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Article

Bridging academia and industry in the era of Industry 4.0 by means of the triple helix: The PLANET4 initiative

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Abstract: Practical Learning of Artificial Intelligence on the Edge of Industry 4.0 (PLANET4) is a cross-disciplinary initiative funded by the European Commission under the Erasmus+ program that embodies the triple helix model of collaboration between academia, industry, and administration. It aims to bridge the gap between academic teaching and practical applications in the context of Industry 4.0. PLANET4 focuses on developing hard skills in artificial intelligence, industrial Internet of things, and cloud and edge computing, along with the soft competencies required to manage changes in the industrial ecosystem. It involves three phases: (1) training needs analysis, taxonomy development, and workshop design; (2) collection of best practices and training material design; and (3) implementation of the PLANET4 learning course. This paper presents the materialization of these phases into a blended learning course, highlighting the integration of the triple helix model and the European Commission's support for academia-industry collaboration with the aim of improving education quality and promoting Industry 4.0 innovation in Europe.

Keywords: Industry 4.0; Erasmus+; triple helix; blended learning; academia; industry; policy; innovation

1. Introduction

The advancement of the industrial sector, together with the transition to Industry 4.0, has presented a significant challenge: education systems are not equipped to meet the educational needs of tomorrow's workforce. There is a growing gap between the needs of industry and the readiness of professionals to operate effectively in Industry 4.0. According to Horvath and Szabo (2019), new skills and competencies required by new technologies need to be integrated into education systems (Stadnicka et al., 2022). It is projected that by 2025, Germany, a leading country in advanced production technologies, will experience a significant shift due to the adoption of Industry 4.0 technologies. As a result, approximately 610,000 assembly and production jobs are projected to decline, while there will be a notable increase of approximately 960,000 jobs in the fields of data science and information technology (Lorenz et al., 2015). In the context of Industry 4.0, companies are seeking experts with multidisciplinary skills, not traditionally educated engineers, which can help factories create and improve machine and device capabilities using knowledge and skills in embedded and distributed system development (Pejyc-Bach et al., 2020). In addition to this, professionals with soft skills to work in this context are of high importance. In other words, professionals in Industry 4.0 need to know how to communicate, work within groups, be creative, and solve complex problems (Rampasso et al., 2020). Addressing the challenge of adequately preparing students to work in this reality poses a challenge that must be actively tackled.

It is evident that, in this context, universities, as education providers, are not in a position to respond to the problem on an individual basis. Higher education institutions increasingly need to collaborate with other stakeholders to reduce the Industry 4.0-related skills gap (Milken Institute, 2021). Rampasso et al. (2020) state that, "Partnerships between companies and universities should be sought". In the meantime, "Forty-five percent of businesses see funding for skills training as an effective intervention available to governments seeking to connect talent to employment" (World Economic Forum, 2023). That is where a triple helix model comes into focus as a key strategy for integrating these demands. The collaboration of three players: industry, academia, and government, enables to overcome the encountered barriers for the realization of the true potential of Industry 4.0 (Majumdar et al., 2021). The education sector is no exception to this. Education systems face the complex challenge of staying relevant and financially supported in a time of rapid market dynamics. Governments and their funding bodies stimulate new types of research training and promote policies that focus on broader sets of skills (Yang, 2022). As data provided by the US Department of Labour show, the US experienced unusual long-term job growth between 2010 and 2019, even as the Internet of Things revolution was ongoing. This is partly due to successful government efforts to address the need for scalable skills and to prepare the workforce for future challenges (Milken Institute, 2021). In the past, industrial development was driven primarily by industry and governments (Yang, 2022). Nowadays, universities are also making major contributions to industrial development. This change is due to the increasing dependence of government and industrial activities on the advancement of knowledge.

In response to the defined necessity of strengthening the ties between the players of the triple helix model, this study presents the blended learning course developed by the initiative PLANET4 (https://www.planet4project.eu/), which demonstrates how the model of university–industry–government interaction works in practical application. PLANET4, a project funded by the European Commission under the Erasmus+ program, focuses on developing hard skills in artificial intelligence (AI), industrial Internet of things (IoT), and cloud and edge computing (CEC), along with soft competencies required to manage changes in the industrial ecosystem to respond to the needs of Industry 4.0 transformation. By demonstrating this case, the integration of the triple helix model and government (that is, the European Commission) support for academia-industry collaboration will be highlighted. In this context, this paper aims to outline the concepts and requirements for upskilling students in the field of Industry 4.0. The key research question addressed in this study includes an analysis of the effectiveness of an academic course designed for undergraduate and graduate students to address the gap between academic teaching and practical application in the context of Industry 4.0. Specifically, this research aims to answer the following specific questions:

1) Are the designed contents suitable for the acquisition of skills, both soft and hard, to add value in Industry 4.0 scenarios?
2) Up to what extent mastering the hard skills associated to the technical disciplines of Industry 4.0 (i.e., AI, IoT or CEC) helps to master its associated soft skills (i.e., Innovation and Change Management)?
3) Which of the topics associated to Industry 4.0 (i.e., AI, IoT or CEC) seems to present the most difficult content for students?

In contrast to similar research, which tends to rely either on prior traditional hard skills training (Yoshino et al., 2020) or requires the development of entire university programmes (Justason et al., 2018; Savu et al., 2021), this paper proposes a pragmatic and lightweight approach. Our method offers seamless integration into existing curricula, sparing institutions the burden of significant restructuring, while ensuring comprehensive multidisciplinarity through the introduction of key Industry 4.0 technologies, enriching students' skills and aligning programmes with current industrial needs.

The remainder of this paper is organized as follows. Section 2 introduces the previous theoretical and empirical findings motivating this work. Section 3 outlines the research method by highlighting the key components and methods of the PLANET4 course. Section 4 presents cases of how the course has been piloted in four different European countries and the key findings and open issues. Section 5 presents and discusses the results. And the final remarks, which conclude the study, are presented in section 6.

2. Related work and problem formulation

Before developing the course, the PLANET4 Consortium conducted a series of surveys, semi-structured interviews, and literature reviews to perform a training needs analysis among (i) students, (ii) academia, and (iii) companies in the fields of artificial intelligence (AI), Internet of things (IoT), and edge computing (EC). The PLANET4 consortium has published several scientific manuscripts regarding the training needs of these target groups, which provide a literature review, methodology and further analysis: for students, refer to (Paśko et al., 2022); for academia, refer to (Dec et al., 2022); and for companies (or industry), refer to (Stadnicka et al., 2022). The following subsections describe the results of the surveys and interviews regarding the training needs of these stakeholders, and the final assessment.

2.1. Students

Students were asked about their fields of study, their knowledge of each of them, and the tools (e.g., software) they used. A total of 467 students answered that they pursued their studies in fields related to AI, IoT, and EC. Among them, several have pursued studies in more than one field. **Figure 1** shows the number of students declaring knowledge in one or more than one field.

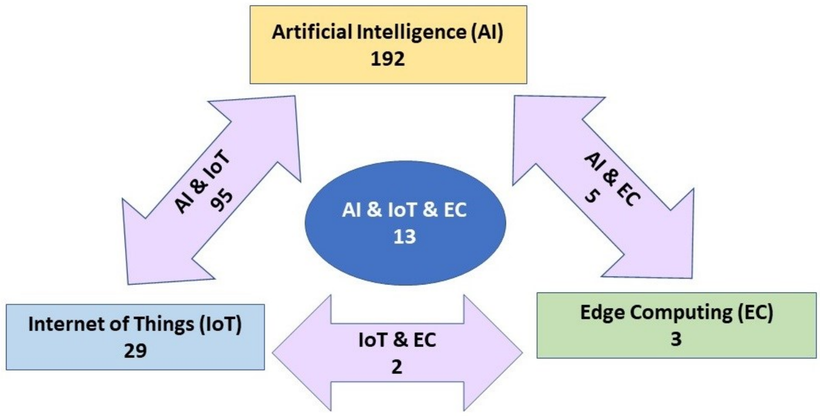

Figure 1. Number of students declaring knowledge of AI, IoT, and EC.

The surveys and interviews further asked students about their expertise in the subareas of these three areas (AI, IoT, and EC). The students' needs are summarized in the following sections for each subarea.

2.2. Artificial intelligence (AI)

The survey showed that students needed improvement in practical and real-life training and AI tooling, but they also expressed the need for a solid AI foundation.

During class training, they were overwhelmed by the information provided during one class. Moreover, they emphasize the need for a better understanding of the mathematical foundations of AI and a better explanation of AI theoretical issues to understand the concept and foster intuition, particularly in the initial stage of AI education. They proposed initiating basic AI learning as soon as during high school. They expressed that a site providing an environment to experiment with AI and a well-organized online site to work on projects for self-study or group work would be valuable.

There is a significant demand for practical AI training. Students need teaching and involvement in partnership projects that apply AI in different fields (cognitive computing, robots, chatbot development, computer vision, healthcare, text mining, natural language processing, finance, risk prediction, game development, time-series analysis, and signal processing) and in processes such as monitoring, deliveries, scheduling problems, cognitive systems, and robots. Moreover, there is a need to familiarize students with the business context of the analysed data and the implementation issues of the developed models in the business field.

Finally, they expressed the need for training in AI-related tooling and the aspects surrounding AI techniques. With regard to tooling, they express their desire for better infrastructure (hardware) with computing power and sophisticated and modern AI software and tools and highlight the need for training in Python, Jupyter Notebook, and MATLAB. Regarding the aspects surrounding AI techniques, students convey the necessity of training in data preparation and real-life datasets.

2.3. Internet of things (IoT)

The survey on IoT showed that students emphasize the need for practical learning in IoT, although they also expressed the need for a basic understanding of the essence of IoT.

They need training in concepts such as privacy, operating system, energy consumption, circuitry, practice on sensors, practice on hardware, Machine 2 Machine (M2M) industrial protocols, distributed computing over IoT networks and IoT maintenance. In addition, education in the field of Application Programming Interface, data processing, data transformation, and big data management is most helpful in mastering IoT.

Finally, they wanted a better availability of IoT in the content of courses at universities (introducing subjects at universities entirely dedicated to IoT) and IoT infrastructure and labs, as they expressed a lack in teaching the application and use cases of IoT and when to choose a solution over another.

2.4. Edge computing (EC)

The survey on EC showed that students were mainly concerned about the lack of theoretical teaching in aspects of EC. Nevertheless, they also pointed out the need for emphasising EC applications. This may be (we suggest) because EC is an emerging field and there are fewer materials on EC than on AI and IoT.

Students expressed the need for education in different fields in the context of EC, including privacy and security, scalability and reliability, speed and efficiency, mobile EC, fog computing, service composition, and service-oriented computing. They highlighted their learning needs in designing and implementing EC middlewares, algorithms, and solutions, thus broadening their hardware and software skills.

Finally, the fields of application highlighted by students were autonomous products, autonomous production planning systems, augmented reality, and autonomy in energy networks.

2.5. Academia

A survey and semi-structured interviews with academics were also conducted. Of the 144 respondents, 86 taught either AI, IoT, or EC. The questions ranged from the area and subareas each person was teaching to how they did it (e.g., project-based), the tools they used and taught (e.g., programming languages), and the difficulties they encountered.

The general impression is that AI is a branch of science that has a large participation in teaching programs, where the main method of teaching is a lecture. Students are taught different AI models, techniques, and applications.

In the case of IoT, we observed that there were fewer academic professionals compared to AI. Teaching programs could contain more issues concerning security and focus on developing practical skills.

Finally, EC is weakly presented in teaching programmes. Academics need to gather business requirements and develop related courses.

We noted that academics need to focus on aspects that overlap with those highlighted by students. Academics need to focus on presenting examples and real-life applications of AI, specifically in the subareas of computer vision, natural language processing, and cognitive computing in industry and Industry 4.0. They also need to focus on data mining and business understanding.

Regarding IoT, teachers need to focus on security issues and present the deployment of IoT products and technologies while discussing how to process the data gathered by intelligent sensors in IoT deployment.

In the case of EC, new study programs in the field of edge computing in cooperation with industry partners must be developed.

Finally, real-life experiences in the form of internships or joint projects would motivate students in all the explored areas.

2.6. Companies

PLANET4 also conducted surveys and interviews to gather information about companies' training needs. The results highlighted the following.

One key area where support is needed is the implementation of integrated IT systems, specifically those of Manufacturing Execution System (MES) and MIS-class, which boast advanced functionalities. Additionally, companies are looking for guidance when it comes to adopting automatic data collection systems that streamline their operations.

Another crucial aspect is the integration of intelligent condition monitoring systems. These systems are particularly valuable when they can predict failures in processes and machines, allowing businesses to be proactive in addressing issues. Companies also recognize the importance of sharing knowledge about practical methods for implementing integrated platforms, which enable seamless data exchange between IT systems and key stakeholders such as suppliers and clients.

In this era of rapid technological advancement, businesses need to remain informed about the latest IT systems, AI, and other Industry 4.0 technologies. Support for knowledge transfer is essential to ensure that these innovations are effectively implemented at the operational level. Furthermore, companies must invest in the development of both technical and soft competencies for their current and future employees.

Information obtained from companies about their needs (Stadnicka et al., 2022) constituted input to the course design process, which will be discussed later in this work. The topics identified by the companies were included in the teaching materials. Depending on how important the topic was for the industry, more or less space was devoted to it in the course. The courses were designed with the active participation of industrial partners who verified the course program as well as the developed materials to meet industry expectations.

2.7. Final assessment

After assessing the needs of students, academia, and companies via surveys, interviews, and bibliographic sources, we concluded the following.

