BIM for Higher Education – Intermediate Report from the ERASMUS+ BIM4HEI Project

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SUMMARY

Many lecturers at university level have noticed that there are serious shortcomings in teaching about the digitalization of the construction industry. This concerns both the challenges of new technologies and the internationalization of construction project management. Architecture, Engineering and Construction (AEC) is currently undergoing a paradigm shift from plan-based to model-based work, called Building Information Modelling (BIM). Higher Education Institutions (HEI) must respond to this. The ERASMUS+ BIM4HEI cooperation between European educational institutions enables the exchange of knowledge, the development of joint action strategies and the mutual evaluation of the teaching materials produced. Practical relevance is ensured through the involvement of professional organizations from the construction industry. The construction industry has a very high interest in digitally competent engineers and in professional training. Building Information Modeling (BIM) provides the ideal core for interdisciplinary and internationalized teaching. BIM promotes collaborative design, construction and operation of the built environment. At its core is the digital building model, i.e. the digital twin of design, construction and operation.

Most of the activities and results of the EU-funded project are intellectual outputs that will be maintained after the end of the project. The partners from the Czech Republic, Portugal and Germany intend to integrate the results into their AEC HEI curricula. The produced contents can also be used for the lifelong learning of AEC professionals, promoted by the associated partners and similar professional bodies or associations of the AEC sector in other countries.

This article first presents the objectives and the project and funding structure of the BIM4HEI education project. Then the concrete results and materials for educational institutions are presented. These are lecture guides and training activities as well as a planned MOOC platform. On the one hand, the specification of the technical topics is in the foreground of all lecture guides. On the other hand, the topics are linked to activating teaching methods. The project partners have a very interdisciplinary approach to BIM. This includes the integration of surveying and geoinformation into BIM education.

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1. INTRODUCTION AND MOTIVATION

Many educators at the university level have identified significant deficiencies in the content and methods of engineering education related to the digitization of the construction industry. This concerns both the challenges posed by emerging technologies and the internationalization inherent in the management of construction projects. Currently, the field of Architecture, Engineering and Construction (AEC) is undergoing a paradigm shift from plan-based methodologies to model-based workflows, particularly with the adoption of Building Information Modeling (BIM). Higher education institutions (HEIs) must respond appropriately to this transformative change. The collaborative initiative BIM4HEI, which brings together three European educational institutions, aims to facilitate the exchange of knowledge, the development of joint strategic initiatives and the mutual evaluation of educational materials. The full title of the presented project is "Development of BIM knowledge in higher education to boost the competencies of young people and reinforce the interdisciplinarity in European universities". Practical relevance will be ensured through the active participation of professional organizations within the construction industry, which have expressed a strong interest in professional BIM education.

The BIM methodology, centered around the "digital building environment" model or the "digital twins" of design, construction and operation, serves as an ideal core for interdisciplinary and internationalized education. BIM is expected to bring about significant changes in the professional performance of individuals in the AEC sector, particularly architects, civil engineers and contractors. Improving the technical skills of young AEC professionals, especially in the fields of civil, structural and geospatial engineering, is the overall objective of the presented project, which is funded by the European Union (EU).

Erasmus+ is the EU's program to support education, training, youth and sport in Europe. It has an estimated budget of 26.2 billion euros. The 2021-2027 program has a strong focus on social inclusion, green and digital transitions, and promoting young people's participation in democratic life. (European Union, 2024)

Since November 2021, the project partners have identified deficiencies in AEC education and held joint meetings for their knowledge exchange on BIM. During the meetings, joint action strategies were formulated and mutual evaluation of educational materials was undertaken. A key objective is to produce and make available open-access resources in multiple languages.

This analysis showed that there is an urgent need for comprehensive information on the teaching of BIM in higher education, with an emphasis on thematic content and didactic methods. The teams agreed that BIM teaching conveys two meta-concepts: digitization and interdisciplinarity. The BIM approach integrates efficiently with specific engineering domains, improves design quality through early error detection, and facilitates efficient facility management. The holistic BIM approach requires interdisciplinary teaching across departments, faculties, and universities to be successful.

