

Participants shared their initial expectations regarding the usefulness of VR simulations in enhancing their understanding of complex concepts before interacting with the system. A majority (57.6%) anticipated that VR would be very useful (4), while 9.1% expected it to be extremely useful (5). 27.3% were moderately convinced (3) of its benefits, and only 6.1% had slight confidence (2), with no participants believing it would be not useful at all (1). These responses suggest a generally positive expectation of VR as a valuable learning tool, though some participants remained uncertain about its impact before direct experience.

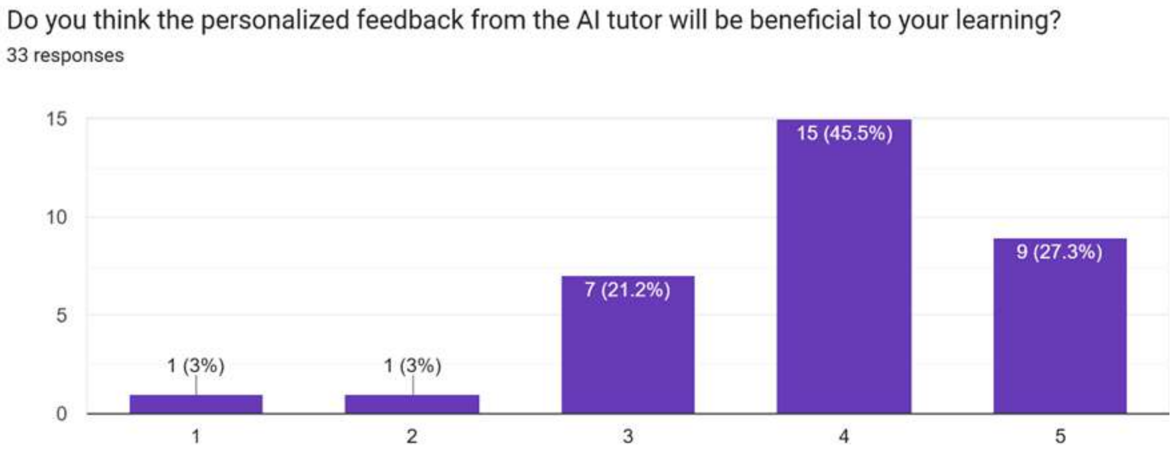


Figure 14 Evaluation 2 - Pre-Survey - Expected Benefit of Personalized Feedback from the AI Tutor

Participants shared their initial expectations regarding the personalized feedback from the AI tutor before interacting with the system. A majority (45.5%) expected the feedback to be very beneficial (4), while 27.3% anticipated it to be extremely beneficial (5). 21.2% were moderately convinced (3) of its usefulness, whereas only a small percentage (3% each) expressed slight confidence (2) or no confidence (1) in its benefits. These results indicate generally positive expectations for AI-driven feedback as a valuable learning support tool, though some students remained uncertain before experiencing it first-hand.

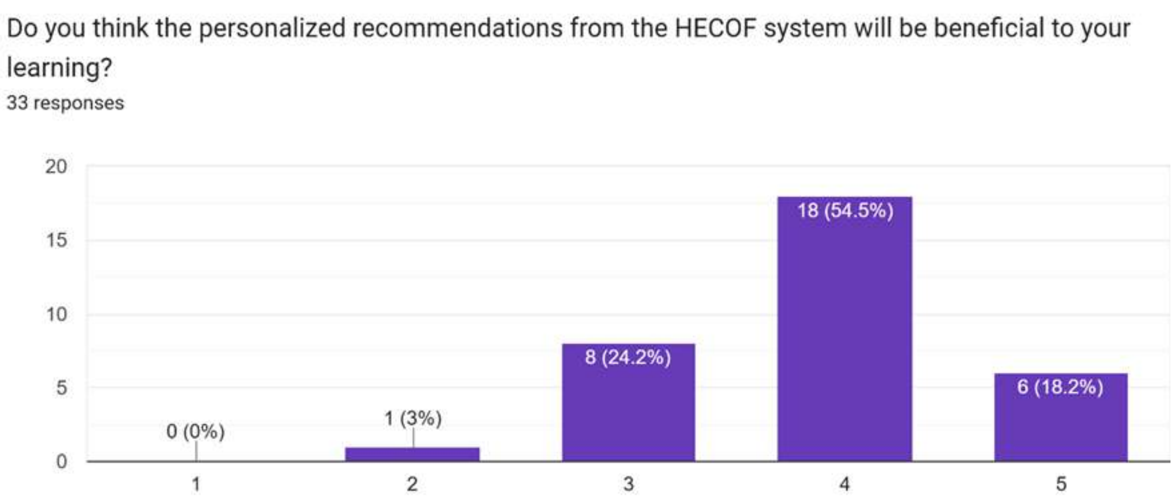


Figure 15: Evaluation 2 - Pre-Survey - Perceived Benefit of Personalized Recommendations from the HECOF System

Participants shared their initial expectations regarding the personalized recommendations from the HECOF system before interacting with it. A majority (54.5%) anticipated that these recommendations would be very beneficial (4), while 18.2% expected them to be extremely beneficial (5). 24.2% were moderately convinced (3) of their usefulness, and only 3% had slight confidence (2), with no participants believing they would not be beneficial at all (1). These responses indicate generally positive expectations toward HECOF's ability to provide meaningful learning support, though some students remained uncertain before experiencing the system first-hand.

6.1.3 Social Presence and Interactions

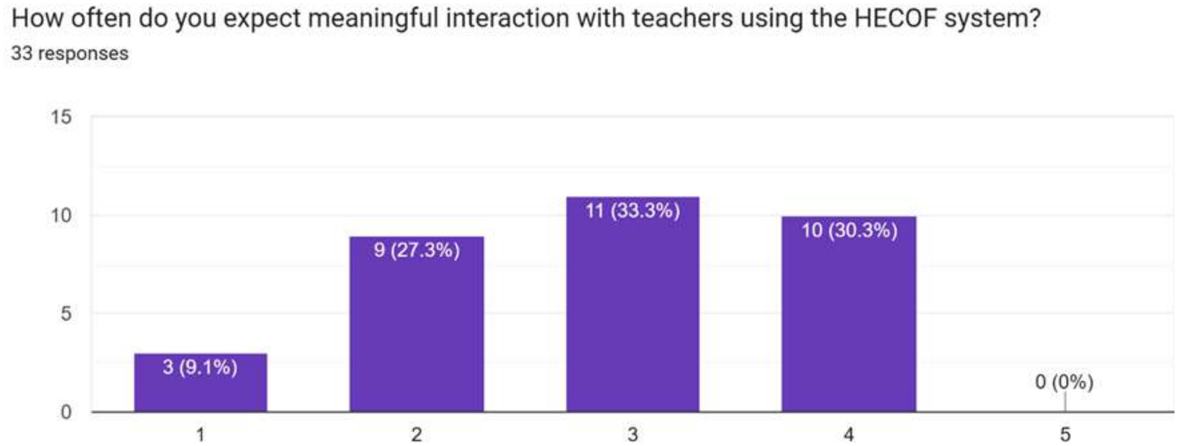


Figure 16: Evaluation 2 - Pre-Survey - Expected Frequency of Meaningful Interaction with Teachers Using the HECOF

Participants shared their expectations regarding meaningful interaction with teachers when using the HECOF system. The majority anticipated moderate to frequent interaction, with 33.3% expecting it sometimes (3) and 30.3% often (4). 27.3% expected rare interaction (2), while a small percentage (9.1%) believed interaction would never occur (1). No participants (0%) expected very frequent interaction (5). These results indicate mixed expectations, with some students anticipating consistent engagement with teachers, while others expected a more self-directed learning experience.

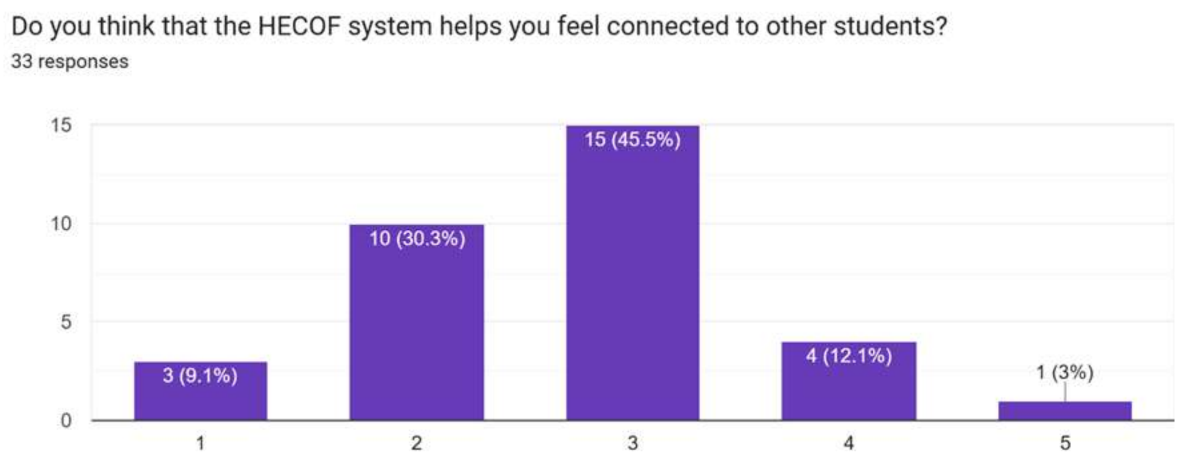


Figure 17: Evaluation 2 - Pre-Survey - Expected Impact of HECOF on Student Connection

Participants shared their expectations about whether the HECOF system would help them feel connected to other students. The majority (45.5%) remained neutral (3), while 30.3% disagreed (2) and 9.1% strongly disagreed (1), indicating that many students were sceptical about the system fostering a sense of connection. A smaller portion of participants (12.1% agreed (4) and 3% strongly agreed (5)), suggesting that only a few students initially expected the system to enhance peer interactions.

6.1.4 Self-Efficacy and Engagement

Figure 18: Evaluation 2 - Pre-Survey – Self-efficacy as initial Confidence in Achieving Mastery

Participants expressed their initial confidence levels regarding their ability to achieve a high level of mastery in the subject by the end of the learning period. The majority (51.5%) felt confident (4) in their ability, while 6.1% were very confident (5). A neutral stance (3) was taken by 33.3%, whereas 9.1% reported slight confidence (2), and no participants indicated a complete lack of confidence (1). These results suggest that most students entered the pilot with a positive or neutral outlook on their ability to succeed, though some remained uncertain about their mastery potential before engaging with the system.

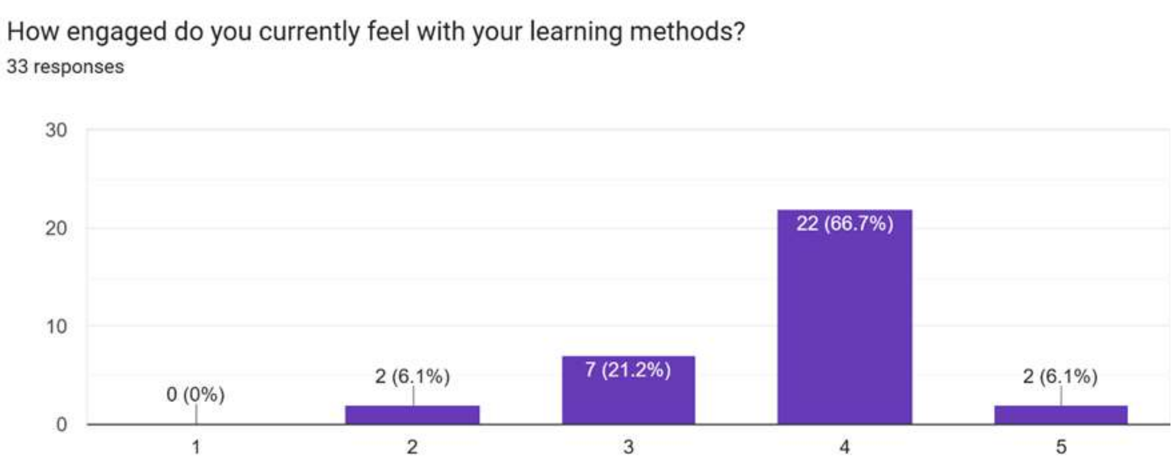


Figure 19 Evaluation 2 - Pre-Survey - Current Engagement with Learning Methods

Participants reflected on their current engagement levels with their learning methods before using the HECOF system. The majority (66.7%) reported feeling engaged (4), while a small percentage (6.1%) described themselves as very engaged (5). 21.2% maintained a neutral stance (3), whereas 6.1% reported slight engagement (2), and no participants (0%) indicated a complete lack of engagement (1). These results suggest that most students felt reasonably engaged with their existing learning methods, though some saw potential for improvement.

Students also described their biggest challenges as an open answer. The responses indicate that students face several key challenges in their learning process.

The most frequently mentioned difficulties include:

- Understanding complex material - many students struggle with comprehending difficult topics, processing large amounts of theoretical knowledge, and applying what they learn effectively.
- Time management & workload - balancing academic workload, assignments, projects, and personal life was a major concern for many students.
- Motivation & engagement - some participants mentioned staying motivated and focused, particularly when faced with difficult coursework or uninspiring teaching methods.
- Lack of practical application- Several students highlighted the lack of hands-on experience, laboratory work, and real-world applications in their studies, suggesting a need for more practical learning opportunities.
- Exams & evaluation - concerns related to oral exams, memorization-heavy assessments, and the pressure of evaluations were also noted.

These findings suggest that students would benefit from more interactive and applied learning methods, improved time management strategies and guidance, and greater support in engaging with challenging material.

6.2 Post-Survey

The post-survey for Evaluation #2 was administered immediately after participants completed their assigned HECOF learning activities, ensuring that impressions and feedback were collected while the experience was fresh in their minds. Students accessed the survey via a secure online link provided through the platform or directly by the implementation teams. The survey aimed to measure changes in perceptions, skills, and confidence compared to the baseline established in the pre-survey, as well as to capture detailed reflections on the system's usability, pedagogical value, and overall learning impact.

The questionnaire included both quantitative and qualitative components. Quantitative items used Likert-scale ratings to assess perceived learning gains, self-efficacy, engagement levels, satisfaction with the system, and ease of use across the AI-driven and VR-based components. Participants evaluated the usefulness of specific HECOF features, such as guided mastery, reinforcement activities, think-pair-share exercises, and the VR laboratory sessions. Qualitative, open-ended questions invited students to elaborate on their favourite aspects, areas for improvement, and suggestions for future system development. Responses were anonymised and aggregated, allowing for a comprehensive analysis of trends and recurring themes. This post-survey process provided essential insights into the educational effectiveness of HECOF, validating its strengths while highlighting actionable areas for refinement in future deployments.

6.2.1 Perceived Learning Gain

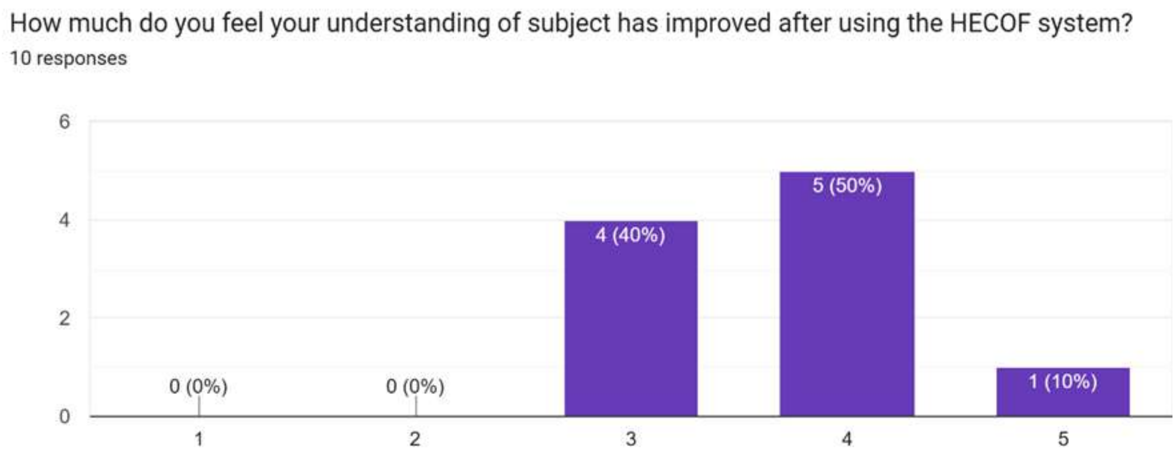


Figure 20: Evaluation 2 - Post-Survey - Perceived Improvement in Subject Understanding After Using HECOF

Participants assessed how much their understanding of the subject improved after using the HECOF system. Half of the respondents (50%) reported a significant improvement (4 - Very much), while 40% indicated a moderate improvement (3 - Moderately). A smaller portion (10%) felt their understanding was extremely improved (5). Notably, no participants rated their improvement as slight (2) or non-existent (1). These findings indicate that the HECOF system contributed positively to students' learning, though the extent of improvement varied among individuals.

