BIM-enabled Learning Environment (BLE) – Pilot Modules

By: University of Bologna, Italy

July 2023

Co-funded by the Erasmus+ Programme of the European Union

PROJECT DELIVERABLE DETAILS

Project Type	Erasmus+ KA203 Strategic Partnership
Project Acronym	BENEDICT
Grant Agreement Number	2020-1-EE01-KA203-077993
Project Full Title	BIM-enabled Learning Environment for Digital Construction
Intellectual Output	O4 Pilot Modules
Output Lead Organisation	UNIBO – University of Bologna
Dissemination level	Final version to be public
Due date for deliverable	August 2022

DOCUMENT VERSION HISTORY

Version	Date	Comments
0	27th April 2023	Template for completion of sections by partners
1	24th July 2023	First draft by all the partners
2	29th August 2023	Final version

TABLE OF CONTENTS

Executive Summary

The aim of this document is to report on the design and implementation of pilot modules that were developed by each of the partner universities in order to demonstrate how the BIM-enabled Learning Environment (BLE) platform can be used to effectively deliver BIM-enabled learning for the Real Estate and Construction (REC) sector. The 3 pilot modules – on Design Management, Time Management and Risk Management - were co-developed during the second year of project implementation (2021-2022) in collaboration with the Centre for Engineering Pedagogy at TalTech who also led the development of evaluation and assessment tools for BIM-enabled learning. The design and content of all 3 pilot modules were demonstrated along with the BLE platform to a wide range of stakeholders at two Multiplier Events (in Tallinn in June 2022 and October 2022).

The actual teaching of the pilot modules to students took place during the 2022/2023 academic year and, for all 3 pilot modules, the feedback received from both teachers and students was highly positive. This confirms the effectiveness of BIM-enabled learning as an appropriate innovation for knowledge and skills development in the REC sector. It also serves to validate the usefulness of the BIM-enabled Learning Environment (BLE).

As part of Intellectual Output O4 – Pilot Modules, a toolbox for the evaluation and assessment of BIM-enabled learning was also developed and this is reported in a separate document. In addition, the course manuals for all 3 pilot modules which provide comprehensive teaching materials for each of the modules have been developed and are available for public use (reported under Intellectual Output O5 – Guidance Materials). These manuals have also been translated into local languages and are available from the project website (www.benedictproject.eu).

1 Introduction

1.1 Background and purpose

Digitalization is transforming the real estate and construction (REC) sector and a key feature of this transformation is Building Information Modelling (BIM). BIM refers to the digital representation of buildings and construction operations and it offers opportunities for improving education and training through data rich virtual environments in which project-based learning experiences can be designed and delivered. This could fundamentally change the education and training of REC sector professionals from managers to site workers.

The BIM-enabled Learning Environment for Digital Construction (Benedict) project is an Erasmus+ Strategic Partnership between Tallinn University of Technology (TalTech), Tampere University (TAU) and the University of Bologna (UNIBO) aimed at leveraging the possibilities of BIM to enhance education and training by developing an innovative, BIM-enabled Learning Environment (BLE). The BLE platform is an integrated Moodle – DiStellar installation that is publicly available at www.bim-enabled-learning.com .

To demonstrate the application of the BLE in learning, the project team has developed a series of three pilot course modules that apply BIM-enabled learning using the BLE. These are:

1) Design Management - lead by TAU;

2) Risk Management - lead by TalTech;

3) Time Management - lead by UNIBO.

1.2 Objectives and scope

The pilot modules were designed to demonstrate how teachers and students of construction-related disciplines can leverage Building Information Modelling (BIM) in their learning activities for:

• Visualizing the project

• Simulating building scenarios

• Analyzing and designing buildings and building elements

• Identifying conflicts between systems

• Developing estimates, e.g. for materials quantities (bill of quantities BOQ), activity durations (time schedules), costs (budget)

• Design and build decisions

• Project and construction management applications. In particular 4D BIM applications that can simulate and describe construction project execution.

All partners were actively involved in the design, development and validation of the learning activities. A comprehensive evaluation tool to assess the modules was developed and applied by the Centre for Engineering Pedagogy at TalTech. (The resulting evaluation and assessment toolbox for BIM-enabled learning has been separately reported). The pilot modules were demonstrated to stakeholders at the Benedict project's 2nd Multiplier Event that was held in Tallinn in June 2022 and were directly used to teach students during the 2022/23 academic year in all 3 partner universities.

1.3 Structure of the report

After this introduction, in section 2 the pilot module development methodology is described. The three pilot modules descriptions (i.e. Design Management, Risk management and Time management) are provided in section 3, while the implementation and the stakeholder feedback is presented in section 4. In section 5 the module assessment evaluation method is presented, while the stakeholder feedback, by teachers and students, is presented in section 6. Conclusions are drawn in section 7.

2 Pilot module development methodology

The development of the pilot modules in the Benedict project involved a systematic and collaborative approach. This section outlines the methodology employed by the project team to ensure the successful creation of the BIM-enabled learning modules. Before commencing the development process, a thorough needs analysis was conducted. This analysis aimed to identify the specific educational requirements and challenges within the REC sector that could be addressed through the implementation of BIM-enabled learning. The needs analysis involved engaging with industry professionals, educators, and students to gain insights into the existing gaps and opportunities for improvement. The pilot module development process was a collaborative effort involving all partner institutions: Tallinn University of Technology (TalTech), Tampere University (TAU), and the University of Bologna (UNIBO). Each institution took the lead in developing one of the three pilot modules, namely Design Management, Risk Management, and Time Management. The design phase involved regular meetings and consultations among the project team members to ensure a shared understanding of the learning objectives, content, and assessment strategies for each module. The collaborative design process allowed for the integration of diverse perspectives and expertise from the partner institutions, resulting in comprehensive and well-rounded learning experiences. Once the design phase was completed, the content development phase began. Subject matter experts from each partner institution collaborated to create the learning materials for their respective modules. These materials included lecture slides, case studies, interactive exercises, video lectures and assessments, all tailored to leverage the capabilities of BIM and the BLE platform. The content development process also involved the integration of real-world examples and industry best practices to ensure the relevance and practicality of the learning materials. This approach aimed to bridge the gap between academic knowledge and industry requirements, preparing students for the challenges they would encounter in their future careers. The BLE platform served as the foundation for delivering the pilot modules. The project team worked closely with the platform developers to ensure seamless integration of the learning materials within the BLE environment. This involved configuring the platform to support BIM-related functionalities, such as 3D visualization, collaborative modeling, and data analysis tools. The integration process also included the creation of user-friendly interfaces and navigation structures, ensuring that students could easily access and engage with the learning materials. Additionally, the project team conducted extensive testing and quality assurance to identify and resolve any technical issues, ensuring a smooth and efficient learning experience for the students. Throughout the development process, the pilot modules underwent continuous evaluation and feedback cycles. The feedback received from these evaluations played a crucial role in refining and enhancing the pilot modules. It allowed the project team to identify areas of improvement, address any shortcomings, and incorporate suggestions for future iterations. The iterative nature of the development process ensured that the modules were continuously optimized to meet the evolving needs and expectations of the target audience. By following this methodology, the Benedict project successfully developed the pilot modules, providing students and educators with innovative and engaging learning experiences that leverage the power of BIM-enabled learning.

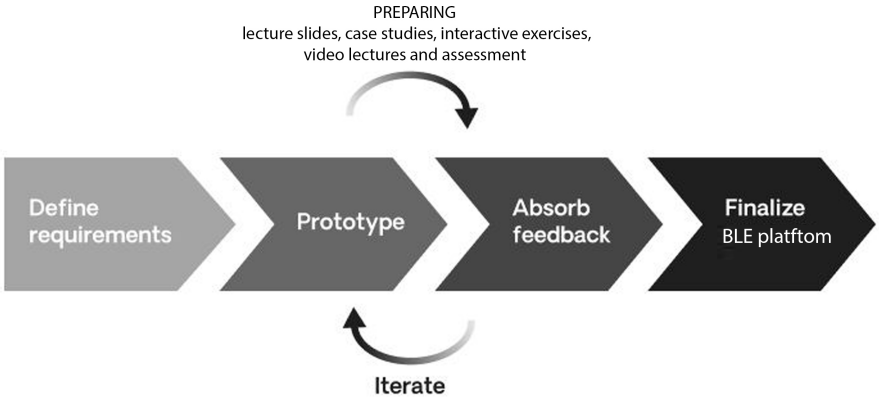

Figure 1 - Pilot module development methodology

3 Pilot module descriptions

3.1 Design Management module – Tampere University

3.1.1 Background to the Design Management module

Design Management was chosen as a topic as collaboration and coordination are at the centre in design management. These functions and competences are becoming more and more important in the Real Estate and Construction industry. BIM is argued to enable improved collaboration and coordination not only due to its highly visual nature, but more due to the technical abilities for sharing information and for 3D coordination. Therefore, this topic suited well to test BIM-enabled learning. Concept design stage was chosen as a more specific stage to be focused on. This enabled the focus on analysis, simulation and integration execution and the length was also suitable for the initial pilot module implementation, to test the concept.

3.1.2 Learning outcomes of the module

On completion of this module, the student:

- understands the concept design stage processes, the connection between different roles, design disciplines and design options;
- Understands their own role and is able to function in their role independently and to collaborate and communicate with other stakeholders; and
- knows the common BIM requirements and is able to apply them into their role specific tasks.

3.1.3 Summary of content

The module focuses on the concept design of a project, and on the analysis, simulation and integration execution, not on the actual design tasks in the project.

Topics include, but are not limited to

- Spatial programme evaluation
- Design review
- Design schedule development

- Cost estimation
- Model validation

Documentation of meeting minutes and agendas

3.1.4 Module delivery process

Students work individually and collaboratively on a simulated project to complete concept design stage activities. As design management happens between multiple parties in a project, students adopt the roles of these parties to work together as a design management team. Faculty's role is to facilitate the process and to provide feedback and advice as needed.

The module consists of:

1. An introductory lecture on Building Information Management
2. Four design management meetings (Figure 2):
   I. Opening meeting for project introduction and role selection
   II. 1st design meeting to discuss the design
   III. 2nd design meeting to discuss the further developed design
   IV. Stage gate meeting to conclude the concept design stage

.

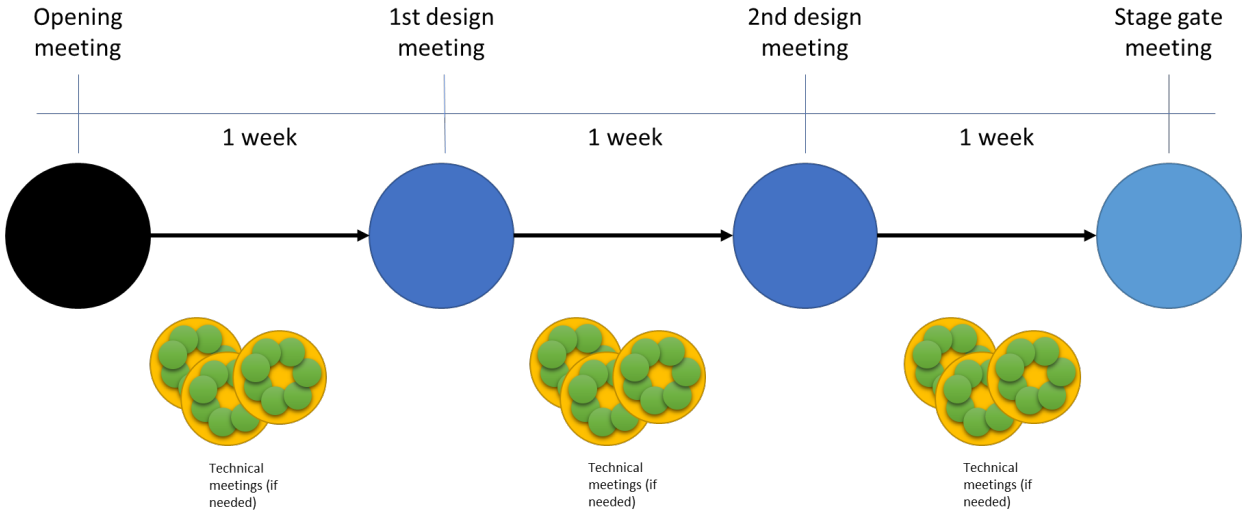

Figure 2 - Process map for Design Management module delivery

3.1.5 Assessment approach

Formative assessment is provided at the end of each meeting in the form of teacher feedback. Summative assessment is based on students' active participation in the meetings and in performing the required role-specific tasks. A pass/fail grading system is recommended for this module as it is based on active collaboration and the focus should be on ensuring that all students are engaged and actively work through their role-specific activities. It is also possible to arrange a quiz at the end of the module to test how well the students have achieved the learning outcomes. For the initial pilot module implementation at Tampere University, as it formed part of a larger course, a few module-related questions were included in the overall course exam.

3.2 Time Management module – University of Bologna

3.2.1 Background to the Time management module

The construction industry is renowned for its complex and time-sensitive projects, making effective time management a critical skill for professionals in this field. To address this need, a time management course was introduced, specifically designed for individuals pursuing careers in the construction industry. This course emphasizes the integration of Building Information Modelling (BIM) technology, which plays a pivotal role in optimizing project timelines, facilitating collaboration, and streamlining processes. By combining time management principles with the power of BIM, this course equips students with the necessary skills to excel in the fast-paced world of construction. The time management course aims to equip students with the essential tools and strategies to effectively manage time, resources, and project schedules. By incorporating BIM software into the curriculum, students will learn how to leverage this technology to enhance their time management abilities, improve project planning, and optimize construction processes. Students will learn how to utilize BIM software to create comprehensive project schedules, incorporating tasks, milestones, and dependencies. By visualizing project timelines and critical paths, students can effectively allocate resources, monitor progress, and ensure that construction projects stay on track. The time management course in the construction industry, incorporating Building Information Modelling (BIM), provides students with essential skills to excel in their careers. By leveraging BIM's capabilities, students can effectively plan, schedule, and manage construction projects, optimizing resource allocation, improving communication, and mitigating risks. This course equips students with the necessary tools to navigate the complexities of the construction industry, ensuring successful project outcomes and enhancing their professional profiles.

3.2.2 Learning outcomes of the module

On completion of the time management module, it is expected that the student:

- is able to describe the process, tools and techniques of project time management in construction (in a BIM-based work process).
- understands scheduling and project scheduling concepts.
- understands construction job site and site optimization concepts.
- understands the BIM workflow with respect to job site design, project time management and more generally.
- is able to apply the project time management process, tools and techniques in a realistic project scenario.
- can evaluate project schedule, estimate activity durations and resource allocation in terms of their relative significance towards total project duration.
- can critically analyze the construction job site and the industrial workflow of operations in order to recommend improvements.

3.2.3 Summary of content

The module focuses on the project time management process, including construction job site design, using real

project data within a BIM-based work flow.

Topics include, but are not limited to:

- Terms and concepts of time management
- Activity duration estimation and resource allocation
- Tools and techniques for project scheduling and control
- Design of construction job site – workplace design and requirements
- Occupational health and safety standards for construction
- Time management within the BIM work flow.

3.2.3 Module delivery process

Students work individually and collaboratively as needed on a simulated project to complete construction planning and scheduling activities. As construction management include multiple activities, methods and tools, students perform construction planning working together as construction management team. Faculty's role is to facilitate this process and to provide feedback and advice as needed.

The time management module consists of:

1. An introductory lecture – focusing on BIM-based time management principles and process;
2. Three project planning workshops at the pre-construction and construction stages:

i. Project Planning – focus on WBS creation, activity duration estimation (pre-construction stage);

ii. Project Job site design – focus on workplace design and construction processes (pre-construction stage);

iii. Project Scheduling – focus on Project Scheduling and BIM 4D (construction stage).