Most lecturers also agreed that the teaching approach should include teaching BIM concepts through application-based stories, focusing on the different roles in a BIM project, as also outlined in the buildingSMART Standard "Building information modeling - Qualifications - Fundamental knowledge" (VDI/bS, 2019). Examples tailored to specific disciplines serve to highlight four roles as information user, author, coordinator and manager. Teachers and students should always be aware of which of these roles a particular unit is designed for:

1) **Model user**: Students engage with BIM through 3D visualization, understanding the spatial relationships of components, and recognizing multi-criteria ordering structures. The core message emphasizes that BIM is a database, not a drawing, and emphasizes the unified storage of data for design, construction, and operation, thereby reducing redundancy.

2) **Model creation**: Active creation of BIM models is essential for students to grasp BIM paradigms. Modeled components, uniquely addressable through an ID, have topological relationships and are instantiated using prototyping mechanisms. Spatial structuring, parameterization of 3D geometries, and use of component lists for quality assurance are key aspects.

3) **Model coordination and verification**: Model coordination, essential for higher-level quality assurance, involves spatially and semantically disjoint models. The goal is to detect clashes and gaps, emphasizing the importance of coordinated 3D models to avoid spatial conflicts. Automated model checking increases the efficiency of digital, model-based planning.

4) **Management and collaboration strategies**: BIM management requires knowledge of model use, creation, and coordination. This includes understanding the purpose of BIM models, preparing people for BIM projects, designing information management contracts, defining levels of information needs, and addressing IT structures and data formats for model exchange.

In the remainder of this paper, some related work is briefly presented (Section 2), with the focus not BIM itself, but on practical didactic implementation in the BIM teaching context. In the main part, section 3, the interim results of the project work packages are presented - these are *Lecturing Reference Guide* (BIM Teaching Approach), *Short Training Activities for Students*, *BIM Practical Tool* and *Massive Open Online Courses* (MOOC). The Lecturing Reference Guide and the BIM Practical Tool will be discussed in detail as they are almost complete at this stage. The *Short Training Activities for Students* and the MOOC are still a work in progress and will be delivered during 2024.

2. RELATED WORK

Building Information Modeling technology has been around for more than two decades, but its integration into construction processes has been slow. Recent trends, spurred by government requirements for BIM certification in public works, highlight the growing importance of BIM in the construction sector. To prepare future professionals, BIM should be included in university curricula. However, there is a lack of common strategies and standards among universities currently implementing BIM, with different universities adopting different approaches to BIM integration, reflecting a lack of standardized methodologies. It is emphasized that BIM education involves more than just teaching new software; it requires a shift in teaching and learning methodologies.

A literature review by Besné et al. (2021) identifies four types of interventions for BIM implementation: academic guides, curriculum reviews, development of plans/protocols, and integration into courses/projects/activities. In terms of teaching techniques, problem-based learning (PBL), gamification, and integration of BIM into existing courses are recommended methods.

Developed at McMaster University, PBL emphasizes student ownership, lifelong learning, and problem-solving skills. The seven-step PBL cycle includes problem identification, analysis, definition of knowledge gaps, information gathering, problem-solving, and presentation. While PBL is primarily used in medical education, it is also used in architecture, engineering and construction, and geodesy and GIS. In the field of transport engineering, PBL is being explored through the LBS2ITS Erasmus+ project (https://lbs2its.net/), showing positive experiences and skills development.

The "BIM Game" project, a collaboration across European countries, uses gamification to teach collaborative working in BIM. Through narrative scenarios aligned with ISO 19650 guidelines (International Standard Organization, 2018), participants take on roles in the building lifecycle. Evaluation includes badges and level achievements that encourage engagement and knowledge retention. (Grunwald and Heins, 2024)

Studies, such as Ferrandiz et al. (2018) evaluate the incorporation of BIM into courses originally designed for AutoCAD. Results indicate improved work efficiency, motivation, and student satisfaction. However, challenges arise from the simultaneous use of different software.

Besné et al. (2021) review shows positive impacts on student collaboration, communication, and project development skills. However, challenges include interoperability issues, instructor focus on analysis and collaboration rather than information management, and the need for critical thinking skills rather than software knowledge.