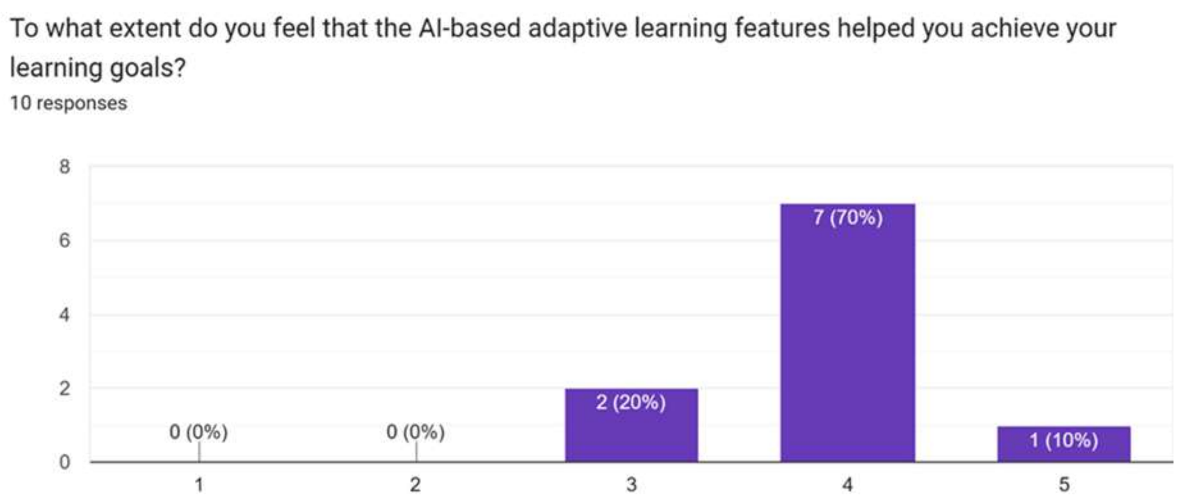


Figure 21: Evaluation 2 - Post-Survey - Effectiveness of AI-Based Adaptive Learning in Achieving Learning Goals

Participants evaluated how well the AI-based adaptive learning features helped them achieve their learning goals. The majority (70%) reported that the features were considerably helpful (4), while 10% found them fully effective (5). A smaller portion (20%) felt they were only somewhat helpful (3), and no participants rated them as slightly helpful (2) or not helpful at all (1). These results indicate that most students found the AI-based adaptivity beneficial for their learning, though only a few considered it completely effective.

6.2.2 Learning Experience Rating

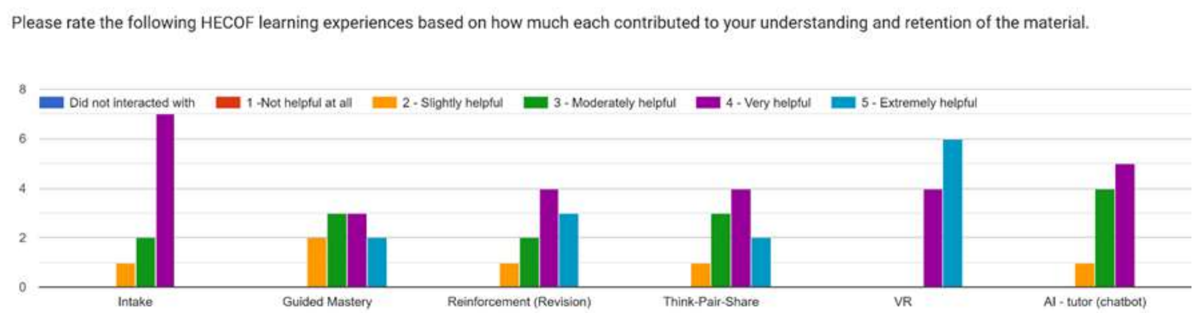


Figure 22: Evaluation 2 - Post-Survey - Perceived Helpfulness of HECOF Learning Experiences

Participants rated how different HECOF learning experiences contributed to their understanding and retention of material. The VR learning experience received the highest ratings, with a majority marking it as extremely helpful (5). The AI tutor (chatbot) was also well-received, with many participants rating it very or extremely helpful. Guided Mastery, Reinforcement (Revision), and Think-Pair-Share activities were generally rated moderately to very helpful, with only a few students finding them slightly helpful. These findings suggest that students found AI-driven Virtual tutor and immersive VR learning experiences the most impactful.

In an open question about which HECOF learning experience (Intake, Guided Learning, Reinforcement, Think-Pair-Share, VR Learning Loop) students believe most helped you to achieve your learning goals, participants identified the VR Learning Loop as the most preferred, indicating that they found it immersive, and hands-on simulations being highly effective. Some participants emphasized that VR helped them visualize complex processes and engage actively with the material.

Other learning experiences, such as Think-Pair-Share and Reinforcement (Revision), were also valued. Some students preferred collaborative learning with the AI (Think-Pair-Share), while others found repetition and revision beneficial for reinforcing concepts. Intake was mentioned once, but Guided Learning was not explicitly selected, suggesting that students leaned towards more interactive and practical learning methods.

These findings indicate that students responded best to immersive and interactive learning, with VR proving to be the most impactful tool in the HECOF system, followed by the AI-based interactivity in learning experience.

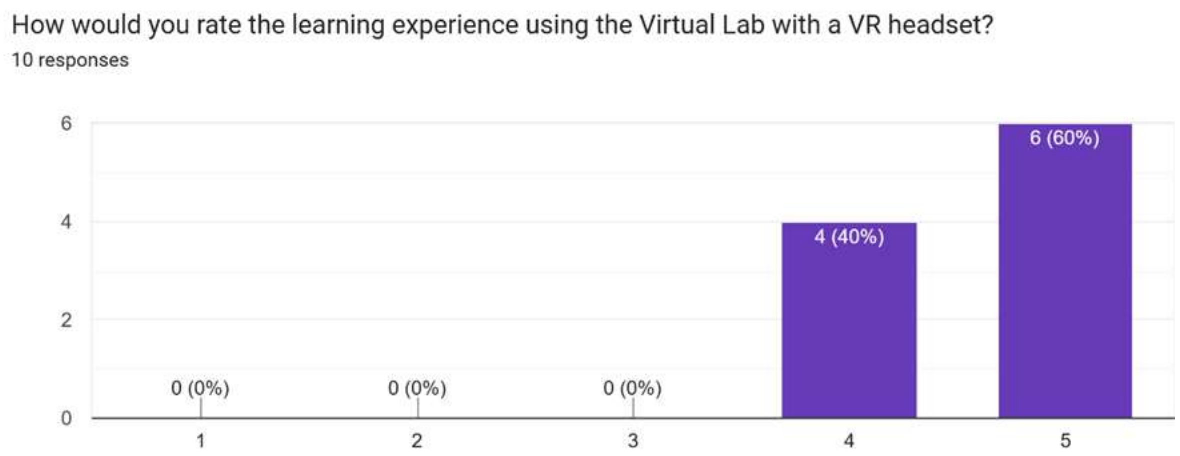


Figure 23: Evaluation 2 - Post-Survey - Learning Experience Using the Virtual Lab with a VR Headset

Participants rated their learning experience using the Virtual Lab with a VR headset. The majority (60%) found it extremely helpful (5), while 40% rated it as very helpful (4). Notably, no participants rated the experience as moderately helpful (3), slightly helpful (2), or not helpful at all (1). These results indicate a highly positive reception of the VR-based learning experience, suggesting that students found the immersive environment effective for understanding and engaging with the material.

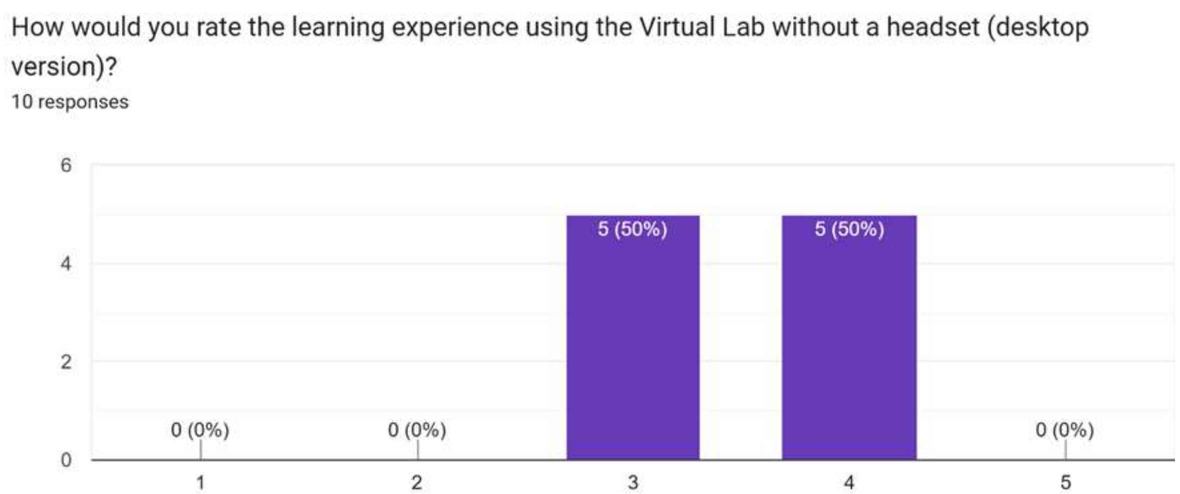


Figure 24: Evaluation 2 - Post-Survey - Learning Experience Using the Virtual Lab Without a Headset (Desktop Version)

Participants rated their learning experience using the Virtual Lab without a VR headset (desktop version). The responses were evenly split, with 50% rating it as moderately helpful (3) and 50% as very helpful (4). No participants rated the experience as extremely helpful (5), slightly helpful (2), or not helpful at all (1). These results suggest that while the desktop version was considered useful, it was perceived as less impactful than the fully immersive VR headset experience.

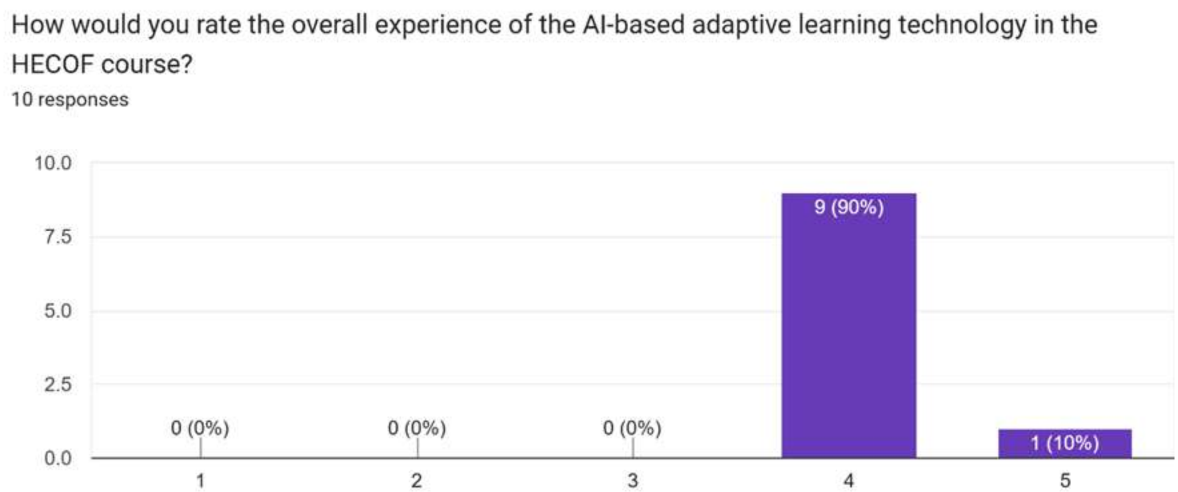


Figure 25: Evaluation 2 - Post-Survey - Overall Experience with AI-Based Adaptive Learning Technology

Participants rated their overall experience with the AI-based adaptive learning technology in the HECOF course. The majority (90%) rated their experience as good (4), while 10% found it excellent (5). Notably, no participants rated the experience as fair (3), poor (2), or very poor (1). These results suggest that students had a generally positive experience with the AI-driven adaptive learning technology.

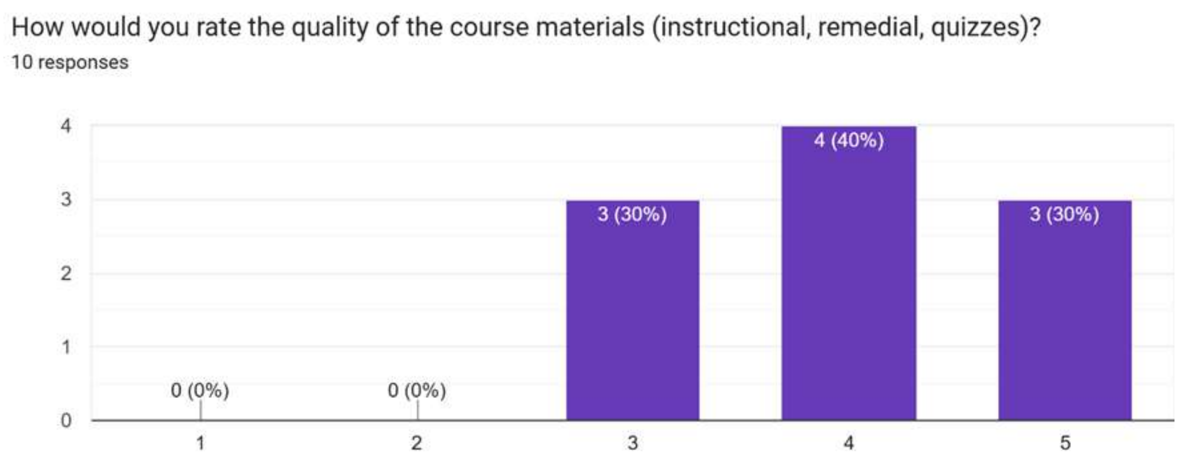


Figure 26: Evaluation 2 - Post-Survey - Quality of Course Materials

Participants rated the quality of the course materials, including instructional content, remedial resources, and quizzes. The majority of students provided positive feedback, with 40% rating the materials as good (4) and 30% considering them excellent (5). Another 30% rated the quality as fair (3), while no participants rated it as poor (2) or very poor (1). These results indicate that while the course materials were generally well-received, a few of the students found them only moderately effective, suggesting room for improvement in content creation.

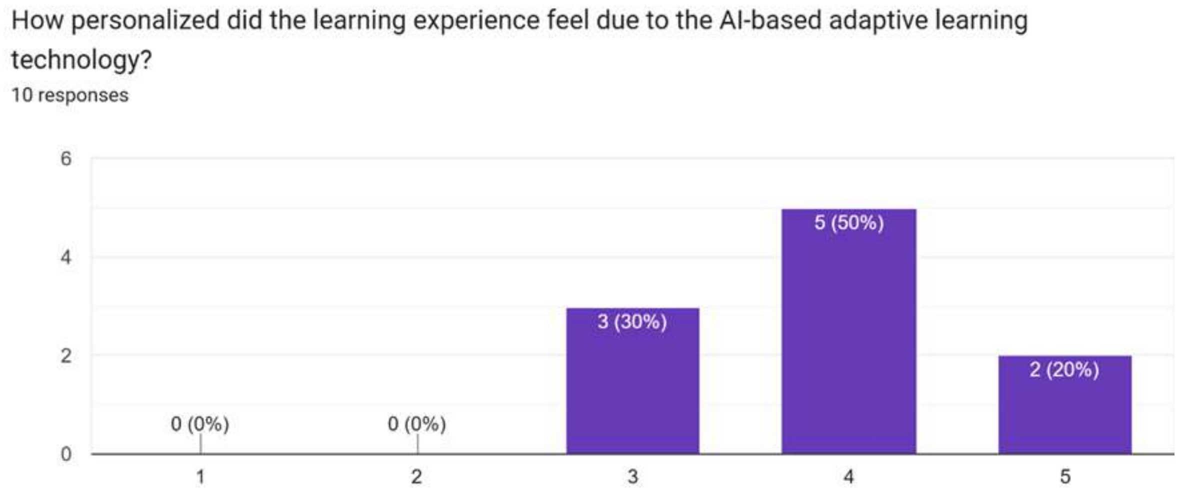


Figure 27: Evaluation 2 - Post-Survey - Perceived Personalization of Learning Experience Due to AI

Participants rated how personalized the learning experience felt due to the AI-based adaptive learning technology. The majority (50%) felt that the experience was moderately personalized (4), while 20% rated it as highly personalized (5). Another 30% found it somewhat personalized (3), with no participants rating it as slightly personalized (2) or not personalized at all (1). These results suggest that most students recognized a good degree of personalization in their learning experience.