The need for training arises because of several factors. First, there is a disparity between what academics teach and what students actually know. This can result in situations in which students' knowledge falls short of expectations based on academic teaching. One possible cause for this discrepancy is the ineffectiveness of learning tools. Although lectures are commonly used by academics, students consider them to be the least effective. Instead, they found project-based learning and problem-based learning to be the most impactful methods.

However, there are instances in which students possess knowledge beyond academic teaching. This can be attributed to the omission of up-to-date topics in the educational programs. However, with easy access to information on innovative technologies, students can learn from sources other than university courses. They can also take advantage of the increasing availability of online courses, many of which are open and free. This allowed students to acquire knowledge independently. Online resources such as videos also contribute to their learning. However, a pertinent question arises: How can students discern the quality and worth of courses available on the internet? What are the consequences of students possessing inadequate knowledge and applying it to real-world scenarios?

To address these concerns, it is crucial to develop new courses or enhance the existing ones to ensure that students receive valuable knowledge during their education. This requires motivating academics to improve their courses and providing them with case studies that facilitate better explanations of industrial problems and solutions involving AI, IoT and EC. Additionally, relevant topics related to current industrial challenges should be incorporated into educational programs to keep them up-to-date.

Therefore, in the frame of the PLANET4 project it is proposed the use a Blended Learning in teaching process and a course in the triple helix model for Industry 4.0 was developed and then implemented. The expected learning outcomes for the course and the pilot implementation process in four European universities (Poland, Spain, Greece, Italy) are presented in the following sections of this work, together with the results of the course evaluation by the students participating in it.

As part of the research, industrial challenges were identified (Stadnicka et al., 2022), which were the basis for designing case studies presenting challenges and ways of solving them in specific companies, as well as challenges that students solved under the supervision of a teacher during the course. This provided students with the opportunity to learn about different challenges and how to deal with them, and to have a personal hands-on analysis of a challenge to better understand the methodology of analysis and solution finding.

3. Materials and methods

The research method employed in this study involves the implementation of a specific course designed to evaluate the effectiveness of addressing the gap between academic teaching and practical application in the context of Industry 4.0. This section outlines the course description and structure, which serve as the basis for assessing the effectiveness and practical applicability of the PLANET4 initiative within the Triple Helix framework in Industry 4.0 education.

The PLANET4 course project follows a comprehensive approach that encompasses hard skills in artificial intelligence, industrial Internet of things, and cloud and edge computing, as well as soft competencies necessary for managing the changes introduced in the industrial ecosystem. It is structured in a manner that allows for the integration of theoretical knowledge and practical application, facilitating a holistic understanding of Industry 4.0 concepts and their implementation in real-world scenarios.

This section outlines the key components and modules of the course and highlights the learning objectives, methodologies, and activities involved. Furthermore, it presents the course structure, including the sequence and duration of modules, workshops, and assessments. By employing a blended learning approach that combines online resources, virtual sessions, and hands-on workshops, the course aims to provide an immersive and interactive learning experience for participants.

The effectiveness of the course will be evaluated using various metrics, such as participants' performance, engagement, and feedback.

3.1. Course organization

The overall goal of the PLANET4 course is to provide effective training on the hard and soft skills necessary for professionals to add value to Industry 4.0 scenarios. In this regard, the course is articulated into three teaching areas:

a) Teaching area 1: Fundamentals of Industry 4.0. This unit introduces the Industry 4.0 concept and provides training on the fundamentals of its enabling technologies: artificial intelligence, cloud and edge computing, and Internet of Things.
b) Teaching area 2: Innovation and change management. This unit provides training on the required soft skills to add value in Industry 4.0 scenarios: collaboration in multidisciplinary teams, human-centred design and lean strategies, and fast pretotyping.
c) Teaching area 3: How to solve Industry 4.0 challenges. This unit provides hands-on training on how to identify and analyse industrial needs, propose feasible technological solutions to solve industrial challenges, and appropriately structure the proposed solutions. Thus, students are asked to solve Industry 4.0 challenges, first individually and then in groups.

3.2. Expected learning outcomes

The expected learning outcomes to be gained by students upon completion of the course are as follows:

- LO1. Students will be able to define Industry 4.0 and explain its impact on the manufacturing industry and society.
- LO2. Students will have a solid understanding of the enabling technologies of Industry 4.0, including artificial intelligence, cloud and edge computing, and Internet of things.
- LO3. Students will be able to use data mining and analysis tools to extract insights from large datasets and make data-driven decisions for Industry 4.0 environments.
- LO4. Students will be able to understand the challenges of designing and implementing cloud-based and local-based (i.e., edge-based) automated solutions to optimize production systems and other industrial processes.
- LO5. Students will have a good understanding of IoT and IIoT technologies, and their applications in Industry 4.0.

- LO6. Students will be able to identify and analyse industrial needs, propose a fast prototypal way to test solutions to solve industrial challenges, and appropriately structure the proposed ideas.
- LO7. Students will have the soft skills necessary to add value in Industry 4.0 scenarios, including collaboration in multidisciplinary teams, applying human-centred design, and using lean strategies to propose innovative solutions.

3.3. Course topics and learning methodology

The course is designed to be used using the blended learning methodology, which combines traditional in-presence teaching with online learning activities. This methodology provides a flexible and highly customizable course that combines the benefits of both face-to-face and online learning in terms of student engagement and effective content delivery. In this regard, each teaching area uses different learning methodologies and activities:

- Teaching area 1: Fundamentals of Industry 4.0. This teaching area covers the following topics: Introduction to I4.0, data science, artificial intelligence and machine learning, Internet of things and industrial IoT, and cloud and edge computing. The lessons associated to these topics have been designed to be implemented using self-paced learning methodology. That is, all the course materials (i.e., video-lectures, supporting documents, assignments, assessment activities) in this teaching area are available for students and delivered through an e-learning environment (e.g., Moodle) so that they can be asynchronously consumed at their own time according to their own needs, learning styles, and preferences. To accommodate students with diverse backgrounds and learning styles in the course, using this methodology in the initial part of the course allows for a more personalized approach, giving students the freedom to spend extra time on concepts that they find more challenging and progress more quickly through topics that they find easier.
- Teaching area 2: Innovation and change management. This teaching area covers the following topics: Innovation and the product, design thinking, human-centred design, pretotyping, and a final wrap-up presentation. These lessons have been designed to be implemented using the flipped-classroom methodology. In this way, the traditional roles of classroom activities and homework are reversed, so students are assigned to watch or read instructional materials (such as videos, articles, or podcasts) prior to class, which frees up class time for more interactive and collaborative activities such as group discussions, problem-solving exercises, and projects. The contents designed for this teaching area have been designed to be delivered in either online (i.e., e-learning) or in-presence scenarios.
- Teaching area 3: How to solve I4.0 challenges: These lessons challenge students to conduct brainstorming sessions and hands-on activities by exploiting the benefits of teamwork using the problem-based learning approach delivered in an in-presence environment.

The connection between these teaching areas and the learning outcomes proposed in section 3.2 is exhibited in **Table 1**.

Table 1. Connection between teaching areas, their associated topics, and the learning outcomes of the course.

Teaching area	Topic	LO1	LO2	LO3	LO4	LO5	LO6	LO7
Fundamentals of Industry 4.0	Introduction to I4.0	X						X
	Data science, artificial intelligence and machine learning		X	X	X			
	Internet of things and industrial IoT		X			X		
	Cloud and edge computing		X	X				
Innovation and change management	Innovation and the product							
	Design thinking							
	Human-centred design						X	X
	Pretotyping							
	Final presentation							
How to solve I4.0 challenges	Individual challenge						X	X
	Team challenge							

3.4. Estimated workload

The estimated workload of each one of the teaching areas is detailed in **Table 2**.

Table 2. Estimated workload of each teaching area.

Teaching area	In-presence hours[1]	Study hours[2]	Overall hours	Comments
Fundamentals of Industry 4.0	19	17	36	Each one of the lessons of this teaching area are designed to require 1 h of workload to be appropriately read. Additionally, each one of the lessons (except lessons 1 and 4) are designed to require 1 extra hour of study time to solve the associated learning activities.
Innovation and change management	14	21	35	Each one of the lessons of this Teaching Area are designed to require 2 h of students' workload (except the first and the last lessons that should last 1 h). Additionally, three lessons (21, 23, and 25, see **Table 3**) are designed to require 7 extra hours of study time to solve the associated learning activities.
How to solve Industry 4.0 challenges	7	21	28	The hands-on activities associated with this Teaching Area motivate students to spend a lot of time out of the regular hours.

[1]In-presence hours consider the number of hours that students spend on attending the lectures and/or reading the training materials.
[2]Study hours consider the number of hours that students spend on solving the assignments, conducting assessment activities, and studying the training materials.

Table 3 contains the summarised details regarding the implementation of the pilot action. To keep the information concentrated in one table, we visualise each institution's implementation time period with a different cell colour.

It can be seen that the whole PLANET4 course estimates 99 h of students' effort to successfully meet the expected learning objectives, which corresponds to 4 ECTS.

Table 3. Detailed implementation plan for each university.

Teaching area	Topic	Lessons	Time period
Fundamentals of Industry 4.0 (TA1)	Introduction to I4.0	1–4	3/10/22-16/10/22
			31/10/22-6/11/22
			28/10/22–13/11/22
			5/12/22-10/12/22
	Data science, artificial intelligence and machine learning	5–9	3/10/22-23/10/22
			7/11/22-13/11/22
			7/11/22–27/11/22
			12/12/22-16/12/22
	Internet of things and Industrial IoT	10–14	17/10/22-6/11/22
			14/11/22-20/11/22
			21/11/22–27/11/22
			9/01/23-13/12/23
	Cloud and edge computing	15–19	7/11/22-27/11/22
			20/11/22-27/11/22
			28/11/22–9/12/22
			16/01/23-20/01/23
Innovation and change management (TA2)	Innovation and the product	20	17/10/22-23/10/22
			28/11/22-11/12/22
			10/12/22–16/12/22
			20/09/22-29/09/22
	Design thinking	21–22	24/10/22-30/10/22
			12/12/22-21/12/22
			17/12/22–23/12/22
			03/10/22-06/10/22
	Human-centred design	23–24	31/10/22-6/11/22
			09/01/23-22/01/23
			24/12/22–13/1/23
			10/10/22-14/10/22
	Pretotyping	25–26	7/11/22-13/11/22
			23/01/23-29/01/23
			14/1/23–20/1/23
			17/11/22-21/11/22
	Final presentation	27	14/11/22-20/11/22
			02/02/23
			20/1/2023
			26/10/22
How to solve I4.0 challenges (TA3)	Individual challenge	28–29	3/10/22-30/10/22
			30/01/23-03/02/23
			23/1/23–17/2/23
			Not done
	Team challenge	30	14/11/22-27/11/22
			30/01/23-22/02/23
			6/2/23–22/2/23
			24/03/22

PRZ - POLAND | URL - SPAIN | UOI - GREECE | UNIPI - ITALY

3.5. Proposed implementation

The PLANET4 course was created with the intention of being adaptable to various learning environments and easily replicable by universities that are not partners in the PLANET4 consortium. As a result, there is a great deal of flexibility when it comes to organizing and implementing course materials, whether in full (i.e., the three teaching areas) or in part (i.e., some teaching areas or even some lessons). The course's teaching areas have been designed to be self-sufficient and autonomous, making it possible for other universities to reuse them with very little (or no) effort on decoupling them from the remainder of the course. In addition, this gives high flexibility in the order in which content is delivered to students.

Nevertheless, there is a logical order for content organization. That is, the course should start with the fundamentals of Industry 4.0, continue with the innovation and change management teaching area, and finish by putting everything together solving Industry 4.0 challenges.

The first teaching area can be grouped into four knowledge modules: Introduction to Industry 4.0, artificial intelligence and machine learning, industrial Internet of things, and cloud and edge computing. Although the first module should precede the other ones, the last three modules can be implemented either sequentially (regardless of their order) or in parallel. During the pilot course, we saw that allowing students to take the three modules in parallel was a little bit overwhelming for them (i.e., they seemed a little bit scared of the amount of work that they had to face at a time). Therefore, we suggest the sequential implementation of these modules.

As far as the second teaching area is concerned, it can be grouped into five knowledge modules: Innovation and the product, design thinking, human-centred design, pretotyping, and final case presentation. As these knowledge modules are cumulative, it is strongly recommended that they be implemented sequentially. It is worth noting that this final case presentation will integrate the developments carried out during the whole teaching area.

Finally, as far as the third teaching area is concerned, it is advised that students first face the challenge of solving individually and later export what they have learned in the team challenge solving.

4. Case

The university partners (with the collaboration of Industrial partners) of the PLANET4 project were responsible for designing and developing a wealth of didactic material to be offered to the European I4.0 related parties (academia, companies and public bodies), so as to skill and/or reskill the workforce and inform policymakers in the emerging I4.0 related technologies and their application in modern societies. The didactic material was uploaded to the project's e-learning platform (Moodle) and exhaustively tested by engineering (last semester) and master students of the four university partners during a whole semester within the context of a pertinent course before its official launch.

The four university partners that carried out the pilot action were as follows:

d) Rzeszów University of Technology (PRZ)—Poland

e) Ramon Llull University (URL)—Spain
f) University of Ioannina (UOI)—Greece
g) University of Pisa (UNIPI)—Italy

The e-learning platform testing constitutes a prerequisite and a valuable procedure for ensuring the proper quality of the offered tool. Besides, it is a means of obtaining real feedback and useful insights into the core of the process so that to improve the weaknesses identified through it. In other words, it represents the touchstone for coming to a conclusion regarding the intervention's success. Roughly speaking, the benefits of the pilot testing of an e-learning platform are:

- Identifying and fixing technical issues.
- Ensuring compatibility with different devices and browsers.
- Ensuring content accuracy.
- Assessing user experience (usability, accessibility, and platform navigation).
- Ensuring security.

