BIM and Energy Efficiency training requirement for the construction industry

IOP Conf. Series: Earth and Environmental Science **297** (2019) 012037 doi:10.1088/1755-1315/297/1/012037

BIM and Energy Efficiency training requirement for the construction industry

Sunil Suwal[1], **Maaria Laukkanen**[1], **Päivi Jäväjä**[1], **Tarja Häkkinen**[2], **Sylvain Kubicki**[3]

1. Metropolia University of Applied Sciences, Espoo, Finland.
2. VTT Technical Research Center of Finland, Espoo, Finland.
3. Luxembourg Institute of Science and Technology (LIST), Luxembourg.

Abstract. Construction industry has a wide impact to our built environment. It plays a vital role for governments and supports in both developed and developing economies. The industry supports economic growth of a nation through various trades and activities as well as provides new jobs. It is one of the largest industrial sectors that has a projected output of 13.5% by 2025. Climate change, resource depletion and rapid urbanization are the most severe amongst the challenges we face today. The construction industry alone is responsible for 20% of the global energy consumption and approximately one-third of energy-related CO2 emissions. The industry entails the high energy saving potentials and provides various opportunities to implement sustainable solutions to decrease the environmental impacts and thus lower greenhouse gas emissions. In the construction projects today, we can implement different energy efficiency strategies and products virtually during the planning phases of the construction projects using model based environment and tools commonly known today as virtual design and construction (VDC) as well as building information modeling (BIM). We can accurately simulate and calculate the impacts and thus support the increasing demand of complex high-performance buildings in order to effectively address energy and carbon reduction targets. However, one of the key challenges, the industry faces is the availability of skilled workforce and experts that have enough BIM and energy efficiency skills. The paper addresses such needs and presents the current status of a H2020 project with a focus on defining roles and responsibilities construction project stakeholders have for the energy efficiency measures along the different project phases. It also provides an outlook for the development of the learning outcomes based on knowledge, skills and competence (KSC) framework as well as systematically presents the base for harmonization of the learning outcomes at the EU level.

1. Introduction

Construction is important and the impact of the construction industry is huge. It strongly affects our society, economy as well as our environment. It is a determinant of where and how almost everyone lives, works and plays. The built environment heavily influences quality of life. The construction industry alone amounts for a total of 6% of global GDP and plays a vital role for governments and

supports economic development both in both developed and developing economies. It accounts for about 5% of total GDP in developed countries, while in developing countries it tends to account for more than 8% of GDP. While the construction industry has a direct impact on economic growth of a nation, it is also the single largest global consumer of resources and raw materials.
Climate change, resource depletion and rapid urbanization are the most severe amongst the challenges we face today. The construction industry alone is responsible for 20% of the global energy consumption and approximately one-third of energy-related CO2 emissions. Whereas our built environment utilizes the world's 40% of energy, 50% of natural resources and contributes to 40% of carbon dioxide emissions.[1]

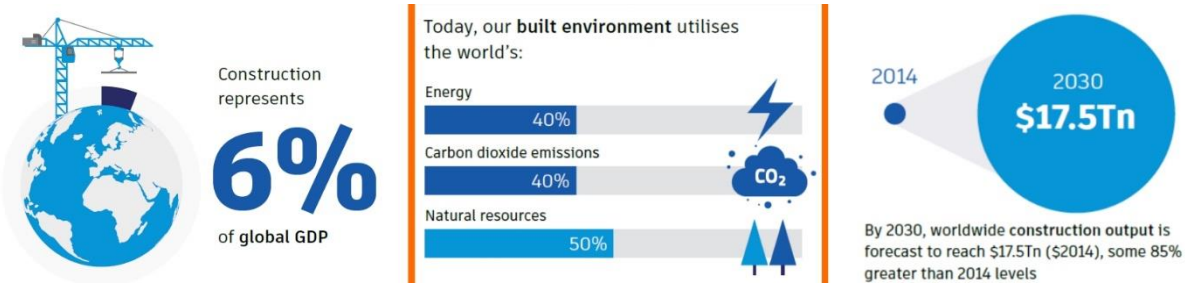

Figure 1: Impacts of the construction industry (Left: World Economic Forum, Middle and Right: Global construction 2030 as seen in Constructing with the power of digital, Autodesk)[2]