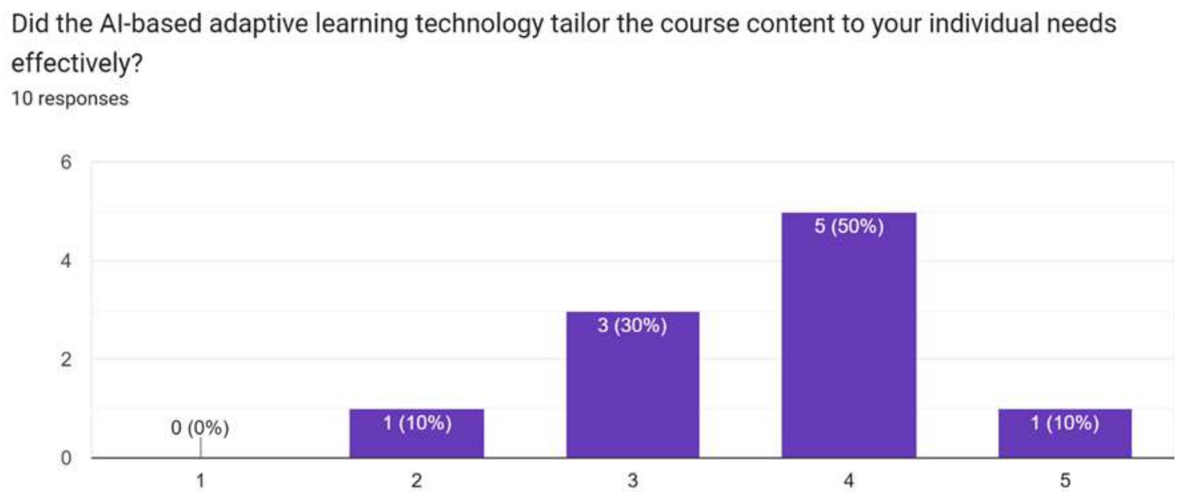


Figure 28: Evaluation 2 - Post-Survey - Effectiveness of AI-Based Adaptation of Course Content

Participants evaluated whether the AI-based adaptive learning technology effectively tailored the course content to their individual needs. The majority (50%) agreed (4) that the AI adapted the content well, while 10% strongly agreed (5). However, 30% remained neutral (3), and 10% disagreed (2), indicating some uncertainty or dissatisfaction with the level of personalization. No participants strongly disagreed (1). These results suggest that while most students found the AI adaptation beneficial, there is room for improvement.

In an open question about suggested improvements, participants suggested improvements for the AI-based adaptive learning technology. The most common recommendation was the improvement of quiz design and structure, including better-formulated questions and more diverse formats.

Other suggestions included:

- More insightful AI feedback - participants felt the AI should provide deeper explanations on questions.
- More diverse question formats - a broader range of question types beyond multiple choice was requested.
- Chatbot enhancements for follow-up questions - some students wanted the ability to ask for more information after answering incorrectly.
- Better accessibility to learning materials - some students found it difficult to locate relevant course materials and requested easier access.

These responses indicate that while students found the AI useful, they desired more depth, variety, and adaptability in assessments and feedback.

Participants shared additional feedback about their experience with the course. The most frequent theme was positive feedback on engagement and learning, with students appreciating the interactive and engaging nature of the course.

Other feedback includes:

- Technical issues and course progression concerns - participant noted that they were forced into a revision cycle without being able to progress.
- Need for better question clarity and diversity - some students found repetitive questions and issues with ambiguous or unclear answer choices.
- Gratitude for participation - participant expressed appreciation for being part of the evaluation and contributing to improving learning methods.
- VR experience praised – participant specifically highlighted that the VR experience was exciting.

These insights suggest that while most students had a positive experience, improving question quality and course flexibility could further enhance the learning experience.

6.2.3 Self-Efficacy and Engagement

6.2.3.1 Perceived Improvement in Self-Efficacy

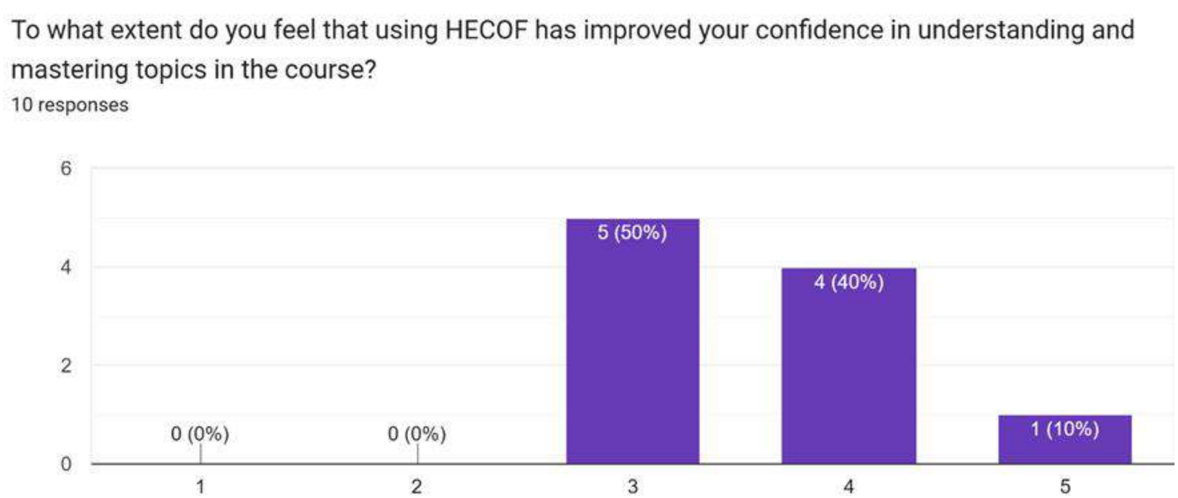


Figure 29: Evaluation 2 - Post-Survey - Improvement in Confidence in Understanding and Mastering Topics

Participants reflected on how using HECOF improved their confidence in understanding and mastering course topics. The majority (50%) rated their confidence improvement as moderate (3), while 40% found it significant (4). A smaller portion (10%) reported an extreme confidence boost (5), and no participants rated their improvement as slight (2) or non-existent (1). These results suggest that HECOF contributed positively to students' confidence levels, though for most, the improvement was moderate rather than transformative.

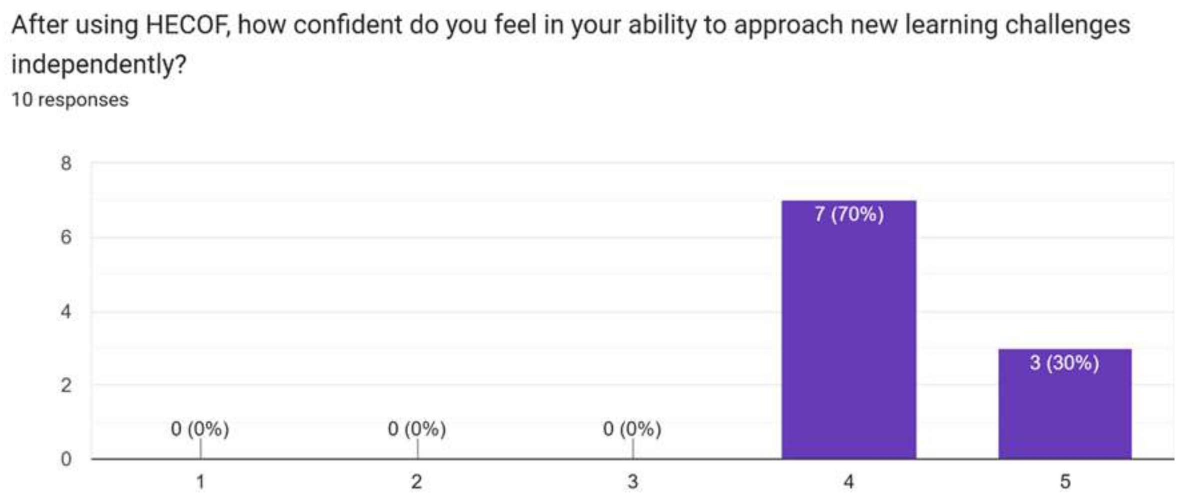


Figure 30: Evaluation 2 - Post-Survey - Confidence in Approaching New Learning Challenges Independently

Participants rated their confidence in approaching new learning challenges independently after using HECOF. The majority (70%) felt confident (4) in their ability to tackle new challenges, while 30% reported feeling very confident (5). Notably, no participants rated their confidence as neutral (3), somewhat confident (2), or not confident at all (1). These results suggest that HECOF had a strong positive impact on students' self-reliance in learning, equipping them with the skills and confidence to navigate new academic challenges independently.

6.2.3.2 Perceived Engagement

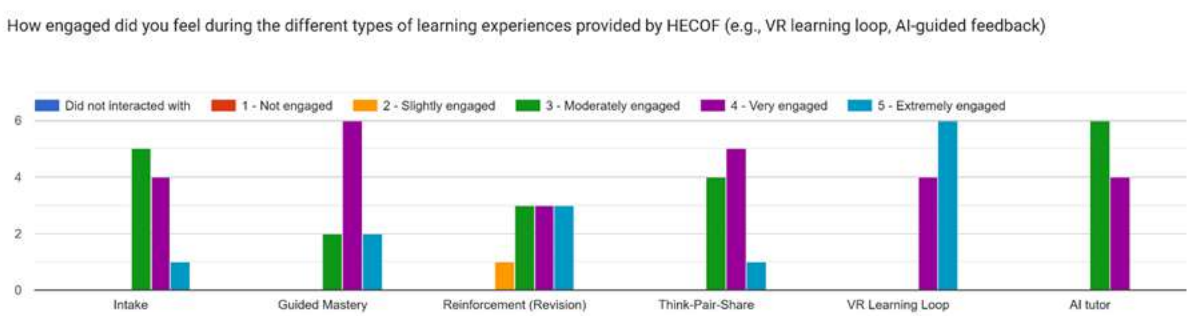


Figure 31: Evaluation 2 - Post-Survey - Engagement Levels Across HECOF Learning Experiences

Participants rated their engagement levels across different HECOF learning experiences, including VR Learning Loop, AI tutor, Think-Pair-Share, Reinforcement, Guided Mastery, and Intake. The VR Learning Loop received the highest engagement levels, with a notable proportion of students rating them as very or extremely engaging. Think-Pair-Share, AI tutor and Reinforcement, Guided Mastery activities also showed good engagement. These results suggest that students were most engaged in immersive and interactive learning experiences, such as VR and AI-driven feedback.

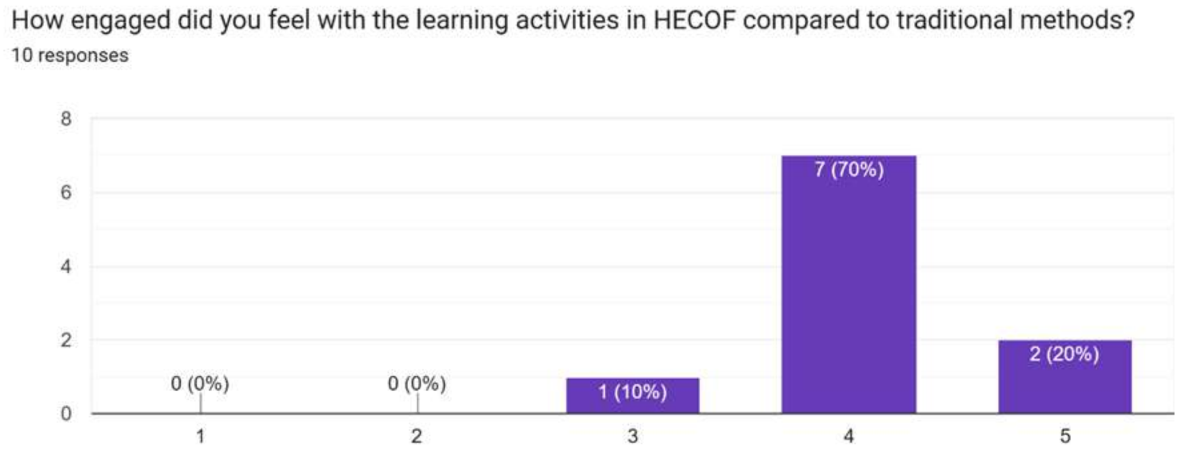


Figure 32: Evaluation 2 - Post-Survey - Engagement with HECOF Compared to Traditional Learning Methods

Participants rated their engagement with HECOF learning activities compared to traditional methods. The majority (70%) found HECOF activities very engaging (4), while 20% rated them as extremely engaging (5). A small percentage (10%) reported moderate engagement (3), and no participants rated their engagement as low (1 or 2). These results indicate that HECOF provided a significantly more engaging learning experience compared to traditional methods, with most students feeling highly involved in the interactive activities.

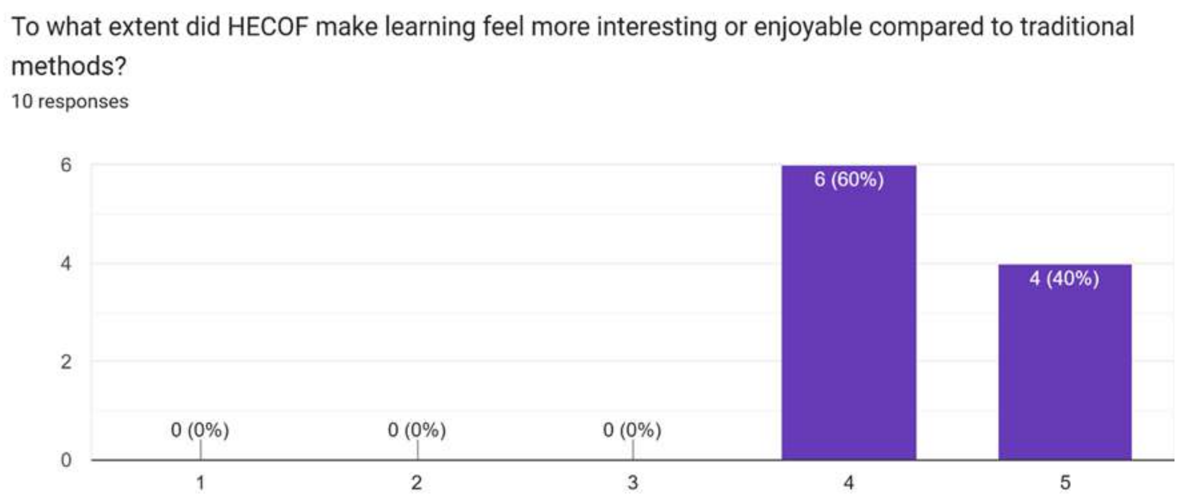


Figure 33: Evaluation 2 - Post-Survey - Perceived Enjoyment of Learning with HECOF Compared to Traditional Methods

Participants assessed how HECOF made learning more interesting or enjoyable compared to traditional methods. The majority (60%) rated it as considerably more engaging (4), while 40% found it greatly more enjoyable (5). No participants rated the experience as moderately (3), slightly (2), or not at all enjoyable (1). These results indicate that HECOF significantly enhanced student engagement and enjoyment, making learning more interactive and appealing compared to traditional methods.

6.2.3.3 Positive and Negative Aspects of Using AI in HECOF

Participants shared both positive impacts and challenges associated with the AI-driven personalization in HECOF.

Positive Impacts:

- The most commonly mentioned benefit was the AI's ability to help students identify areas for improvement, guiding them toward focused revision.
- Many participants also reported improved concept understanding and an efficient, quick learning process.
- Some students felt that the AI encouraged learning motivation and increased confidence in subject knowledge.