The partner organisation responsible for designing, developing, and maintaining the e-learning platform (URL, Spain) collected the names and emails of all the participating students, alongside the teachers/tutors of each university, to create accounts and provide the corresponding credentials for signing in.

Since the initial intention of the course design was to be flexible, scalable, and adaptable, the implementation of the pilot action was realised with different sequences in the participating universities. The proposed implementation plan was rather a suggestion and was not strictly followed. Nevertheless, all the organising parties complied with the general conditions and prerequisites. Below, a categorisation of these conditions/prerequisites is attempted:

- The students' target group was engineering (last semester) and master students, given that they acquire basic knowledge and familiarisation with the course content.
- At least two teachers/tutors with experience in I4.0 technologies should be involved from each university to provide guidance and supervise the progress.
- Each university partner should involve at least 30 students in the pilot process to reach the number of 120 students in total.
- The engagement with Teaching Area (TA) 3 must follow that of TA1 and TA2. TA3 is largely based on the terms and methods described within the former. As a consequence, their conclusion is imperative before proceeding to TA3 in order for the students to have already become acquainted with and assimilated the terminology, the different technologies, the use cases described, and the human-centred problem-solving. To sum up, there lies a logical sequence that should not be overlooked.
- The finalisation of TA2 may proceed after that of TA1's, or they can be implemented in parallel since there was no direct correlation between them.

As already mentioned, the platform ought to have been tested by at least 120 fully engaged students in order for the process to be granted with success. The number of students who ultimately actively participated in the process much surpassed the initial target. The table below shows the number of participants from each university (country). There are two columns regarding the number of participants: those that, in the first place enrolled, and those that were actively engaged in the process. The latter can be easily determined after checking who has completed the self-assessment quizzes and presented his/her project.

Table 4. Number of participants from each university.

University/Country	Number of enrolled students	Number of actively participating students
PRZ/Poland	57	55
URL/Spain	43	34
UOI/Greece	39	34
UNIPI/Italy	45	33
TOTAL	184	156

The **Table 4** demonstrates that the vast majority of the students were much interested in the courses and their content. Even after facing some difficulties, most of them achieved reaching the end of the pilot action. Concerning the students who abandoned the procedure in the middle, some claimed personal issues, while others referred to their inability to follow the course pace.

The designed course was assessed through evaluation questionnaires completed by students after each TA, which comprised of closed- and open-ended questions. Specifically, in TA1, close-ended questions were grouped into two categories: assessing course satisfaction and assessing attendance motivation. For subsequent TAs, a third group of questions was also imposed regarding the "Effectiveness of the Course". Concerning the open-ended questions, TA1 featured four questions, TA2 had three, and TA3 had five. Detailed questionnaires can be found in the Appendix.

Quantitative analysis of the close-ended responses utilized a 5-point Likert Scale, with **Figure 2** illustrating the average scores across the three evaluated aspects for each TA. For a comprehensive breakdown of individual average scores and response distributions for each question, see Appendixes A–C.

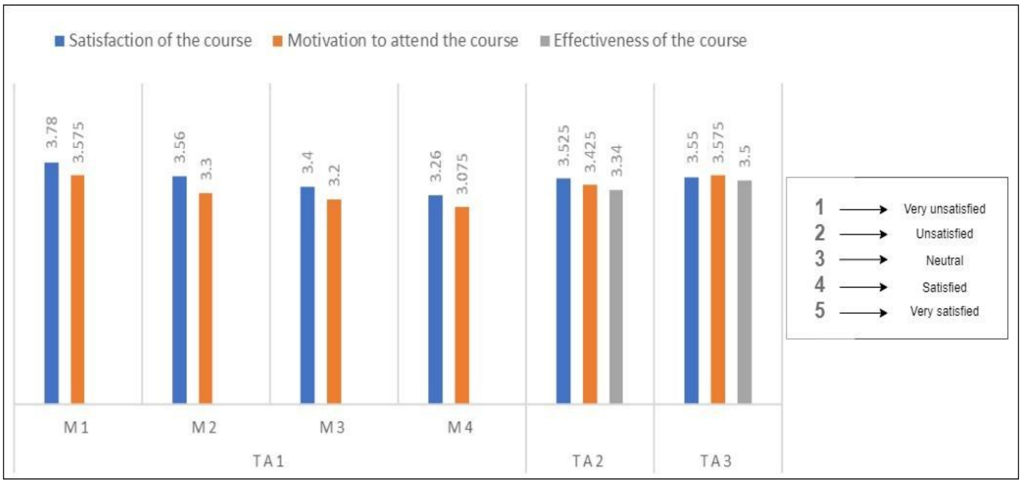

Figure 2. Evaluation results for each TA and each Module of TA1.

Overall, the results showed that students generally felt satisfied with the course components and were granted above-average grades. Specifically, certain areas of TA1, such as content relevancy, clarity of video lectures/training materials, and the module's usefulness for students' careers, consistently received higher evaluations.

In addition, while questions regarding attendance motivation and course effectiveness generally scored slightly lower than those focused on satisfaction, they did not detract significantly from the overall positive reception of the course. Furthermore, an interesting finding can be observed when focusing on the grades of every module in TA1. Both the levels of satisfaction and motivation gradually decreased, which may reveal the underlying fatigue in completing all tasks at the expected time. This should be heavily considered, and proper adjustments should be made to reduce the workload burden or extend the available time.

The internal consistency and reliability of the close-ended questionnaire items across the different modules and teaching areas were quantitatively assessed using Cronbach's alpha coefficient (Cronbach, 1951). This measure, calculated using the formula:

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K} \sigma_{Y_i}^2}{\sigma_X^2}\right) \tag{1}$$

where K is the number of items, $\sigma_{Y_i}^2$ is the variance of each item, and σ_X^2 is the total variance of the summed items, indicated whether the questions within each course aspect—satisfaction, attendance motivation, and effectiveness—were consistently measuring the same characteristics.

Table 5. Cronbach's alpha coefficients for satisfaction, motivation, and effectiveness across various teaching areas and modules.

Teaching areas (TAs)	Modules	Dimension	Cronbach's alpha
Teaching area 1	Module 1	Satisfaction	0.867
		Motivation	0.955
	Module 2	Satisfaction	0.958
		Motivation	0.973
	Module 3	Satisfaction	0.943
		Motivation	0.962
	Module 4	Satisfaction	0.955
		Motivation	0.958
Teaching area 2	-	Satisfaction	0.952
		Motivation	0.936
		Effectiveness	0.95
Teaching area 3	-	Satisfaction	0.941
		Motivation	0.94
		Effectiveness	0.964

As detailed in **Table 5**, the satisfaction dimension in TA1-Module 1 scored a Cronbach's alpha of 0.867, while the motivation dimension scored an alpha of 0.955. Subsequent questionnaires within this teaching area also demonstrated high reliability, with alphas ranging from 0.943 to 0.958 for satisfaction, and 0.962 to 0.973 for motivation. Questions on effectiveness in TAs 2 and 3 showed alphas of 0.95 and 0.964, respectively, with the satisfaction and motivation dimensions in these areas similarly consistent, showing alphas of 0.952 and 0.936 for teaching area

2, and 0.941 and 0.94 in TA3. These scores, all above the acceptable threshold of 0.7, affirm the statistical reliability of the questionnaires in measuring the targeted dimensions. However, these high alpha values could indicate question redundancy, prompting us to consider whether some questions could be omitted to streamline the questionnaire for future evaluation.

A deeper insight into students' opinions regarding the testing experience can be gained through the qualitative analysis of open-ended questions. The students' answers displayed great diversity and, in some cases, were contrary. To this end, we attempted general categorization into groups of replies with similar meanings. The visual representation of the qualitative feedback of students for each TA is presented in Appendixes A to C. It is worth mentioning that some of the responses did not make sense or were out of context. Moreover, responses such as "I like everything/I do not like anything" without any justification cannot be considered for additional analysis.

Qualitative feedback from the questionnaire revealed varied student experiences across TAs. Students particularly valued the educational approach, emphasizing project-based learning and collaborative group work, while they appreciated the course's relevance, particularly when topics were linked to real-world applications. However, in parallel, students desired more real-world applications and case studies to enhance their understanding of theoretical concepts. Furthermore, some feedback indicated that the course was overly technical, the workload was intense, and the questions more complex and demanding, which sometimes detracted them from the learning experience. For this reason, they suggested adjusting the course load to be challenging yet not discouraging.

Additionally, having three TAs in one semester was considered excessive by some students. Technical issues were also noted, particularly with respect to video quality, while some students found the videos redundant and expressed a preference for written material only. Furthermore, there was a call to make the course more interactive, to increase its appeal and engagement. All comments provided valuable material for the improvement/revision stage described below.

5. Results and discussion

According to the training needs described in section 2 and the methodology and results presented in sections 3 and 4, relevant conclusions can be drawn on the effectiveness and practical applicability of the PLANET4 course.

First, the training needs of hard skills on AI, IIoT, Cloud Computing (CC), and EC for Industry 4.0, addressed in teaching area 1, received contradictory feedback due to the variety of the profiles of students enrolled in the course. While some students found it too generic, others found it too technical, which is mainly due to the different backgrounds of these topics, even from students from the same degree. In the latest version of the course, this is being addressed by adding more external resources, so that students with different backgrounds can take the most from the training. Furthermore, there was an extended opinion about the positive value of the real-world practical examples included in each module and the need for further details on Industry 4.0 challenges. Along this line, Module 1 was extended and restructured.

Regarding the AI contents, they were generally positively evaluated by the students who participated in the pilot action. A substantial portion of them considered this course particularly useful for their careers. This answer demonstrates AI's potential and impact on our professional life. Students at large acknowledge the usefulness of studying AI technologies and their applications since they deem them as a kind of foundation to build and evolve their careers. In particular, the participants emphasised the necessity of presenting modern real-life use cases and asked for more since they link theory and practice. Students are fed up with standalone theoretic courses. In the same context, they expressed positive opinions about the experimental part, that is, the hands-on coding. In addition, they thought of the AI courses series as well-structured, explanatory and with clear objectives. Moreover, they were satisfied with the variety, breadth, and extent of the didactic material offered. Visualization of the results is another asset that the students identified to help them assimilate knowledge. On the other hand, most of the negative reviews focused on the workload volume. They stressed that more time was needed to be fully engaged with all the parts to benefit the most from this course. The quality of the videos was also another issue that was negatively commented on. To this end, the responsible partner undertook to improve the material accordingly. All in all, as anticipated, the replies demonstrated a degree of diversity; this can be easily justified due to the heterogeneous pool of students who participated in the pilot action (they come from different countries, have different backgrounds, etc.). Despite this, the general trend shows that the majority embraced the initiative. Of course, the PLANET4 partnership took into account all the comments, tried to address most of them, and provided the public with a revised and refined version.

In the case of IIoT, on the basis of the feedback received from the trainees, it can be concluded that the students liked the clarity of goals, clear presentation of the courses and adequate amount of information the most. Also brainstorming included in the course and teamwork were considered as important elements of the course. Moreover, the presentation of the essence of integrated systems and their everyday use were appreciated. In addition, the students particularly appreciated the lessons on cybersecurity and examples of IIoT applications in production systems. On the other hand, for some students the vocabulary used was new and they found it difficult to express their opinions or take quizzes during the course. Suggestions for improvement included adding videos showing the robots working or the location of sensors (e.g., "More videos from external sources and use cases") as well as simulations. In our opinion, it would be valuable to provide students with links to relevant videos available on the Internet or give students the task to search for such videos and share links on the platform. For some students the course was too long, the topics were unnecessarily repeated in different lessons and were presented too generally. Students also pointed to the need to focus more on examples. In conclusion, it can be said that students' opinions depended on their initial knowledge. Sometimes revisiting a topic while presenting it in a different context is helpful for some students to understand the topic, while for others it is unnecessary.

Although CEC had the lowest students' satisfaction and engagement ratings, this module received fewer (negative) comments in the open-question sections of the students' satisfaction surveys. This was probably due, first, because it was the last module of TA1, and many students felt exhausted from the workload associated with the previous modules of this TA; but also, it is important to highlight a general claim on further explanations in all the lessons of this module, which could be justified by the fact that CC and especially EC are topics with a low presence in current curricula (and in the Internet) and students have more difficulties in following them as well as raising more interest in learning further in them. To address this concern, the content of the training course should be delivered over a broader time span.

The training needs for soft skills were addressed in TA2. In this case, students claimed more support from teachers, basically because the flipped-classroom methodology—which is notoriously different from what they are used to—made them feel uncomfortable, but the results obtained from their work were very satisfactory, and thus, was only considered a side effect due to their lack of experience with this teaching methodology.

Finally, the training needs in the business context were addressed in TA3, how to solve I4.0 challenges using project-based learning in both an individual and a group manner. This is for sure the most innovative part of the course, as it allowed students to evaluate their previously acquired knowledge during the course in real-world scenarios. The tool based on taxonomies developed for this module, available at http://taxonomy.planet4project.eu/, is indeed an interesting new site providing an environment for practical training involving AI, IIoT and EC technologies for real Industry 4.0 challenges (Figliè et al., 2024).