The industry entails the high energy saving potentials and provides various opportunities to implement sustainable solutions and processes to result in better and sustainable built environments. By 2030, worldwide construction output is forecast to increase by 85% greater than that of 2014 levels. This directs to the growing demand of both skilled and unskilled workforce at very high levels. Furthermore, the technological advancements today have reshaped out way of working in most of the industries. Construction industry professionals need to embrace the knowledge, the skills and the competencies of various tools and processes incorporated for enhancing the construction projects. More specifically, the construction industry has a great inclination today towards the use of the model based tools and processes commonly known today as virtual design and construction (VDC) as well as building information modeling (BIM). VDC and BIM can be actively implemented for the construction projects to accurately simulate and analyze the impacts of different sustainable solutions. BIM and Energy Efficiency competence today is considered very important.

This paper presents the ongoing results of BIMEET (BIM-based EU -wide Standardized Qualification Framework for achieving Energy Efficiency) research program funded under H2020 program. BIMEET project aims to leverage the take-up of ICT and BIM through a significant upgrade of the skills and capacities of the EU construction workforce. This paper provides an overview of the BIMEET project and discusses the current development of learning outcomes for different roles required for different stakeholder training to support BIM based energy efficiency.

2. Performance based buildings

The ideas of performance-based building formulate an important basis for the formulation of the learning outcomes with regard to energy-efficiency and BIM. Performance approach is concerned with what the building is required to do, and not with describing the technical solutions i.e. how it is constructed [3]. A prescriptive approach describes an acceptable solution while a performance approach describes the required performance. The performance approach is the practice of thinking and working in terms of ends rather than means. Performance requirements do not say anything about the ways and means of buildings, e.g. the types of materials, the dimensions, and sizes of building parts, or the methods of construction, but they define the required end result.

Performance based approach is important to consider in customer-driven processes to enable owners and users to present what the building is required to do instead of describing how it is constructed. Performance based and qualitative requirements give a better basis for innovative design solutions than a prescriptive approach [4 5].

Building performance requirement is the minimum acceptable level of a critical property (ISO 6707-1 2014). The overall performance of a building is based on diverse aspects such as energy performance, fire safety, structural safety, acoustics, thermal comfort, and the quality of indoor air, among others. Requirements on sustainability increase the number of aspects and also environmental concerns need to be considered. There have been many attempts to outline building performance and describe different performance aspects with the help of indicators [6 7 8 9] ISO 21929-1 [10] presents indicators of a sustainable building with the help of 14 aspects of sustainable building: (1) Emissions to air, (2) Amount of non-renewable resources consumption by type, (3) Amount of fresh water consumption, (4) Amount of waste generation by type, (5) Change of land use, (6) Access to services by type, (7) Accessibility, (8) Indoor conditions and air quality, (9) Adaptability, (10) Life Cycle Costs, (11) Maintainability, (12) Safety, (13) Serviceability and (14) Aesthetic quality. A standard indicator of building energy efficiency is annual energy consumption (kWh/m2) as a function of climate, envelope design, heating ventilation and air-conditioning (HVAC) systems, and occupant behaviour, among other parameters[11].

3. Learning outcomes

Learning outcomes are the explicit statements of what a learner is expected to know, understand and is able to do after the completion of a learning activity. Learning outcomes discussed refer to the intended leaning outcomes (ILOs) rather than achieved learning outcomes (ALOs). Learning-outcomes-based frameworks enable the comparison of qualifications across different types of institutions and stakeholders. By providing a common language makes it possible to compare qualifications over national borders.