Challenges Faced:

- Most participants reported no challenges, indicating a generally smooth experience.
- The most common issue was a lack of clarity in how to use the AI tools effectively.
- Additional challenges included first-time VR experience difficulties and questions appearing before the related subject was taught (i.e., as part of the diagnostic)

These insights suggest that while AI-driven personalization was beneficial for identifying weaknesses and improving engagement, there is room for improvement in usability and instructional clarity.

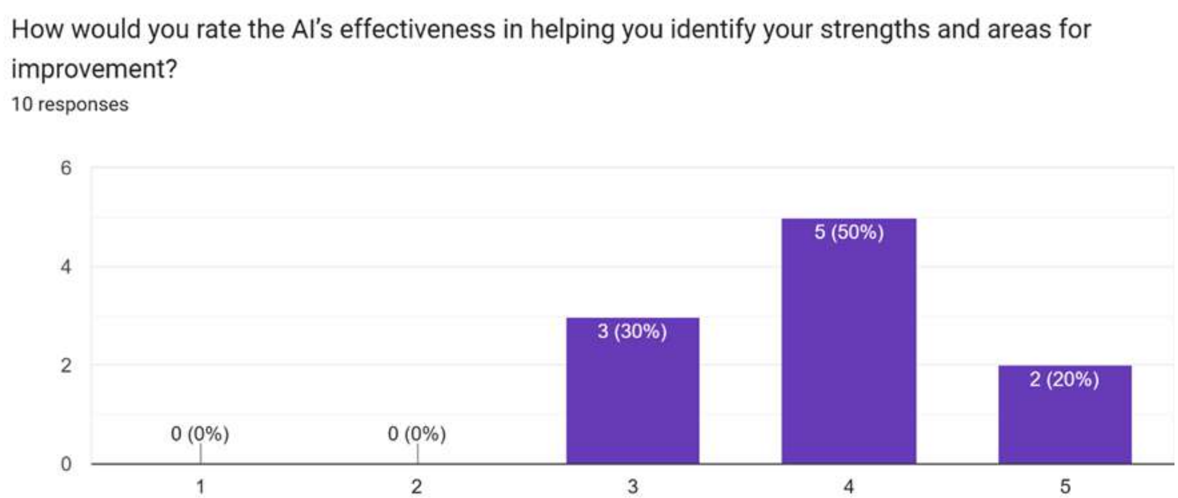


Figure 34: Evaluation 2 - Post-Survey - AI's Effectiveness in Identifying Strengths and Areas for Improvement

Participants rated the AI's effectiveness in helping them identify their strengths and areas for improvement. The majority (50%) found the AI very effective (4), while 20% rated it as extremely effective (5). A smaller portion (30%) rated it as moderately effective (3), and no participants rated it as slightly effective (2) or not effective at all (1). These results suggest that the AI was generally successful in guiding students toward self-assessment, though some felt its effectiveness could be improved further.

6.2.3.4 Perceived Usefulness

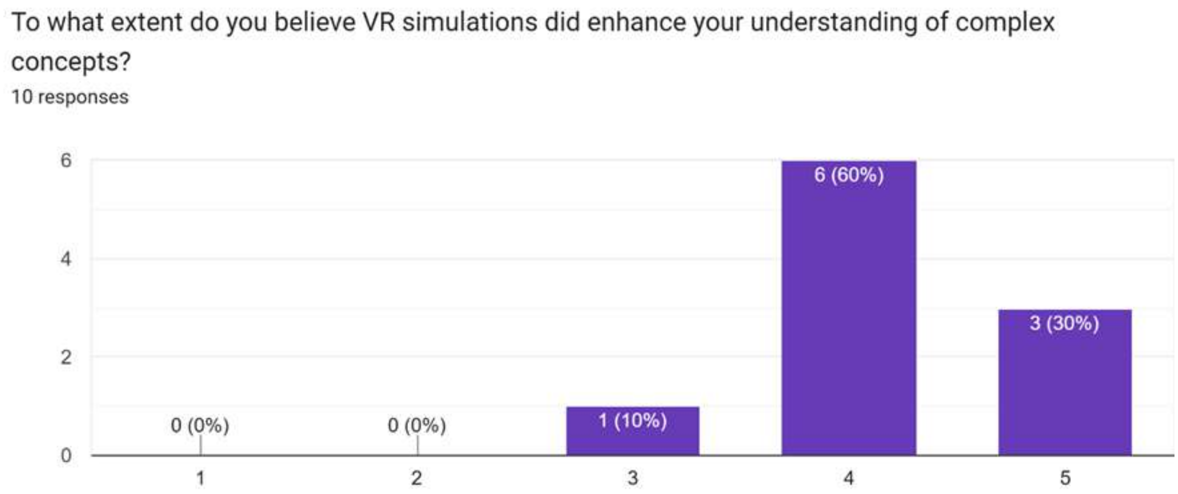


Figure 35: Evaluation 2 - Post-Survey - Perceived Usefulness of VR Simulations for Understanding Complex Concepts

Participants rated how VR simulations enhanced their understanding of complex concepts. The majority (60%) found them very useful (4), while 30% rated them as extremely useful (5). A smaller portion (10%) rated VR as moderately useful (3), and no participants found it slightly useful (2) or not useful at all (1). These results indicate that VR simulations were highly effective in supporting learning, with most students finding them a valuable tool for grasping complex concepts.

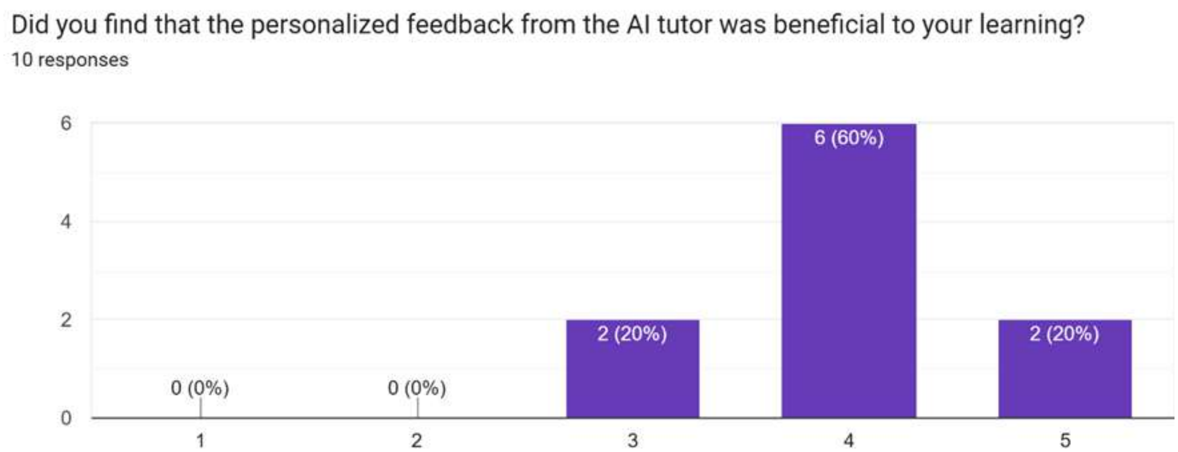


Figure 36: Evaluation 2 - Post-Survey - Perceived Benefit of AI Tutor's Personalized Feedback

Participants rated the benefit of personalized feedback from the AI tutor for their learning. The majority (60%) found the feedback very beneficial (4), while 20% rated it as extremely beneficial (5). Another 20% considered it somewhat beneficial (3), and no participants rated it as slightly beneficial (2) or not beneficial at all (1). These results suggest that the AI tutor's personalized feedback was well-received, with most students finding it a valuable tool for improving their learning process.

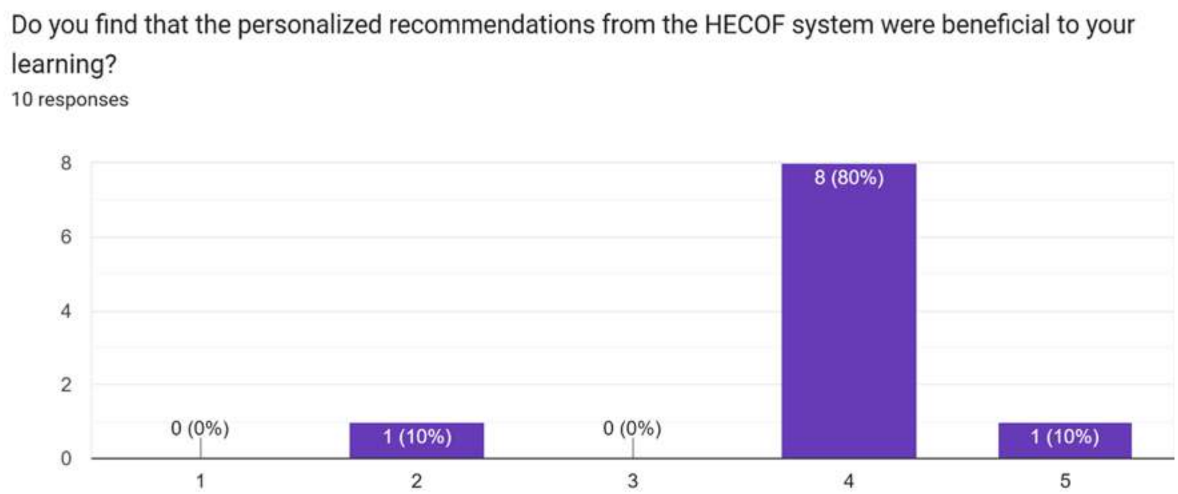


Figure 37: Evaluation 2 - Post-Survey - Benefit of AI Tutor's Personalized Feedback

In Evaluation 1 - Post-Survey, participants assessed how beneficial the personalized feedback from the AI tutor was for their learning. The majority (60%) rated it as very beneficial (4), while 20% found it extremely beneficial (5). Another 20% considered it somewhat beneficial (3), with no participants rating it as slightly beneficial (2) or not beneficial at all (1). These results suggest that the AI tutor's personalized feedback was well-received, playing a key role in helping students enhance their understanding and learning process.

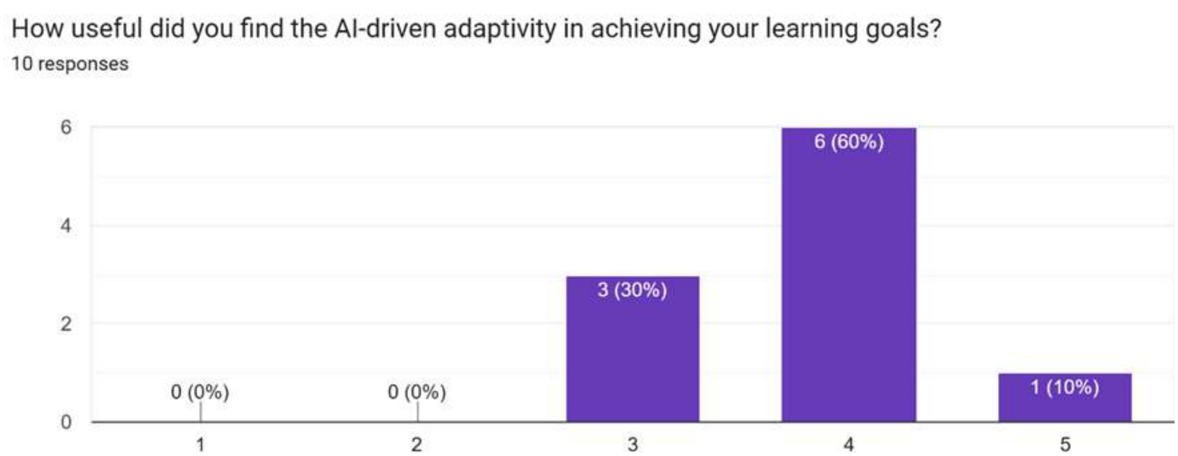


Figure 38: Evaluation 2 - Post-Survey - Usefulness of AI-Driven Adaptivity in Achieving Learning Goals

Participants rated the usefulness of AI-driven adaptivity in achieving their learning goals. The majority (60%) found it very useful (4), while 10% rated it as extremely useful (5). Another 30% considered it moderately useful (3), with no participants rating it as slightly useful (2) or not useful at all (1). These results indicate that AI adaptivity played a significant role in supporting students' learning goals, though there is room for improvement to make it even more impactful.

6.2.4 User Satisfaction

6.2.4.1 Overall User Satisfaction

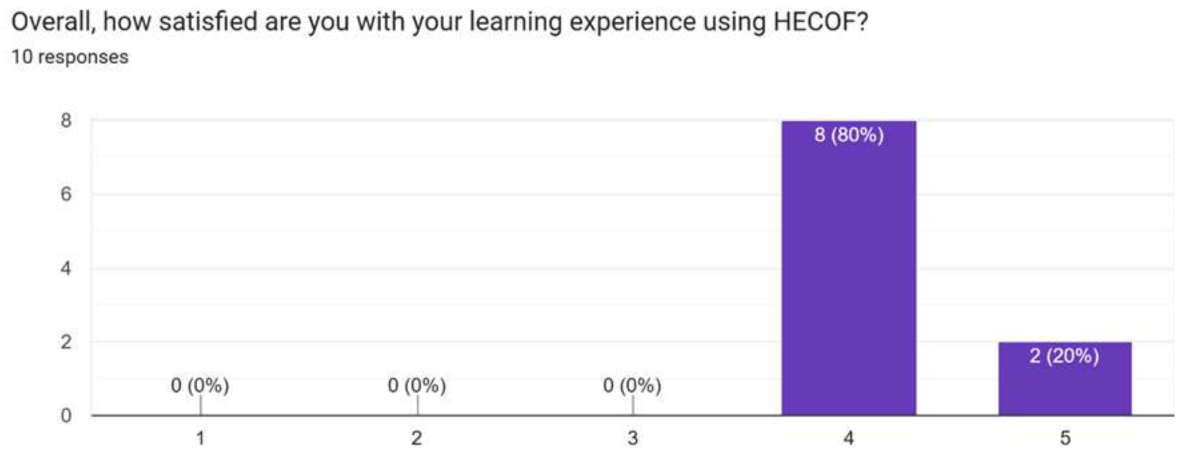


Figure 39: Evaluation 2 - Post-Survey - Overall Satisfaction with HECOF Learning Experience

Participants rated their overall satisfaction with their learning experience using HECOF. The majority (80%) reported being satisfied (4), while 20% were very satisfied (5). No participants rated their experience as neutral (3), somewhat dissatisfied (2), or very dissatisfied (1). These results indicate a high level of satisfaction among students, suggesting that HECOF was effective in delivering a positive and engaging learning experience.

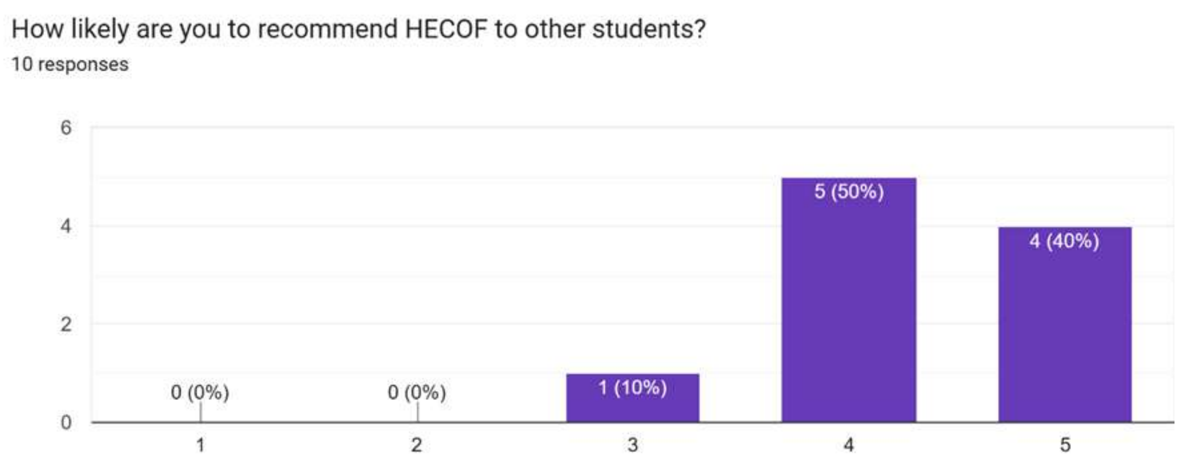


Figure 40: Evaluation 2 - Post-Survey - Likelihood of Recommending HECOF to Other Students

Participants rated how likely they were to recommend HECOF to other students. The majority (50%) indicated they were likely (4) to recommend it, while 40% were very likely (5). A small percentage (10%) remained neutral (3), and no participants rated their likelihood as unlikely (2) or very unlikely (1). These results suggest that HECOF was generally well-received, with most students willing to recommend it to their peers.