In order to better assess the effectiveness of the course in students with an industrial profile, an additional group of 18 industry workers was invited to take the PLANET4 course. This group of students rated the course with an average grade of 4.17 (out of 5) with a standard deviation of 0.68. Note that this is grade is considerably higher than the one given by academic students (see **Figure 2**). Additionally, these industry workers were asked to provide feedback about (1) the methodology of the course (i.e., blended learning) and (2) possible improvement directions to make the course more effective. The most interesting quotations are in what follows:

> "It can greatly help industrial partners to identify solutions toward their needs", "A good way to research possible solutions for our projects", "Knowledge transfer between academia and industry is a great initiative. The first presentation could be clearer", "It is very useful, as it addresses the need for a consistent methodology when deciding the approach to any new industrial project", "include in the syllabus systems improvement to optimize production times and resources", "Talk more about the topic at hand, rather than doing a task that can be done outside of a meeting", "Simplify and select the most important technologies".

As it can be seen in these excerpts, company workers generally acknowledge the relevance and usefulness of the course while few of them also suggest making it more concise or less practical. Considering this feedback, authors believe that the course contents could be customized (i.e., cropped) to the type of student profile that is expected to attend (e.g., managers, senior workers, newcomers).

Finally, **Table 6** shows the obtained average grades of students who took the

PLANET4 course. Also, it shows the percentage of students who passed each one of the modules that articulate the course.

Table 6. Average grades and percentage of students who passed the course.

Teaching area	Topic	Average grade (attended)	Passed students	
			Topic	Teaching area
Fundamentals of Industry 4.0	Introduction to I4.0	8.22	90%	88%
	Data science, artificial intelligence and machine learning	7.44	84%	
	Internet of things and industrial IoT	6.92	81%	
	Cloud and edge computing	8.64	97%	
Innovation and change management	Innovation and the product	A	98%	83%
	Design thinking	A	91%	
	Human-centred design	A	84%	
	Pretotyping	A	73%	
	Final presentation	A	71%	
How to solve I4.0 challenges	Individual challenge	8.3	100%	100%
	Team challenge	9.1	100%	100%

It is worth noting that teaching area 1 and 3 (fundamentals of Industry 4.0 and how to solve I4.0 challenges respectively) used quantitative grades (0 being the lowest and 10 being the highest), teaching area 2 (innovation and change management) used letter grades (D being the lowest and A being the highest). As it can be seen, the obtained grades are pretty high and the number of students who passed the course is high as well, which reflects the involvement and motivation of students.

Overall, in light of these results, it seems that the PLANET4 course has deeply contributed to filling the gap between academic teaching and practical application in the Industry 4.0 context.

6. Conclusions

This paper contributes to filling the gap between academic teachings and practical applications in the context of Industry 4.0 by proposing a blended learning course developed within the EU-funded Planet4 project (https://www.planet4project.eu/). First, the results of a training needs analysis motivate this research, then, the research method on how the course has been designed is described, and finally, the evaluation of its effectiveness based on the participants' performance, engagement, and feedback after its implementation is discussed. From the collected data, it is now possible to answer the proposed research questions that motivate this work:

1) Are the designed contents suitable for the acquisition of skills, both soft and hard, to add value in Industry 4.0 scenarios? The results obtained by students through the three teaching areas that articulate the PLANET4 course are considered satisfactory and statistically significant. Given this, and taking into consideration the contents that have been the object of study and work in the

teaching areas, students have obtained knowledge to be able to (as the goal of the course states) identify and analyse industrial needs, propose feasible technological solutions to solve industrial challenges, and appropriately structure the proposed solutions as it has been shown in teaching area 3.

2) Up to what extent mastering the hard skills associated to the technical disciplines of Industry 4.0 (i.e., AI, IoT or CEC) helps to master its associated soft skills (i.e., innovation and change management)? 88% of the students have passed the teaching area "Fundamentals of Industry 4.0" and 87% have passed "innovation and change management". These results allow us to affirm that the contents that have been designed for the first module contribute effectively to achieve the learning outcomes proposed for the second module. Note that learning outcomes 1 to 5 and 7 are aligned with learning outcome 6, so the aforementioned contents should allow students (as stated in the corresponding learning outcome) to identify and analyse industrial needs, propose a fast prototypal way to test solutions to solve industrial challenges, and appropriately structure the proposed ideas.
3) Which of the topics associated to Industry 4.0 (i.e., AI, IoT or CEC) seems to present the most difficult content for students? The lessons aimed to the acquisition of knowledge about "IIoT systems" and "communication protocols" show average grades of 6.47 and 6.17 (out of 10) respectively. These results, together with an average grade for the Teaching Area of 6.92 and a successful rate (score equal or above 5.0) of 75% and 73% respectively, are the lowest grades of the entire course. Consequently, it is the IIoT (Internet of things and industrial IoT) module that seems to present the greatest challenge to the students in comparison with those of the areas "data science, artificial intelligence and machine learning", and "cloud and edge computing". Probably, this is connected to the fact that industrial IoT topics are not currently covered in-depth in current engineering undergraduate programmes (Dec et al., 2022).

While most of the literature about University-Industry collaborations focuses on technology transfer issues (Rantala et al., 2021), this work addresses the former relation from an academic perspective, where a clear gap between real world industrial needs and current academic teaching (or students' acquired knowledge) is detected and addressed in the context of Industry 4.0.

Following a triple helix approach, the presented work has been supported by the EU Commission in the context of an Erasmus+ program, and involves partners from Industry and University around Europe. But in this line, the role of Administrations should be further enhanced if we want the courses developed within Erasmus+ projects to have a real impact on our society. Currently, the introduction of a course in the official curricula is a long process (e.g., up to two years in Spain), and of course, this should be shorter considering the fast pace of technological evolution.

Author contributions: Conceptualization, JN and ACC; methodology, RF; software, VC and MT; validation, DS, GD and AZ; formal analysis, CS; investigation, XSB, AB, LP, MT and RF; resources, CS; data curation, IB and ŁP; writing—original draft preparation, JN and ACC; writing—review and editing, JN; visualization, IB, MT and RF; supervision, GD; project administration, CS; funding

acquisition, JN. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest: The authors declare no conflict of interest.

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Appendix A

This appendix visually presents the results of the questionnaire for teaching area 1, covering both the closed-ended and open-ended questions.

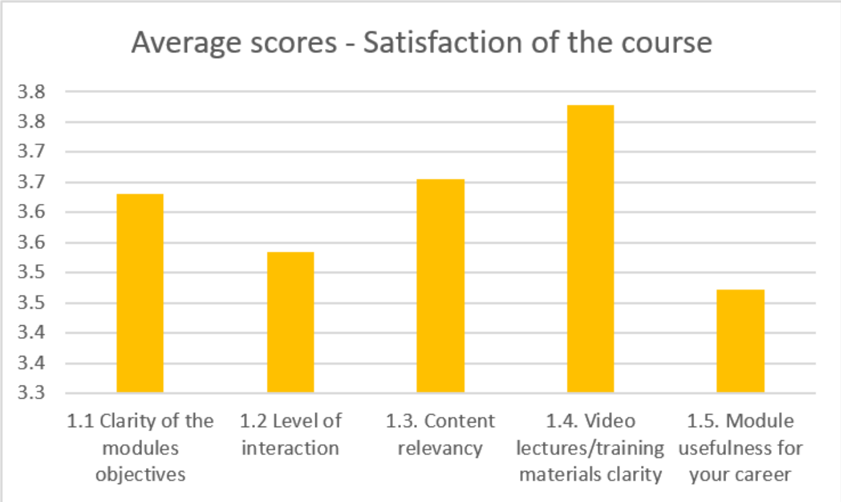

Figure A1. Average satisfaction scores in teaching area 1—Module 1.

Figure A1 presents the average scores for each question within the first category (satisfaction of the course) of teaching area 1—Module 1. All scores are considered satisfactory, as they exceed 3.5.

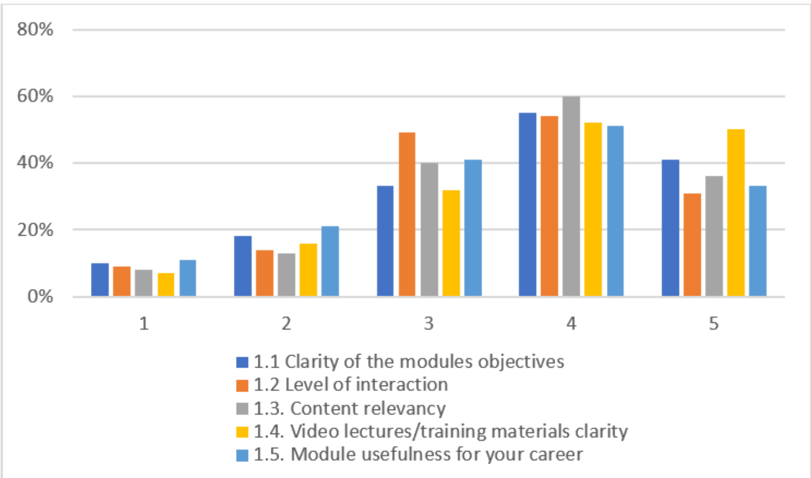

Figure A2. Distribution of satisfaction response scores for teaching area 1—Module 1.

Figure A2 illustrates the distribution of the response grades for each question in the first group of teaching area 1—Module 1. Most responses received a grade of "4," while about 80%–85% of the responses for all questions are graded with a 3, 4, or 5. Notably, the fourth question, concerning the clarity of video lectures/training materials, received the highest scores.

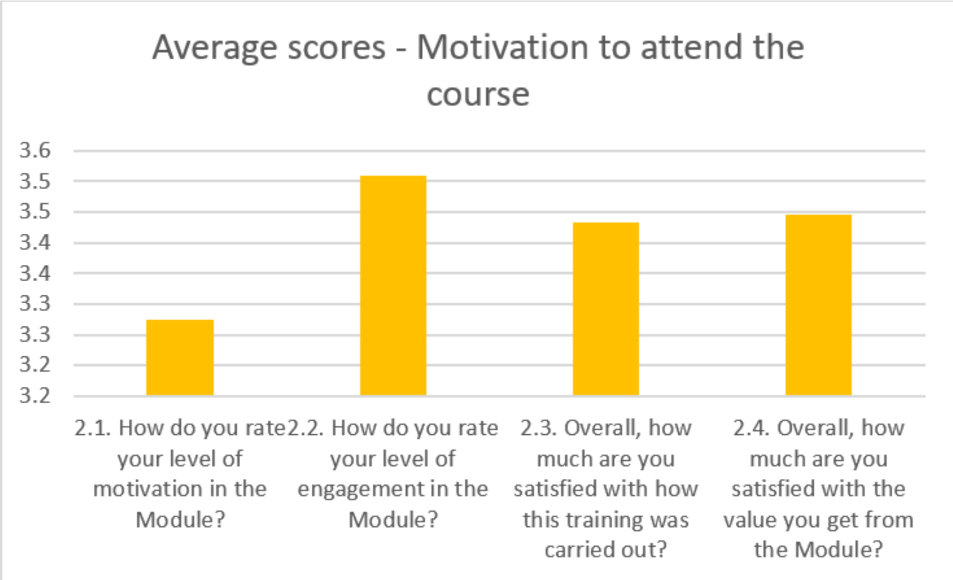

Figure A3. Average scores for motivation to attend questions in teaching area 1—Module 1.

Figure A3 presents the average scores for the second group of questions (motivation to attend the course) of teaching area 1—Module 1. These scores range from 3.3 to 3.5, which is slightly lower than that of the first group but still considered satisfactory.

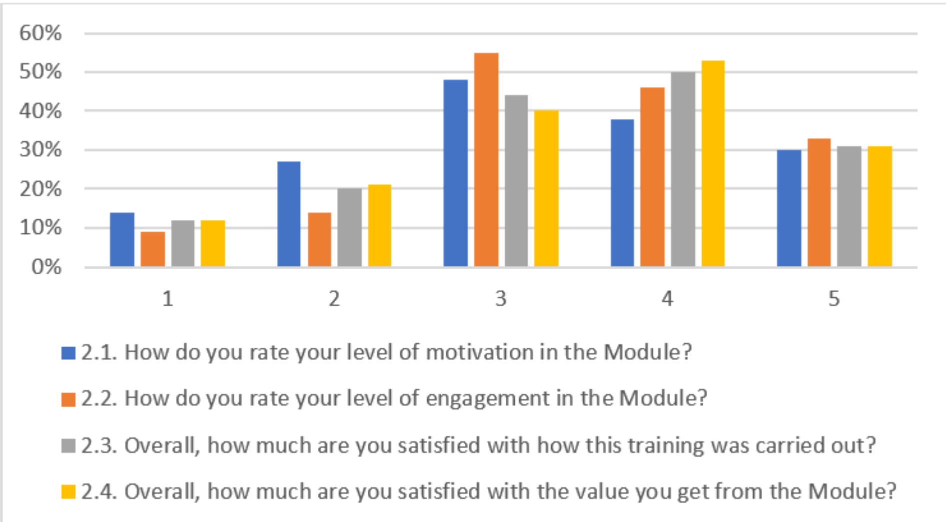

Figure A4. Distribution of motivation response scores for teaching area 1—Module 1.

Figure A4 illustrates the distribution of response scores for the second group of questions of teaching area 1—Module 1, with "3" and "4" accounting for the majority of responses. Compared to the previous group, there is a noticeable shift in the distribution towards lower values.

The results for the remaining modules in teaching area 1 exhibit similar patterns. **Figures A5–A16** show the outcomes of these modules.