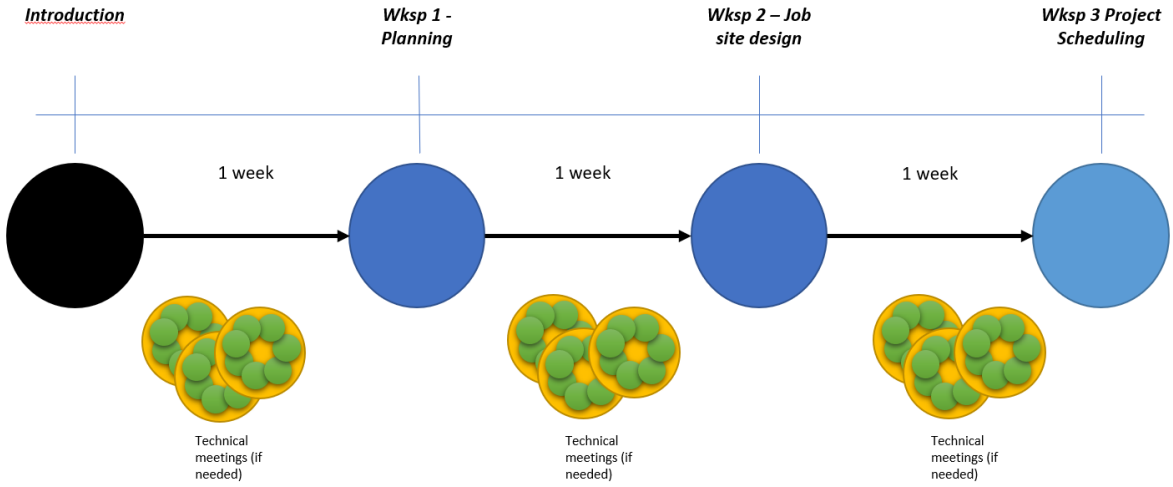

Figure 3 - Timeline for the time Management module delivery

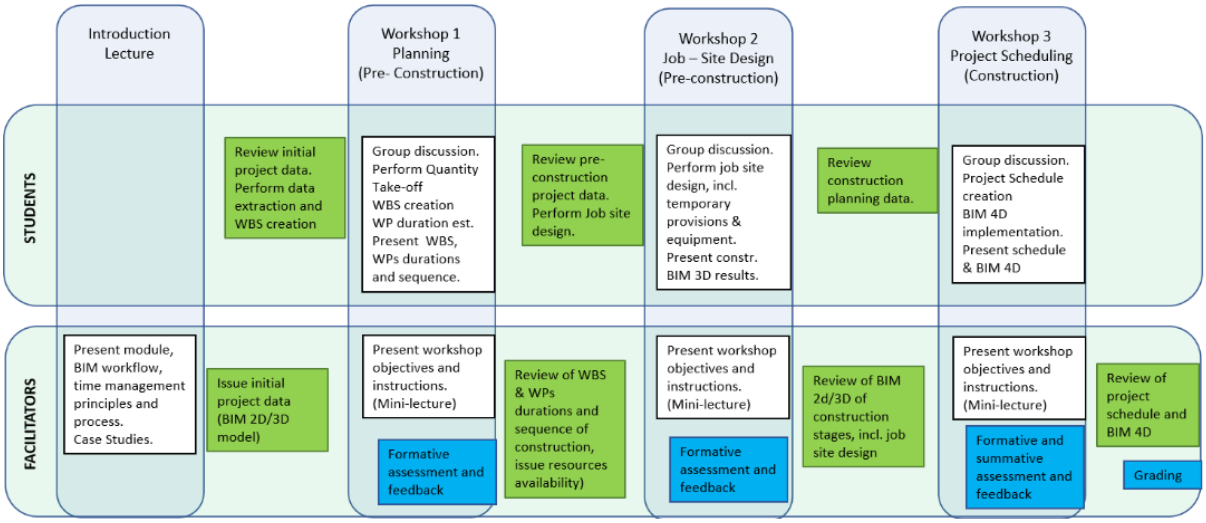

Figure 4 - Process map for Time Management module delivery

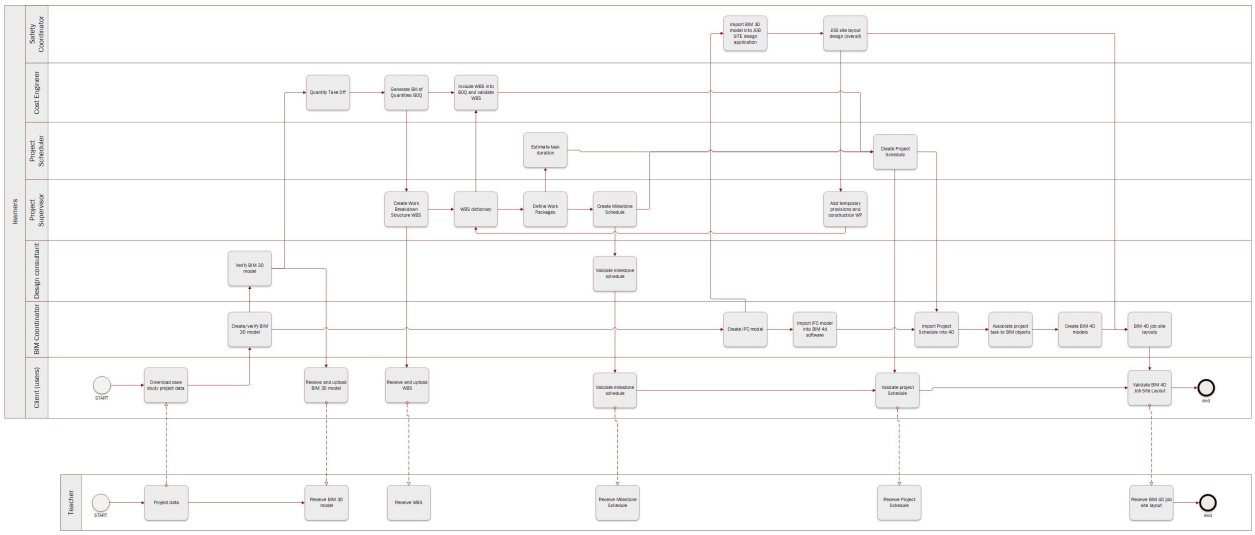

Figure 5 - Detailed Process map for Time Management module delivery with construction management roles

3.2.4 Teaching Methods

Students work individually and collaboratively as needed to complete the learning activities. A project work is undertaken by small groups of students. Introductory lectures are offered to introduce the module, the project, and construction management body of knowledge, particularly focusing on time management tools and methods. BIM

as a concept is considered a pre-requisite of the pilot module and 4D BIM process is presented. Supporting resources on specific topics are offered as needed during the module.

Faculty's role is to facilitate this process and to provide feedback and advice as needed.

Delivery mode options:

- Fully online
- Mixed online and on-campus
- Hybrid (some attending online and some on-campus)
- Fully on campus

3.2.5 Assessment approach

Formative assessment at and after each workshop as faculty and peer feedback. Summative assessment is based on participation and contribution. Grade: A, B, C (pass) / D, E, F (fail) (also includes: grade recovery assessment options C, D, E). For the initial pilot module implementation in Unibo as it formed part of a larger course, a few time management-related questions covering the material of the pilot module were also included in the overall course exam.

.

3.3 Risk Management module – Tallinn University of Technology

3.3.1 Background to the Risk Management module

Risk Management was chosen as a suitable topic to include in the pilot modules because, while it is not commonly associated with typical, current BIM workflows in industry, it is highly dependent on project contextual understanding and historical project data which can and should be enhanced through the use of BIM. Therefore, the risk management topic offers an opportunity to explore the explanatory power of BIM (primarily through visualization of the project) and for systematically structuring historical project data so that it is readily available for analysis. From the point of view of BIM-enabled learning, risk management, particularly qualitative aspects of risk identification and analysis, benefit from techniques that allow students to efficiently understand (complex) construction projects through visualization. For quantitative risk analysis, on the other hand, the benefits of BIM relate to the accessibility of systematically structured project data and, BIM-enabled learning must allow efficient data extraction (and, ideally, data input) from (and to) BIM models.

As with the other pilot module topics, risk management is closely bound with the project development process and is also best carried out in collaborative, multidisciplinary groups. Thus, the pilot module was arranged around a series of risk management workshops carried out by students in groups.

3.3.2 Learning outcomes of the module

On completion of this module, the student:

- is able to describe the process, tools and techniques of project risk management (in a BIM-based work process).
- understands risk and project risk management concepts.

- understands the BIM work flow with respect to risk management and more generally.
- is able to apply the project risk management process, tools and techniques in a realistic project scenario.
- is able to decompose the scenario into constituent elements and analyse risks associated with each element.
- is able to evaluate the identified risks in terms of their relative significance and recommend appropriate mitigation actions.
- is able to critically analyse and reconsider the risk management process and the industrial work flow in order to recommend improvements.

3.3.3 Summary of Content

The module focuses on the project risk management process (including both qualitative and quantitative risk analysis) using real project data within a BIM-based work flow.

Topics include:

- Terms and concepts of risk management
- The process of risk management in projects
- Tools and techniques for achieving each stage of the risk management process
- Project risk management standards
- Risk management within the BIM work flow;
- Practical risk management on the basis of real project data;
- How risk and risk management link to wider ideas in construction, science and society.

3.3.4 Module delivery process

The module consists of:

3. An introductory lecture – focus on risk management principles and process
4. Three risk management workshops:
    I. At the project preparation stage – focus on qualitative risk analysis
    II. At the pre-construction stage – focus on quantitative risk analysis
    III. At the construction completion stage – focus on documentation and lesson-learning

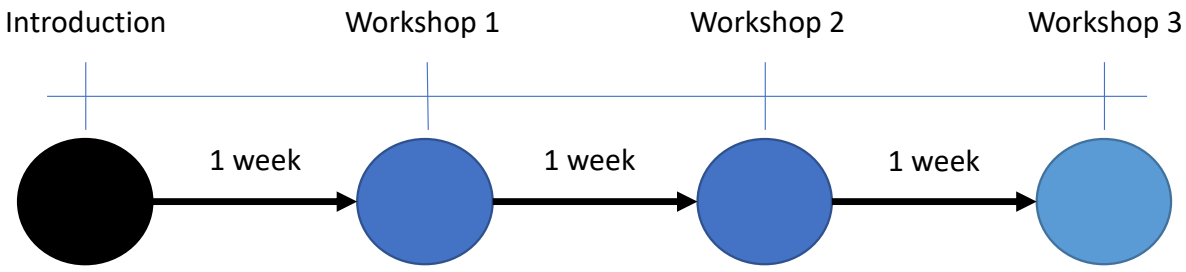

Figure 6 - Timeline for the Risk Management module delivery

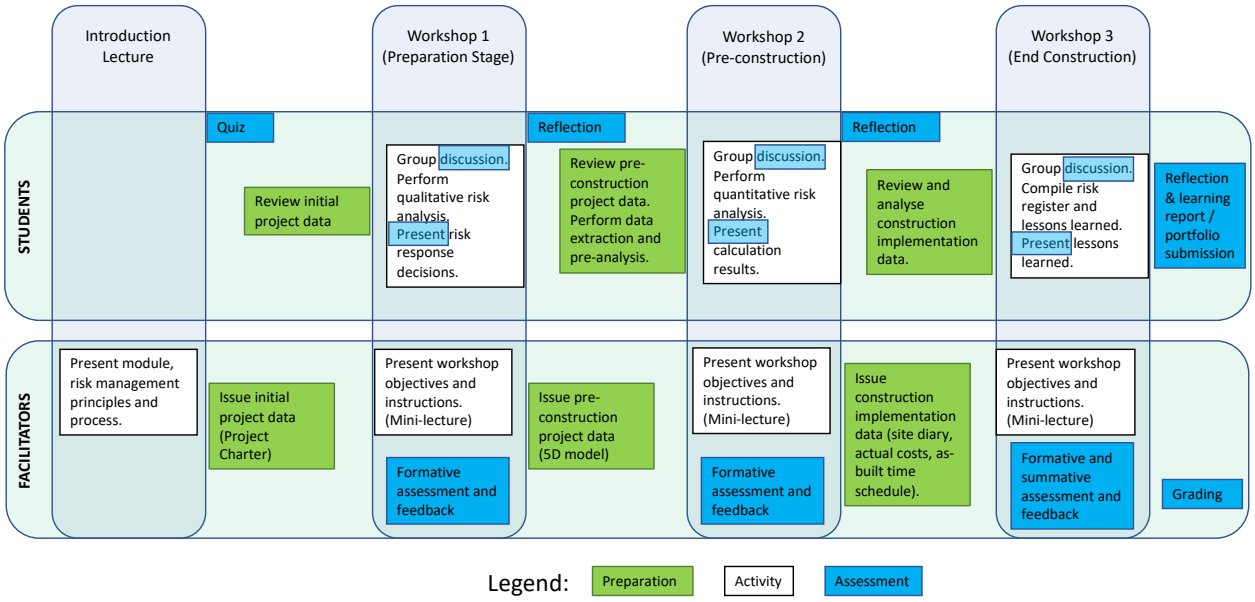

Figure 7 - Process map for Risk Management module delivery

3.3.5 Assessment approach

Formative assessment is provided during and after each risk management workshop in the form of peer and teacher feedback. Summative assessment is based on students' active participation and also their individual reflection on the module and what they have learned. A pass/fail grading system is recommended for this module as it is based on group work and the focus should be on ensuring that all students are engaged and actively work through all the module activities. It is also possible to incorporate quiz questions relating to risk management principles and risk management process-based assessment in an exam format. For the initial pilot module implementation in TalTech, as it formed part of a larger course, a few risk management-related questions covering the material of the pilot module are also included in the overall course exam.

4 Implementation and stakeholder feedback

The Implementation of the three modules took place in the three universities in the Academic Year 2022/23. All the modules were delivered as part of larger courses belonging to the ordinary study plans of the students. The delivery as part of curricular courses was planned to ensure full accessibility of the pilot modules to students, and as an improvement of education provided.

The stakeholder feedback included the students' and teachers' opinion of all the three modules. A comparison of both feedback was provided to direct future implementations.

4.1 Implementation of the Design Management module

The Design Management pilot module was delivered at Tampere University in September-October 2022 with 13 Sustainable Urban Development degree students. The module was part of a third year Construction Management

course (5 ECTS).

The module was delivered face-to-face on campus in four design management meetings as described under 3.2.3. However, the module is well suited to be delivered fully online or in a hybrid-mode as well. The duration of each construction management meeting was two hours, plus an introduction lecture. There was also a supporting Introduction to Building Information Management lecture as the students had very little understanding of building construction, construction management, or BIM when the course started. Students worked independently in the design management meetings and support was offered after and between the meetings for the students to prepare for the next meeting.

4.2 Implementation of the Time management module

The Time Management pilot module was delivered at University of Bologna in September-November 2022 with 19 Building Construction Engineering degree students. The module was part of a third year Construction Management course, termed Building Sites and Production, at the Ravenna Campus of Unibo (6 ECTS).

The module was delivered face-to-face on campus with an introductory lecture and 3 time management workshops as described under 3.1.4. However, the module is well suited to be delivered fully online or in a hybrid-mode as well. The duration of the introductory lecture and of each construction management workshop was two hours. There was also a supporting lecture to Building Information Modelling as the students had very little understanding of BIM when the course started. Other topics addressing construction management methods and tools were delivered in the hosting course. Students worked independently between the time management workshops and support was offered during the workshops to prepare for the next one.

4.3 Implementation of the Risk Management module

The Risk Management pilot module was delivered in Tallinn University of Technology in the spring semester of the 2022/2023 academic year to a class of 26 students. The students comprised fourth year civil engineering students from a 5-year integrated masters' in civil engineering programme and first year master's students in a 2-year master's in civil engineering programme. The module was taught as part of a larger (9 ECTS) course on Construction Investments and Project Management.

For the Introduction lecture, and risk management workshops #1 and #3 together with their accompanying mini-lectures, the module was presented in an online-only format. Risk management workshop #2 together with its mini-lecture, on the other hand, were implemented in a face-to-face mode in a physical classroom to most of the students with the materials also made available online for those students who could not physically attend. This arrangement was necessitated by the module teacher's travel schedule in that the teacher was only physically and temporaneously available for risk management workshop #2. As this implementation arrangement proved fully acceptable and convenient to students, it also served to demonstrate that online, hybrid and in-class delivery modes were all feasible for this module.

5 Module assessment and evaluation

A detailed study of suitable assessment and evaluation techniques for the BIM-enabled learning concept was carried as part of this same intellectual output (Intellectual Output O4 – Pilot Modules). The purpose of the study was to design a toolbox to support the BENEDICT project modules meet their objectives by identifying and recommending contemporary tools for the analysis, assessment and evaluation of the modules and the student learning achieved

through them. The scientific basis, design principles, and tools for assessment and evaluation are all described in a separate BENEDICT project report which is entitled: *BIM-enabled Learning - Toolbox for Assessment and Evaluation*.

6 Stakeholder feedback on the modules

6.1 Teachers' feedback

6.1.1 Teachers' feedback of the Design Management module

Module students were given brief descriptions of their roles on Moodle and negotiated their roles efficiently. The first meeting was a workshop in which students learned about their roles and what was expected of them. The lecturers provided further advice during the meetings to help the students understand what was expected of them, especially for students who had to play roles in the disciplines of structural and geotechnical engineering. The project (a sports hall) and the design model of the conceptual phase were suitably simple as the students had very limited knowledge of building construction. In the future, a more complex project could be used with participants who already have a deeper knowledge of construction. The evaluation of the meeting workshop appears below.

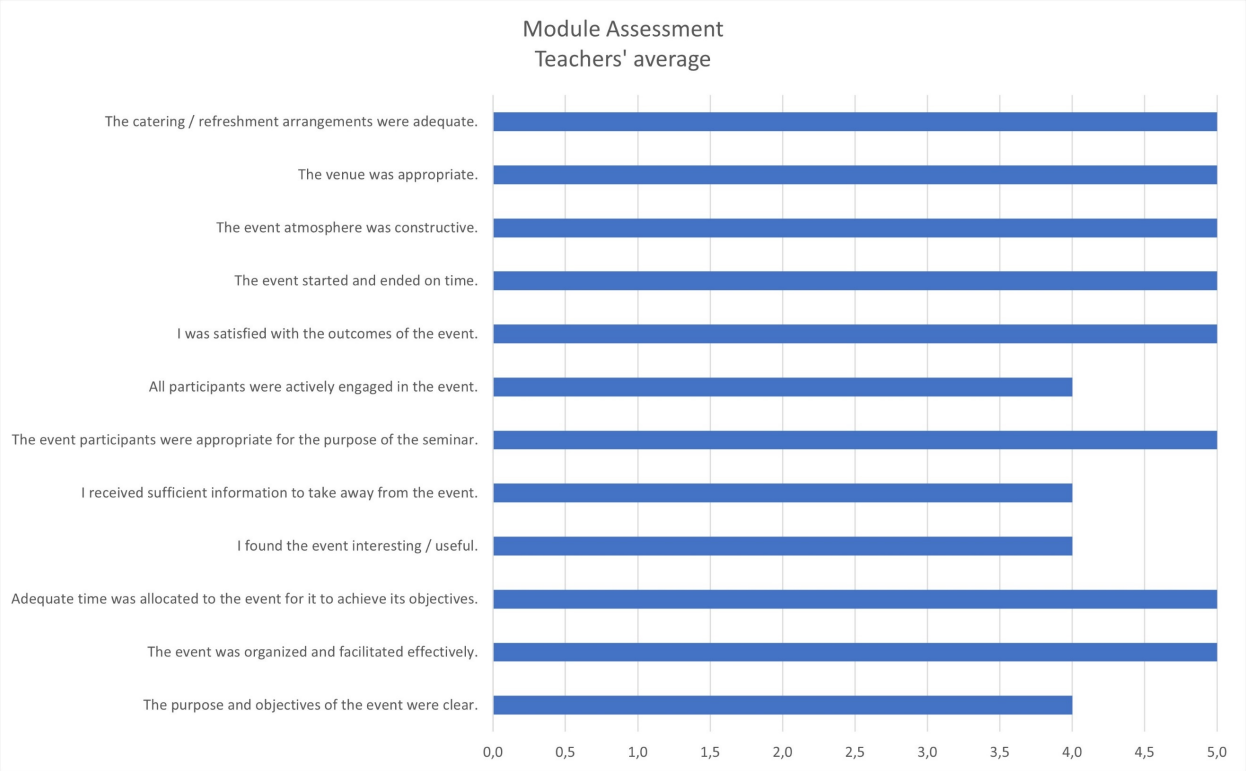

Chart 1 – Design Management Module – Teachers' Feedback

6.1.2 Teachers' feedback of the Time Management module

The Time Management Module, part of Building Sites and Production, held by UniBO met with a positive response

from the teachers, who recorded significant student participation, especially with regard to the practical aspect of creating the 4D animation depicting all phases of the construction process of their architectural project.