6.2.4.2 Usability of Learning Loops and VR Experiences

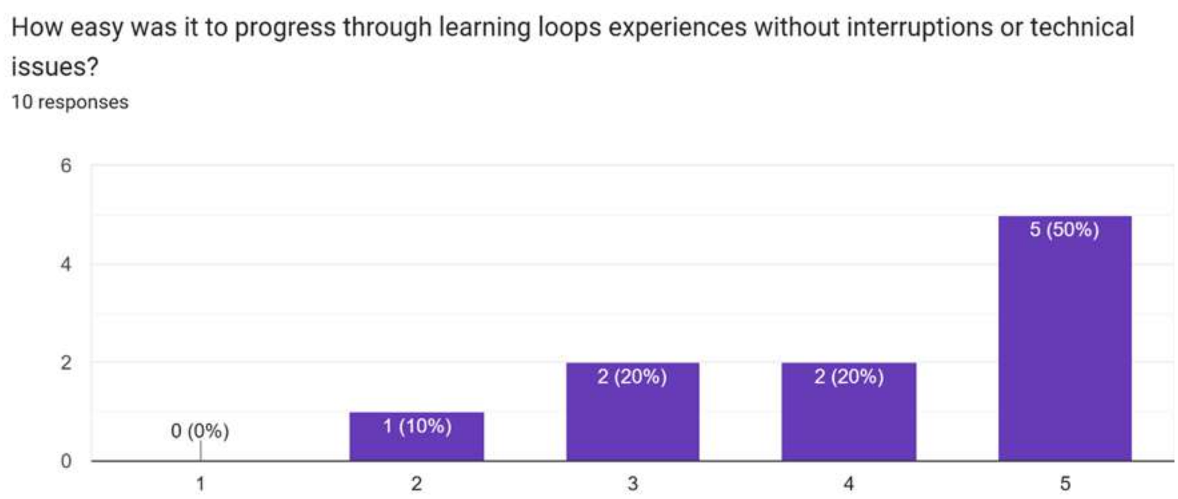


Figure 41: Evaluation 2 - Post-Survey - Ease of Progression Through Learning Loops Without Interruptions

Participants rated how easy it was to progress through learning loops without interruptions or technical issues. The majority (50%) found it very easy (5), while 20% rated it as easy (4). Another 20% remained neutral (3), and 10% found it difficult (2). No participants rated their experience as very difficult (1). These results suggest that most students had a smooth learning experience, but a small portion encountered some challenges or disruptions.

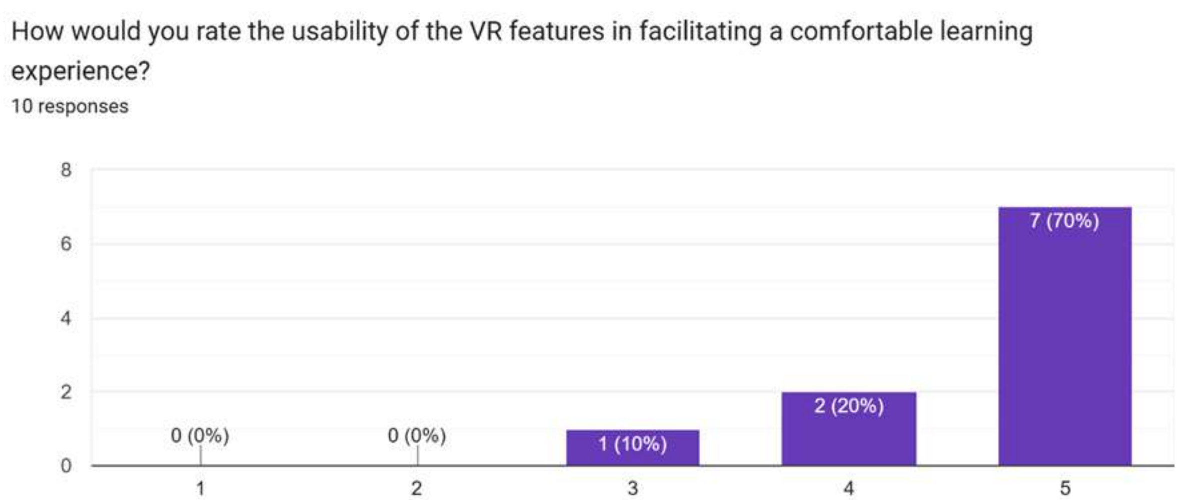


Figure 42: Evaluation 2 - Post-Survey - Usability of VR Features for a Comfortable Learning Experience

Participants rated the usability of the VR features in facilitating a comfortable learning experience. The majority (70%) rated the usability as excellent (5), while 20% found it very good (4). A smaller portion (10%) rated it as good (3), with no participants rating the experience as fair (2) or poor (1). These results indicate that the VR features were highly effective in providing a comfortable and user-friendly learning experience for most students.

6.2.5 System Usability

6.2.5.1 Overall System Usability

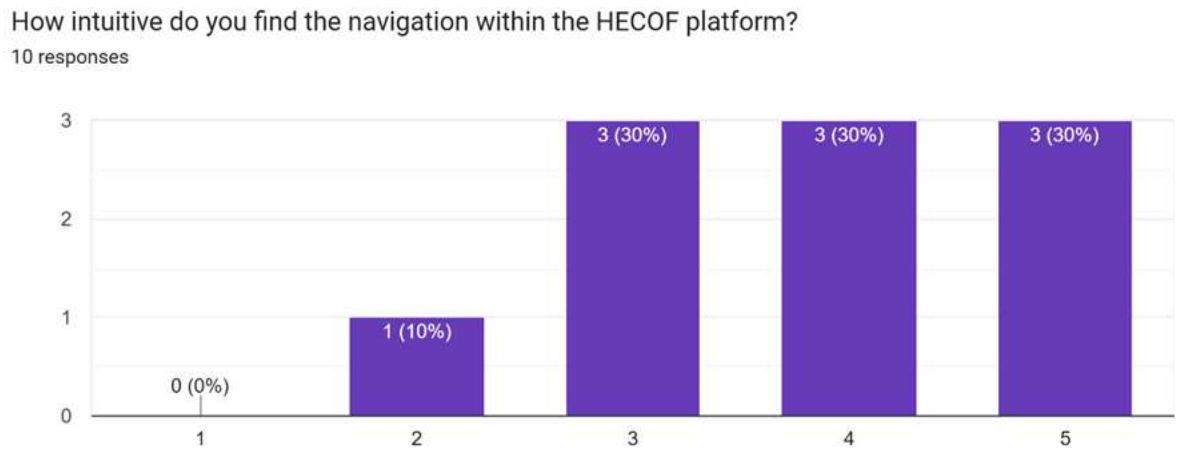


Figure 43: Evaluation 2 - Post-Survey - Intuitiveness of Navigation in the HECOF Platform

Participants rated the intuitiveness of navigation within the HECOF platform. The majority of responses were distributed across neutral (30%), easy (30%), and very easy (30%), suggesting that most users found the platform relatively straightforward to navigate. However, 10% of participants found navigation difficult (2), while no one rated it as very difficult (1). These results indicate that while the platform was generally intuitive for most users, some encountered minor difficulties that could be addressed for a smoother experience.

6.2.5.2 Virtual AI Tutor Usability and Usefulness

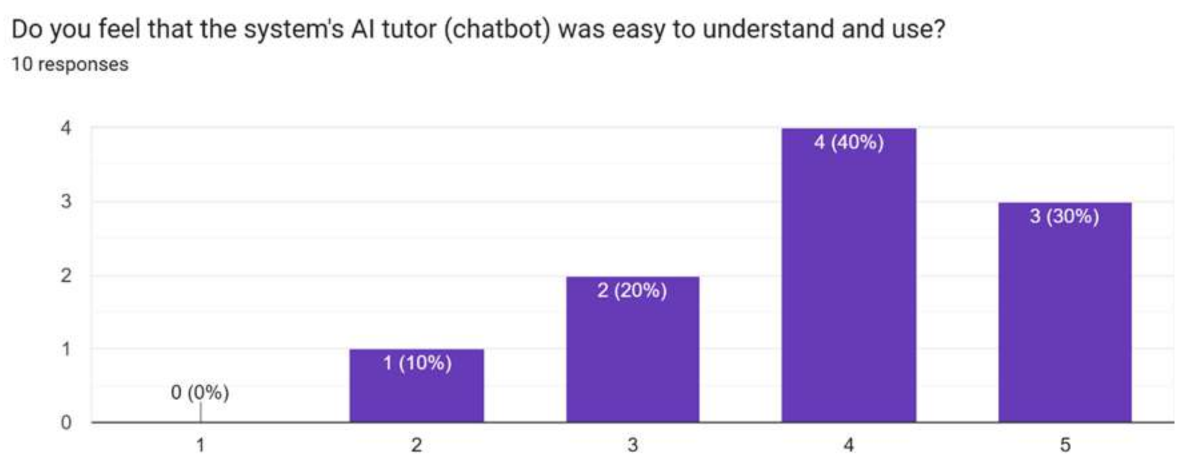


Figure 44: Evaluation 2 - Post-Survey - Ease of Understanding and Using the AI Tutor (Chatbot)

Participants rated how easy the AI tutor (chatbot) was to understand and use. The majority (40%) agreed (4) that the chatbot was easy to use, while 30% strongly agreed (5). Another 20% remained neutral (3), while 10% disagreed (2). No participants strongly disagreed (1). These results suggest that most students found the AI tutor user-friendly, but a small portion encountered some usability challenges that could be refined for better accessibility.

6.2.5.3 Learning Analytics usability

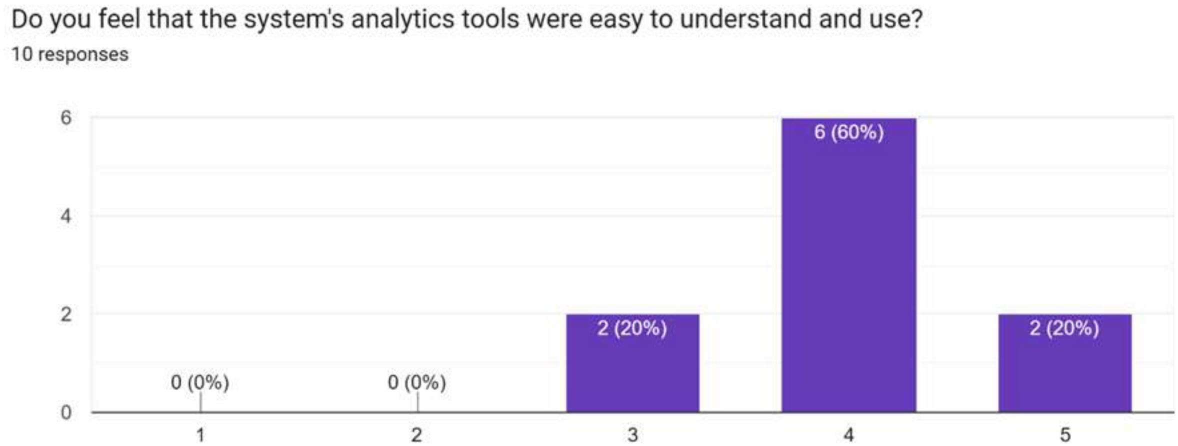


Figure 45: Evaluation 2 - Post-Survey - Ease of Understanding and Using System Analytics Tools

Participants rated the ease of understanding and using the system's analytics tools. The majority (60%) agreed (4) that the tools were user-friendly, while 20% strongly agreed (5). Another 20% remained neutral (3), and no participants disagreed (2) or strongly disagreed (1). These results indicate that most users found the analytics tools accessible and intuitive, but a few participants felt there was room for improvement in clarity and usability.

6.2.5.4 Learning Loops Usability

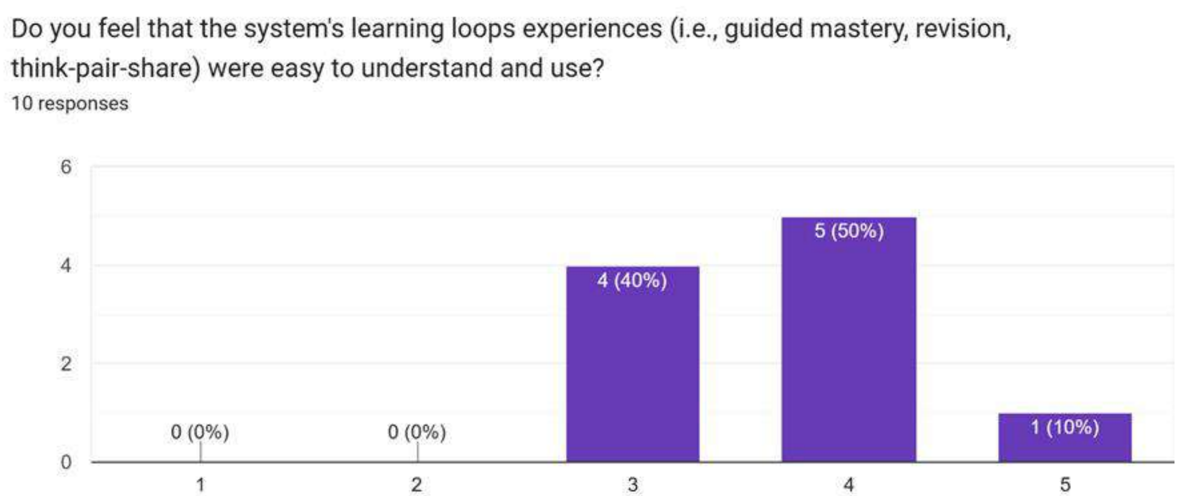


Figure 46: Evaluation 2 - Post-Survey - Ease of Understanding and Using Learning Loops

Participants rated the ease of understanding and using the system's learning loops experiences (guided mastery, revision, think-pair-share, etc.). The majority (50%) agreed (4) that the learning loops were easy to use, while 10% strongly agreed (5). Another 40% remained neutral (3), with no participants disagreeing (2) or strongly disagreeing (1). These results suggest that most students found the learning loops accessible and functional, but a significant portion remained neutral, indicating potential areas for refinement to improve usability.

6.2.5.5 VR Usability

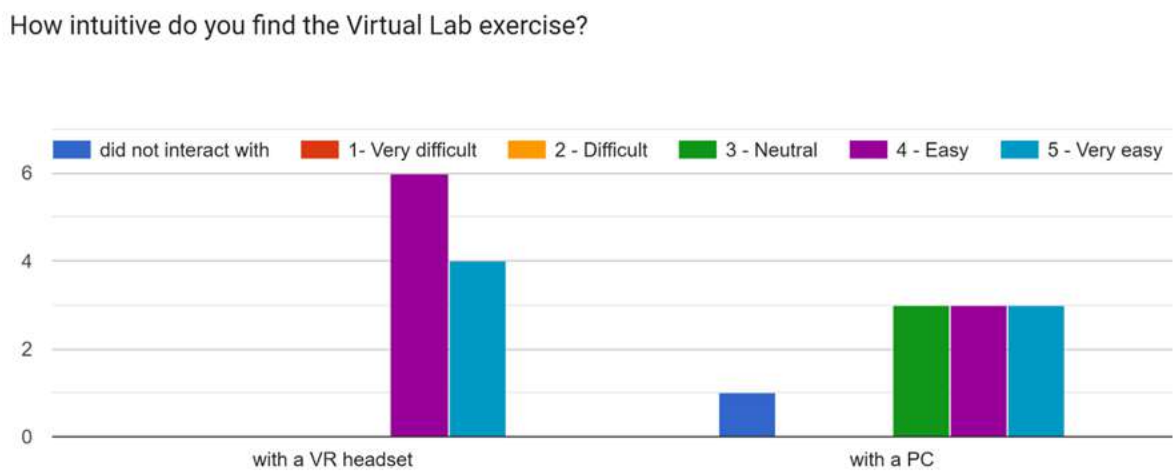


Figure 47: Evaluation 2 - Post-Survey - Intuitiveness of the Virtual Lab Exercise with VR and PC

Participants rated the intuitiveness of the Virtual Lab exercise using both a VR headset and a PC. For the VR headset, responses were split, with some participants finding it very easy (5) while others did not interact with it. For the PC version, participants generally rated it as neutral (3), easy (4), or very easy (5), suggesting a more consistent usability experience compared to the VR version. These results indicate that while the Virtual Lab was generally considered intuitive, there were differences in ease of use between the VR and PC versions, with VR posing some challenges for some users.