In the context of using virtual reality in teaching geospatial surveying, Bolkas et al. (2023) state that the integration of immersive technologies must take place under a theoretical framework to identify and achieve specific pedagogical goals. The authors also rightly point out the massive additional work that educators must undertake to maintain the hardware and software in their universities.

While different curricula and methodologies exist around the world, there is a need for a unified approach to BIM education. In an era of lifelong learning, education does not end at university. All authors are currently active in regional and national professional associations and chambers. There is also a lot of practical "related work" going on. Collaboration between academia and industry, including qualified experts, is seen as critical to bridging the gap between education and industry expectations. However, university education must not be reduced to clicking instructions for a specific software, but a holistic set of methods must be developed. After all, students are expected to lead digital transformation processes as young professionals after graduation.

3. ERASMUS+ BIM FOR HIGHER EDUCATION

3.1 Lecture Reference Guide and Method Reader

The Lecture Reference Guide has around 60 pages and explains the introduction and importance of Building Information Modeling (BIM). The focus is on the required competencies according to ISO 19650, including organizational and individual requirements as well as continuous improvement. The various competence areas and learning outcomes, from BIM history to software tools, are considered in detail, supplemented by several competence matrices, for example, as shown in **Error! Reference source not found.**.

The section on **BIM teaching** emphasizes the establishment of a digital mindset, the integration of BIM courses into curricula and the use of didactic principles. Particular attention is paid to teaching the differences between BIM, CAD and GIS, and the use of engaging teaching and assessment methods. The promotion of a lifelong learning community is seen as crucial, supported by a method reader.

Table 1 BIM Competence matrix for undergraduate and graduated studetens

Individual Requirements	**Standards**	**Workflows and Processes**		**Software Application**	**Data exchange and Information Management**	
Technical competence	BIM standards and guidelines	BIM workflows	Collaborative working practices	BIM software applications	Data exchange standards	Information manage-ment
Information management competence	BIM Execution Plan (BEP)	Common Data Environ-ment (CDE)		BIM software applications	Information exchange standards	Information manage-ment principles
Quality management competence	BIM standards and guidelines	Quality assurance processes	Quality control processes	BIM software proficiency	Information exchange protocols	Model manage-ment
Collaboration competence	BIM Standards and Protocols	BIM Coordi-nation	Communi-cation and Leadership	BIM Collaboratio n Tools	Model Manage-ment	Model Manage-ment
Data security and privacy competence	BIM security and privacy standards	BIM data classify-cation and handling	Secure storage and access control	Risk management and mitigation	Secure data exchange and collabo-ration	Legal and contractual require-ments
Contractual and legal competence	Understand ing of BIM standards and protocols	BIM Protocol	Construction and procurement laws	Standard forms of contracts	Intellectual property	Implication s of BIM-related techno-logies

There is also a focus on **integrating BIM into curricula**, both through exclusive BIM modules and through the use of BIM in 'traditional' lessons. The consideration of prior knowledge from secondary school and the integration of BIM in final projects are highlighted.

Additionally, a **Method Reader** was developed that gives instructors a collection of more than 35 teaching methods that can be put into practice in lectures or exercises. Each teaching method is explained with a fact sheet. The description of the method is so general that they can also be used in other teaching areas apart from BIM. However, some of the general methods are given hints for implementation in BIM teaching.

The Method Reader divides the "tools" into three functional categories:

1. In the category *Introduction/Repetition*, there are methods that introduce a lesson and/or enable querying of the learning objectives from the last lesson and, if necessary,

repetition.

2. The category *Teaching Methods* is intended to house the tools that are used to impart new knowledge.

3. In the category *Feedback/Testing*, the methods should be available that can help the teacher to check whether the learner has received the taught matter, whether he or she has understood it, and whether the teacher needs to follow up again.

The Method Reader is provided for educators when preparing a course. If the content to be taught is clear, teachers can, for example, choose one teaching tool for each lecture. The general description of the teaching tool must then be specified for BIM topics, e.g. for teaching the IFC schema or types of CDE.