The students found the module very informative and useful, appreciating the use of real projects as practical examples and realising how useful this could be for their work.

The module was engaging and well organised and the students demonstrated that they learnt a lot about time management in a construction sector.

The module evaluations were divided into 4 areas: Module Organisation, Knowledge & Background, Expectations and Assessment of skill enhancement.

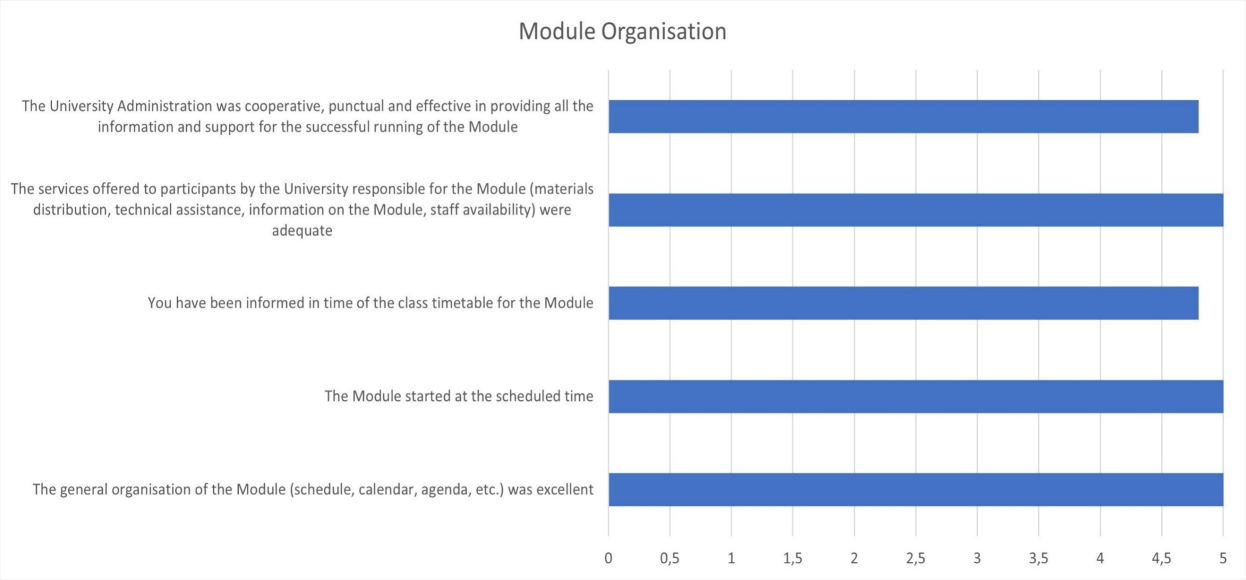

Chart 2 – Time Management Module – Teachers' Feedback – Module Organisation

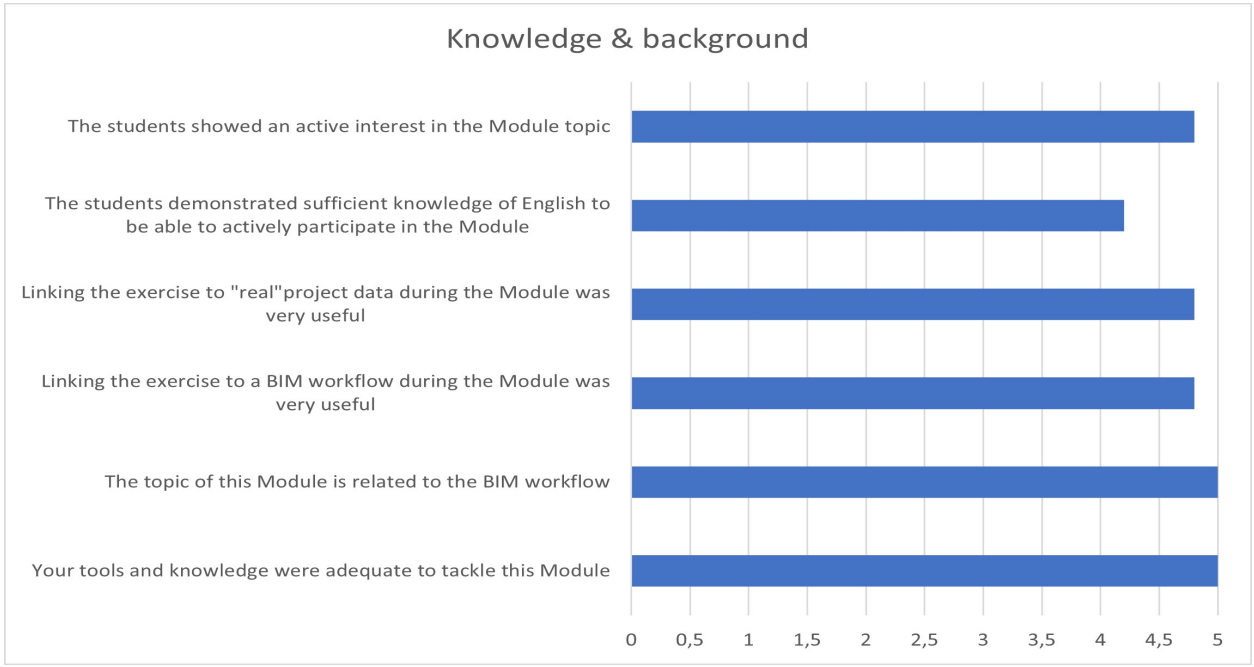

Chart 3 – Time Management Module – Teachers' Feedback – Knowledge & Background

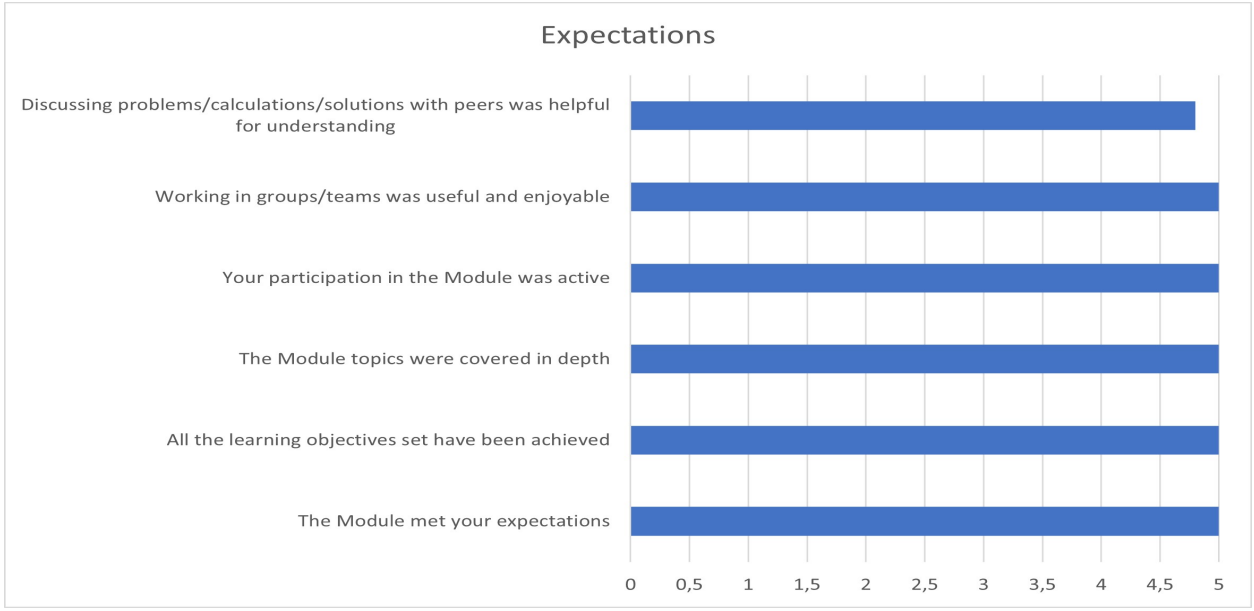

Chart 4 – Time Management Module – Teachers' Feedback – Expectations

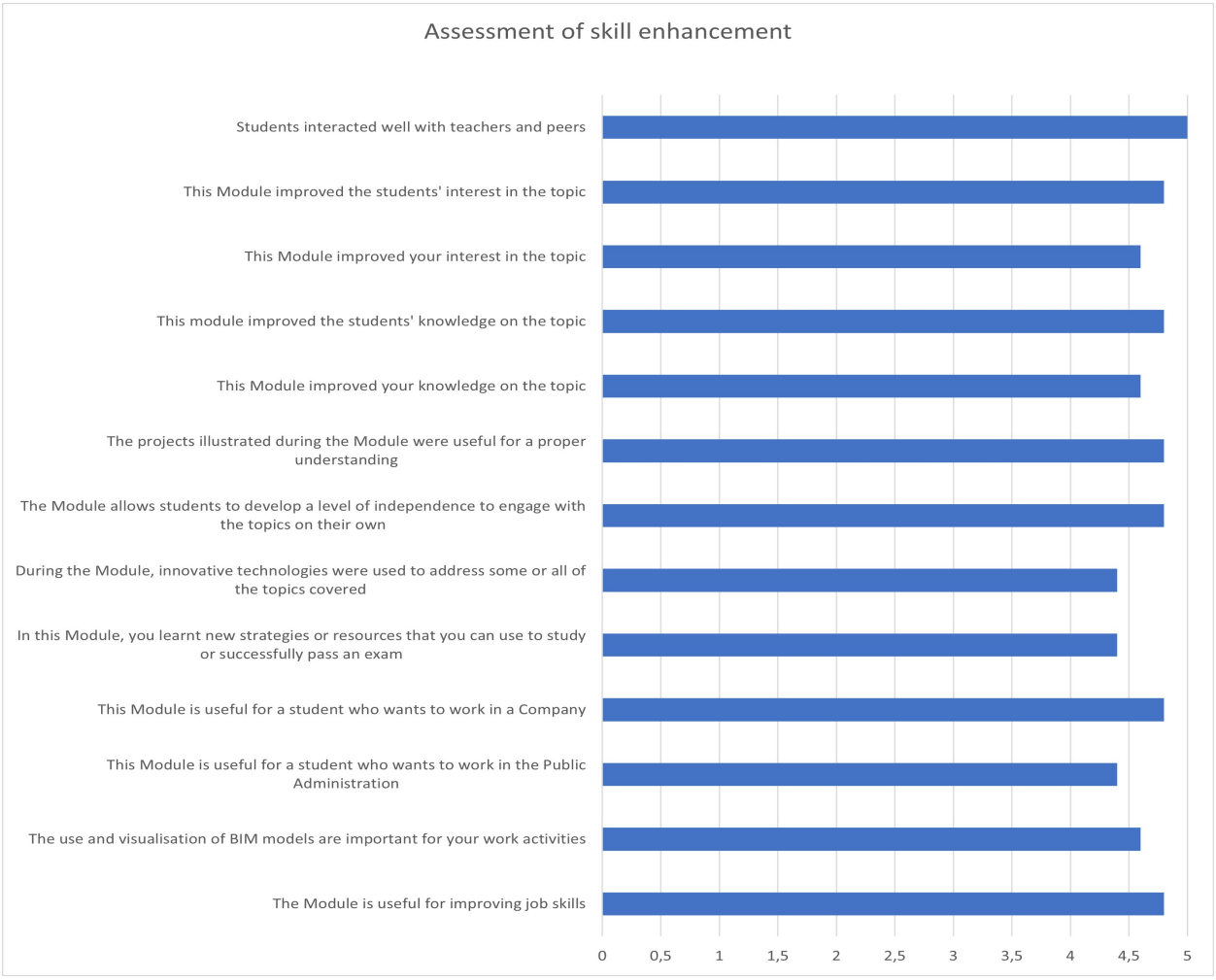

Chart 5 – Time Management Module – Teachers' Feedback – Skill Enhancement

6.1.3 Teachers' feedback of the Risk Management module

The students found the module very informative and useful, interesting and engaging. Some aspects, such as the quantitative analysis part using Monte Carlo simulation, were found to be not so easy but still very challenging to deal with. The students considered the module an excellent experience that allowed them to learn a lot about risk management in a BIM-enabled context.

The module evaluations were divided into 4 areas: Module Organisation, Knowledge & Background, Expectations and Assessment of skill enhancement.