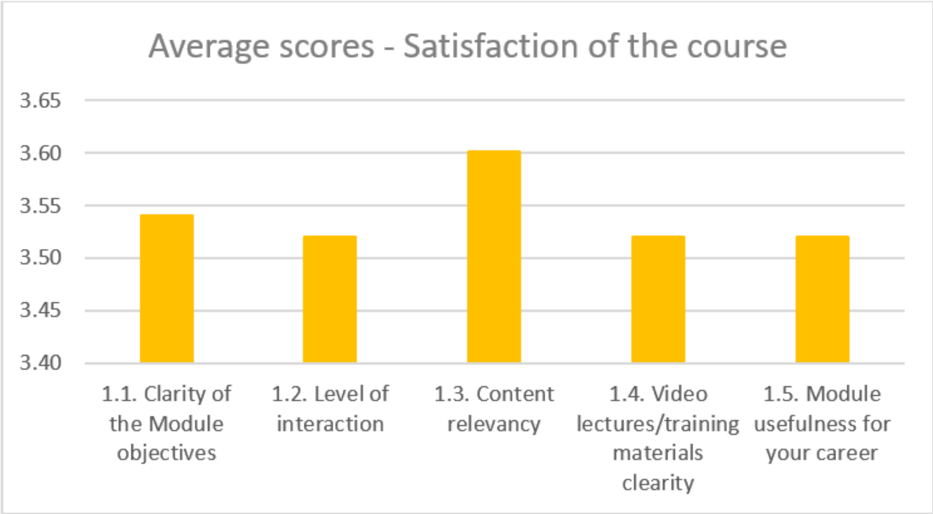

Figure A5. Average satisfaction scores in teaching area 1—Module 2.

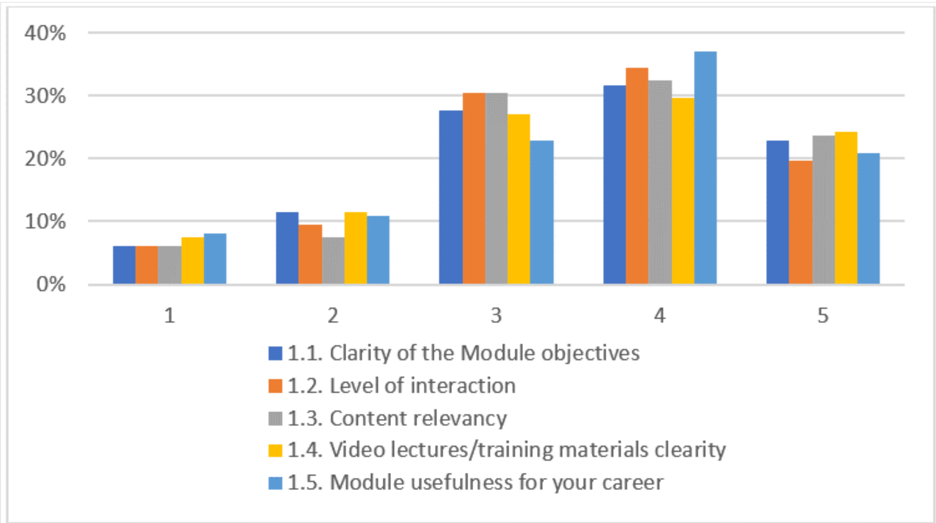

Figure A6. Distribution of satisfaction response scores for teaching area 1—Module 2.

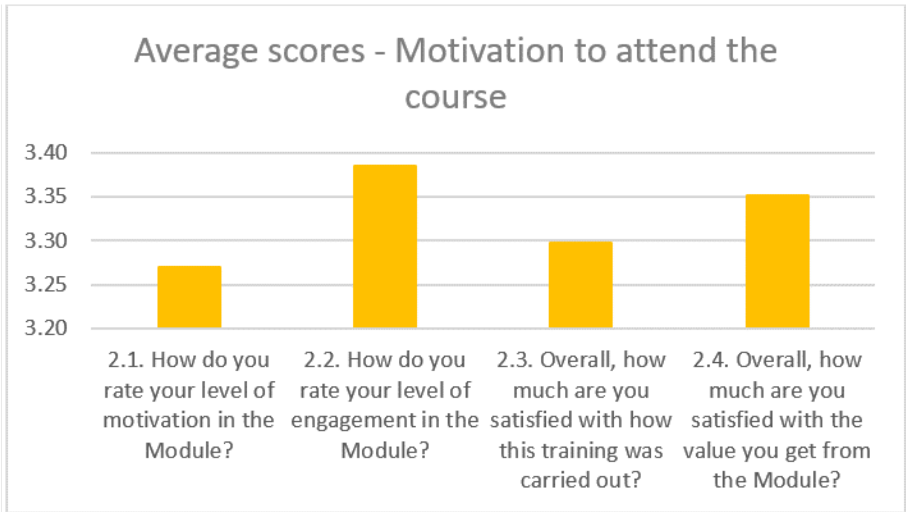

Figure A7. Average scores for motivation to attend questions in teaching area 1—Module 2.

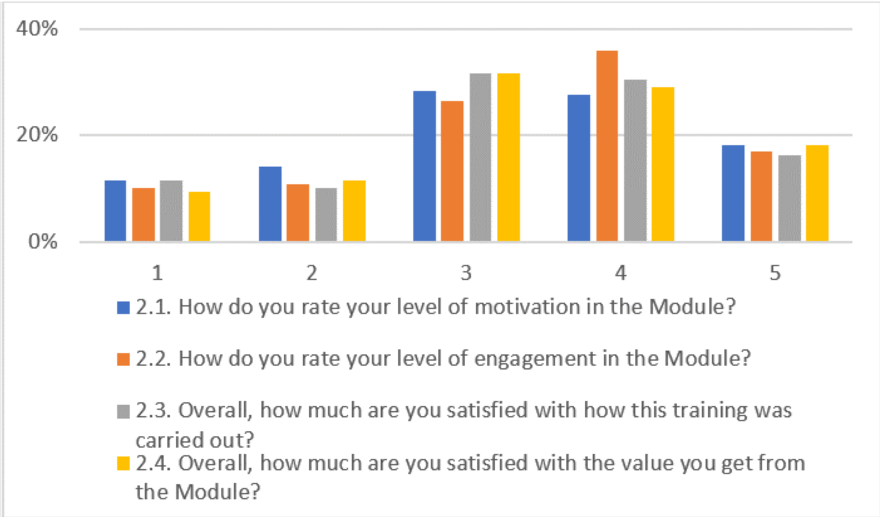

Figure A8. Distribution of motivation response scores for teaching area 1—Module 1.

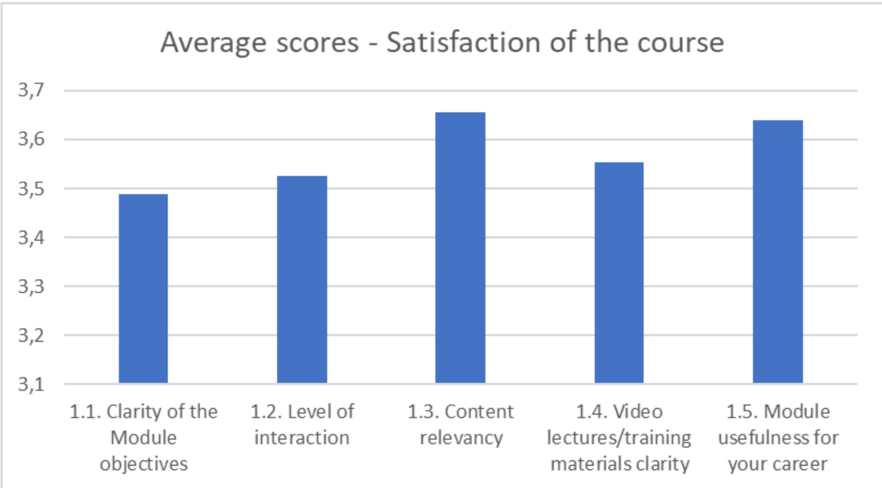

Figure A9. Average satisfaction scores in teaching area 1—Module 3.

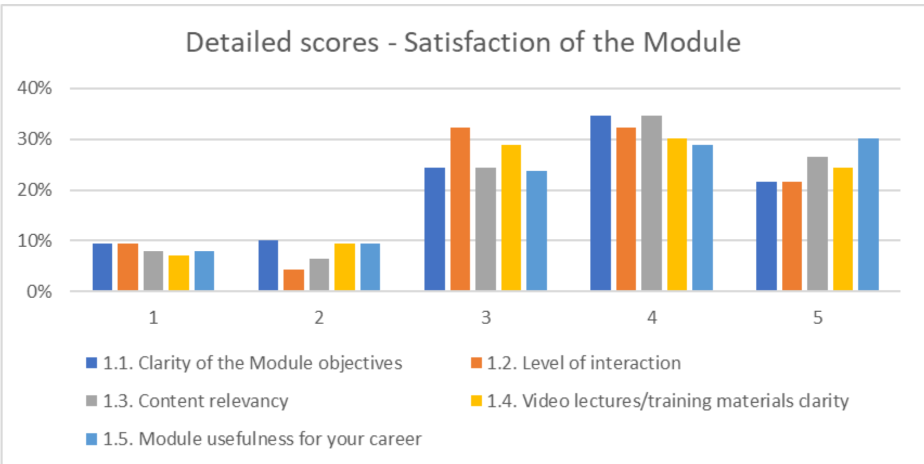

Figure A10. Distribution of satisfaction response scores for teaching area 1—Module 3.

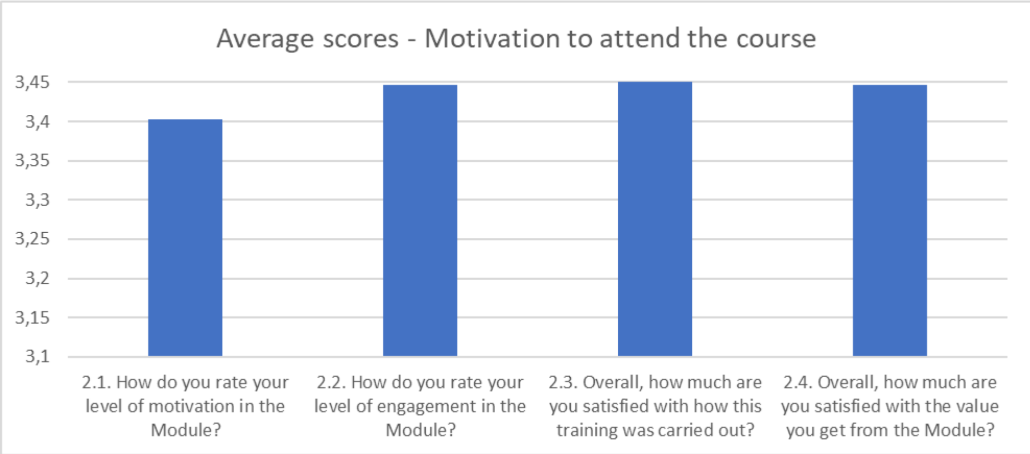

Figure A11. Average scores for motivation to attend questions in teaching area 1—Module 3.

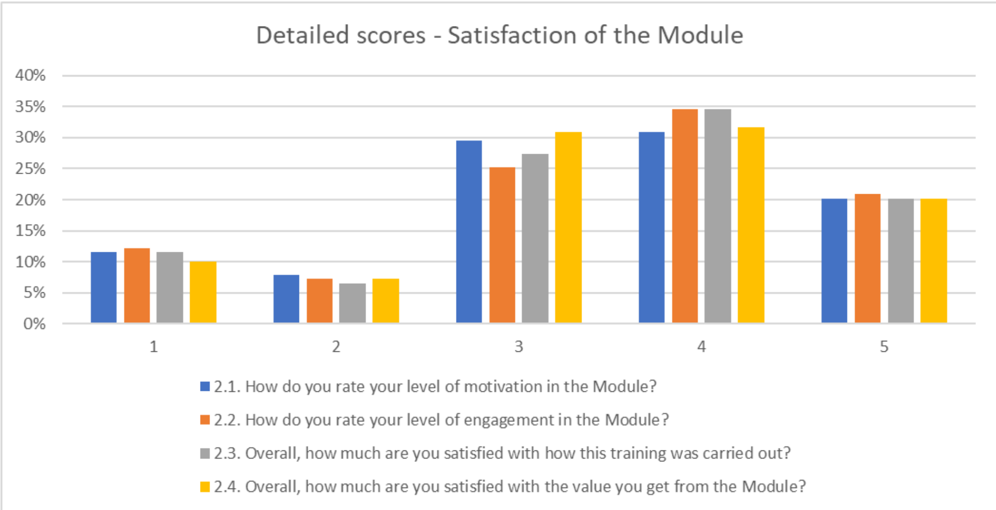

Figure A12. Distribution of motivation response scores for teaching area 1—Module 3.

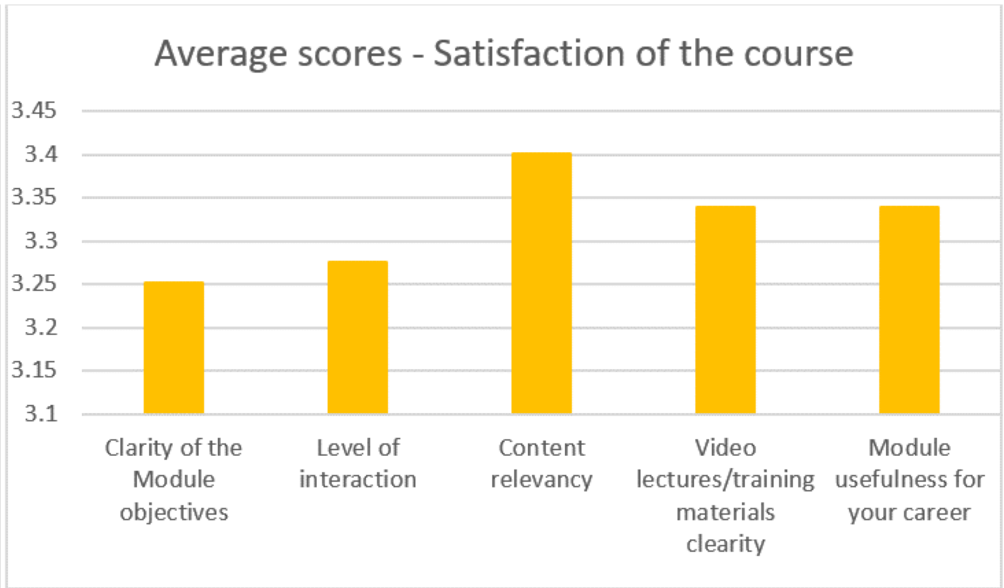

Figure A13. Average satisfaction scores in teaching area 1—Module 4.