> *"Learning outcomes are attributed to individual educational components and to programmes at a whole. Learning outcomes are specified in three categories – as knowledge, skills and competence. This signals that qualifications – in different combinations – capture a broad scope of learning outcomes, including theoretical knowledge, practical and technical skills, and social competences where the ability to work with others will be crucial*."[12]

Learning outcomes are valuable. Bloom's taxonomy and revised Bloom's taxonomy is the most often used frequent tool while developing learning outcomes. The cognitive domain of the Taxonomy comprises of six hierarchical levels of learning. The categories are ordered form simple to complex and from concrete to abstract[13] with a focus towards the level of cognitive processing required in the levels of learning particularly termed as low level thinking skills (LOTS) and high level thinking skills (HOTS) as shown in Figure 2. Carefully established learning outcomes prioritize the application of knowledge and equally play an important role as their use within a unit of instruction primarily guides learning and assessment activities that enhances student engagement and learning. [14] The approach adopted to describe and develop EU wide learning outcomes is based on the principles of the European Qualification Framework (EQF) particularly focusing on the KSC framework and the use of action verbs in relation to what a learner should know, have skills and be competent on.

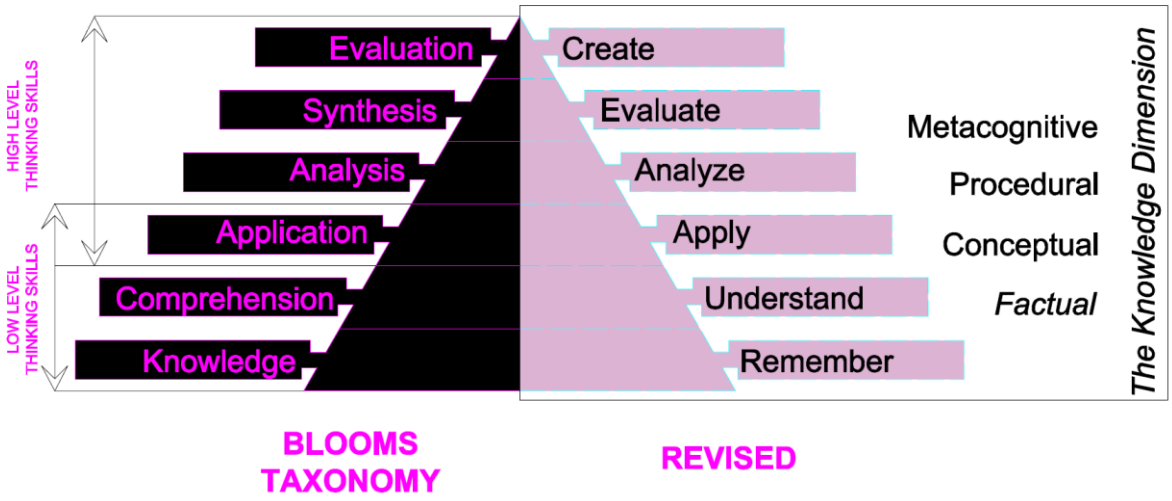

Figure 2: Bloom's taxonomy and revised Bloom's taxonomy hierarchical levels

The process used to develop the learning outcomes furthermore also relates to the case based approach. It focuses on mapping the standard RIBA Plan of Work stages and identified stakeholders followed by the process to defining learning outcomes for the role based courses. The three categories of KSC should be collectively perceived and should not be read in isolation from each other. Figure 3 highlights some of the action verbs used to define the levels of taxonomy in the cognitive domain. An example showing the basic structure of learning outcomes are presented in the Figure 3.