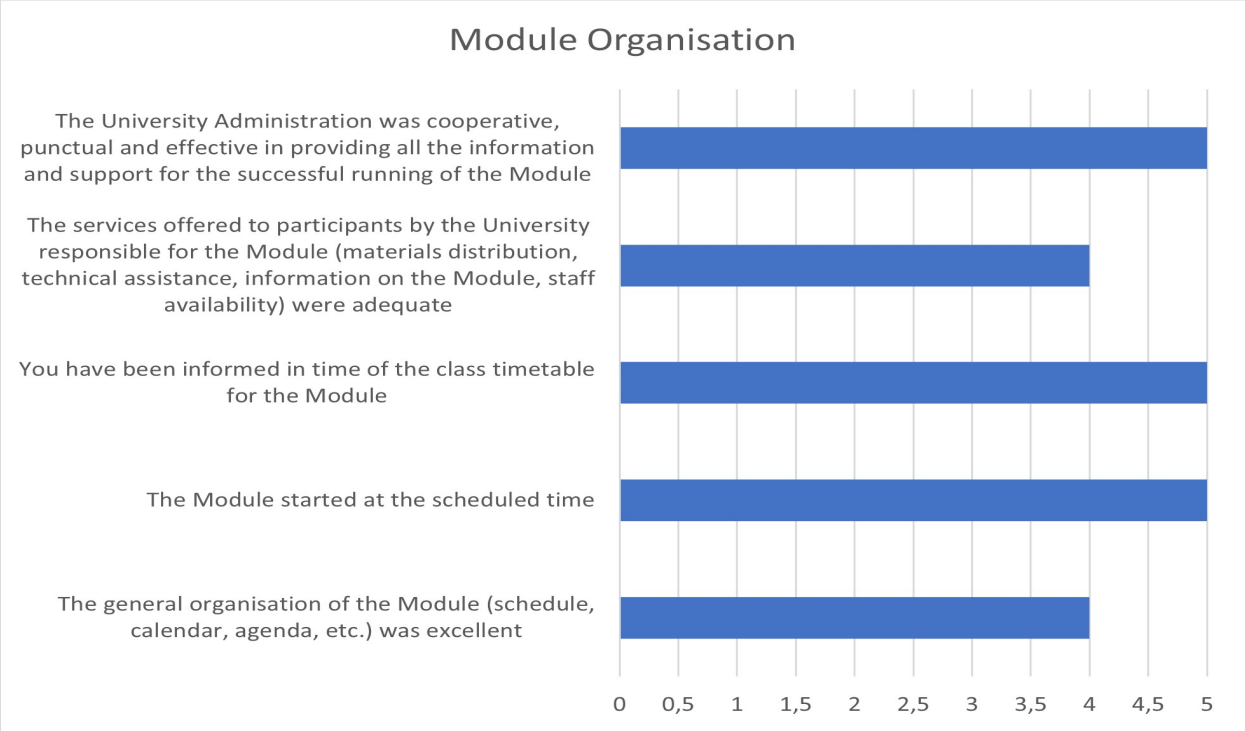

Chart 6 – Risk Management Module – Teachers' Feedback – Module Organisation

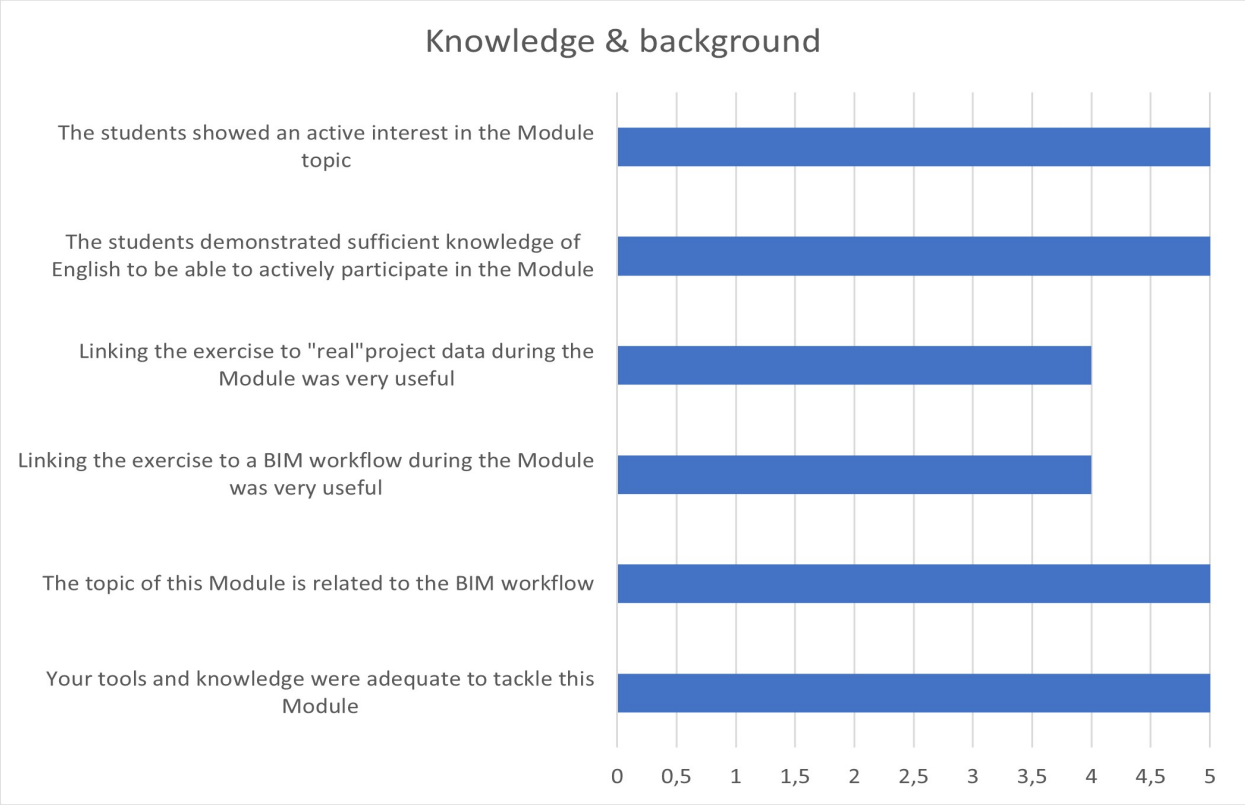

Chart 7 – Risk Management Module – Teachers' Feedback – Knowledge & Background

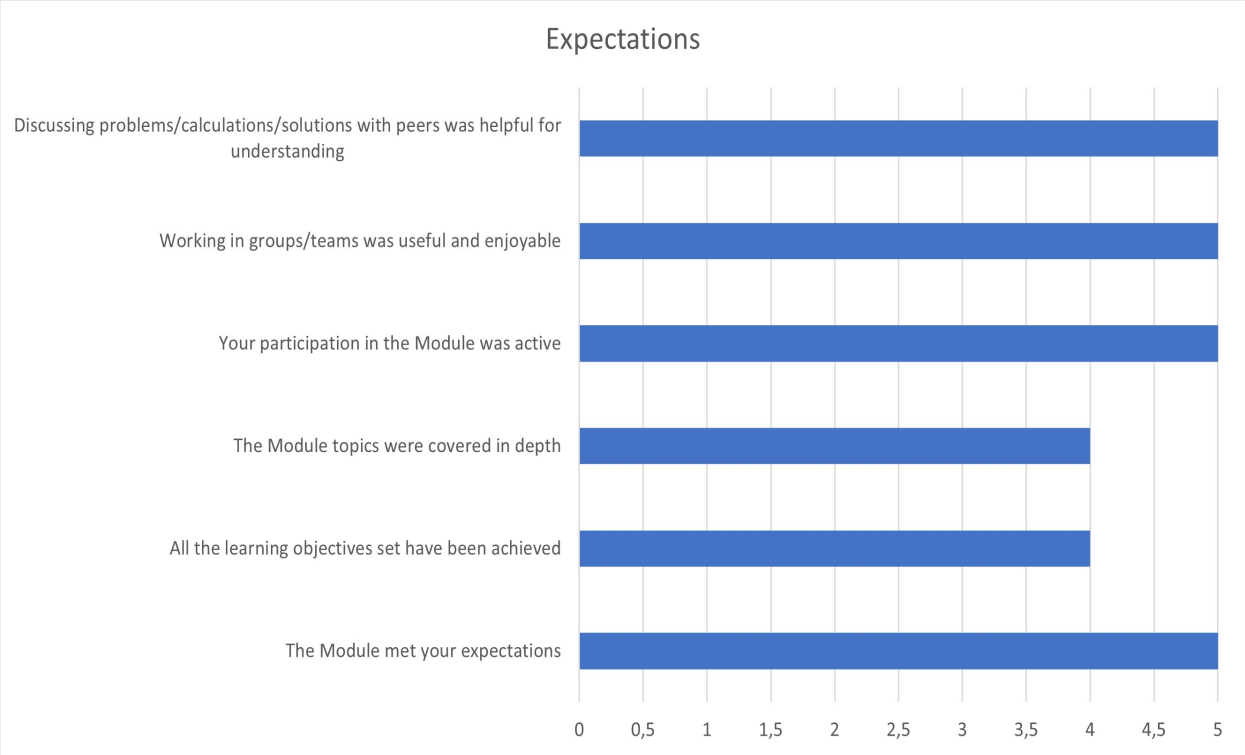

Chart 8 – Risk Management Module – Teachers' Feedback – Expectations

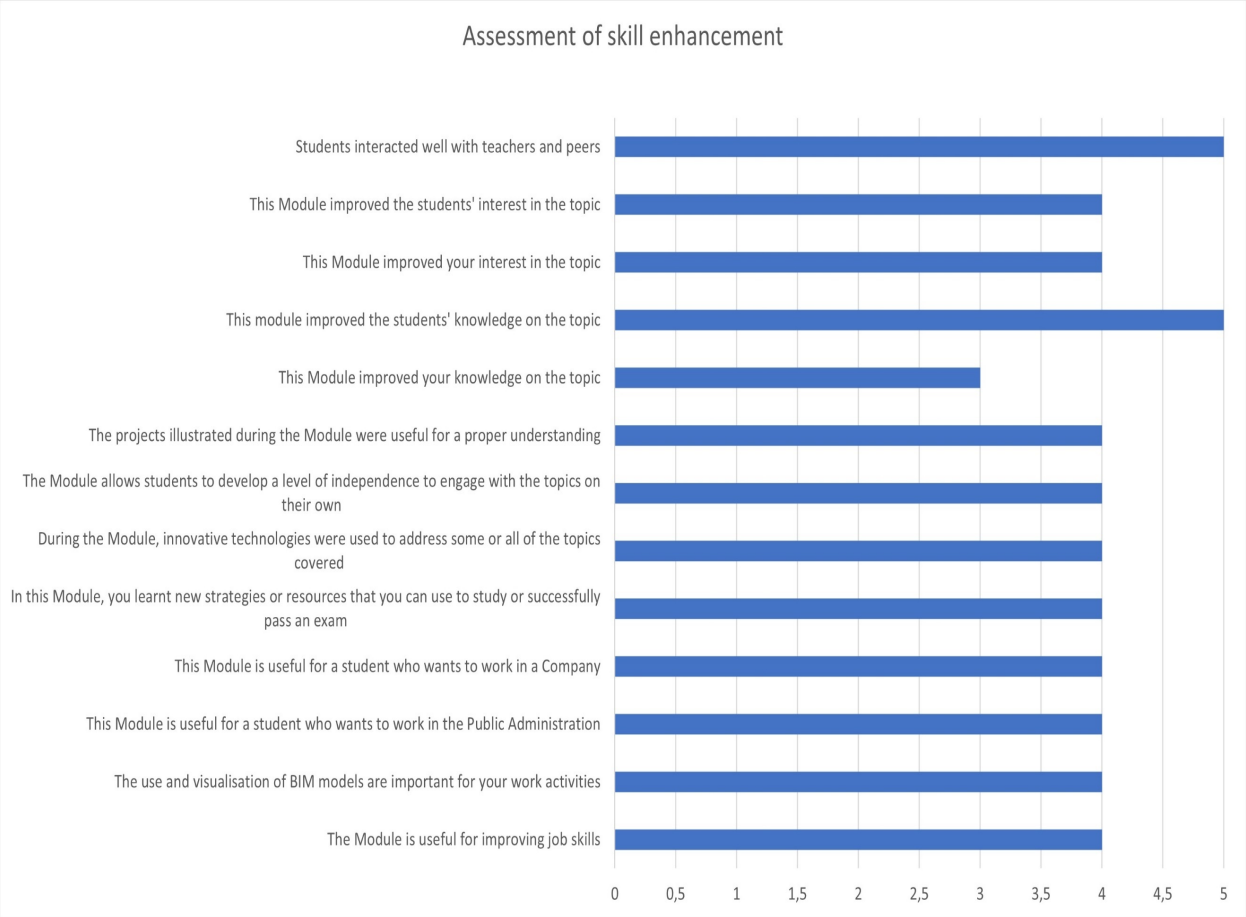

Chart 9 – Risk Management Module – Teachers' Feedback – Skill Enhancement

6.2 Students' feedback

6.2.1 Students' feedback of the Design Management module

The students rated the experience positively and felt they learned a lot. In fact, in their opinion, the initial workshop event was well organised and scheduled. In conclusion, their feedback was positive, they found the event very clear, useful for their growth and knowledge.

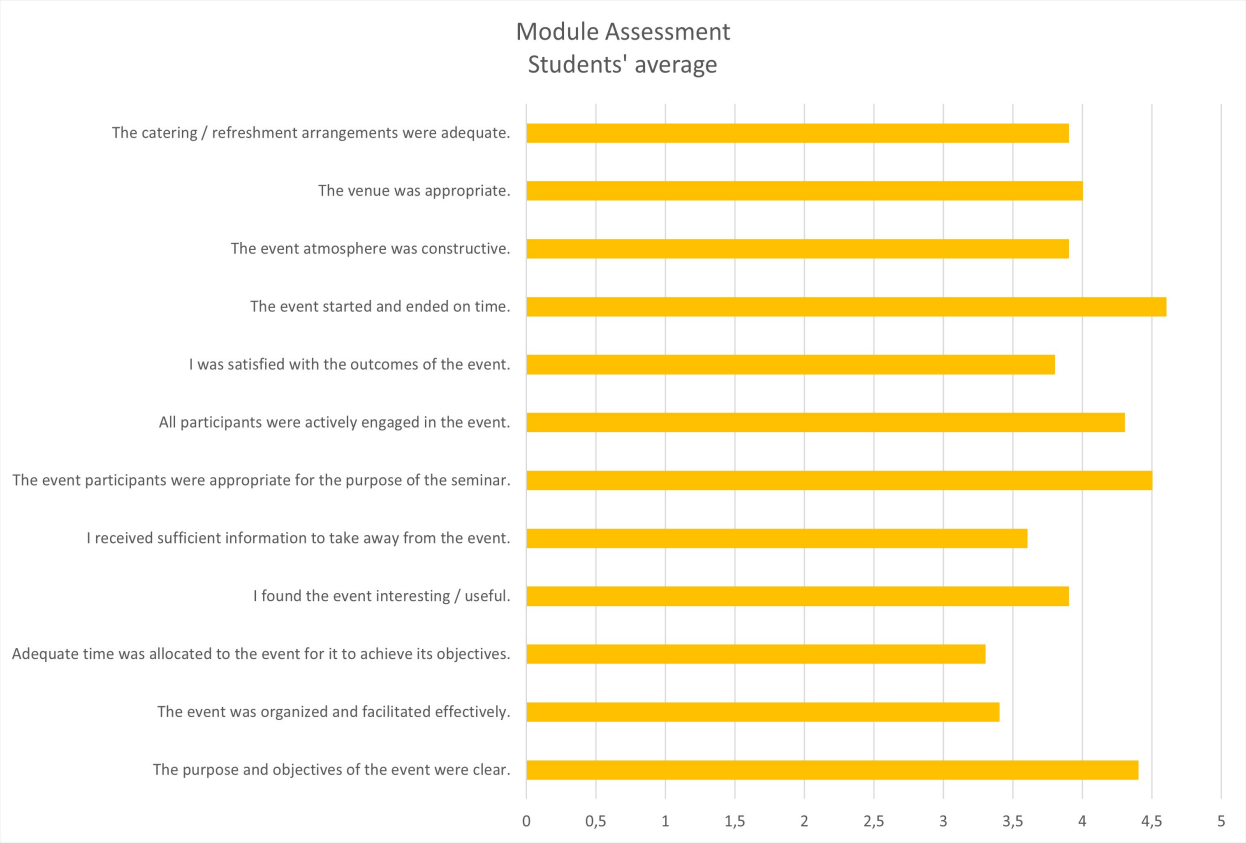

Chart 10 – Design Management Module – Students' Feedback

6.2.2 Students' feedback of the Time Management module

The students in the Time Management module, part of Building Sites and Production, held by UniBO confirmed the positive expectations of the Teachers, understanding the importance of the Module both in terms of possible future job opportunities and for the innovation proposed within the Module where, through the use of BIM software, they were able to model and create 4D animation of the construction site phases of their architectural project.

The students found the module very useful, especially for improving their professional skills in the construction sector. They appreciated the use of BIM in a site management context. The module was considered to be well organised and the students showed that they have learnt how to manage time in the construction process.

The module evaluations were divided into 4 areas: Module Organisation, Knowledge & Background, Expectations and Assessment of skill enhancement.