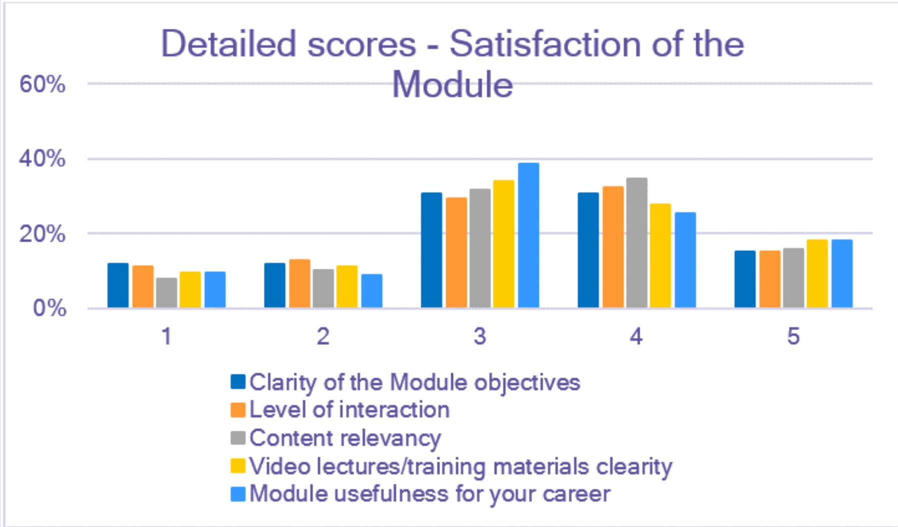

Figure A14. Distribution of satisfaction response scores for teaching area 1—Module 4.

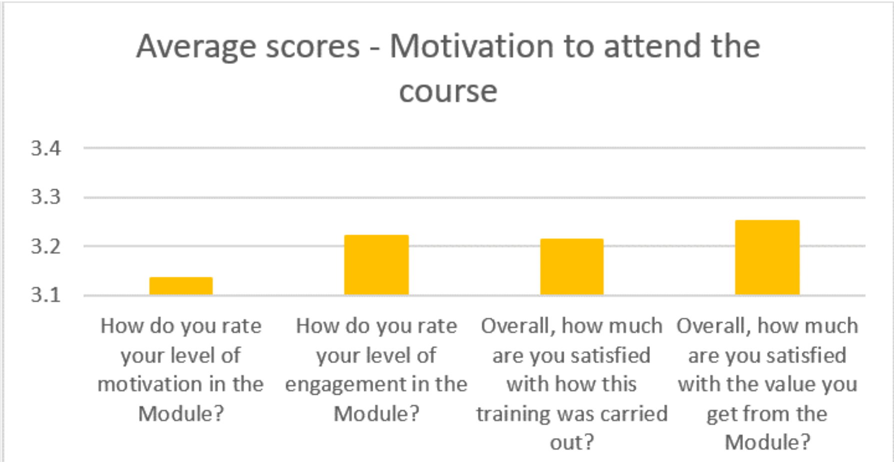

Figure A15. Average scores for motivation to attend questions in teaching area 1—Module 4.

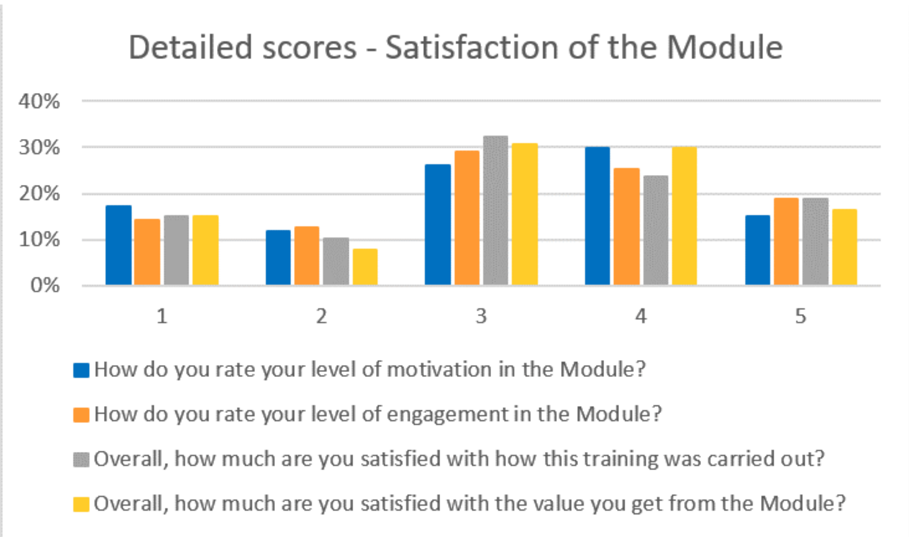

Figure A16. Distribution of motivation response scores for teaching area 1—Module 4.

Figures A17–A19 summarize the qualitative data collected from the open-ended questions of teaching area 1, reflecting the students' feedback on various aspects of the modules.

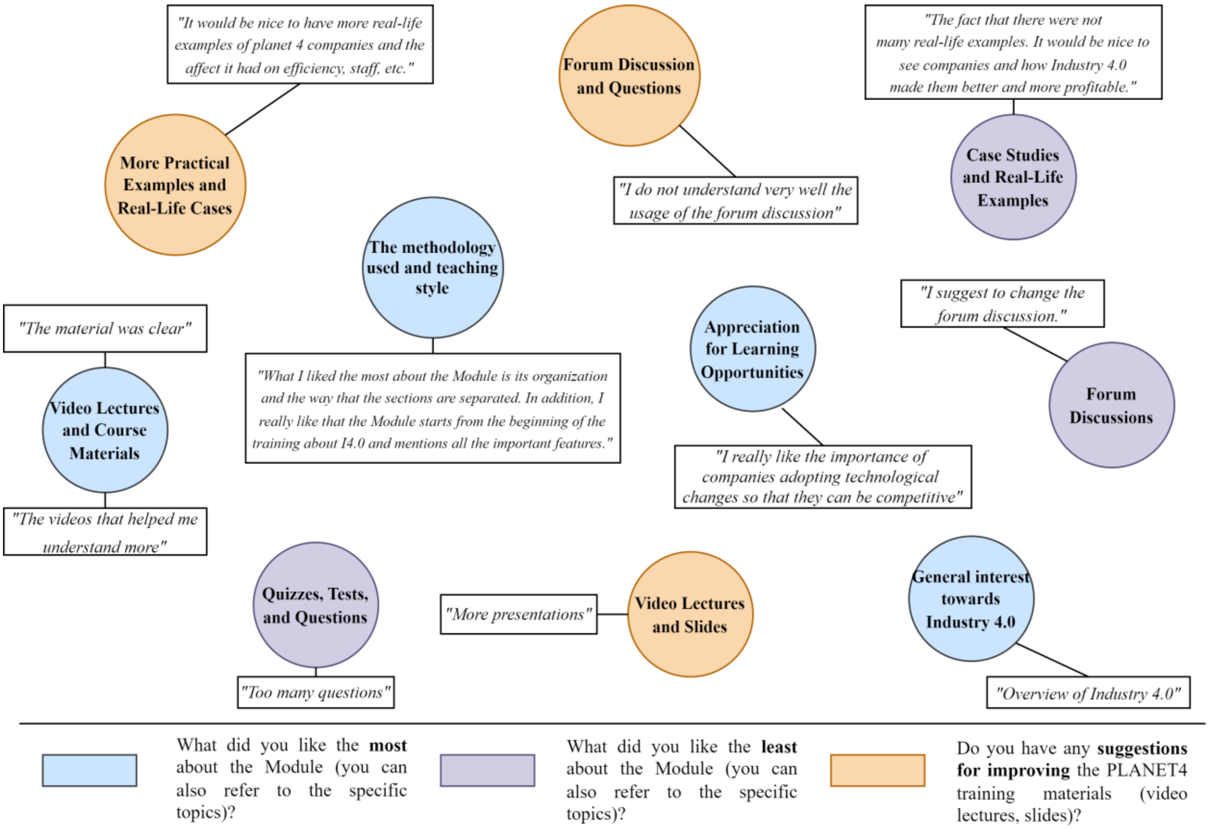

Figure A17. Qualitative feedback from students on teaching area 1—Module 1.

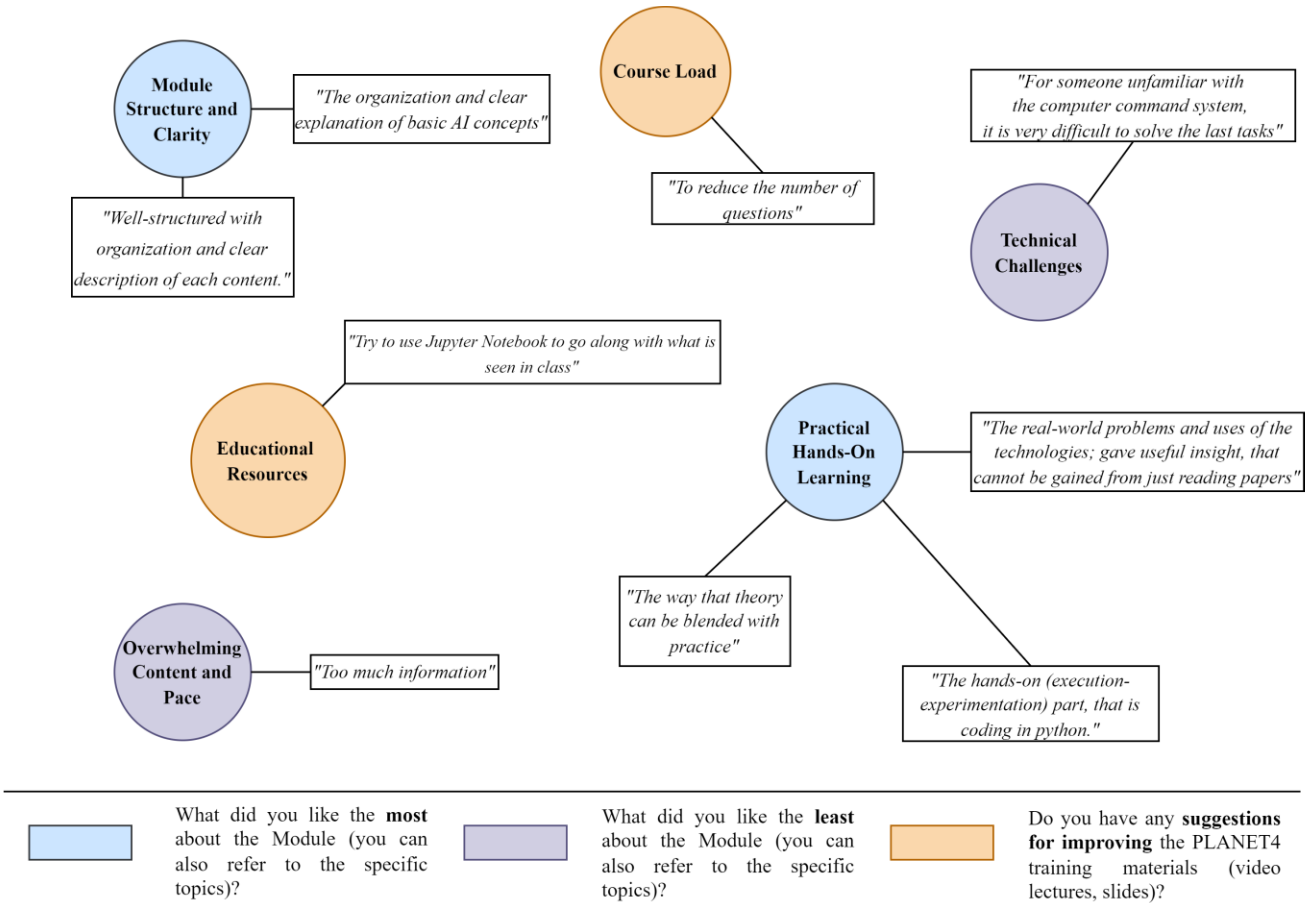

Figure A18. Qualitative feedback from students on teaching area 1—Module 2.