6.2.5.6 Virtual AI Tutor Usability and Usefulness

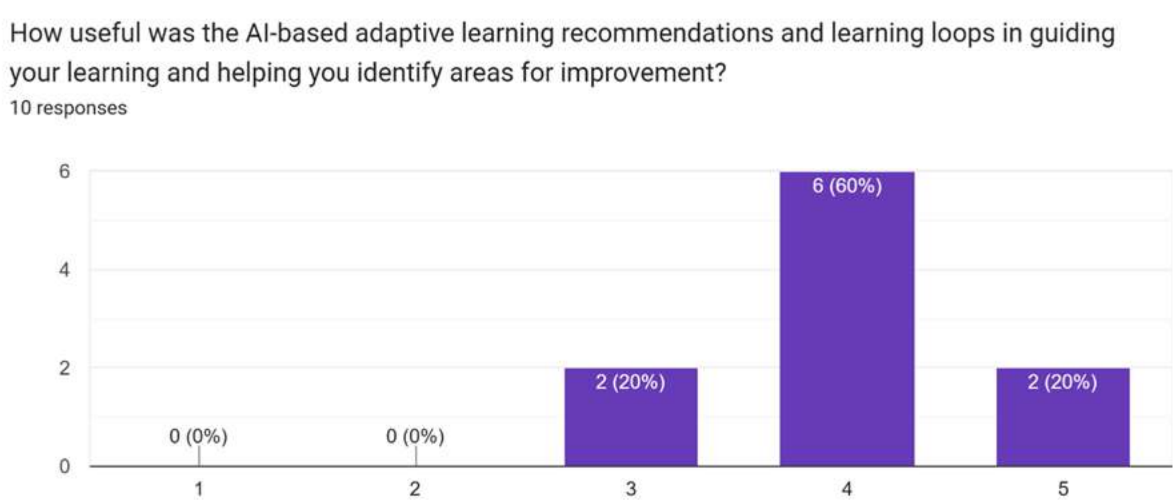


Figure 48: Evaluation 2 - Post-Survey - Usefulness of AI-Based Adaptive Learning Recommendations

Participants rated the usefulness of AI-based adaptive learning recommendations and learning loops in guiding their learning and identifying areas for improvement. The majority (60%) found them very useful (4), while 20% rated them as extremely useful (5). Another 20% considered them moderately useful (3), with no participants rating them as slightly useful (2) or not useful at all (1). These results suggest that AI-driven adaptivity played a significant role in enhancing students' learning experiences, with most finding it a valuable tool for improvement.

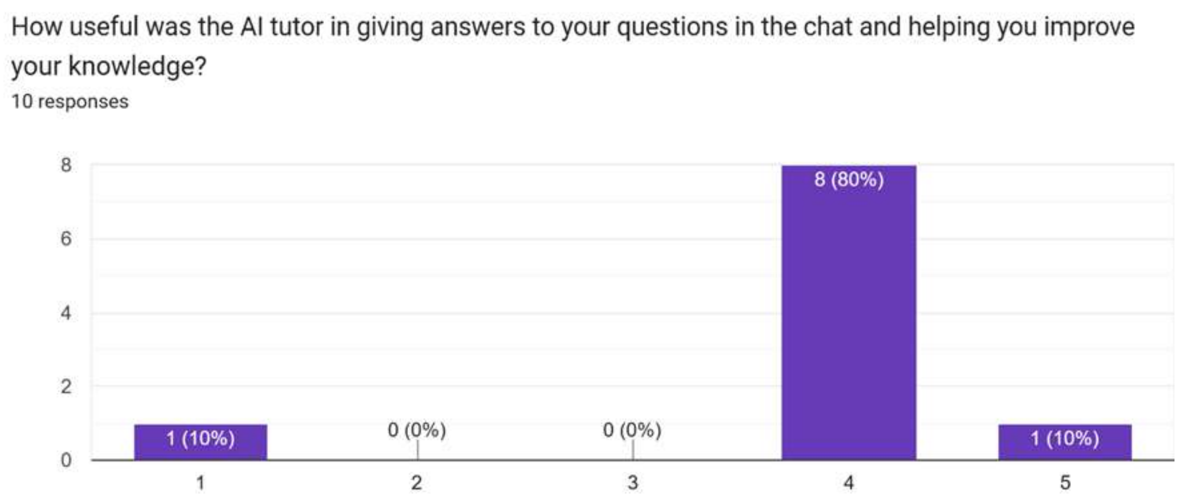


Figure 49: Evaluation 2 - Post-Survey - Usefulness of AI Tutor in Answering Questions and Enhancing Knowledge

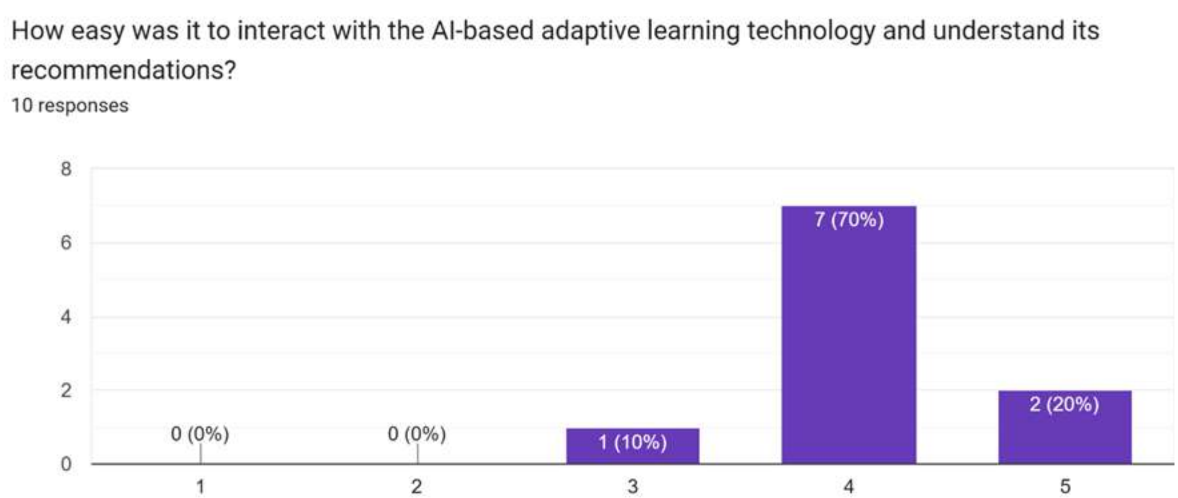


Figure 50: Evaluation 2 - Post-Survey - Ease of Interaction with AI-Based Adaptive Learning Technology

Participants rated the ease of interacting with the AI-based adaptive learning technology and understanding its recommendations. The majority (70%) found it easy to use (4), while 20% rated it as very easy (5). One participant (10%) remained neutral (3), and no participants found it difficult (2) or very difficult (1). These results suggest that the AI-based adaptivity was generally user-friendly and accessible, though some minor improvements could enhance clarity and interaction.

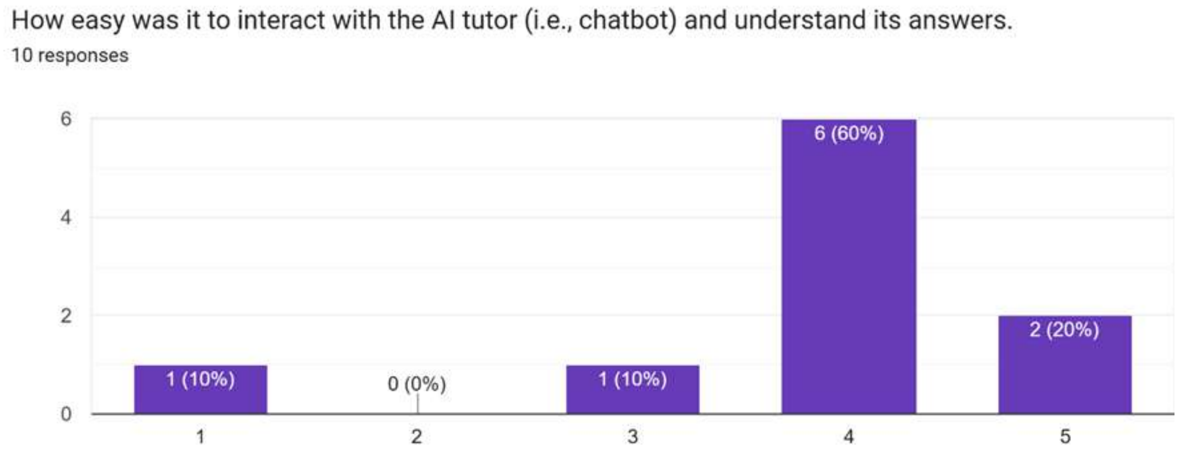


Figure 51: Evaluation 2 - Post-Survey - Ease of Interaction with the AI Tutor (Chatbot)

Participants rated the ease of interacting with the AI tutor (chatbot) and understanding its answers. The majority (60%) found it easy to use (4), while 20% rated it as very easy (5). A small percentage (10%) remained neutral (3), while another 10% found it very difficult (1), with no participants selecting difficult (2). These results suggest that while most students found the AI tutor accessible and understandable, some faced challenges that may require improvements in clarity and responsiveness.

6.2.6 Social Presence and Interactions

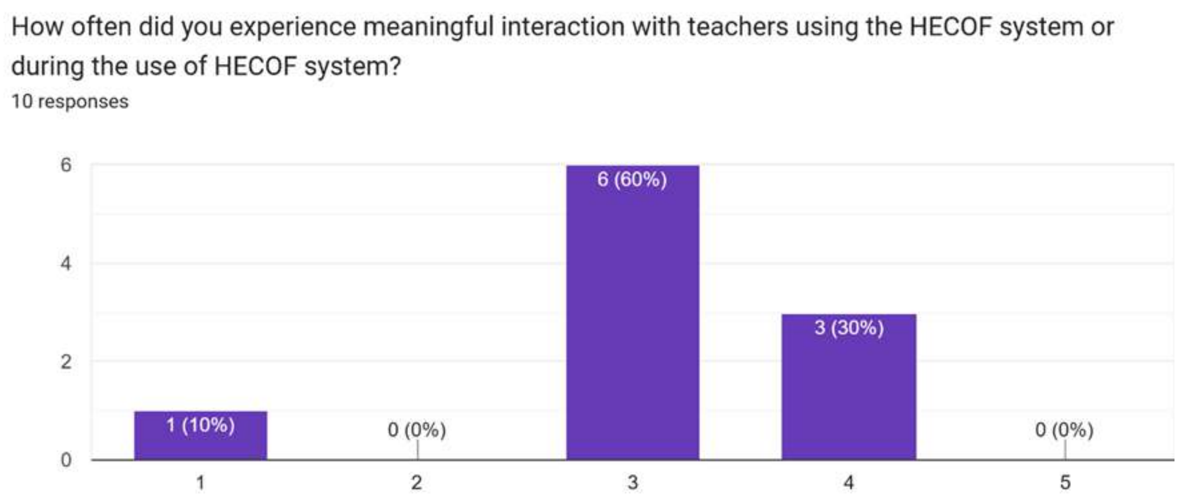


Figure 52: Evaluation 2 - Post-Survey - Frequency of Meaningful Interactions with Teachers

Participants rated the frequency of meaningful interactions with teachers while using the HECOF system. The majority (60%) reported that they sometimes (3) experienced meaningful interactions, while 30% found them to occur often (4). A small percentage (10%) indicated they never (1) had meaningful interactions, with no participants selecting rarely (2) or very often (5). These results suggest that while some teacher-student engagement took place, there is room for improvement in fostering more frequent and meaningful interactions.

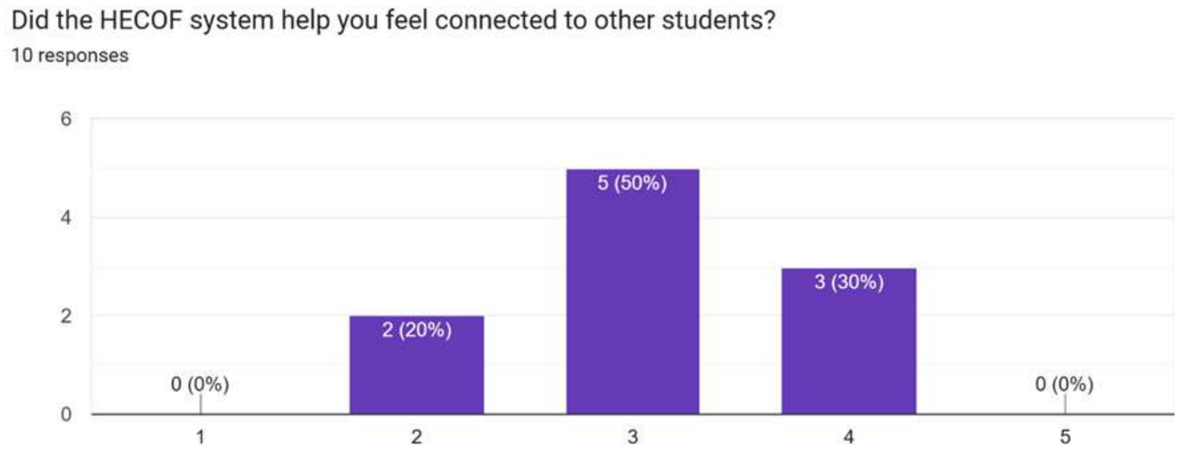


Figure 53: Evaluation 2 - Post-Survey - Student Connection Through HECOF

In Evaluation 1 - Post-Survey, participants rated the extent to which the HECOF system helped them feel connected to other students. The majority (50%) remained neutral (3) on the system's ability to foster peer connection, while 30% agreed (4) that it helped them feel connected. A smaller proportion (20%) disagreed (2), and no participants strongly agreed (5) or strongly disagreed (1). These findings suggest that while HECOF provided some level of student connectivity, there is potential for enhancement in fostering a more interactive and collaborative learning environment.

6.2.7 Students' Recommendations and Feedback

6.2.7.1 Students' Improvement Recommendations for HECOF

Participants provided diverse recommendations for enhancing the HECOF system, particularly regarding VR experiences, AI adaptivity, and overall usability. Several responses highlighted the need for improving the VR environment, suggesting enhanced graphics and physics to create a more realistic and user-friendly experience. Additionally, some recommended increasing the complexity of the VR simulations, considering that the system is designed for adult learners.

Regarding AI-driven adaptivity, suggestions included better question structuring, and more interactive learning approaches. A common concern was the difficulty in locating lesson introductions and key learning materials, with some participants advocating for brief introductory slides in each lesson to provide clearer guidance.

The usability and accessibility of HECOF were also discussed, with proposals for allowing both hands to be used simultaneously in the VR lab, integrating a voice feature in the chatbot for greater inclusivity, and offering a less guided experience to encourage independent exploration and problem-solving. While some found the system well-organized, they expressed the need for a balance between structured learning and self-directed discovery.

These insights provide actionable areas for improvement, emphasizing the importance of realistic and engaging VR environments, refined AI personalization, and enhanced usability features to optimize the learning experience in HECOF.

6.2.7.2 Key Moments where the HECOF system made Learning Easier or More Rewarding

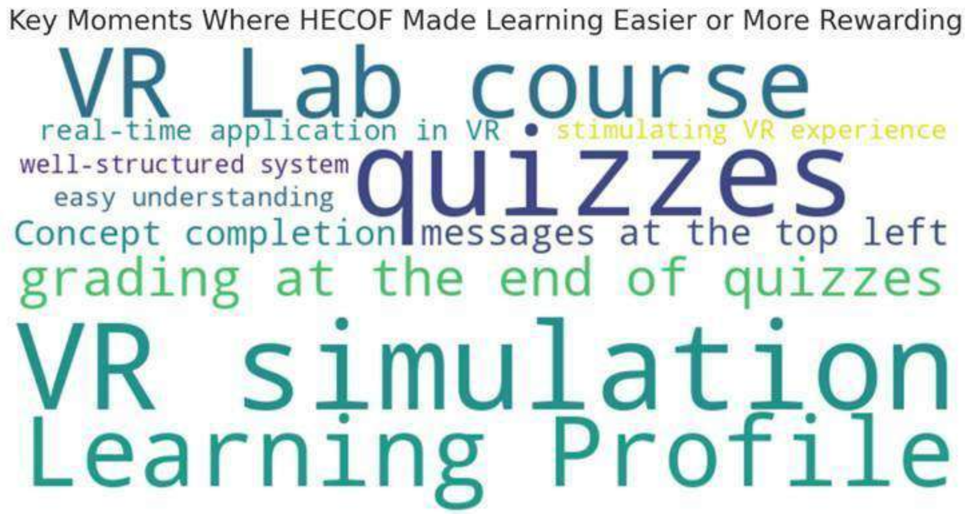


Figure 54: Evaluation 2 - Post-survey: word-cloud - Key moments where HECOF made learning easier or more rewarding

Participants highlighted several key moments where the HECOF system made learning easier or more rewarding. The VR simulation was frequently mentioned as a pivotal experience, providing an immersive and interactive way to apply theoretical knowledge in real time. Many students found the VR Lab course particularly engaging, as it allowed them to visualize and reinforce learning. Additionally, adaptive quizzes were identified as rewarding, especially with elements like the Learning Profile updates and grading at the end of quizzes, which provided immediate feedback and a sense of accomplishment. Some participants also appreciated the concept completion messages and structured feedback, which contributed to a more guided learning process. The system's overall structure was praised for being well-organized, with many noting how the adaptive elements contributed to a smooth and intuitive learning experience.