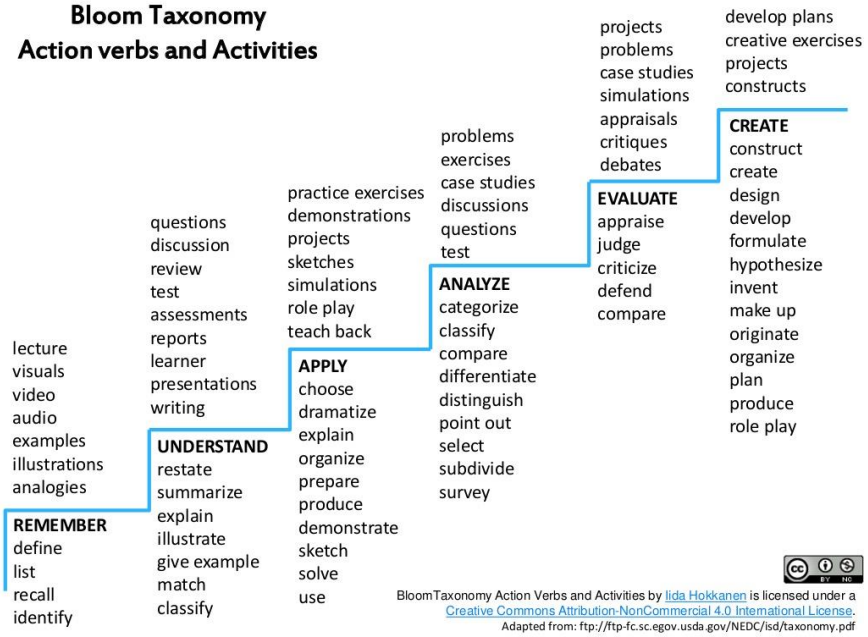

Figure 3 Bloom taxonomy action verbs and activities (Iida Hokkanen 2015) [15]

4. European wide learning outcomes

BIMEET collects, creates and validates the required knowledge, skills and competencies for different stakeholders of a construction project with respect to BIM and energy efficiency. The basic method for defining role based skills, knowledge, competence and finally learning outcomes was based on the following procedure:

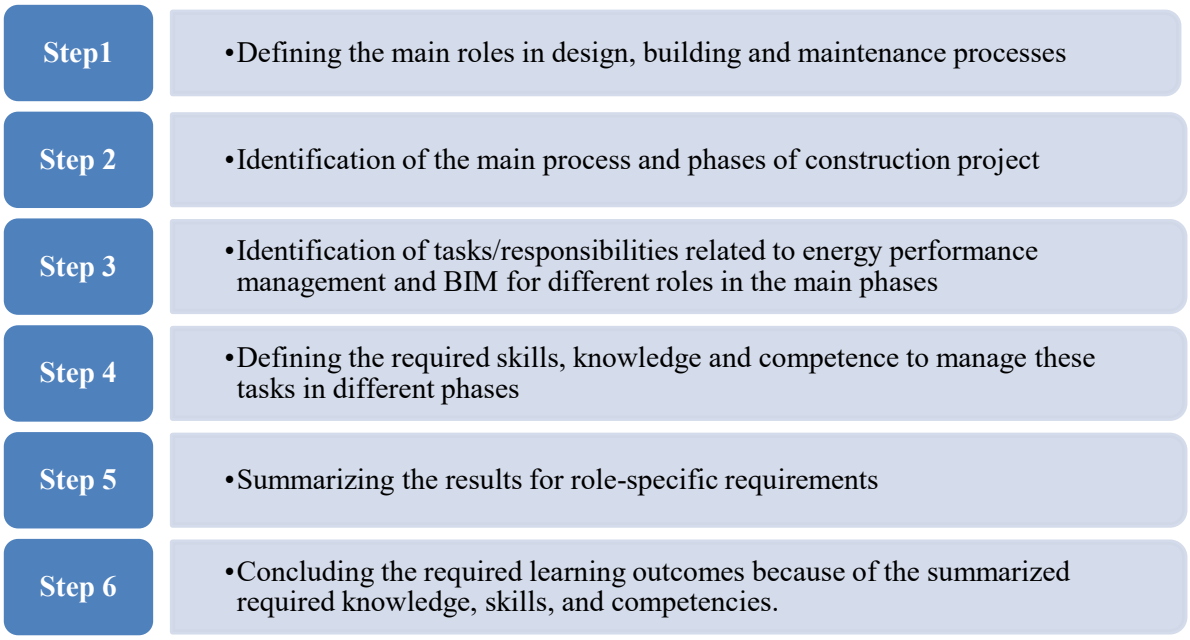

Figure 4: Procedure for defining KSC and LO

During this procedure, national guides for plans of works for different roles and national guides for common BIM requirements were made use of in defining phases, tasks and roles. For example in Finland, guides for plan-of-work have been formulated for architectural design, structural design, HVAC/MEP design, and management of building projects. The following Table 1 presents the results for one selected role - Chief designer - as an example of the results.

Table 1: An example of Skills, Knowledge, Competence and Learning outcomes for Chief designer in Finland

Skills	• Skills for BIM-based collaboration such as with the help of CAVE (computer aided virtual environment) and Big Room working • Basic skills in using assessment and optimisation tools • Skills in using visualisation tools to enable good information sharing in the design team and with the construction site management • Skills in using model checking tools - such as Solibri and NavisWorks - for quality assurance • Skills in using project data management systems (file based or model based) • Skills in using electronic services provided by the building permission authorities • Skills in Presentation of animated models, gaming models, and virtual models
EQF	

	Levels 6 - 7
Knowledge	• Excellent knowledge about national guidelines for building information modelling (COBIM) • Comprehensive knowledge about BIM terminology and definitions • Good understanding about the use of BIM authoring software • Excellent knowledge about the aspects of building performance and impacts (financial and environmental) and related indicators and benchmarks, labels and certificates • Understanding about needs of initial data and the potentials of different surveys and building inventions in refurbishment projects • Understanding about the feasibility with the help of different kinds of concept solutions • Understanding about the importance of systematic modelling and data management • Knowledge about the effect of orientation, volume and space design, and main product type selections on energy performance and building performance and knowledge about alternative potential solutions to fulfil the set targets • Knowledge about the potentials of different assessment, calculation and optimisation tools for parametric iteration and design of performance aspects • Knowledge about electronic application process and its data format requirements • Understanding about input and output data requirements of different design domains in general and especially in detailed technical design and understanding about data needs in specific tasks (such as bill of quantities and environmental assessment), and procurement processes. • Knowledge about the information requirements in quality control and assurance process in construction • Knowledge about data and information requirements of sustainable care and maintenance processes EQF Levels 6 - 7
Competence	Competence to use knowledge and skills • to understand owner's targets and feasibility with the help of different kinds of concept solutions • to lead the design team to prepare, compare and improve alternative concepts • to direct the design towards set targets utilizing the capacity of different kinds of digital assessment and simulation methods. • in collaborative BIM-based working together with the owner/project manager, users, building authorities, and other stakeholders. • to lead the preparation of the presentation materials and presentation agenda to support owner's effective decision-making and opinion formation of other stakeholders

	• to take care and lead the tasks related to the electronic building permission process including communication with the building authorities. • to verify the achievement of the targets on the basis of the results received with the help of different kinds of assessment, simulation and labelling tools. • to lead the process resulting in the publication of the merged model (as designed) together with all needed information to support sustainable procurement, construction and maintenance EQF Levels 6 - 7
Learning outcomes	Proven ability based on exams • about good theoretical in overall design principles for sustainable and energy-efficient buildings Proven ability based on exams and demonstration • about design management supervising the overall design quality of each design domain taking care of the compatibility and the achievement of set targets Proven ability based on exams and demonstration • about good understanding and skills in applying collaborative processes and data management systems

Comparison between gained learning outcomes within countries involved in the project (Luxemburg, France, Finland, Greece and United Kingdom) were then collected, compared and studied. Learning outcomes from other standards and EU projects were studied and made use of in order to formulate first draft of European wide stakeholder specific learning outcomes. The identified other projects that had relevance to the subject matter are as follows:

- BIMcert: Project learning tools, focus on testing the BIM approaches to green and passive building design https://energybimcert.eu/ (Partners from: UK, Ireland, Portugal, Macedonia, Croatia)
- BIMplement: BIM and quality control approach to achieve energy efficient buildings www.bimplement-project.eu (Partners from: France, Netherlands Lithuania, Spain and Poland)
- NET-UBIEP: Aims at increasing energy performance of buildings by wide spreading the use of BIM www.net-ubiep.eu (Partners from: Croatia, Spain, Estonia, Italy, Slovak, Denmark, Lithuania)

The information thus generated and developed were compiled and tracked into a “Super matrix” as and information storage and to map the existing learning outcomes for the specified roles. The process of formulating the EU level learning outcomes and the structure of “Super matrix” is explained in Figure 5 and Figure 6 respectively.

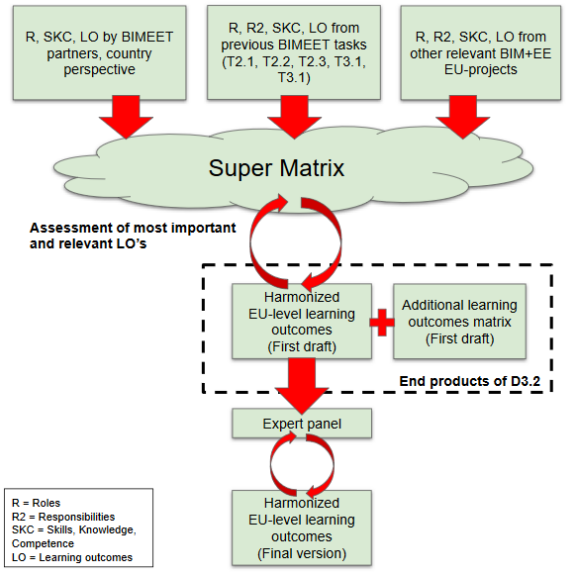

Figure 5: Process and content development of Super matrix

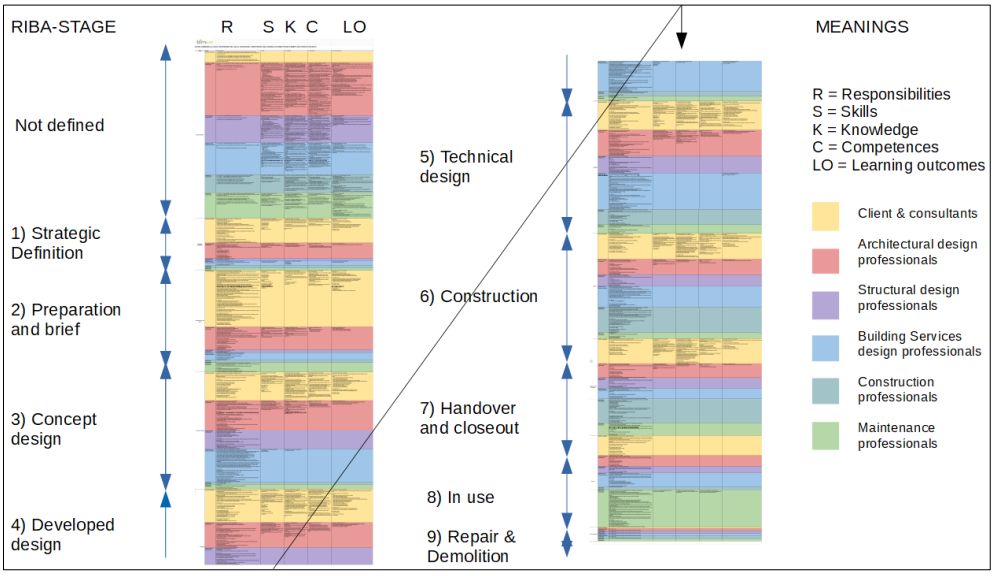

Figure 6: Data collection and structure of the Super matrix

Construction industry and building projects have several roles and stakeholders. The four main role categories were identified in earlier deliverables of BIMEET to generalize the roles during a constructin project. The roles idenfied are that of Client, Designers/Design Consultant, Contractor/Sub-contractor, Facility/Asset management[16]. The existing roles (as well as emerging roles like BIM coordinator, BIM manager) have been mapped at a general level to the four sectoral groups. However when defining and detailing out the EU wide learning outcomes, design consultant: Architect, Structural engineer, Building services engineer are mentioned by all partners and the generalized roles based upon the information related with BIM and EE KSC. The selected roles and their EU learning outcomes for BIM and EE trainings are presented in the Results and Conclusion section.