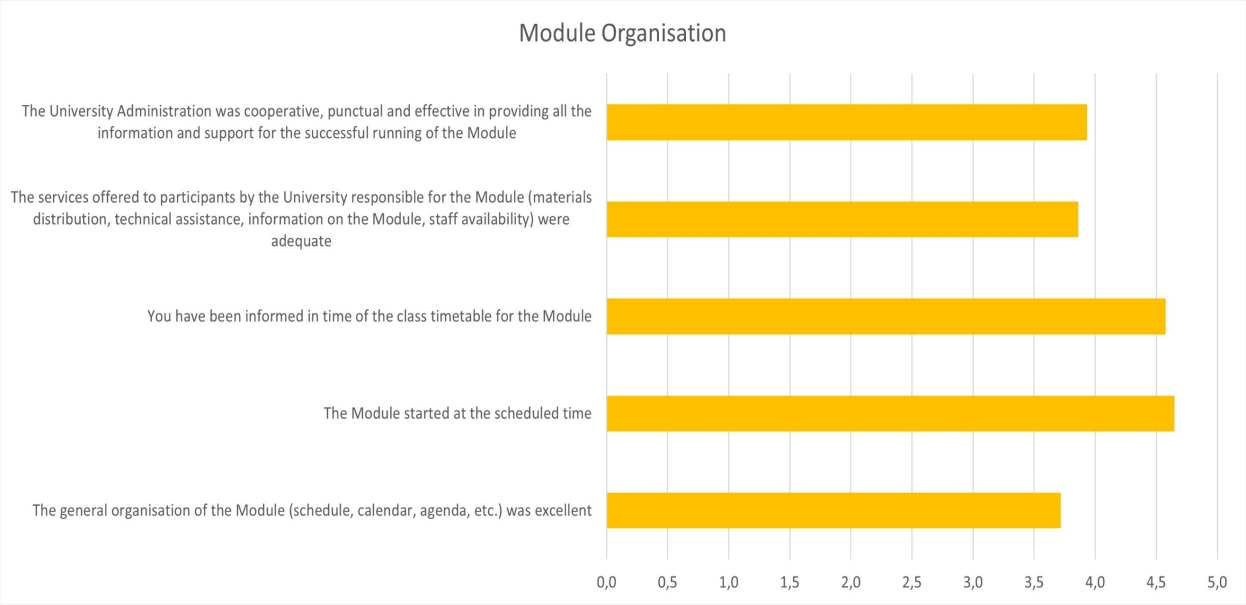

Chart 11 – Time Management Module – Students' Feedback – Module Organisation

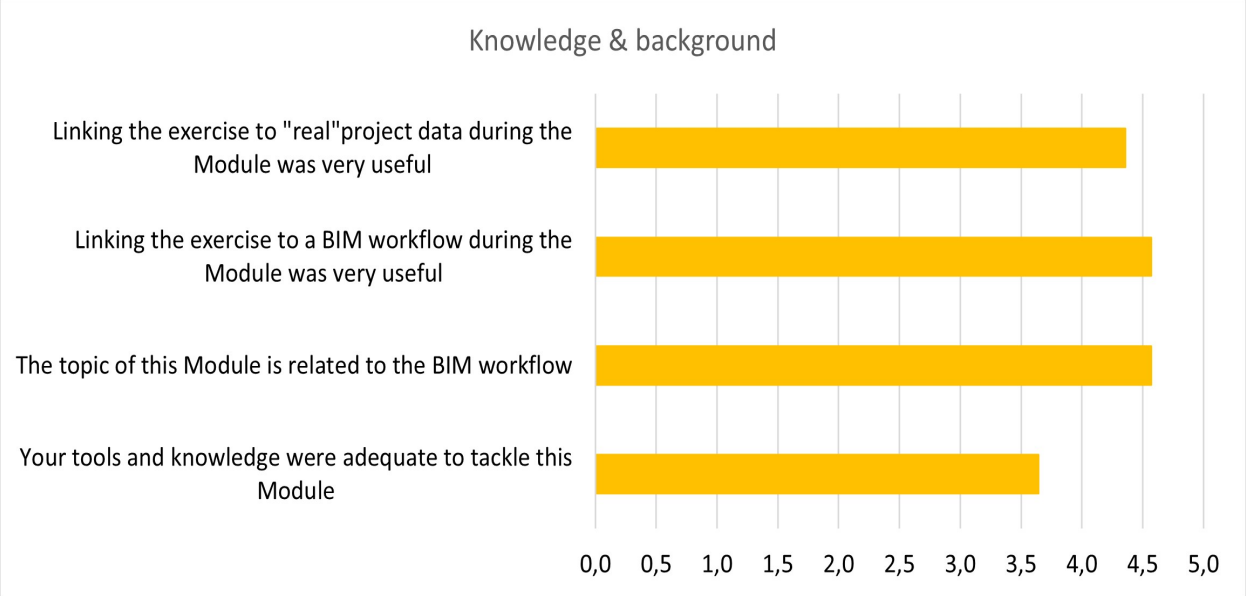

Chart 12 – Time Management Module – Students' Feedback – Knowledge & Background

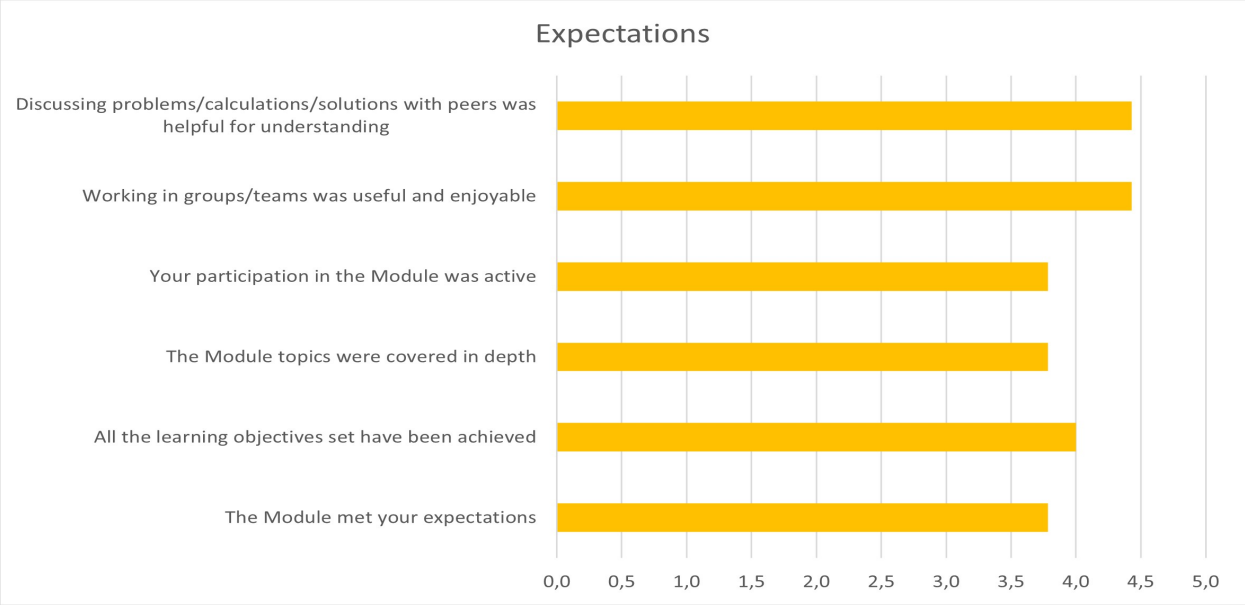

Chart 13 – Time Management Module – Students' Feedback – Expectations

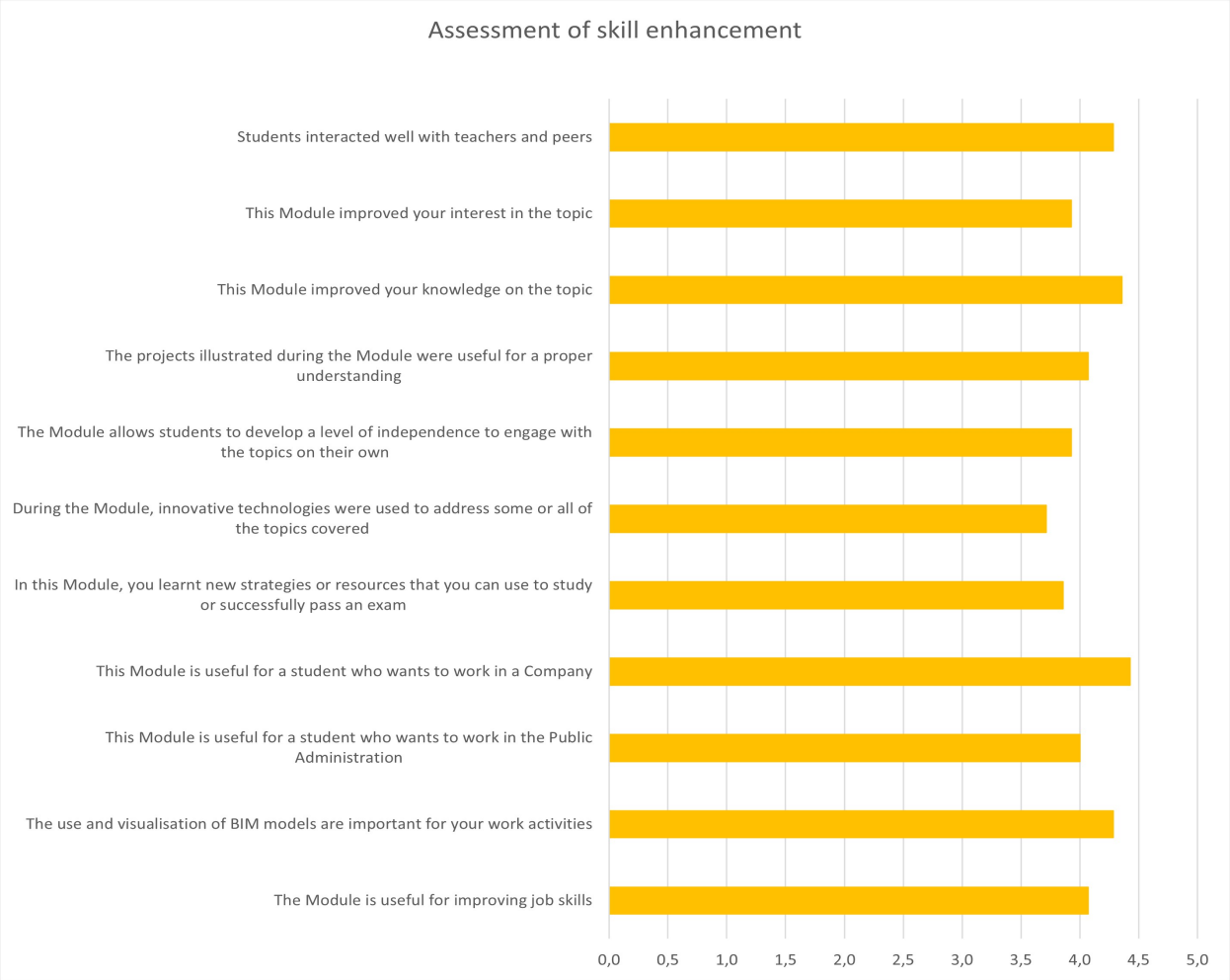

Chart 14 – Time Management Module – Students' Feedback – Skill Enhancement

6.2.3 Students' feedback of the Risk Management module

The module was very clear, and the materials were well organised.

The students found it very useful to link the exercise to a BIM workflow during the module, finding that it helped them understand how risk management concepts can be applied in a real-world context.

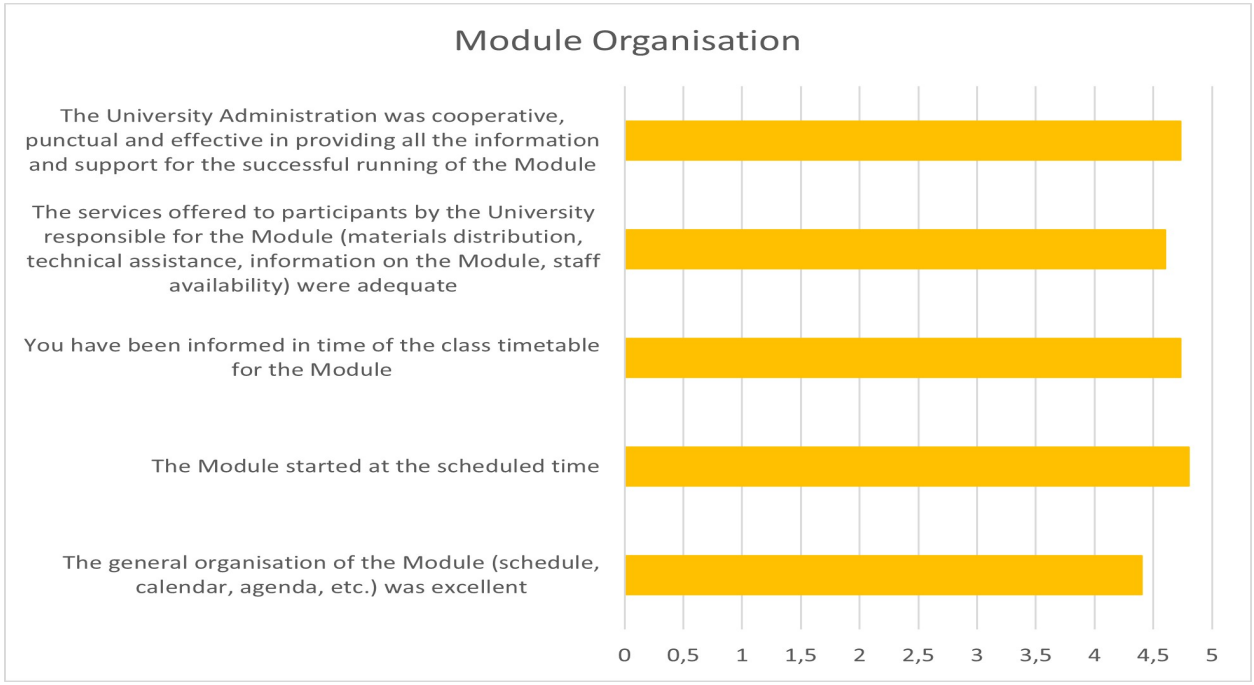

Chart 15 – Risk Management Module – Students' Feedback – Module Organisation

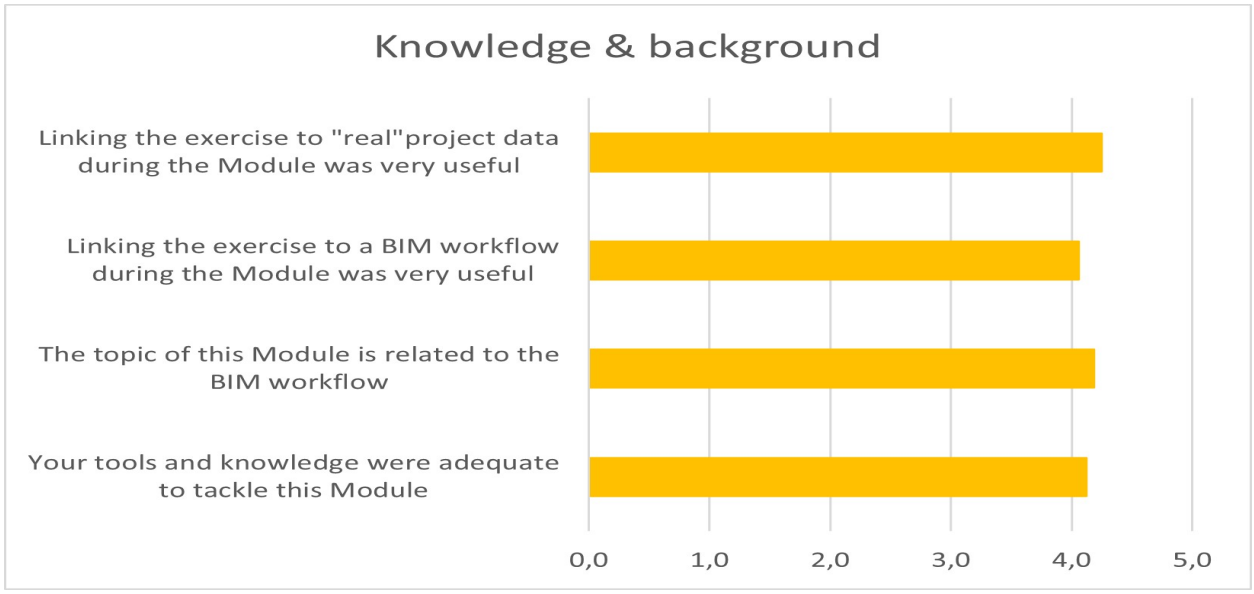

Chart 16 – Risk Management Module – Students' Feedback – Knowledge & Background

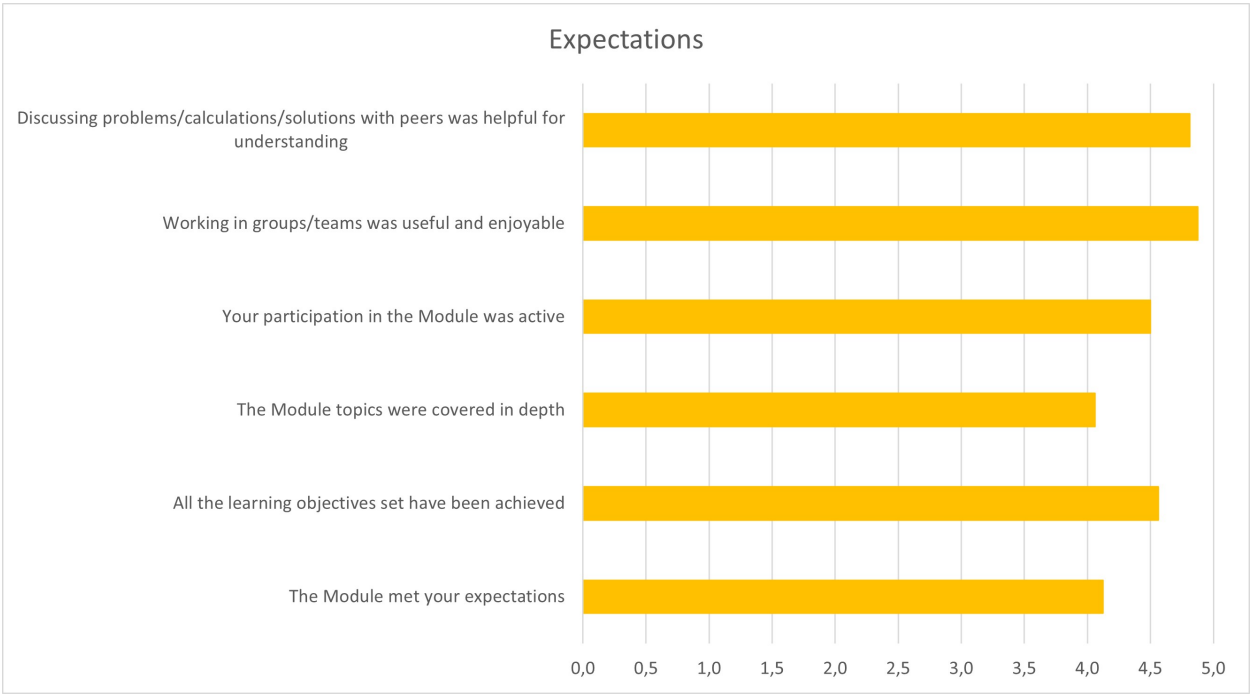

Chart 16 – Risk Management Module – Students' Feedback – Expectations

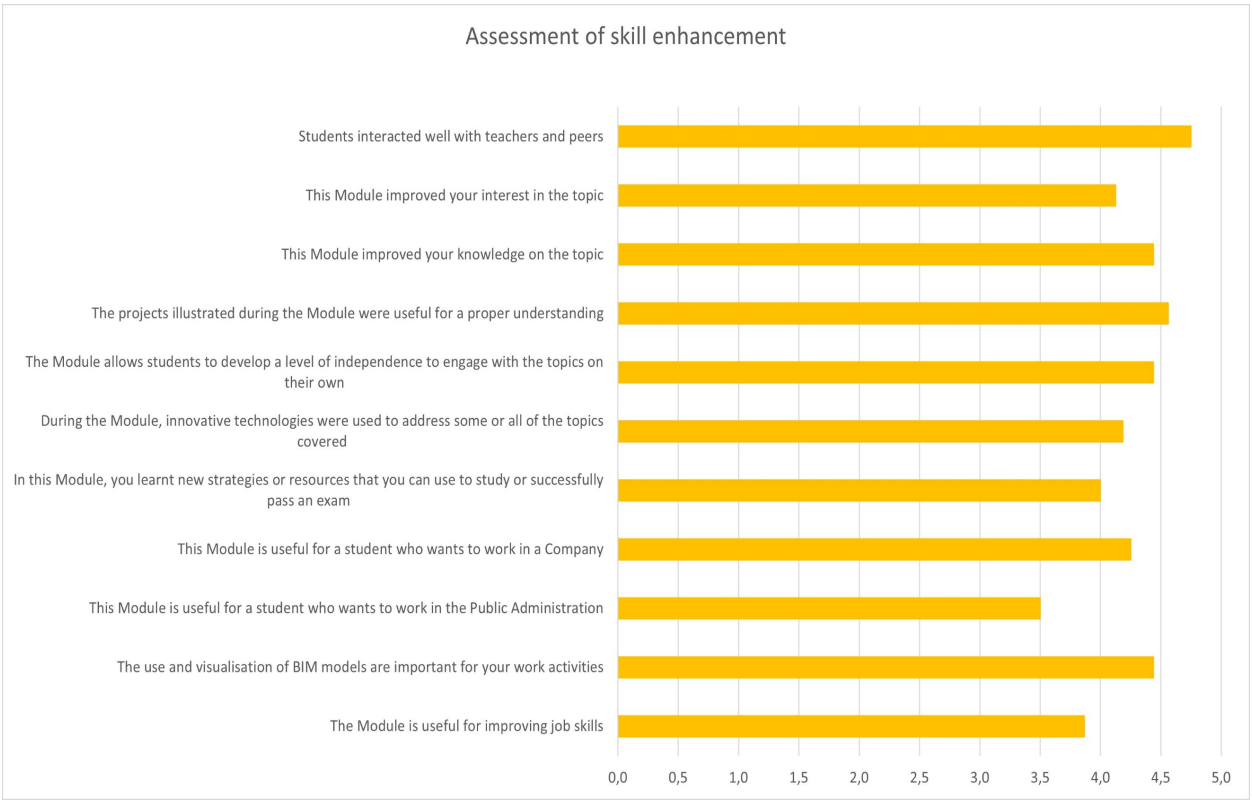

Chart 17 – Risk Management Module – Students' Feedback – Skills Assessment

6.3 Feedback comparison

6.3.1 Feedback comparison for the Design Management module

Feedback on the Design Management module was considered positive overall by both students and lecturers. However, on a teaching and organisational level, thought has already been given to how to improve it for the next version, through the use of more complex projects that involve students more closely.