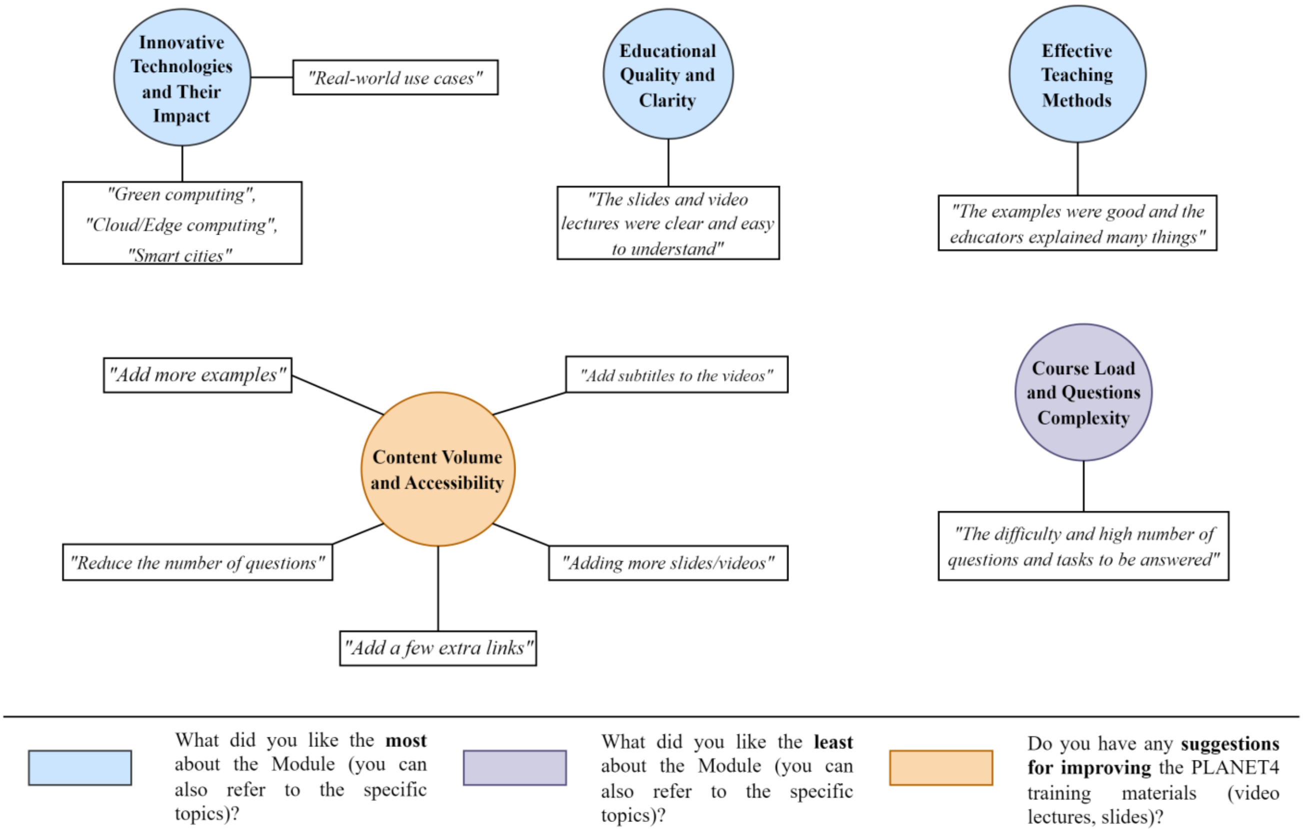

Figure A19. Qualitative feedback from students on teaching area 1—Module 3 and 4.

Appendix B

This appendix visually presents the results of the questionnaire for teaching area 2, covering both the closed-ended and open-ended questions.

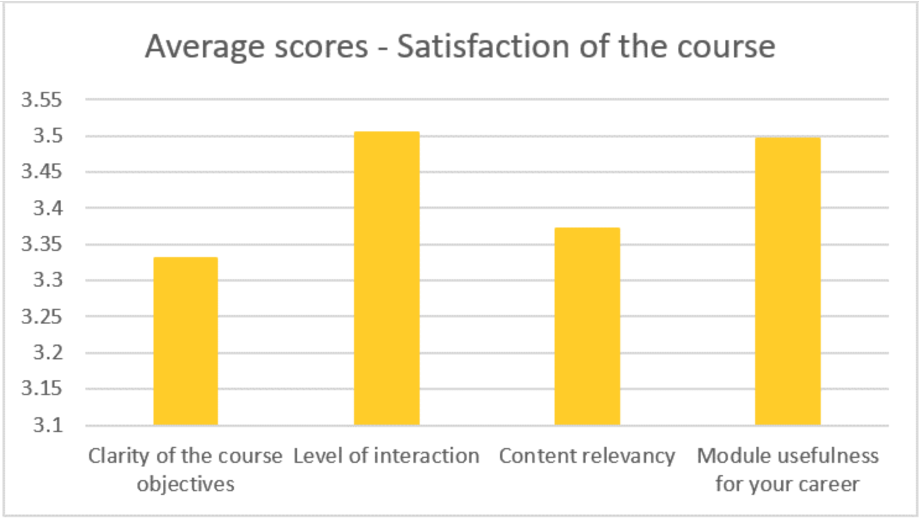

Figure B1. Average satisfaction scores in teaching area 2.

Figure B1 shows the average scores for the first group of questions of teaching area 2, indicating satisfactory feedback. In detail, questions on the interaction level and the module's usefulness to students' careers scored marginally higher.

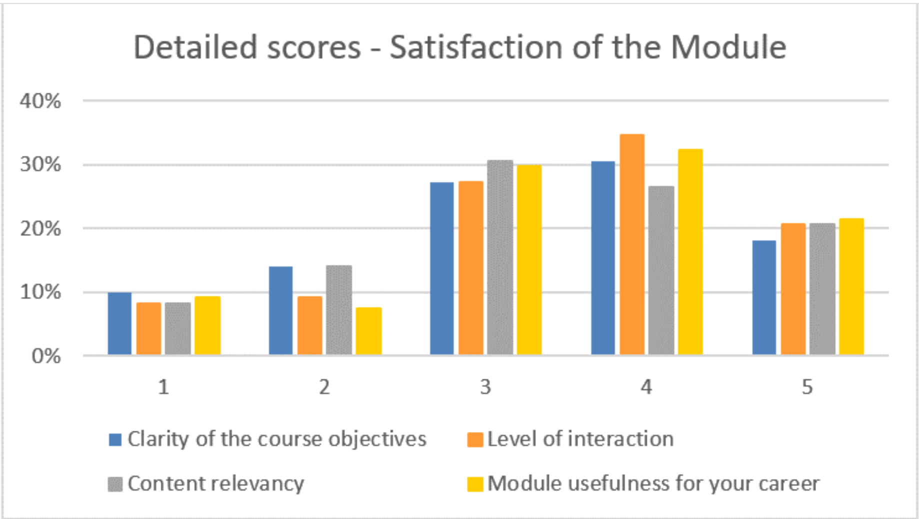

Figure B2. Distribution of satisfaction response scores for teaching area 2.

Figure B2 details the distribution of response grades for each question of the first group, with "4" being the most prevalent grade, while 80% of the responses fall between grades "3" and "5." Notably, the second question, about the clarity of the course objectives, has the highest average score of 3.5, likely reflecting the effectiveness of the flipped classroom teaching methodology used in this TA.

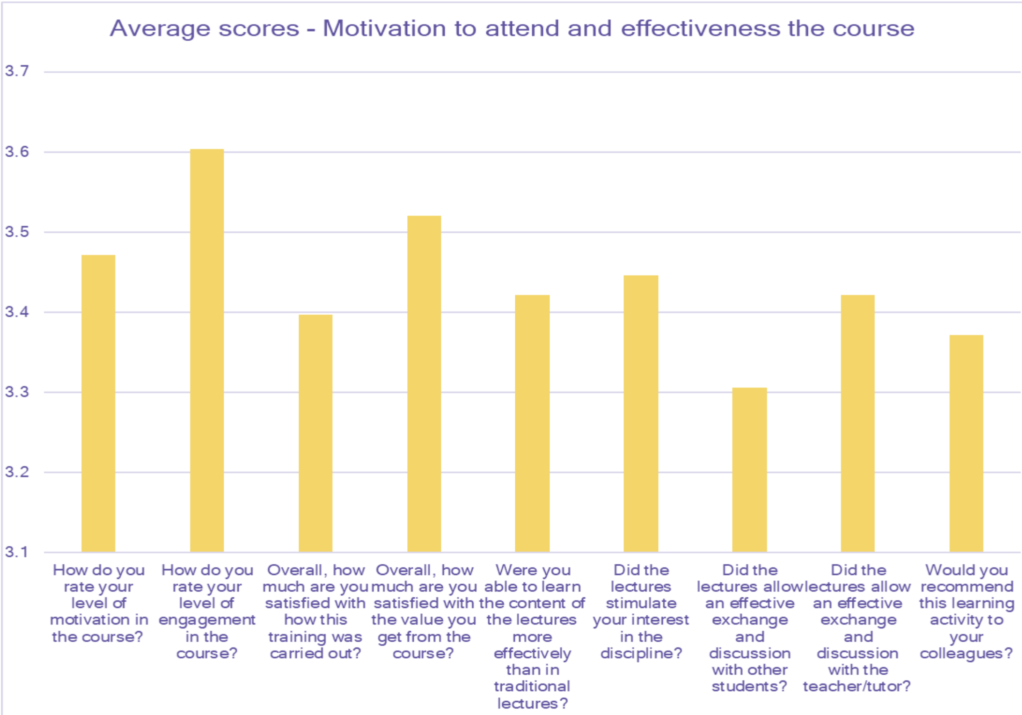

Figure B3. Average scores for motivation and effectiveness in teaching area 2.

Figure B3 shows the average response scores regarding the motivation to attend and course effectiveness, with each averaging approximately 3.4. These scores are comparable to those of the first group of questions on module satisfaction and are considered satisfactory.

Figure B4. Distribution of motivation and effectiveness response scores for teaching area 2.

Figure B4 illustrates that the "4" is the most common grade. Despite a slight decrease compared to the previous question group, a significant majority of the grades (81.6 %) were still within the 3–5 range, suggesting that the students were reasonably satisfied with this module.

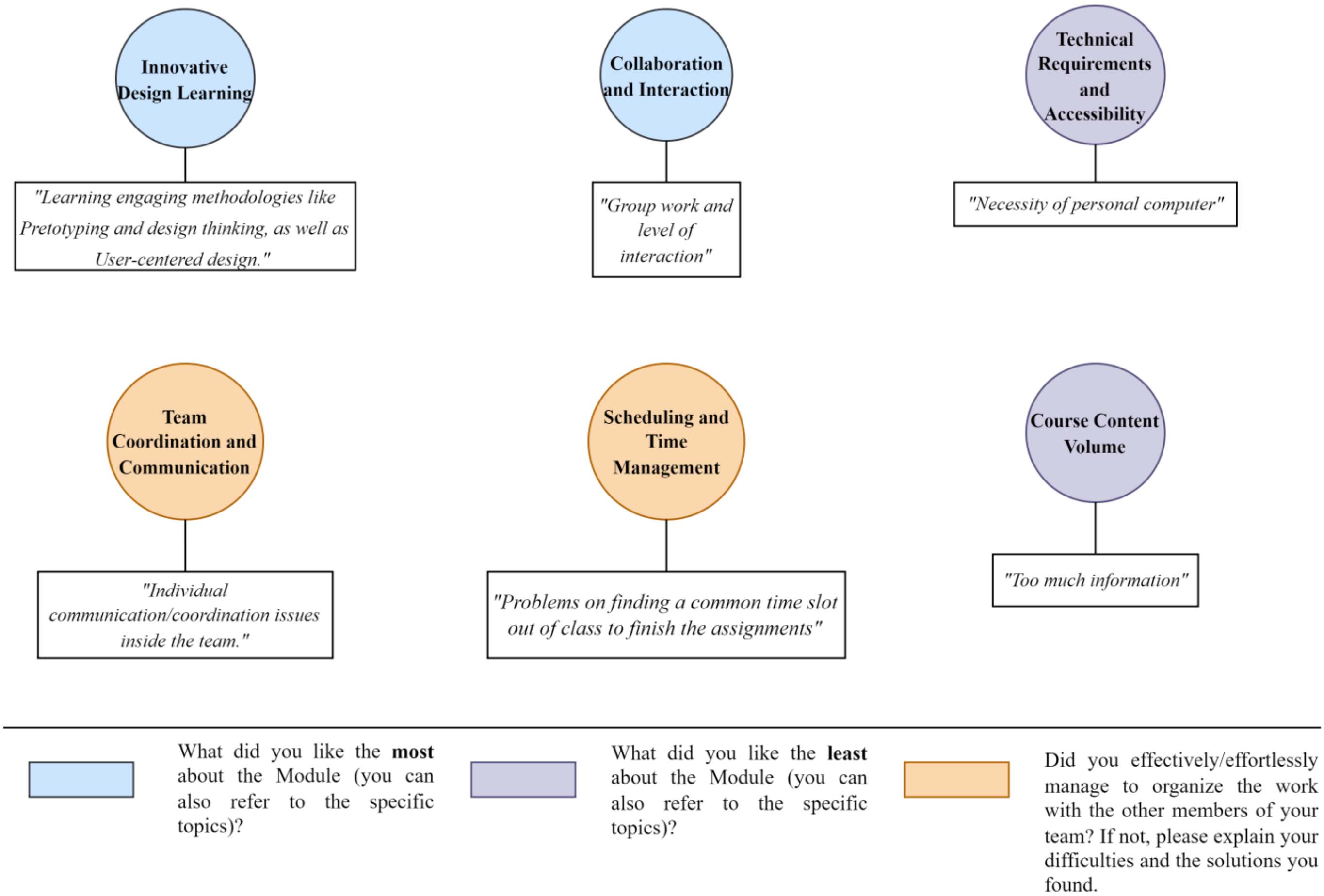

Figure B5. Qualitative feedback from students on teaching area 2.

Figure B5 provides a summary of the qualitative data from the open-ended questions in teaching area 2, encapsulating student feedback on various aspects.