5. Results and Conclusions

The work resulted in proposing 6 - 8 specified groups of learning outcomes for the each selected main category role. Each of the groups consists of 4 - 14 learning outcomes that clarify and supplement the required qualifications for the selected roles. The categories of roles that were chosen for the EU-wide approach are presented in Table 2.

Table 2: Role groups and selected roles

Role Group	Roles
Client & Clients advisors	Client, Project manager, BIM manager, BIM coordinator, Briefing consultant
Architectural design	Architectural Design and BIM Coordinator, Chief Designer, Architect, Assistant designer
Structural design	Structural design and BIM coordinator (structural), Assistant designer
Building services design	HVAC and Energy design and BIM coordinator (HVAC), Assistant designer
Construction work	Site manager, construction site workers and installers
Maintenance work	Maintenance operator, property manager, care taker

Thus developed European wide learning outcomes for different stakeholders are grouped into a generalized focus that they provide. An example of such groupings for architectural design role group is presented in Table 3 and Table 4 presents EU learning outcomes (LO1) and (LO2) for the same role group mapped with the EQF levels as an example.

Table 3: Learning outcome groups and their main focus for architectural design role group

Role Group	Roles
Architectural design	• (LO1) Fundamentals of BIM and principles of its uses with respect to building life-cycle • (LO2) Fundamentals of sustainable and energy-efficient buildings and building performance • (LO3) Leading of design process, supporting the client and other stakeholders in decision making • (LO4) Implementation of energy performance, building performance and sustainability targets into design process. • (LO5) Production of BIM models with accurate and required information content for the different uses and phases of a building project. • (LO6) Collaboration, communication and visualization with help of BIM • (LO7) Implementation of target and quality management procedures in the building project. • (LO8) Skills for relevant software and interfaces between software.

Table 4: EU wide learning outcomes 1 and 2 for architectural role group (CD = Chief Designer; ARCH = Architectural design and BIM Coordinator; ASS = Assistant designer)

		EQF Levels		
	Learning outcomes	CD	ARCH	ASS
LO1	**Learner is able to explain the fundamentals of BIM and the underlying principles of uses with respect to building life-cycle.**	**6**	**6**	**3**
1.1	Recall essential contents, summarize and give examples of BIM terminologies, definitions and standards.	6	6	3
1.2	Recall essential contents, summarize and give examples of overall BIM process for a building's life cycle.	6	6	3
1.3	Explain and use standard information exchange processes for different design domains in general and especially in detailed technical design.	5	5	2
1.4	Explain the essential issues related to information management, data transfer and sharing.	5	5	2
1.5	Explain the added value of using open file formats (i.e. IFC) to ensure interoperability.	5	5	2
1.6	Recall, summarize and explain essential contents and relevant parts of national BIM guidelines.	6	6	3
LO2	**Learner is able to explain the fundamentals of sustainable and energy-efficient buildings and building performance.**	**4**	**6**	**2**
2.1	Explain and give examples of aspects and terminologies of energy and building performance.	6	6	2
2.2	Describe the financial and environmental aspects and related indicators, benchmarks and certification systems of energy and building performance.	2	6	2
2.3	Explain the issues that affect energy performance of buildings and demonstrate competence in domain specific solutions.	4	6	1
2.4	Explain relations between life-cycle costs, energy performance and building performance.	4	6	2
2.5	List and explain the core concepts of sustainable building rating and certification systems.	4	4	2
2.6	Summarize and give examples about the potentials of renewable energy sources applicable to buildings including district-scale solutions.	4	4	1
2.7	Point out legislation and regulations related to energy performance, thermal comfort and air quality.	6	6	3

The EU learning outcomes developed are further to be validated for their use in developing BIM and EE trainings with an input from BIM EE expert panel in coming work deliverables. These would then further be used for defining national level learning outcomes for the project partner countries in the project. The validated learning outcomes will thus be used as the base for specifying the BIM and EE related training outcomes for the EU.