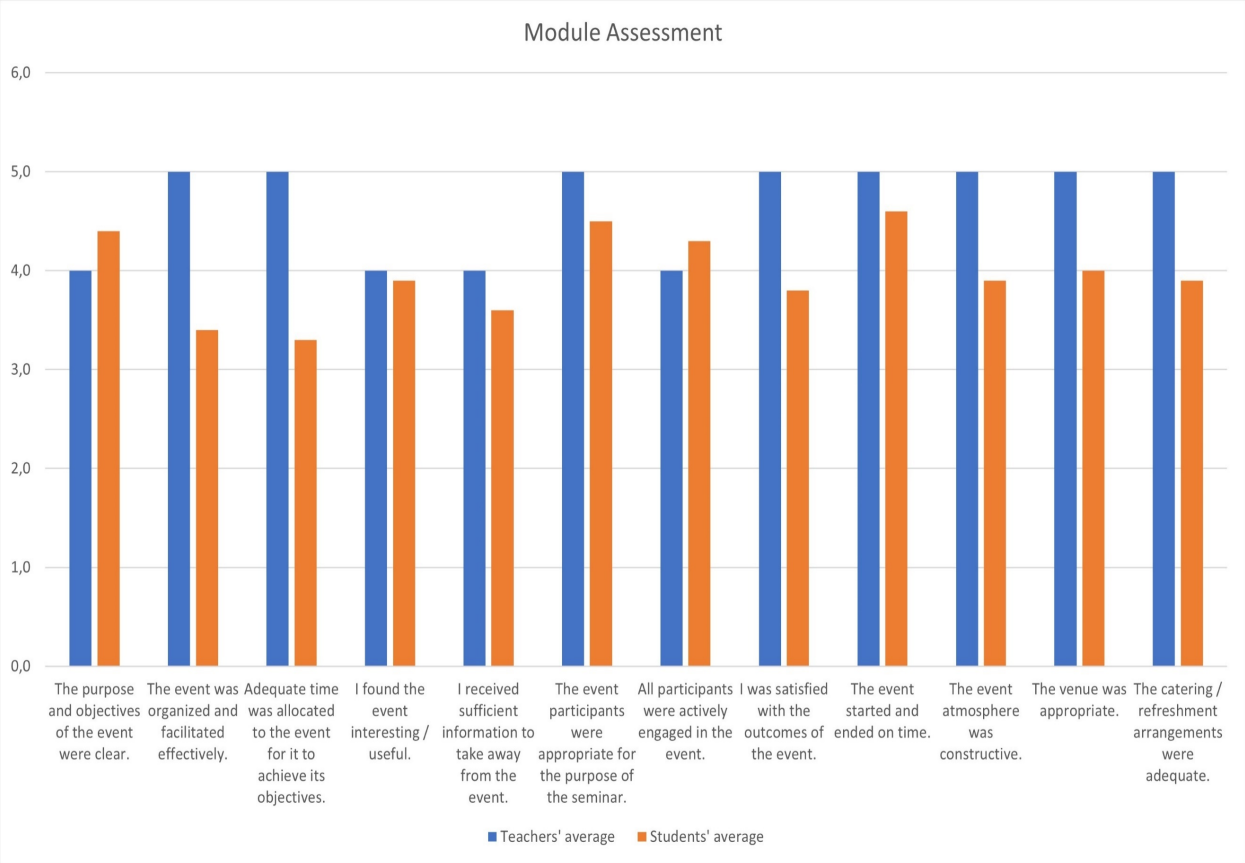

Chart 18 – Design Management Module – Feedback Comparison

6.3.2 Feedback comparison for the Time Management module

Comparing the feedback from students and teachers allows us to understand the positive trend that has been maintained. It is possible to see how expectations and final assessment remain constant among the teaching staff and instead undergo a positive increase in student evaluations. In conclusion, the feedback from teachers and students indicates that the module was an overall positive experience.

The module evaluations were divided into 4 areas: Module Organisation, Knowledge & Background, Expectations and Assessment of skill enhancement.

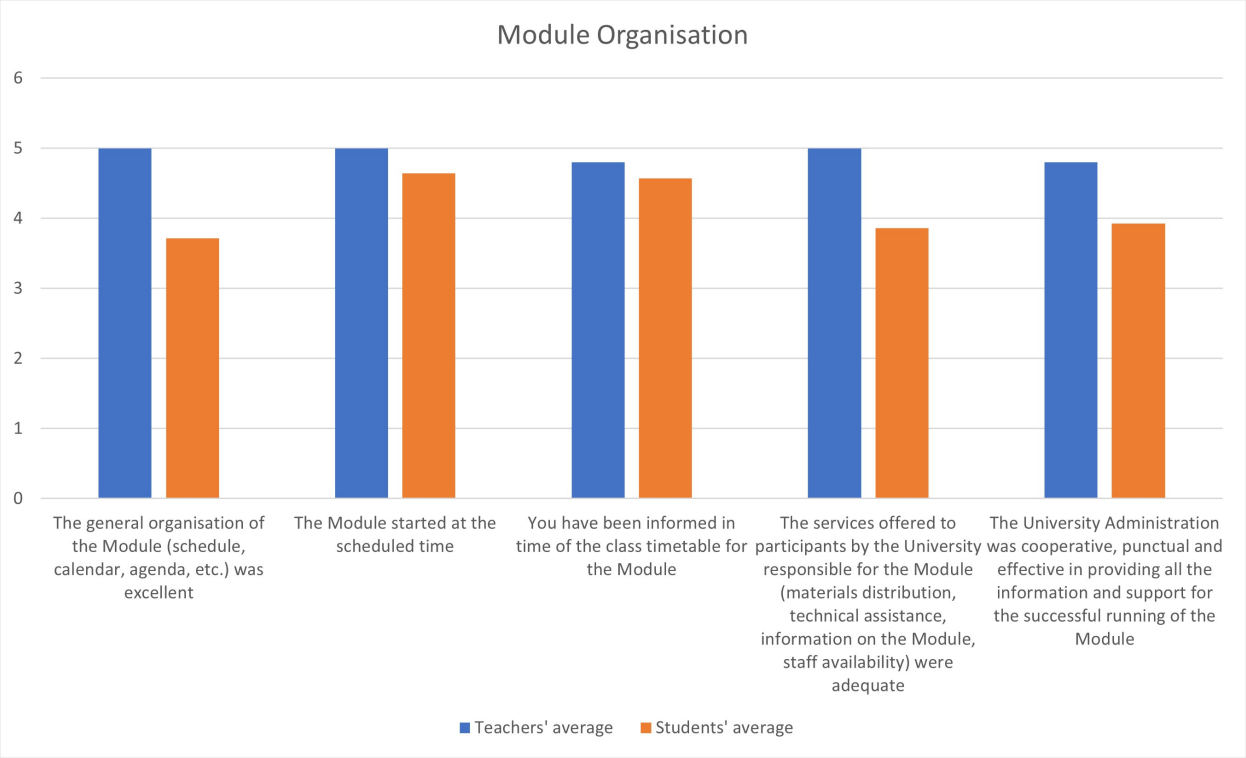

Chart 19 – Time Management Module – Feedback Comparison – Module Organisation

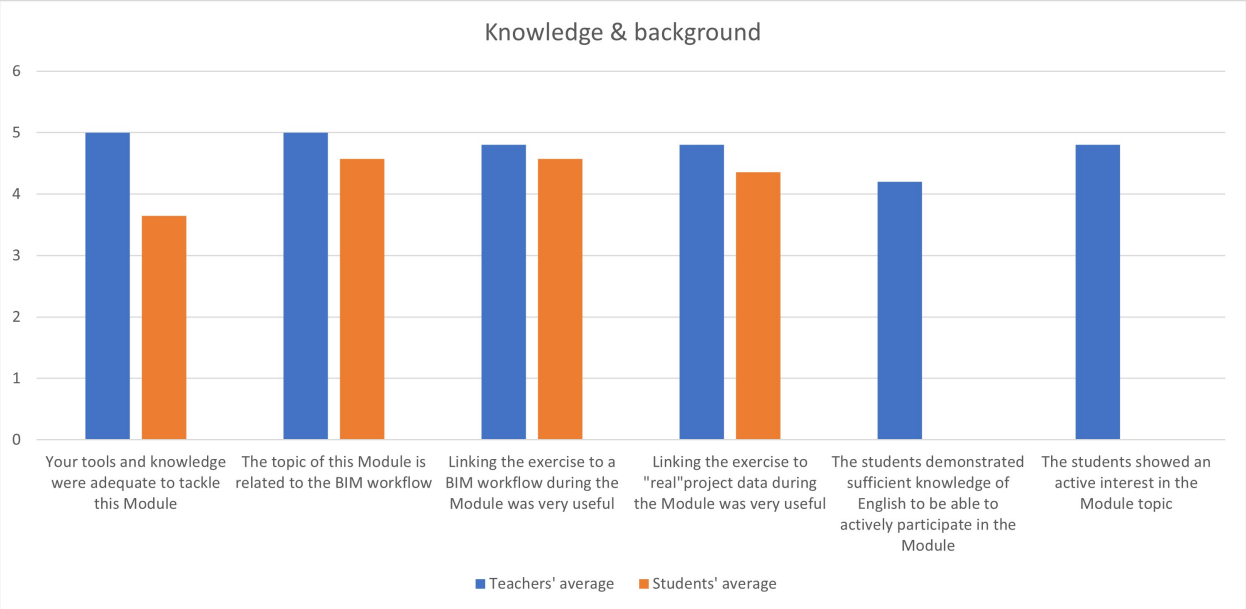

Chart 20 – Time Management Module – Feedback Comparison – Knowledge & Background

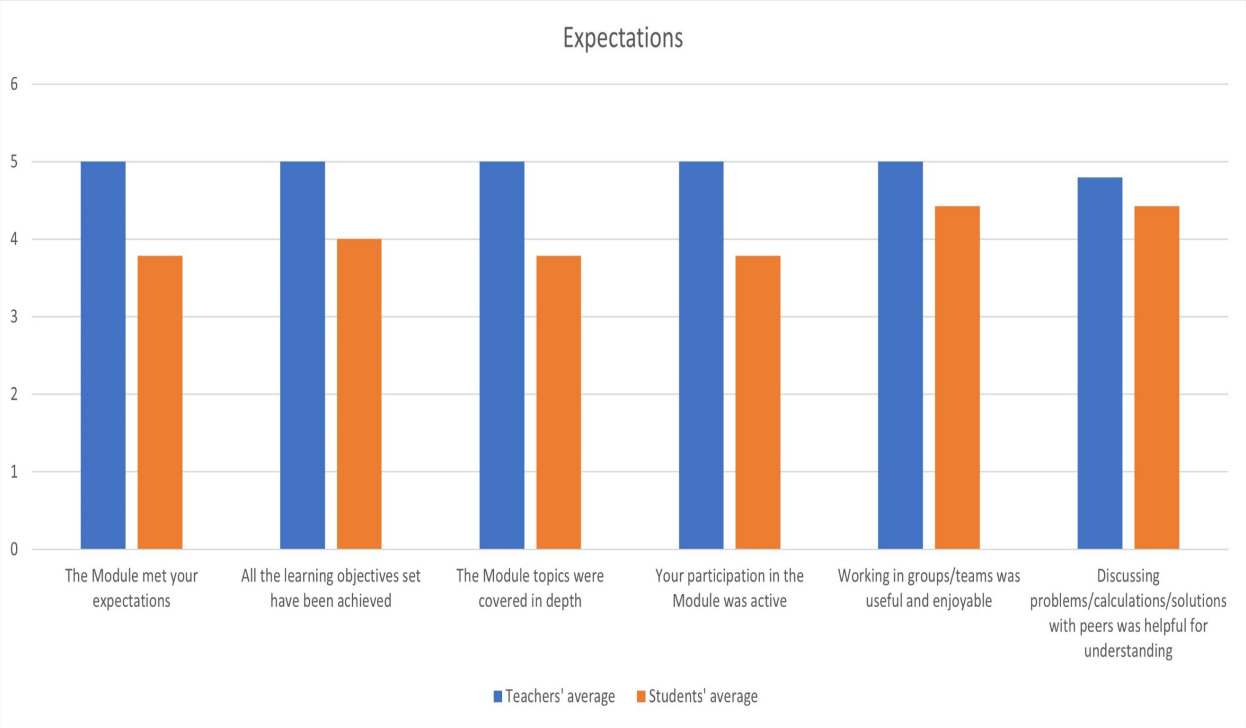

Chart 21 – Time Management Module – Feedback Comparison – Expectations

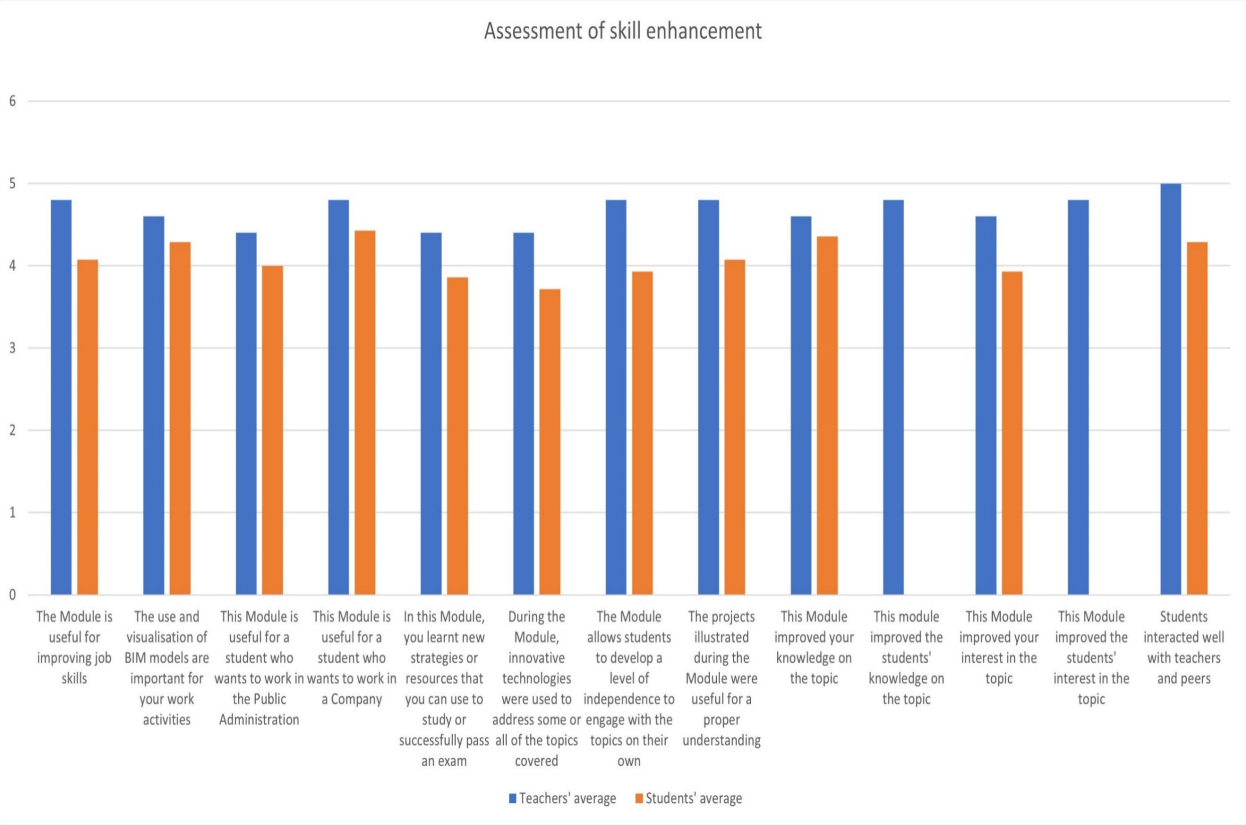

Chart 22 – Time Management Module – Feedback Comparison – Skills Enhancement

6.3.3 Feedback comparison for the Risk Management module

Feedback from teachers and students indicates that the module was an overall positive experience. Although the module is already characterised by the opportunity to work on real projects and the use of innovative technologies to address some of the topics covered, it will be constantly updated to maintain high standards so that it can be increasingly useful for students.

The module evaluations were divided into 4 areas: Module Organisation, Knowledge & Background, Expectations and Assessment of skill enhancement.