For example, “Method 15 - Active Structuring” is one of the presented methods for Teaching/Repetition. The students receive a prepared set of cards with terms, texts and/or pictures. These have to be put into a meaningful order. “Active structuring” is particularly suitable when the problem is complex but hierarchically ordered. For example, forms of solid representation, the object-oriented inheritance structure of the IFC scheme, legal norms of civil engineering or geoinformation could be deepened and repeated. This method is good for repeating a topic that has already been dealt with or for working out an overview of a complex topic.

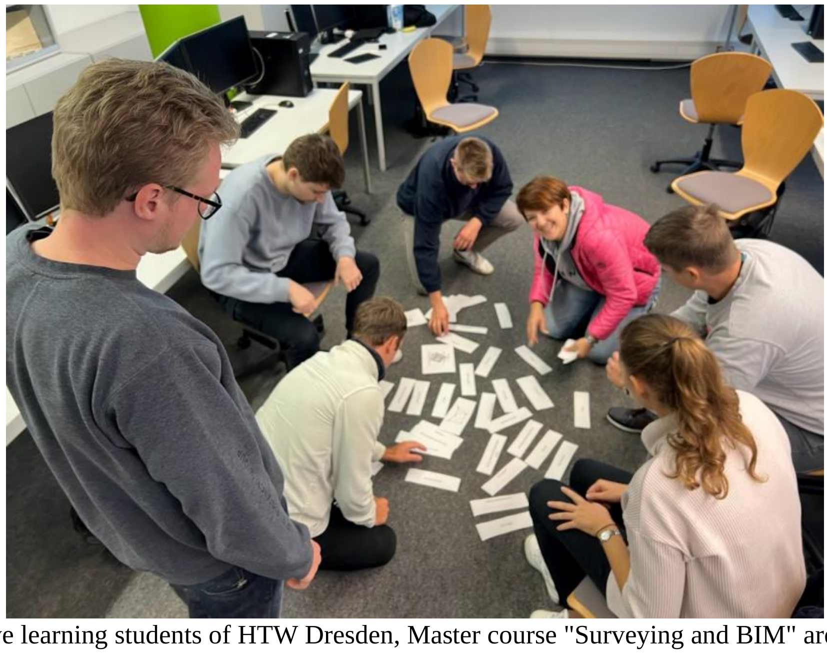

Figure 1 For active learning students of HTW Dresden, Master course "Surveying and BIM" are asked to structure unordered paper cards. The cards display names of concepts, IFC entities and small figures of different geometric representation types for solid modeling.

During the ERASMUS+ project BIM4HEI, the experience of the teachers using the method reader as inspiration for their teaching was consistently positive. Even very complex and supposedly boring topics, such as data schemas or BIM management roles, can be taught in an exciting way with activating teaching. Resulting in better learning outcomes for the students.

Despite all the enthusiasm for activating teaching methods, however, it must be noted that technically interested students must not be overwhelmed with too much didactic frippery. It is important to keep a balance between "classical" lectures/exercises and modern activating methods.

3.2 Short Training Activities for Students

The three-day short training activities for students will be realized in summer 2024 in Prague, Aveiro and Dresden. Each BIM course will involve 20 students from each organizing partner. Lecturers from each project partner will participate in order to peer review of the teaching activities. The workshop is organized as follows:

Day 1) **BIM Introduction**, including basic lecture on BIM stories and roles and practical modeling with a BIM authoring tool. Includes guided hands-on component-based modeling of a small building and building elements.

Day 2) **GeoBIM and Information Management**, including a design-thinking workshop on the differences between BIM and GIS, a lecture on georeferencing and geometric-topological modeling, hands-on model building (georeferencing) in CAD/BIM, a workshop on conceptual modeling, and a short lecture on exchange standards such as IFC, BCF, and bsDD.

Day 3) **Collaboration and CDE**, including basic lectures on ISO19650 project management and security requirements, CDE workflows and functionalities for the collaborative process of managing information and information containers (data) as a solution that fits the management and project processes inherent to BIM (process) and functionality and performance requirements. Different technical solutions for metadata processing will be discussed and best practice examples from professional partners

The workshops to be held with students during the BIM4HEI project phase will serve as a feedback loop for the development of the teaching materials.

3.3 BIM Practical Tools

The BIM practical tools are the other main output of the project. The three partners developed prototypes that will support the practical lessons and practices.