Acknowledgement
The authors acknowledge financial support from the European Commission (H2020) to the BIMEET project, grant reference: 753994.

References

[1] World Economic Forum. (2016). Shaping the Future of Construction: A Breakthrough in Mindset and Technology. Cologny, Switzerland: World Economic Forum.
[2] Autodesk. Construction with the power of digital. https://damassets.autodesk.net/content/dam/autodesk/www/AEC-Solutions/pdf/fy18-aec-construction-manifesto-single-page_EN-US.pdf [Accessed: Feb 1, 2019]
[3] CIB 1982. CIB Report. Working with the Performance Approach in Building. CIB Publication no. 64. Rotterdam, Netherlands, 1982, 30 p.
[4] Eriksson, P. and Westerberg, M. (2011). Effects of cooperative procurement procedures on construction project performance: A conceptual framework, International journal of project management 29: 197 208
[5] Sexton, M. and Barrett, P. (2005). Performance-based building and innovation: balancing client and industry needs, Building Research & Information 33(2): 142 148.
[6] Alwaer, H. and Clements-Croome, D. J. (2010). Key performance indicators (KPIs) and priority setting in using the multiattribute approach for assessing sustainable intelligent buildings, Building and Environment 45(4): 799 807.
[7] Augenbroe, G. and Park, C.-S. (2005). Quantification methods of technical building performance, Building Research & Information 33(2): 159 172.
[8] Loomans, M. G. L. C., Huovila, A., Lefebvre, P., Porkka, J., Huovila, P., Desmyter, J. and Vaturi, A. (2011). Key Performance Indicators for the Indoor Environment, In Proceedings World Sustainable Building Conference SB11, Helsinki, pp. 1666 - 675.
[9] Frandsen, A. K., Bertelsen, N. H., Haugbølle, K., Porkka, J., Huovila, P., Hietanen, P., Widén, K., Hansson, B. and Karud, O. J. (2010). Performance Indicator Framework, In V. Huovila, P., Karvonen, A. & Raasakka (Ed.), Proceeding of Sustainable Building Conference SB10, Espoo: Finnish Association of Civil Engineers.
[10] ISO 21929-1. (2011). Sustainability in building construction - Sustainability indicators - Part 1: Framework for the development of indicators and a core set of indicators for buildings. International Standard ISO 21929-1.
[11] IEA ECBCS Annex 53. (2013). Annex 53 Total Energy Use in Buildings: Analysis & Evaluation Methods
[12] Users'Guide, E. C. T. S. "Luxembourg: Publications Office of the European Union." DOI 10 (2015): 87192. https://europass.cedefop.europa.eu/sites/default/files/ects-users-guide_en.pdf
[13] Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. Theory into practice, 41(4), 212-218.
[14] University of Toronto. Centre for Teaching Support and Innovation, and Emily Gregor-Greenleaf. Developing Learning Outcomes: A Guide for Faculty. Centre for Teaching Support and Innovation, University of Toronto, 2008. https://teaching.utoronto.ca/wp-content/uploads/2015/08/Developing-Learning-Outcomes-Guide-Aug-2014.pdf
[15] Honkkannen, I. (2015). Bloom taxonomy action verbs and activities. https://www.slideshare.net/IidaHokkanen/bloom-taxonomy-action-verbs-and-activities [Accessed: December 10,2018]
[16] BIM for Energy Efficiency Training (BIMEET). (2018). Deliverable D3.1