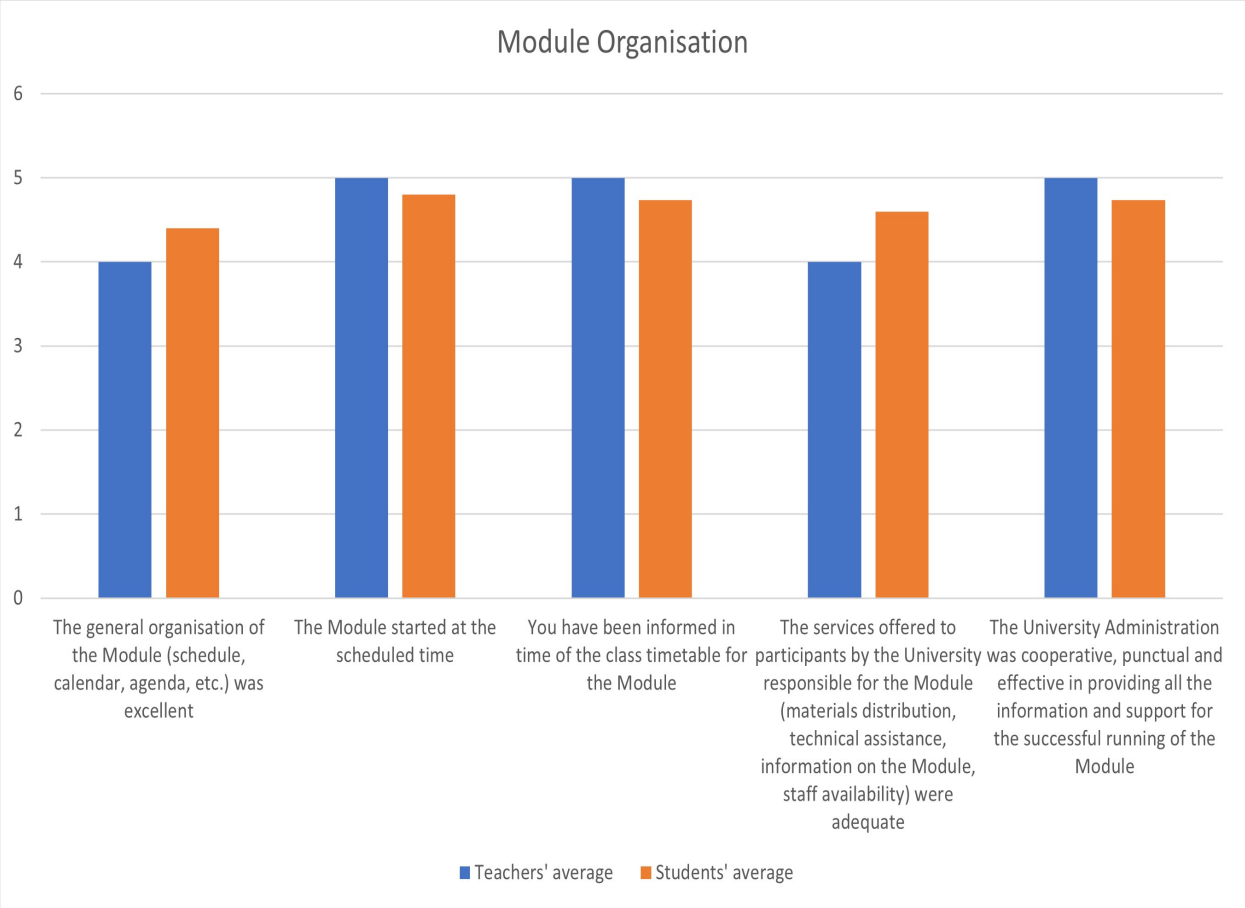

Chart 23 – Risk Management Module – Feedback Comparison – Module Organisation

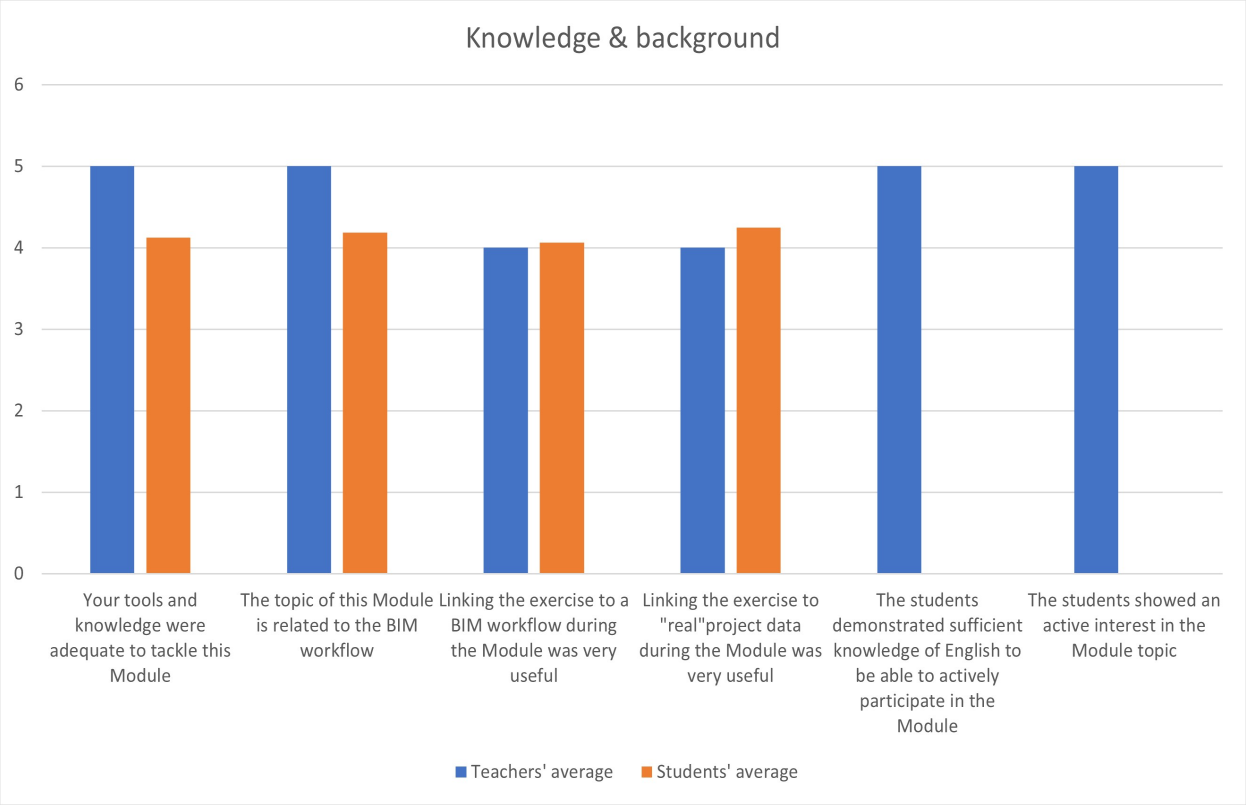

Chart 24 – Risk Management Module – Feedback Comparison – Knowledge & Background

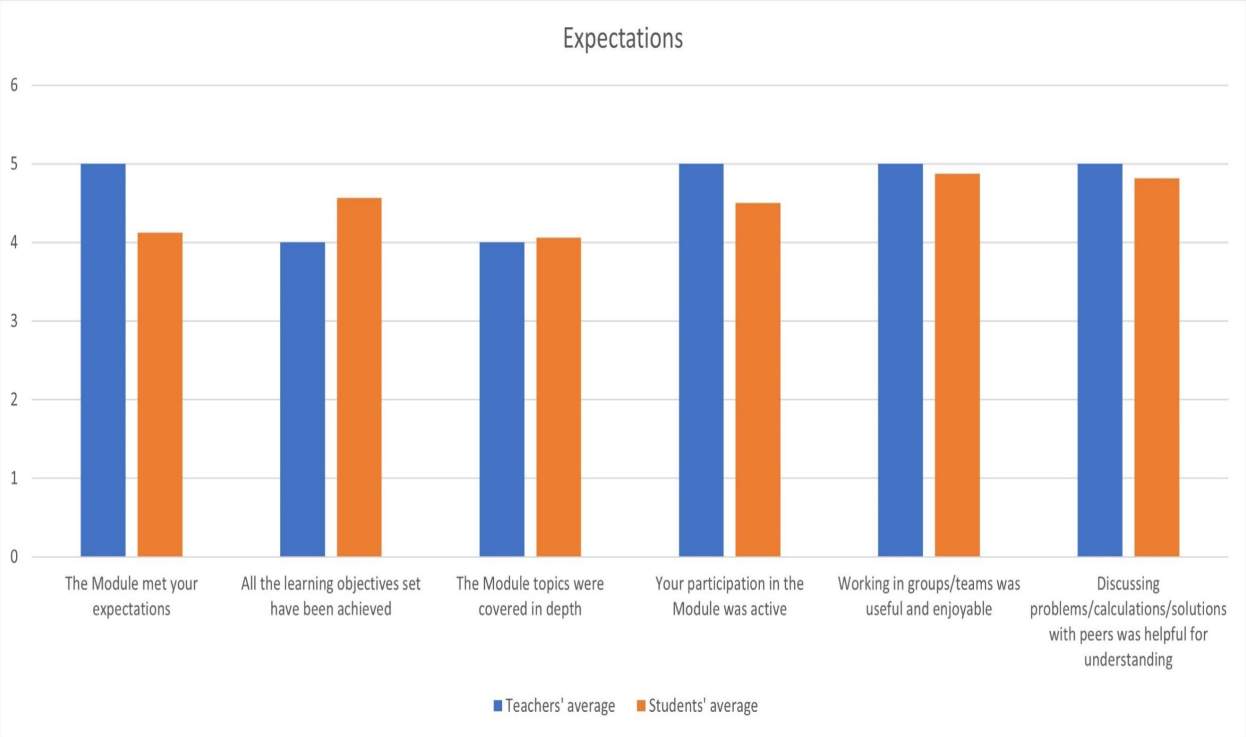

Chart 25 – Risk Management Module – Feedback Comparison – Expectations

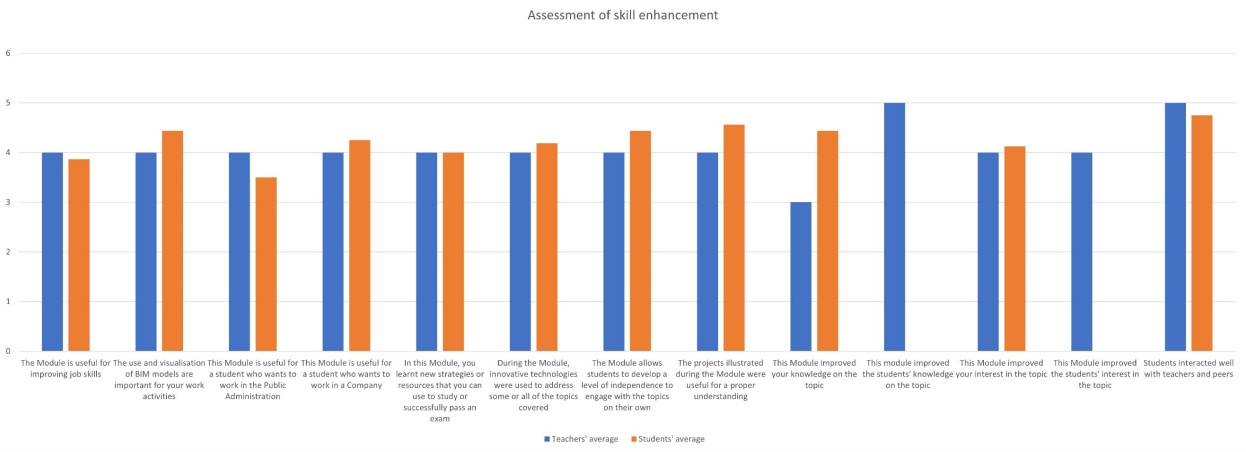

Chart 26 – Risk Management Module – Feedback Comparison – Skill Enhancement

7 Conclusions

The 3 pilot modules – on Design Management, Time Management and Risk Management - were intended to demonstrate the concept of BIM-enabled learning and the functioning of the BIM-enabled Learning Environment (BLE) within real taught courses. They were co-developed by the 3 partner universities during the second year of

project implementation (2021-2022) in collaboration with the Centre for Engineering Pedagogy at TalTech who also led the development of evaluation and assessment tools for BIM-enabled learning. The design and content of all 3 pilot modules were demonstrated along with the BLE platform to a wide range of stakeholders at two Multiplier Events (in Tallinn in June 2022 and October 2022).

The actual teaching of the pilot modules to students took place during the 2022/2023 academic year. In the case of teaching the Design Management module in Tampere, this implementation took place in parallel with the finalization of the assessment and evaluation tools. Consequently, the student and teacher feedback received for the Design Management module took a different form to the feedback received in relation to the Time and Risk Management modules which were implemented slightly later by which time the evaluation and assessment tools had been finalized.

In the case of all 3 pilot modules, the feedback received from both teachers and students was highly positive as shown in section 6 above. This confirms the effectiveness of BIM-enabled learning as an appropriate innovation for knowledge and skills development in the REC sector. It also serves to validate the usefulness of the BIM-enabled Learning Environment (BLE).

As part of Intellectual Output O4 – Pilot Modules, a toolbox for the evaluation and assessment of BIM-enabled learning was also developed and this is reported in a separate document. In addition, the course manuals for all 3 pilot modules which provide comprehensive teaching materials for each of the modules have been developed and are available for public use (reported under Intellectual Output O5 – Guidance Materials). These manuals have also been translated into local languages and are available from the project website (www.benedictproject.eu).

REFERENCES

Underwood, J., Khosrowshahi, F., Pittard, S., Greenwood, D. and Platts, T., (2013). Embedding Building Information Modelling (BIM) within the taught curriculum: Supporting BIM implementation and adoption through the development of learning outcomes within the UK academic context for built environment programmes. Available at: https://www.heacademy.ac.uk/system/files/bim_june2013.pdf (Accessed 30 September 2018).

Witt, E. & Kähkönen, K. 2019A. BIM-Enabled Education - a Systematic Literature Review, Emerald Reach Proceedings Series, Emerald Publishing Limited, Vol. 2, pp. 261–269

Witt, E. & Kähkönen, K. 2019B. A BIM-Enabled Learning Environment: a Conceptual Framework, Emerald Reach Proceedings Series, Emerald Publishing Limited, Vol. 2, pp. 271–279

APPENDIX – Pilot module course outlines

(Begins on next page)

University:	Tampere University	
Degree programme:	Sustainable Urban Development (Bachelor's degree)	
Course title:	Construction Management (host course)	
University module code:	RAK.TA.270 (host course code)	
Professor/Professors:	Kalle Kähkönen	
Academic Year:	2022/2023	
Basic information	Level:	Bachelor
	Year of the degree programme:	3rd year of the Bachelor
	Number of Credits:	5 ECTS
	Duration - number of semesters:	1 period (half a semester)
	Duration - months:	2
	Number of hours:	135
	Which semester(s) of study programme:	Autumn
	Planned start / Planned end	Start of period 1/End of period 1
	Language:	English
	Modules:	
	Status:	Compulsory for Technology Major
	Minimum of compulsory hours of attendance	Not applicable
Additional information	Prerequisite courses:	No
	Complementary/subsequent courses:	No
	Presence of tutors to support teaching:	Yes
	Maximum number of students who can take the course (if the course is limited in number):	20
	Expected Number of students to attend the course:	15
Course contents	**The pilot module is part of a course RAK.TA.270 Construction Management. The above information is for the whole course. This section and the sections below discuss the pilot module details. The pilot module is called BIM-enabled Design Management.** The pilot module will focus on the concept design, and on the analysis, simulation and integration execution, not on the actual design tasks in the project. Indicative topics (role specific, please see Teaching methods for more details on the roles): • Spatial programme evaluation • Design review • Design schedule development • Cost estimation • Model validation • Documentation of meeting minutes and agendas	
Learning outcomes	As learning outcomes of the module, the student • understands the concept design stage processes • understands the connection between different roles, design disciplines and design options; • understands their own role during the concept design • is able to function in their role independently and to collaborate and communicate with other stakeholders • knows the common BIM requirements • is able to apply the common BIM requirements into their role-specific tasks.	