Table 2 Practical BIM tools for teaching including comprehensive technical guidelines

Name	Level/Duration	Description
BIM Views and Queries	Bachelor /120 min	BIM is a database - not a drawing! An (almost) finished geometric-semantic BIM model is provided, which the students have to expand e.g. with queries and dimensions.
BIM-Construction with Components	Bachelor /180 min	The component makes the difference! Students learn object-structured, parametric modeling of geometry and semantics on a simple component.
Coordinate systems in Revit	Bachelor & Master /180 min	BIM is coordination! To use environmental data in a BIM project, the construction model must be geo-referenced. Students learn about the different CAD/BIM software cooperation systems and how geodata can be imported into BIM software
Collaboration with BCF	Bachelor & Master /120 min	BIM is collaboration! With two small models, the students learn how to carry out a collision analysis and how to communicate identified clashes in the team with BCF.
Visual Programming with Dynamo	Master /180 min	BIM is automation! The students learn how to automatically read exchange information requirements given as spreadsheet, add parameters to specific components and populate the parameters with given data. The exercise is successful, if the property sets are exported to IFC.
Information Modeling and IFC	Master /270 min	The complex exercise first introduces the basics of information modeling. ER, EXPRESS, EXPRESS-G are used here. It is worked with the text editor and Excel. The IFF topic is then introduced. Finally, students learn how to parameterize the IFC export from a CAD/BIM system in order to generate "good" IFC models.
…		More to be delivered in the final project phase

Together with the didactic concepts from the Lecture Reference Guide and the practical experience with the students, the exercise instructions completed so far form the basis for the MOOC.

4. CONCLUSION AND OUTLOOK

This paper is an interim report, but the project is progressing rapidly. In fact, the authors underestimated the complexity of the project when they applied for the grant. The original goal of developing a standardized teaching concept for BIM was abandoned in favor of modular teaching materials. The teaching requirements are too diverse, as the disciplines, the curriculum and the level of knowledge of the students are very different. The teachers' perspectives on BIM are also very different: while the IT-oriented teachers focus on the structure of the schema and the automation potential, the Engineering and business management-oriented teachers are more interested in the management methods, e.g. ISO19650. Interdisciplinary work on the digitalization of the construction industry in an international context is challenging - but also fun. For the teachers and the students.

The final success of the project can only be evaluated once the teaching materials have been fully practiced and tested with the students. But even after completion, the materials will need to be constantly adapted to new technological trends - the BIM environment is evolving rapidly.

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BIOGRAPHICAL NOTES

Alexander Bong, born in 1994, has completed a three-year training as a surveying technician as well as a Bachelor's degree in Geomatics and a Master's degree in "Geoinformatics / Management". He has been working as a research assistant at HTW Dresden since November 2023. He is head of the SV Strehla soccer department and a member of the Junior Team of the German Football Association (DFB).

Vladimír Nývlt, born 1952. Graduated in 1976 as a Ing. In Civil Engineering from Czech Technical University (CTU). Worked in construction companies since 1976, began to teach at CTU dept of applied informatics in 1986. Completed his MBA study, focused on informatics at Northumbrian University in Newcastle in 1992 and began to work for companies in SW delivery and development (SAP, HP, …). In 2014 went back to teaching, completed Ph.D. at CTU in 2016. His main focus and research topics are BIM and information and knowledge management in construction industry.

Hugo Rodrigues, born in 1980. Graduated in 2003 in Civil Engineering, and got the PhD Degree in 2012 from the University of Aveiro. Since 2020 is associated Professor at the University of Aveiro and has taught several topics related to the structural behaviour of structures. One of the main research topics is BIM applied in the maintenance of existing buildings.

Christian Clemen, born 1976. Graduated in 2004 as a Dipl.-Ing. in Surveying from the Technical University of Berlin. From 2004 to 2010 he was an Assistant at the Department of Geodesy and Geoinformation, Technical University of Berlin. Since 2013 he has been a full professor at the HTW Dresden, University of Applied Sciences. He teaches adjustment calculation, CAD and BIM. His research topic is BIM from a geomatics perspective.

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