Appendix C

This appendix visually presents the results of the questionnaire for teaching area 3, covering both the closed-ended and open-ended questions.

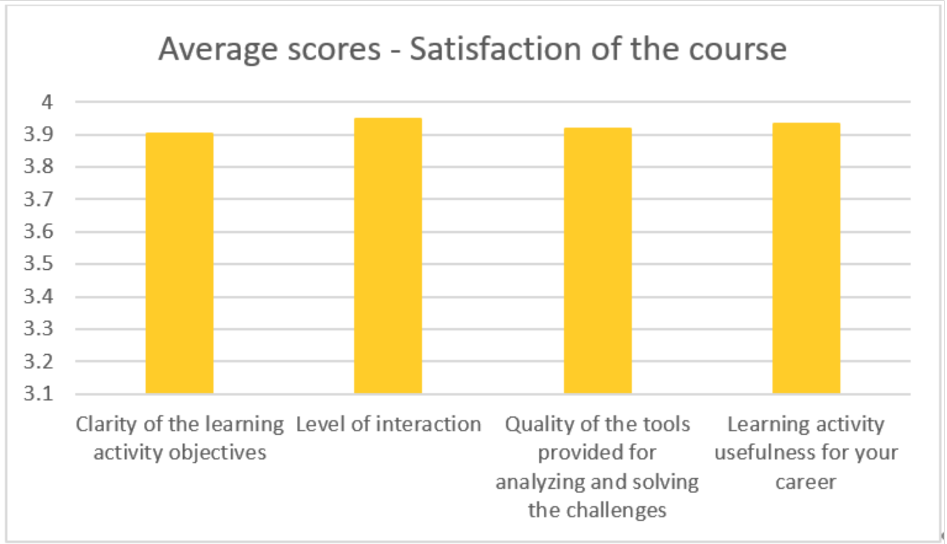

Figure C1. Average satisfaction scores in teaching area 3.

Figure C1 presents the average scores for the first group of questions, showing a notable increase compared to the previous units, with ratings above 3.9.

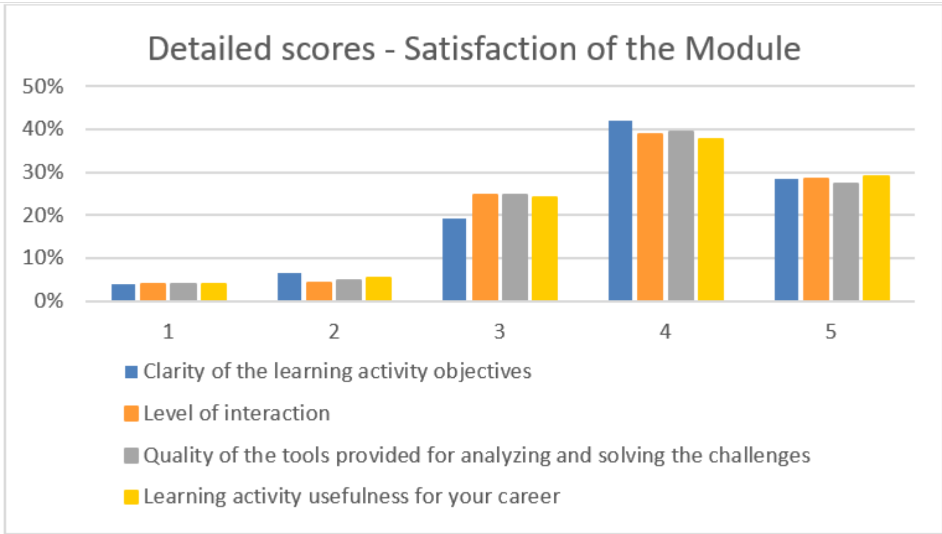

Figure C2. Distribution of satisfaction response scores for teaching area 3.

Figure C2 analytically illustrates the distribution of grades for each question, revealing that most responses received a “4” or “5.” Furthermore, 90.8% of the responses were within the 3–5 grade range, with 67.8% scoring 4 or 5.

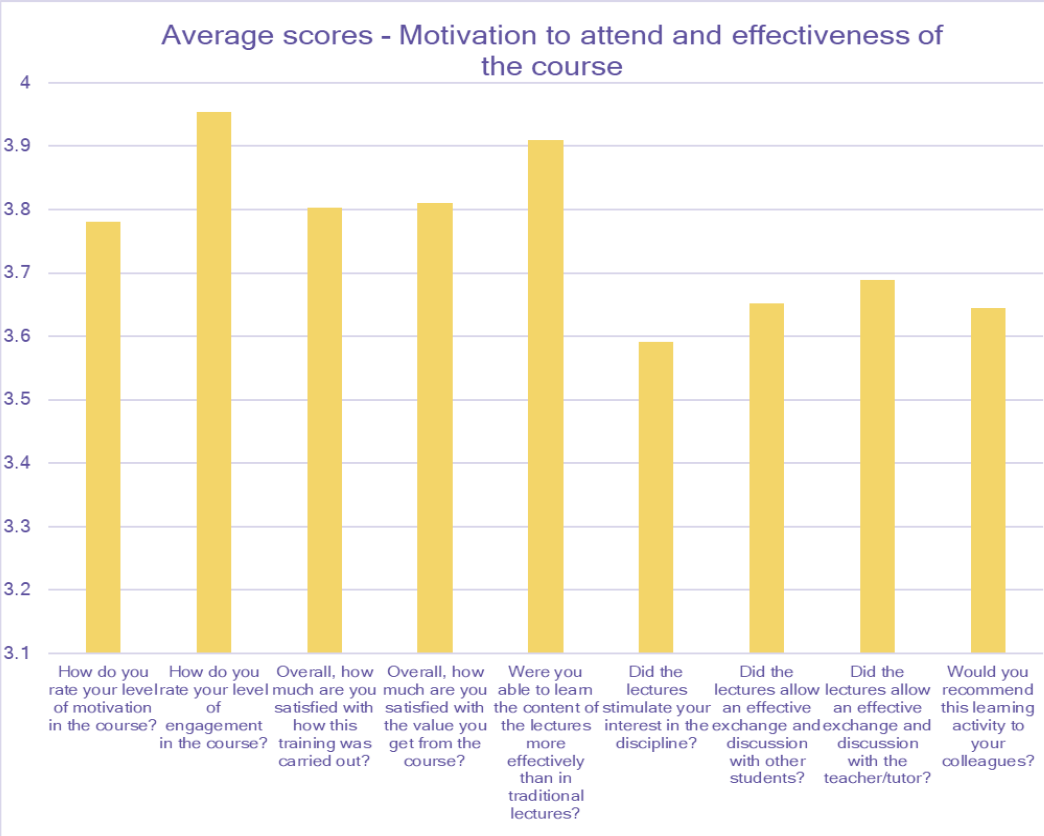

Figure C3. Average scores for motivation and effectiveness in teaching area 3.

Figure C3 displays the average scores for the second group of questions on student motivation to attend and course effectiveness. These scores were similar to those of the first group of questions regarding module satisfaction, indicating that the results were satisfactory.

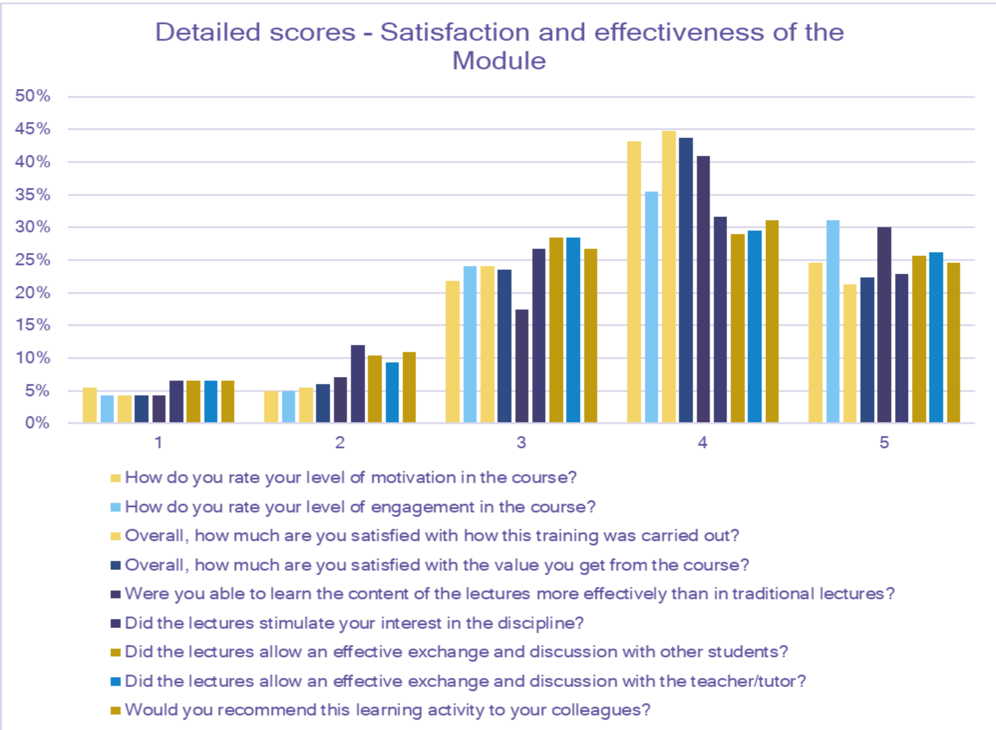

Figure C4. Distribution of motivation and effectiveness response scores for teaching area 3.

Figure C4 displays the distribution of response scores, with "4" being the predominant grade. Although there was a slight decrease in average grades compared to the previous question group, a majority of 86.6% of the grades fell between 3 and 5, suggesting that students were reasonably satisfied with this module.

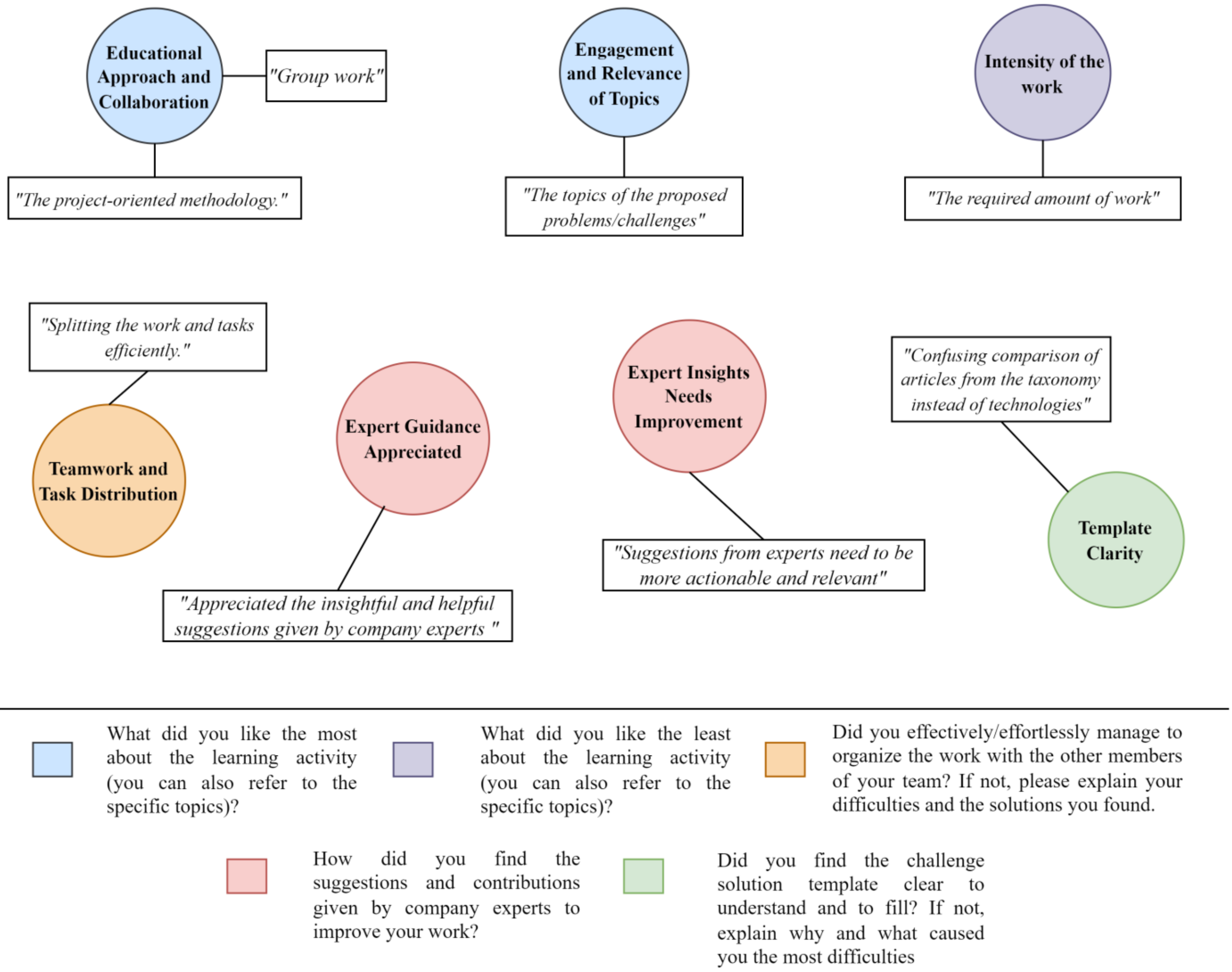

Figure C5. Qualitative feedback from students on teaching area 3.

Figure C5 provides a summary of the qualitative data from the open-ended questions in teaching area 3, encapsulating student feedback on various aspects.