6.2.7.3 Additional Suggested Improvements for HECOF

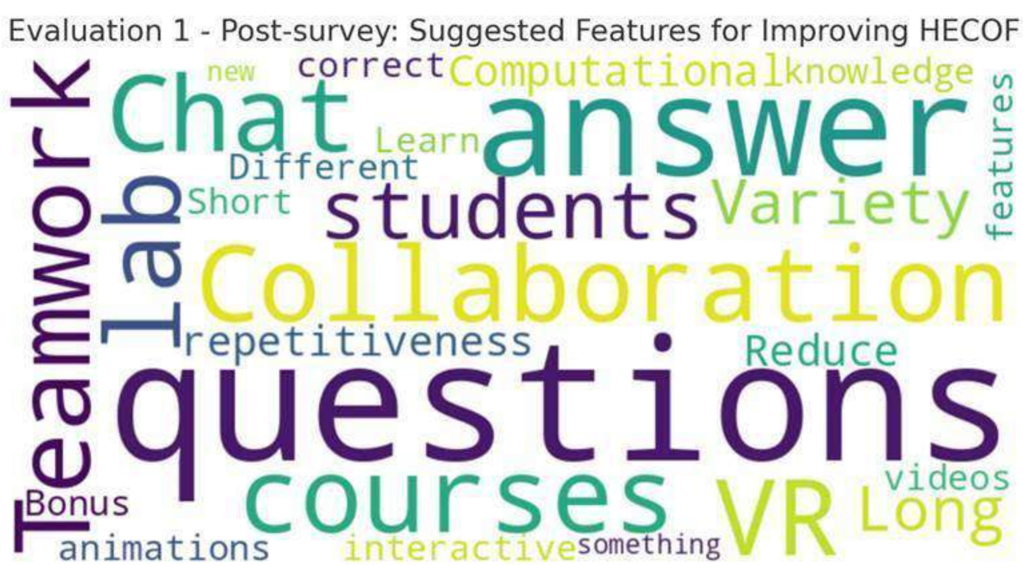


Figure 55: Evaluation 2 - Post-survey word-cloud: Suggested Features for Improving HECOF

Participants suggested additional enhancements to improve the HECOF system. A key theme was increasing interactivity, with multiple respondents advocating for a more engaging learning experience through collaboration in VR lab courses and student-to-student chat features. Another common recommendation was diversifying assessment methods, with requests for a broader range of question types, including long-answer and computational questions, and reducing the repetition of existing questions.

Additionally, participants emphasized the need for improved content, suggesting more visually engaging instructional elements such as short videos, animations, and interactive features that provide additional knowledge incentives for correct answers. Some also recommended refining AI adaptivity to better tailor content to individual learning styles and preferences (taking into consideration that multiple content types should be available). Overall, these suggestions indicate a strong preference for a more dynamic, personalised, and interactive learning experience.

6.2.7.4 Likelihood of Continued Use and Recommendations for HECOF

The responses indicate a strong inclination toward continued use of the HECOF system, particularly for complex subjects that benefit from interactive and immersive learning. Several participants emphasized its effectiveness in making learning more enjoyable and accessible. The VR and AI-driven elements were highlighted as unique features that distinguish HECOF from traditional learning methods.

Many respondents stated they would encourage others to try HECOF, noting its novel approach and ability to simplify difficult concepts. Some mentioned that their future use would depend on their career path, but they would still recommend the system to younger students for its innovative and engaging qualities. This suggests that HECOF has successfully positioned itself as a valuable tool in higher education, especially in technical and engineering-related fields.

6.2.7.5 Memorable Experiences of Overcoming Learning Challenges with HECOF

The responses reveal mixed feedback regarding whether HECOF helped students overcome specific learning challenges. While some participants stated they could not recall a particular moment, others pointed to key features that significantly supported their learning.

The VR simulation was a notable tool for overcoming conceptual barriers, as it allowed students to conduct experiments and fully grasp theoretical concepts in a practical, immersive way. Additionally, the revision of theoretical questions and instant personalized feedback helped reinforce knowledge and correct mistakes in real-time, enhancing understanding.

Although some students did not experience a major learning challenge, the general sentiment suggests that HECOF provides useful resources to tackle difficulties effectively. Its AI-driven feedback and VR-enhanced learning stand out as pivotal in bridging gaps in comprehension and offering tailored guidance.

6.2.7.6 Most Impactful Features of HECOF for Learning Enhancement

The majority of respondents highlighted the VR experience as the most impactful feature of HECOF. The immersive nature of the VR lab course allowed students to engage in hands-on learning, closely simulating real-life laboratory experiences. This feature particularly benefited students who learn best through visualization and interaction, making complex concepts more accessible and easier to retain.

Additionally, revision exercises and personalized chatbot explanations were recognized as valuable tools for reinforcing learning. The AI-driven feedback helped students quickly identify mistakes and understand key concepts without requiring extensive effort, making the learning process more efficient, engaging, and interactive. The overall sentiment suggests that HECOF successfully enhanced the learning experience by integrating adaptive AI feedback and immersive VR simulations.

6.3 Impact Assessment

6.3.1 Education Technology Market

The **global Education Technology Market size**, presented in Figure 56, was reported by GRAND VIEW RESEARCH with 163,5 billion US-Dollar and a CAGR of 13.3% and an estimated size of 348,4 billion US Dollar in 2030. The European market is described to gain traction with growing presence of EdTech hubs and increasing attention from venture capitalists, governments, and EdTech accelerators. Share of educational content in the EdTech segment is forecasted to exhibit with the fastest growth in that period[2,3], current market share of software, content and hardware for EdTech and VR in education are illustrated by Figure 57.

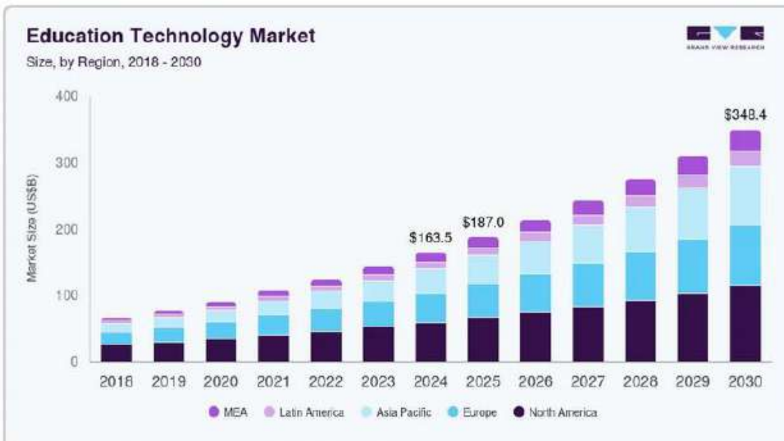
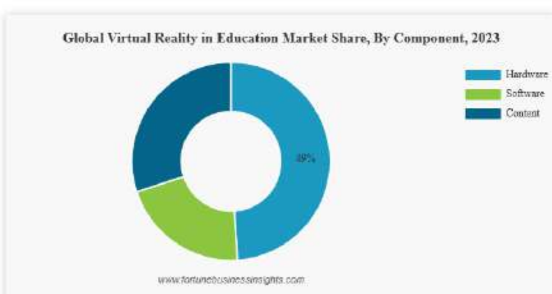


Figure 56: Global Edu Tech Market size by region (GVG)

The World Economic Forum (WEF) forecasted in 2024 800 million K-12 graduates and **350 million post-secondary-school graduates globally** in the next ten years, and expenditure on education around the world is set to hit $10 trillion by 2030. **AI in education** will drive the transformation to personalised and efficient learner experiences. The WEF expects AI in education to grow by around USD 21 billion worldwide by 2028.[4] FORTUNE BUSINESS INSIGHTS (FBUI) reported **VR in education** was valuated at 14.55 billion US Dollar in 2023, with a CAGR of 18.2%.[5]



[2] https://www.grandviewresearch.com/industry-analysis/education-technology-market

[3] https://www.grandviewresearch.com/industry-analysis/education-technology-market

[4] https://www.weforum.org/stories/2024/02/these-are-the-4-key-trends-that-will-shape-the-edtech-market-into-2030/

[5] https://www.fortunebusinessinsights.com/industry-reports/virtual-reality-in-education-market-101696

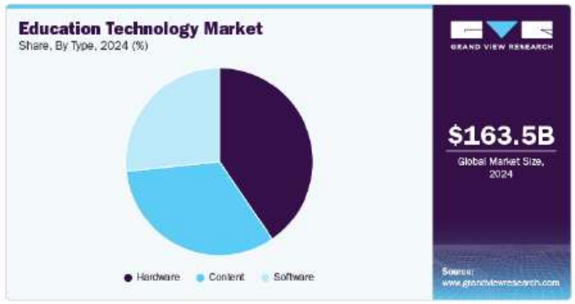


Figure 57: Global Edu Tech (GVG) and VR in education (FBUI) Market share by component

To understand the available platforms (desktop, mobile phone/tablet, headsets) at the user side, technological related metaverse reports provide transferable information. Figure 58 from Roots Analysis[6] is a clear indication that VR based education systems, such as HECOF, should support a desktop version in order to minimise the acquisition costs for students or teaching institutions when they are introduced.

Figure 58: Metavers Market overview by platform (RA)

6.3.2 Stakeholders

The HECOF pilots had a positive and multi-layered impact on the project's key stakeholders, particularly students, educators, and the participating higher education institutions. For students, the pilots provided first-hand exposure to cutting-edge AI-driven adaptive learning and VR-based laboratory simulations, enhancing engagement, motivation, and confidence in tackling complex chemical engineering concepts. This not only improved their perceived learning gains but also broadened their familiarity with innovative digital tools, a skillset valuable beyond the scope of the pilot courses.

For educators, the pilots offered concrete insights into how immersive and adaptive technologies can be integrated into existing curricula to enrich teaching strategies and address individual learning needs. The hands-on experience with configuring AI learning loops, creating VR content, and interpreting learning analytics empowered them to make data-informed pedagogical decisions. At the institutional level, the pilots demonstrated the feasibility and added value of implementing advanced digital learning environments, supporting their strategic goals for digital transformation and

[6] https://www.rootsanalysis.com/metaverse-market (visited 03.07.2025)

modernisation of teaching practices. These outcomes strengthen the case for wider adoption and scalability of the HECOF approach within and beyond the pilot universities.

6.3.3 Entrepreneurship

The HECOF pilots showcased clear entrepreneurial potential by demonstrating how AI-driven adaptive learning and immersive VR training can address market needs in education and professional skills development. The successful implementation at two universities provided a proof of concept that can be adapted for commercial deployment in other academic disciplines and sectors, particularly those requiring complex procedural training. The pilots validated the system's capacity to deliver scalable, personalised, and engaging learning experiences, which can be positioned as a competitive offering in the growing educational technology market.

Moreover, the feedback from students and educators helped refine the value proposition, highlighting features with the strongest user appeal—such as real-time adaptive feedback and highly interactive VR simulations. These insights support the development of sustainable business models, from institutional licensing to sector-specific training solutions, and open opportunities for collaboration with industry partners in education, vocational training, and corporate upskilling. In this way, the pilots contributed directly to laying the groundwork for HECOF's potential market entry and long-term entrepreneurial viability.

6.3.4 Education Institutions

At POLIMI, the second pilot of HECOF engaged thesis and PhD students, who provided valuable feedback on how the system can best complement existing teaching and laboratory practices. Participants highlighted that the VR experience offers a streamlined and focused environment compared to the physical lab, where numerous non-essential objects may be present. This guided setup helps students concentrate on core experimental components, making it an effective introduction to laboratory work. They also noted that while VR cannot replace hands-on practice, it serves as a strong preparatory and reinforcing tool, particularly when combined with adaptive learning features to revisit and consolidate knowledge. Suggestions for future enhancement included the integration of AI-generated, specialised quizzes and in-depth content, further tailoring the system to advanced learners' needs. The pilot also helped outline clear next steps for post-project adoption at POLIMI, such as developing how-to guides, backend hosting arrangements, user management procedures, and content modification workflows. The course instructor expressed strong interest in integrating HECOF into upcoming course editions, recognising its potential to enrich student learning and complement traditional teaching methods.

At NTUA, Evaluation #2 brought together undergraduate, PhD students, and teaching staff, enabling a multi-perspective review of HECOF's application in chemical engineering education. Students appreciated how the VR laboratory simulated the extraction process in a clear and guided manner, supporting conceptual understanding before performing the actual experiment. PhD candidates and instructors, having prior experience with the real lab procedure, noted that the system could significantly enhance preparation, reduce errors during practical sessions, and provide a safe environment for repeated practice. Adaptive learning components were valued for their ability to pinpoint areas for revision and reinforce complex concepts, offering a personalised complement to in-class teaching. The positive reception at NTUA indicates strong potential for embedding HECOF into future courses, both as a preparatory stage before hands-on experiments and as a post-lab reinforcement tool.

6.3.5 Established Business

The HECOF pilots demonstrated potential benefits for established businesses, particularly those operating in sectors requiring specialised technical training, such as chemical engineering and related industries. By combining adaptive AI-driven learning with immersive VR simulations, the system offers a safe and cost-effective environment for practising complex procedures before applying them in real-world settings. This approach could help companies reduce training time, minimise operational risks, and improve knowledge retention among employees. While the pilots focused on academic contexts, the results suggest that HECOF's methodology could be adapted for workforce upskilling and continuous professional development, offering value to businesses seeking innovative training solutions.

7 Conclusion and Future Work

The HECOF project has successfully demonstrated the feasibility, adaptability, and educational value of an AI-driven adaptive learning and VR-based training environment, developed through a state-of-the-art hybrid methodology that combines Lean UX principles, agile co-development, and a phase-driven framework. Starting with co-design activities in WP2 and innovative learning design in WP3, the project advanced through iterative system development in WP4, culminating in structured pilot testing and evaluation in WP5. This process was supported by a robust mixed-methods evaluation framework, integrating technical performance analytics, pedagogical impact measures, and qualitative feedback from users to guide continuous improvement.

Both evaluation cycles confirmed that HECOF delivers tangible benefits to learners and educators. Students reported heightened engagement, improved conceptual understanding, and greater confidence in tackling complex chemical engineering processes. The VR laboratory simulations were praised for offering a clear, guided, and immersive preparation phase before physical lab work, reducing errors and increasing familiarity with procedures. The adaptive learning components proved equally valuable, enabling personalised revision, self-assessment, and targeted support for weaker areas. Educators highlighted the system's potential to enrich course delivery, facilitate data-informed teaching, and complement traditional laboratory practice. Feedback also generated concrete recommendations for enhancement, including refining VR interactivity, enabling AI to generate more specialised content, improving usability, and optimising question diversity and clarity.

The achievement of Milestones MS6 and MS7 reflects the successful implementation and assessment of the HECOF concept in authentic academic settings at NTUA and POLIMI. Beyond the immediate gains for participating students and instructors, the pilots demonstrated the approach's adaptability for broader integration into higher education and potential transferability to professional training contexts in industry. By validating both the technical feasibility and educational impact of immersive, adaptive learning, HECOF positions itself as a forward-looking solution that supports the EU's Digital Education Action Plan. As the project concludes, its outputs will feed directly into WP6 activities on communication, dissemination, and exploitation, ensuring that the HECOF methodology, system, and lessons learned can inform future innovation, adoption, and scaling in digital education and skills development.