Explicit references to BIM learning	Students use BIM in various ways on the module (role specific): • Conduct design reviews by interrogating the model(s) • Conduct design review meetings with the model at the centre • Evaluate the spatial programme and other client requirements by viewing and analysing the model • Estimate cost of the project by information extraction from the model • Project BIM Brief and BIM Execution Plan development • Validate that the models comply with the preliminary modelling requirements as agreed • Evaluate the compliance with town planning by viewing the model	
Teaching methods	This is a project-based module relying on social constructivism and students as independent (from teachers) learners. Students are organised into stakeholder groups (Client, Architect, BIM coordinator, etc.) and, to an extent, students' specialisations (architecture, construction management, structural engineering, etc.). Depending on the students' specialisations and number of students on the module, stakeholder groups' sizes vary from one student to multiple. Students work sequentially and in collaboration to analyse, simulate and integrate the building design using BIM model(s) and other available resources. Students work independently, both individually and as a project team. Faculty members' and industry mentors' role is to facilitate the process at agreed milestones, which include the design review meetings as a minimum. Students run the meetings. Facilitators' role in the meetings is to provide feedback and advice as needed. A kick-off lecture is offered to introduce the project. Supporting resources on specific topics are offered during the module.	
Teaching tools	Tools:	Basic computer hardware
	Software:	Model viewing application, information extraction application, basic office applications, communication applications, project management application (cloud storage)
	Platform:	BLE platform
	All students in their roles use model viewers, basic office applications, communication applications and project management application (cloud storage), when the information extraction application is not necessarily relevant to all roles, the client as an example.	
Assessment methods	Type of exam:	No exam. See details below
	Evaluation (score):	Pass/Fail
	Estimated time for exams for each student	N/A
	Number of exam sessions for each semester	N/A
	Formative assessment is provided at the end of each meeting in the form of teacher feedback. Summative assessment is based on students' active participation in the meetings and in performing the required role-specific tasks. However, for the pilot module implementation, as it formed part of a larger course, a few module-related questions were included in the overall course exam.	
Learning Materials	Core materials:	
	Project scenario including a conceptual architectural BIM model, project goals and a preliminary space program.	
	Supplementary materials:	
	As defined under Pilot module resources	
	On-line resources: (Weblinks):	

	As defined under Pilot module resources
	Other materials (e.g. Videos, Monologues, etc.)
	As defined under Pilot module resources
Pilot module resources	**Design management pilot module resources**

Resource types:

Generic resources	No need to change, updates needed only to maintain currency
Country-specific resources	Need to change when the module is executed in a different country-context (however, change need to be evaluated separately for each module execution)
Project, not country-specific resources	Need to change when the project changes, but can be used in various countries
Project and country-specific resources	Need to change when the project- and the country-context changes
Resources produced by learners (project parties)	Need to be provided by the module facilitator, if the module is not organised synchronously and/or if the roles responsible for the input are not represented by any learner

Resource media type

Text	Text directly on Moodle
PDF	Text etc. file
LR	Lecture recording
Video	Video, external resource
URL	Web page, external resource

All roles (common)	Client (User)	Clients project manager	Lead designer	Architectural designer	Structural engineer	Geotechnical engineer	HVAC and plumbing engineer	Electrical engineer	Cost estimation specialist	Scheduling specialist	Safety coordinator	BIM coordinator	Building permit authority
Supporting resources for all provided by the module developer or the facilitator													
Intro to the module (LR)													
Intro to the project (LR)													
Client needs (PDF)													
Project goals (PDF)													
Preliminary space program (PDF)													
City planning (URL)													
Role-specific supporting resources provided by the module developer or the facilitator													
	Task instructions (Text)	Task instr.	Task instr.	Task instr.	Task instr.	Task instr.	Task instr.	Task instr.	Task instr.	Task instr.	Task instr.	Task instr.	Task instr.
		Meeting agenda example (PDF)							Basics of invesment calculations (LR/PDF)	Design stages and process (LR/PDF)		National BIM guidelines (URL)	
		Meeting minutes example (PDF)							Investment calculation example (PDF)			BEP template (PDF)	
									Cost estimates based on spaces (PDF)			BEP example (PDF)	
Resources for all, produced as interim outputs by learners (project parties) during the module													
Design schedule draft											***Responsible for the input***		
Project BIM Brief												***Responsible for the input***	
Investment calculations									***Responsible for the input***				
Meeting agendas		***Responsible for the input***											
Meeting minutes		***Responsible for the input***											

University:	Tallinn University of Technology	
Degree programme:	Structural Engineering and Construction Management (Integrated Engineering Masters programme) Building and Infrastructure Engineering (Masters programme) Building and Civil Engineering and Architecture (PhD programme)	
Course title:	Risk Management in Construction Projects	
University module code:	EPX---- (module code number to be determined)	
Professor/Professors:	Emlyn Witt	
Academic Year:	2022/23	
Basic information	Level:	Master / PhD
	Year of the degree programme:	4th year of (5-year) Integrated Engineering Masters programme, 1st year of (2 year) Masters programme, optional course for PhD students
	Number of Credits:	3 ECTS
	Duration - number of semesters:	1
	Duration - months:	4
	Number of hours:	80
	Which semester(s) of study programme:	2
	Planned start / Planned end	1st February 2023 - 31st May 2023
	Language:	English
	Modules:	1
	Status:	optional
	Minimum of compulsory hours of attendance	not applicable
Additional information	Prerequisite courses:	no
		(if yes, list)
	Complementary/subsequent courses:	yes
		EPX5310 Construction Investments and Project Management
	Presence of tutors to support teaching:	no
	Maximum number of students who can take the course (if the course is limited in number):	unlimited
	Expected Number of students to attend the course:	20
Course contents	**Introduction** (Lecture, discussion) • Instructions and information for participation in the course. • Formation of student working groups in key stakeholder roles. • Initial instructions to cover the essential pre-information necessary to commence • with the experiential learning activity. **Experiential learning activity** (Group work, lectures, discussions) Students work through a guided, detailed project risk management process (including both qualitative and quantitative risk analysis) on the basis of real project data within a BIM work flow. They do so in teams arranged according to typical industry roles and, in the course of the activity, they explore and discuss in detail the following: • The terms and concepts of risk management; • The process of risk management in projects (plan risk management, risk identification, risk analysis, risk response, monitoring and control, documentation and record keeping / learning for future projects); • Tools and techniques for achieving each stage of the risk management process; • Project risk management standards; • Risk management within the BIM work flow; • Practical risk management on the basis of real project data; • How risk and risk management link to wider ideas in construction, science and society (such as contracts as instruments of risk allocation and transfer, Integrated	

	Project Delivery, statistical inference, climate change and disasters, societal risk and modernity, etc.).
Learning outcomes	The expected learning outcomes for the course are as follows: • Students are able to describe the process, tools and techniques of project risk management. With the BLE learning activity, this relates to a more realistic, detailed BIM-based process. • Students understand risk and project risk management concepts. • Students understand the BIM work flow (as the learning activity takes place within a BIM work flow, students also acquire understanding of this work flow - which increases the learning value beyond the risk management topic). • Students are able to apply the project risk management process, tools and techniques in a realistic project scenario based on real project data and an industrial work flow. • Within the given risk management process and project scenario, students are able to break up the scenario into constituent elements and analyse risks associated with each element. • Students evaluate the risks identified in order to reach a collective judgement concerning the relative significance of each of the identified risks and appropriate mitigation actions. • Students reconsider the risk management process and the industrial work flow in order to recommend improvements.
Explicit references to BIM learning	The idea of the BIM-enabled Learning Environment (BLE) concept is to enable immersive and integrated learning experiences on the basis of real, up-to-date project data from industry. This experiential learning takes place on the basis of a realistic industry work flow that fully utilizes BIM. BIM ensures comprehensive, organised and readily accessible project data. Much of this data is referenced directly to building objects (walls, beams, columns, windows, doors, floor slabs, pipes, etc.) which are represented in a virtual, 3D model of the building so that they can be easily viewed and understood. It therefore enables real, complicated project scenarios to be presented to and efficiently grasped by students. Using an industry BIM work flow ensures that the scenario on which the learning activity (project risk management, in this case) takes place corresponds to industrial reality and also that the data input to the learning activity (Data 1 in Figure 2) is not contrived by the lecturer but rather exists as real project data and is drawn directly from the same sources as would be the case in industry. (It should be noted that this project data must be prechecked and simplified to remove inconsistencies and unnecessary details which could confuse the students.)

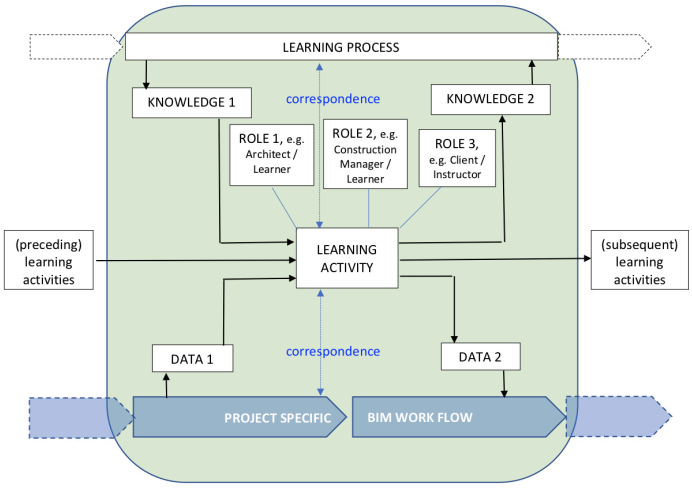

Figure A.1 - The BIM-enabled Learning Environment (BLE) (Source: Witt et al., 2020)

Similarly, by carrying out the learning activity, the project data is further processed and the output data (Data 2 in Figure A.1) feeds directly back into the BIM work flow. The project is thus elaborated and progressed. In this way, the learning activity is intended to resemble a meaningful task in a genuine work context.
In order that students are suitably prepared and able to carry out the learning activity, they will need some pre-instruction (Knowledge 1 in Figure A.1). However, most of their learning occurs within the context of the learning activity itself (Knowledge 2 - Knowledge 1 in Figure A.1).
Ideally, the learning activity is a necessary step in the elaboration / realisation of the construction project. As such, the outputs of the learning activity will be fed back into the project (BIM) data and this, further elaborated project data, will become the basis for further learning tasks later in the project work flow. This potentially provides an opportunity to assess the quality of these learning activity outputs in terms of their subsequent usefulness later in the work flow.

Teaching methods	Learning takes place in groups and follows the roles of typical industry stakeholders (e.g. Client, Designers, Contractors, Regulatory authorities, etc.). The mode of teaching is online with a mixture of synchronous activities (e.g. presentations and discussions) and asynchronous activities (preparatory work, individual contributions to groupwork, etc.) A social constructivist model of learning is followed which acknowledges the (often considerable) prior knowledge and experience of the students in order to both build on it and also leverage it to enhance the learning of fellow students. Knowledge is considered to be sociall constructed, hence the emphasis on group work and discussion. This does not, however, disclude the use of behaviourist learning approaches and individual activities. Learning approaches adopted for this course include: • Problem-based learning (PBL) • Experiential learning • The CDIO approach which stresses engineering fundamentals set in the context of real-world systems and products	
Teaching tools	Tools:	Case study project data resources
	Software:	(Any) IFC reader / model viewer
		(Any) Spreadsheet application
	Platform:	BLE platform / Moodle
	The BLE will serve as the delivery platform for the course and will also provide access to the	

	repository of project data that will provide the input data to the learning activities in the form of one or more ifc files. During the learning activities, relevant data (including spatial geometric, time and cost data) will be identified, extracted and analysed for risk management. Data analysis will be carried out using spreadsheet software applications. For deeper understanding of the project data for the learning activities, an ifc model viewer will be used. For editing / updating of the project data with the outputs of the learning activities, software enabling ifc file editing will be used.	
Assessment methods	Type of exam:	Group presentations, individual learning reflection reports.
	Evaluation (score):	100%
	Estimated time for exams for each student	Dependent on student numbers - approximately 10 minutes per student for group presentation.
	Number of exam sessions for each semester	1
	The course activities are undertaken in the form of group work. This is beneficial because the risk management process is best carried out by diverse groups with complimentary perspectives and experience. It also enables students to discuss their work in groups and learn from each other. Assessment, therefore, must also reflect this and the primary summative assessment tool is a group presentation and discussion - in essence a mini "defence" of the group's work. This is complemented by an individual learning reflection report which each student must complete and submit at the end of the course. In addition, participation metrics also influence students' final grades. (This also resolves the typical institutional expectation of individual grades for students). Formative assessment in the form of short quizzes, discussion questions and reflections are regularly arranged throughout the course to ensure that a high level of student engagement is maintained.	
Learning Materials (Harvard Referencing Style) Readings/Bibliography	Core materials:	
	Instructional video lectures / slides Case project data sets (to be compiled) Calculation templates / worked examples Formative Assessment - quizzes, discussion questions, reflection questions Summative assessment - group presentation template, discussion questions, reflection questions	
	Supplementary materials:	
	Various optional readings (to be determined)	
	On-line resources: (Weblinks):	
	All materials are provided on line.	
	Other materials (e.g. Videos, Monologues, etc.)	
	To be determined.	

Any other useful reference regarding the course	Olowa, T.; Witt, E.; Lill, I. (2021). Building information modelling (BIM) - enabled construction education: teaching project cash flow concepts. International Journal of Construction Management. DOI: 10.1080/15623599.2021.1979300. Witt, E.; Olowa, T.; Lill, I. (2020). Teaching Project Risk Management in a BIM-enabled Learning Environment. Proceedings of 23rd International Conference on Interactive Collaborative Learning "Educating Engineers for Future Industrial revolutions" ICL2020, 23–25 September,2020 Virtual Conference (TalTech, Tallinn, Estonia). Springer, 172−183. (Advances in Intelligent Systems and Computing). DOI: 10.1007/978-3-030-68198-2_14. Witt, E.; Kähkönen, K. (2019). A BIM-Enabled Learning Environment: a Conceptual Framework. In: Witt, Emlyn; Lill, Irene (Ed.). 10th Nordic Conference on Construction Economics and Organization, 2019 (271−279). Emerald. (Emerald Reach Proceedings Series ; 2). DOI: 10.1108/S2516-285320190000002051.

University:	*Alma Mater Studiorum – University of Bologna*	
Degree programme:	*Building Engineering (cod. 9199) (Bachelor's degree)*	
Course title:	*Cantieri e produzione edilizia T / Building Sites and Production T (host course)*	
University module code:	*30982 (host course code)*	
Professor/Professors:	*Marco Alvise Bragadin*	
Academic Year:	*2022/2023*	
Basic information	Level:	*Bachelor*
	Year of the degree programme:	*3° year od the Bachelor*
	Number of Credits:	*6*
	Duration - number of semesters:	*1 semester*
	Duration - months:	*5 months*
	Number of hours:	*60 hours*
	Which semester(s) of study programme:	*1° semester*
	Planned start / Planned end	Start of semester 1/End of semester 1
	Language:	*italian*
	Modules:	*1*
	Status:	*compulsory*
	Minimum of compulsory hours of attendance	*not applicable*
Additional information	Prerequisite courses:	*no*
		(if yes, list)
	Complementary/subsequent courses:	*no*
		(if yes, list)
	Presence of tutors to support teaching:	yes
	Maximum number of students who can take the course (if the course is limited in number):	120
	Expected Number of students to attend the course:	30
Course contents	**The pilot module is part of a course (30982 Building Site and Production). The above information is for the whole course. This section and the sections below discuss the pilot module details. The pilot module is called BIM-enabled Time Management.** The pilot module focuses on the project time management process, including construction job site design, using real project data within a BIM-based work flow. Topics include, but are not limited to: ▪ Terms and concepts of time management ▪ Activity duration estimation and resource allocation ▪ Tools and techniques for project scheduling and control ▪ Design of construction job site – workplace design and requirements ▪ Occupational health and safety standards for construction ▪ Time management within the BIM work flow;	
Learning outcomes	As learning outcomes of the module, the student • is able to describe the process, tools and techniques of project time management in construction (in a BIM-based work process). • understands scheduling and project scheduling concepts. • understands construction job site and site optimization concepts. • understands the BIM work flow with respect to job site design, project time management and more generally. • is able to apply the project time management process, tools and techniques in a realistic project scenario.	

	• can evaluate project schedule, estimate activity durations and resource allocation in terms of their relative significance towards total project duration. • can critically analyze the construction job site and the industrial work-flow of operations in order to recommend improvements. • is able to apply the common BIM requirements into their role specific tasks
Explicit references to BIM learning	Students use BIM in various ways on the module (role specific): • Conduct design reviews by interrogating the model(s) • Conduct design review meetings with the model at university • Evaluate the detailed desing and other client requirements by viewing and analysing the model • Design the 3D BIM model of construction job site • Estimate Work Pakages of the project by information extraction from the model • WBS creation and Project schedule development • BIM 4D model development and evaluation • Validate that the models comply with the preliminary modelling requirements as agreed • Evaluate the compliance with OH& S standards by viewing the model
Teaching methods	This is a project-based module relying on social constructivism and students as independent (from teachers) learners. Students are organised into stakeholder groups (Client / Project Manager, safety coordinator, contractor etc.). Students work individually and in group sequentially and in collaboration to analyse, simulate and integrate the job site design and project schedule using BIM model(s) and other available resources. Students work independently, both individually and as a project team. Faculty members' role is to facilitate the process at agreed milestones, which include the design review meetings as a minimum. Students run the meetings. Facilitators' role in the meetings is to provide feedback and advice as needed. A kick-off lecture is offered to introduce the project. Supporting resources on specific topics are offered during the module.
Teaching tools	Tools: — Basic computer hardware Software: — Model viewing application, information extraction application, basic office applications, communication applications, project management application (cloud storage) Platform: — BLE platform All students in their roles use model viewers, basic office applications, communication applications and project management application (cloud storage), when the information extraction application is not necessarily relevant to all roles, the client as an example
Assessment methods	Type of exam: — No exam. See details below Evaluation (score): — Pass(A ,B,C) / (D,E,F) Fail also includes: grade recovery assessment options C, D, E) Estimated time for exams for each student — N/A Number of exam sessions for each semester — N/A
Learning Materials	Core materials: Instructional video lectures / slides Project design including a detailed architectural BIM model, project goals and site description

(Harvard Referencing Style) Readings/Bibliography	and other construction data. Formative Assessment - quizzes, discussion questions, reflection questions Summative assessment - group presentation template, discussion questions, reflection questions .
	Supplementary materials:
	- various optional readings
	On-line resources: (Weblinks):
	- all materials are provided online
	Other materials (e.g. Videos, Monologues, etc.)
	-- provided online
Any other useful reference regarding the course	Required readings: • class notes “virtuale”: www.virtuale.unibo.it Recommended readings: • Bragadin Marco A., La programmazione dei lavori con i metodi reticolari, Maggioli 2010 • D.lgs. 81/08 e s.m.i. “Testo Unico sulla sicurezza sul lavoro” (TUS) • D.lgs. 36/2023 “Codice dei contratti pubblici” • PMI, Guida al Project Management Body of Knowledge (PMBOK Guide), Ed. PMI, USA standard ANSI 99-001-2004 • RICS. International BIM Implementation Guide RICS Guidance Note, 1st ed.; RICS: London, UK, 2014. • Hinze J.W., Construction Planning and Scheduling. Person, Prentice Hall • Hendrickson C., Project Management for Construction, Carnegie Mellon University, USA. • Trani M.L., Construction Site Design, Maggioli editore. • Semeraro G., Il cantiere sicuro, EPC • Bardelli P.G., Coppo S. “Il cantiere edile” Darrio Flaccovio editore • Rigamonti Giuseppe - La Gestione dei Processi di Intervento Edilizio. Utet 2001 • Frein J. P. (Ed.) Handbook of Construction Management and Organization. Van Nostrand Reinhold