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[5] Matěj Dvořák, et al (2024), "Virtual Reality Sickness and its Impact on the Effectiveness of Virtual Reality Training" https://journal.esrgroups.org/jes/article/view/5602

Appendix A – POLIMI PILOT#2 Report

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

PILOT #2 REPORT

This pilot explores how emerging technologies enhance understanding and engagement in complex scientific topics.

1. Users

Students participating in the pilot: 7

Due to the delay in the implementation of the HECOF system, it was not possible to involve the students of the planned course; thesis and PhD students, both females and males, were involved instead.

2. Pilot outline and tasks

The pilot took place in person in the VR lab at Polimi on June 5th, 9AM to 1PM. Students were asked to carry out a series of tasks:

- Part #1 tasks (desktop computer) – access to the dashboard, take the pre-course survey and diagnostic quiz and adaptive learning
- Part #2 tasks (desktop computer, VR headset and controllers)- VR
- Part #3 tasks (desktop computer) – post-course survey and diagnostic quiz

Pilot outline and tasks are detailed in Annex #1.

During the pilot Polimi staff from Chemistry department and METID collected implicit and explicit feedback from students and any other remarks.

In addition to the HECOF survey, an ad-hoc questionnaire was administered to collect more specific data on Think-Pair Share and VR, whose responses are provided in the Annex #2.

After the end of the pilot students were asked some targeted questions to enrich and clarify information. Questions covered: perceived effectiveness of adaptive learning and VR comparing to traditional learning approaches and main problems encountered.

3. Pilot testers' feedback

Adaptive learning experience

AI tutor

- the button is "AI", not "AI tutor" as it should
- students would expect to have it in the [Course: POLIMI Pilot] home page, instead of having it only after entering a topic
- it doesn't generate graphs or images (optional: getting them from the slides used to train the model). For this course having graphs would have been very useful
- scarcely accurate in the formatting of text (e.g. the system replaces bold formatting with asterisks)
- A student asked to generate a diagram, but the result was a bulleted list (instead of an image as expected by the user)
- Users reported that sometimes the multiple-choice questions already included the answer in it

Topic: recombinant technology

- a student answered correctly 3 open-ended questions; the system then administered 3 new questions, one of which was identical to one of the 3 questions previously answered

VR

- Locker room: some students couldn't grab the coat, others couldn't open the door. It seems it depends on a non-recognition between the controller and the virtual object. It was necessary to restart the app

- Some components cannot be grabbed with the controller
- When assembling the bioreactor, several users accidentally touched the component called “frame”, which came off and could not be reassembled anymore, but users could proceed with the use of the bioreactor even if visually the frame was not assembled with the other components, and the vessel was fluctuating in air.
- The steriliser tends to fall on its own and cannot be recovered (it should come back to the desk like the other components). Moreover after a while the steriliser doesn’t spray anymore if the user clicks on the controller
- Some elements in the locker room (e.g. door) feature wrong shadows

Perceived effectiveness of the VR application comparing to learning the same topic covered through a “traditional" approach

- The VR experience can complement practice in the physical lab, the latter being more complex (e.g. in the physical lab there are many objects which are not needed for experiments together with those which are needed, whereas the VR experience is more guided and with only the useful components available)
- It would be useful to have more options and a less guided modality (e.g. more options in terms of chemical components to be assembled)
- In the challenge mode, the orange shadow for the different components should be removed to test the students’ understanding in assemling the reactor.
- Students declared that time used was fine (they spent almost 40 minutes in total in VR, divided in 2 portions: experimenting the level 2 – guided – and level 3 – challenge)
- The experiment worked well and was realistic. Students ran the experiment more than once changing the parameters and seeing the different results (e.g. overflow, etc…)
- VR complements practice in the physical lab (and can introduce to lab practice), but it does not replace it

Perceived effectiveness of Adaptive learning comparing to learning the same topic covered through a “traditional" approach

- Open ended questions: sets of questions are slightly rephrased and iterated to reinforce learning (1st question more difficult – 2nd question easier – 3rd question): the added value of the 3rd question needs to be increased, especially when the learner answers the 2nd question correctly
- Some questions need to be revised (e.g. some contain the answer in the question or show unclear answers)
- It would be useful to add questions based on images and graphs
- Quizzes: useful to have supporting slides
- Open ended questions: their feedback is effective
- Hints: they are often too generic. It would be useful if, when a question is proposed a second time, it provides more indications
- Adaptive learning useful to support / reinforce what was already learnt; more difficult questions could help to prepare for the exam (in addition to use the system as a self-assessment tool which complements in-class “traditional” activities)
- A useful future development could be to use AI to generate more specialised quizzes and in-depth content

Main problems

- Getting oriented within the VR in terms of buttons and features. The ability of the users to move across the VR and to understand the buttons available would increase if an internal tutorial were offered
- Unexpected reactions of the VR, e.g. if a component is moved accidentally it does not come back to the previous location anymore

ANNEX #1 of POLIMI PILOT #2 REPORT

Document circulated among students for the pilot.

INTRODUCTORY INFORMATION

Objective of the Pilot

Welcome to the HECOF pilot! HECOF is a cutting-edge educational system that blends an AI-based Adaptive Learning System, and a Virtual Reality (VR) Laboratory.

This pilot explores how emerging technologies enhance understanding and engagement in complex scientific topics.

Have your say - your feedback will:

- Help refine a next-generation learning system.
- Contribute to the future of immersive and adaptive education.
- Empower you to master content in a flexible, personalized way.

We appreciate your curiosity, time, and effort. You are helping shape the future of learning!

The steps of your learning journey in HECOF

1. Mastery (AI-Adaptive Learning)

The AI evaluates your responses and adapts the path accordingly:

- May skip known concepts.
- Focus on weak areas.
- Optimize learning time through intelligent estimation of mastery.

2. Think-Pair-Share (AI-Supported)

Practice collaborative reasoning with the AI:

- Think: Reflect on recent correct and incorrect question.
- Pair: Compare or discuss with AI.
- Share: Share your reflection and refine your understanding.

3. Revision

Reinforce understanding through:

- Quick quizzes
- Summaries

4. VR Loop

Apply your knowledge in the VR Lab:

- Interact with simulations.
- Explore through VR experiments.
- Make informed decisions in a hands-on environment.

WHAT TASKS YOU ARE REQUIRED TO CARRY OUT

Part #1
Equipment: desktop computer

ask	uration
)pen the .txt file “HECOF account pilot” on the Desktop and copy/paste the username nd password between***	
:nter the HECOF system with the given credentials (**go to the platform**)	
ill in the Pre-survey on the top left area of the screen, then click on **[Esc > Go to the latform]**	mins
ill in the Pre-diagnostic quiz	0 mins
:lick on **[Fermentation processes and Biopharmaceuticals production] - Intake - itart**	

3a	Answer the questions and read the explanations if needed	-10 mins
3b	Click on **[Think-Pair-Share> Start]** Capture the screen with the explanation with ShareX (look for this icon on the application bar >Capture > Scrolling capture), save the image on the desktop and answer the corresponding questions https://forms.office.com/e/r47pGpSXgS Insert the you wish text by using **[Ask a question]** Capture the screen with the chatbot's response to your question with ShareX (Capture > Scrolling capture), save the image on the desktop and answer the corresponding questions https://forms.office.com/e/r47pGpSXgS	0-15 ıins
	ːlick on **[Polimi Pilot > Recombinant technology]**	0-15 ıins
a	Click on **[Mastery > Start]**, answer the questions and read the explanations if needed	
b	Click on **[Instructional content]** in the pop-up window, answer the questions and read the explanations if needed	0-15 ıins
c	**[Think-Pair-Share> Start]** Capture the screen with the explanation with ShareX (Capture > Scrolling capture), save the image on the desktop and answer the corresponding question: https://forms.office.com/e/r47pGpSXgS Insert the you wish text by using **[Ask a question]** Capture the screen with the chatbot's response to your question with ShareX (Ca > Scrolling capture), save the image on the desktop and answer the correspondir questions https://forms.office.com/e/r47pGpSXgS	0-15 ıins
d	Click on **[AI]** and interact with the AI tutor (e.g. request to generate a diagram or outline of a specific content; request to rephrase or explain a specific content)	

Part #2

Equipment: desktop computer + headset + controller grips

#	Task	Duration
1	Click on **[Exit > Polimi pilot]** Click on **[Perfusion bioreactors > Interacting with Bioreactor Technologies > VR - Start]** and navigate individually the VR with laptop and mouse	
2	Click on **[Exit > Polimi pilot]**, wear VR hearest and grips Click on **[Perfusion bioreactors > Interacting with Bioreactor Technologies > VR - Start]** Answer the corresponding questions ttps://forms.office.com/e/r47pGpSXgS and send the questionnaire	40-45 mins

Part #3

Equipment: desktop computer

#	Task	Duration
1	Fill in the **[Post-course diagnostic quiz]**	5-10 mins
2	Fill in the **[Post-course survey]**	6 mins

Thank you for being a part of this exciting pilot program! Your input and engagement will help create smarter, more human-centered educational experiences.

ANNEX #2 of POLIMI PILOT #2 REPORT

Data collected from the ad-hoc questionnaire on the Think-Pair-Share

What went well in the Think Pair Share?	What issues did you encounter in the Think Pair Share?	What went well in the Think Pair Share?	What issues did you encounter in the Think Pair Share?	What went well in the VR?	What issues did you encounter in the VR?
The chat experience with the AI bot	No issues encountered	I enjoyed the accuracy of AI bot in describing the curiosity I asked	No particular issues encountered	The assembling guide is really helpful and well explained as well as the feeling of being in a laboratory	Sometimes the cleaner did not work on all the pieces
The explanations are clear and useful, the chat is very useful.	Some questions were practically identical. Sometimes more than one answer looks correct.	Useful feedback	During the tests I got 4 loops of 3 questions each, one question repeated, whereas the other were very similar. At a certain point the page changed and strange symbols appeared. The Think Pair Share worked fine	clear instructions, nice evolution in 30 days	some objects, after falling, could not be remounted

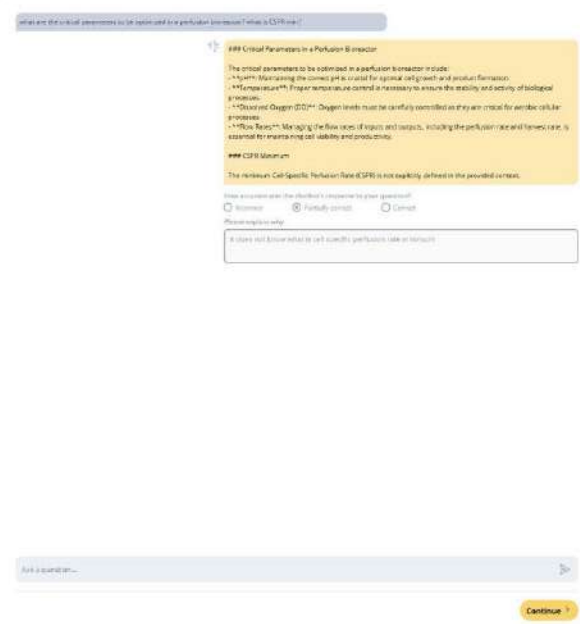
I liked the exhaustive explanation of the wrong answers I gave to learn better the things where I made mistakes.	It doesn't give me the feedback on my answer compared with the correct one: I don't remember what I selected for my answer, it shows me only the corrrect one and I can't compare the two answers.		Sometimes questions were repeated too many times. This helps in understanding better the concepts, but is also annoying writing3/4 times the things.	It was fun, interesting for the guide voice that helps you in knowing what are the different instruments and parts to mount.	Sometimes the ethanol for disenfection doesn't work.
The AI reply is good (as far as I know) but a bit slow, I'd prefer something similar to chatGPT where the reply is given "online" instead of waiting and receiving the answer as a full block after the elaboration.	The formatted text in the replies of the AI are not really formatted (e.g. the titles that should be bold appear as **Title** instead of being bold)	Is good to see also the correct answers I gave with a better explanation about the topic	Sometimes the answers to the questions were a bit non-sense (e.g. "which technique uses cationic polymers for DNA delivery?" correct answer: "cationic polymers"). I'd prefer to see also the wrong answers to be aware of my lack of knowledge (and to treat them like the correct answers, i.e. with better explanation of the topic)	Very interesting to have the slides on one side, the results on the opposite side and the possibility to simulate different environments with the "on-line" results. Steps are well cleared explained. Very good to see every part of a bioreactor, different from the figures on the books.	If you change or unmount something is very difficult to reassemble the system. It needs two/three times before getting confidence with the instrument because some commands are not so intuitive (e.g. grab the coat or push the buttons). Sometimes it was difficult to grab the things.
I liked the suggestions to make you understand what was the right answer, when you did a mistake.	I did not like much the chatbot, which is not so specific and partially answered my question	I liked the explanations of the answers	the questions were really similar and they did not respect the levels of difficulty	I liked the different components details and the assemblying and also the simulation	the spray usually does not work, if you chnage the position of an object you cannote reposition it
the system answer me correctly satisfying my requests	i didn't get issues	the system helped my providing suggestions about how to improve my knowledge about the subject	no isssues	the perfusion reactor simulation	the sanitizer fals inside the lab desk multiple times without the possibility of take it back
It was interesting and useful chatting with AI and asking questions. The concept were synthetized very well.	No issues	Very interesting and very useful hints	no one	It was very helpfull and fun to experience the assembling of a bioreactor and the simulation of an experiment and then the graphic illustrating the difference between the types of bioreactor	It's difficult to understand at the beginning how to move inside the world, sometimes the lab was very far away and different times I was out of the area. Also the object were very far away from me to grab it.

ANNEX #3 of POLIMI PILOT #2 REPORT

Screenshots made by users during the Think-Pair-Share

See screenshot below:

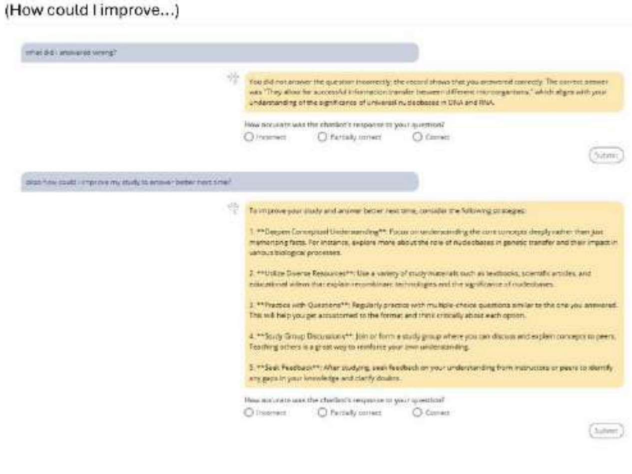
- as in the AI tutor, asterisks replace bold formatting (it reduces readability especially when in long unordered lists)
- answer considered partially correct



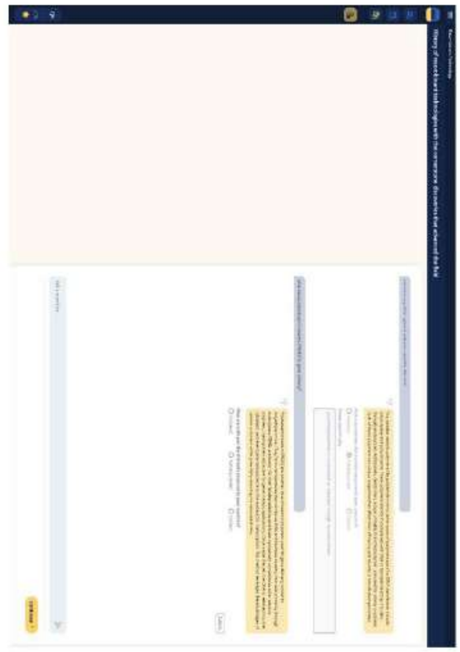
See screenshot below:

- the first AI-based answer expressed unclearly (What did I answer..)
- the second AI-based answer seems to have lost the context related to the previous question, hence providing only very general, non-content-related tips

(How could I improve...)



See screenshot below answer considered partially correct



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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.

(*) *Dissemination level. -Public — fully open (automatically posted online) Sensitive — limited under the conditions of the Grant Agreement EU classified —RESTREINT-UE/EU-RESTRICTED, CONFIDENTIEL-UE/EU-CONFIDENTIAL, SECRET-UE/EU-SECRET under Decision 2015/444*

Co-funded by
the European Union

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