System for Sector-Wide BLE

By: Tampere University, Finland

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Executive Summary

The aim of this document is to explore the possible route towards wide use of BIM for education in the real estate and construction (REC) sector. The vision is that BIM centric education shall be a game changer for education and training in the REC sector. This would address educational institutes and teachers in different levels from vocational schools to high education institutes and private training providers. Education of qualified professionals is the main object of BIM enabled learning. This can target all different professionals in the REC sector: city planners, land surveyors, architects, mechanical and structural engineers, HVAC engineers, electrical engineers, project managers, building inspectors, site workers, etc.

The BIM-enabled learning environment (BLE) platform and its IT prototype were developed in the Benedict project. They present a novel solution for advancing BIM-enabled learning for the REC sector. The BLE platform prototype was planned and developed to be an open, low-cost, flexible, scalable and robust solution for different needs of the REC sector. Basically, the sector-wide use and exploitation have already been seen as design criteria in the beginning of BLE platform development.

The received feedback from BLE pilots together with the data obtained from workshops and survey are very encouraging. The BLE concept, the developed BLE platform and the BLE vision have all been well received. This is indicating that right choices have been made and the path is open for further development. It is possible that new educational innovations can arise when education is to be built extensively around digital building models. These can mean new kinds of educational experiences where logic of learning is moved drastically toward problem-based learning as a collaborative effort. This is just one descriptive example and there can be plenty of other exciting new breakthroughs.

The completed exploratory studies (workshops, survey, feedback from pilots) are showing evidence that the BLE concept and BLE platform as its practical instance are creating working possibilities for renewing education in the REC sector. The sectoral renewing of education can be seen as a transitional change. This is a very demanding, complex and long-term effort. However, this transition is worth targeting since it can be highly beneficial in terms of education effectiveness, employment of new educational possibilities for varying needs of different individuals for the development of their professional skills and for meeting the different growing demands for the REC sector.

1 Introduction

1.1 Background and purpose

With the constantly widening use of digital technologies and particularly building information modelling (BIM) the real estate and construction sector (REC) is facing profound challenges and opportunities. The resulting impacts can be characterised as an overall transformation where all stakeholders, processes and end products need to change for being competent in future. Also, education in the REC sector must change accordingly. This what the BIM-enabled Learning Environment for Digital Construction (Benedict) project is for.

The BIM-enabled Learning Environment (BLE) platform and other relating solutions have been developed in the Benedict project for enabling the development of new construction relating education where BIM technologies would be eminently present. This development manoeuvre can be characterised as experimenting with ideas. It has produced a prototype BLE platform, supporting solutions such as repository of learning resources and three major pilot courses with their implementations. Additionally, the experiments have produced research-based knowledge and understanding for the sector wide use of the gained results.

1.2 Objectives and scope

The aim of this report is to open the possibilities of BLE for its sector wide use. The sectoral ultimate objective would be the renewing of various educational services covering education of new professionals, training of new skills for present staff and continuing education. First, this can embrace public institutional education providers such as vocational education providers and higher education institutions. Second, the targeted solutions can be valuable also for private training service consultants.

The report is composed of four main parts. The first part provides a contextual view over current BIM practices in the REC sector. The construction and real estate sector is highly diverse and complex with its different players of varying sizes, encompassing both public and private interests and having long term impacts on sustainability and well-being of citizens. Not so surprisingly, the BIM practices are rather uneven amongst different companies and in the public sector. The second part of the report covers the sectoral expectations and views for BIM based education solutions. This is based on workshops and questionnaire surveys caried out in the Benedict project. The third part of the report addresses the technical possibilities of the BLE platform and relating learning resources for wider sectoral use. The sectoral dimension was already a starting point of significance for the development of BLE platform. The fourth part of the report is about information channels for reaching targeted sectoral impacts.

2 BIM practices in the construction sector

2.1 Development of BIM practices

Companies, public institutions and governments have turned their attention on digitalisation and BIM technologies for having major transformation of real estate and construction sector. Governments in different regions have presented mandatory requirements for the use of BIM in construction projects, Figure 1 (Paul, 2018). The governments are clearly driving for the acceleration of BIM adoption. This is first to address the public works such as infrastructure investment projects, public building construction and social housing construction. The usual next step is to expand the requirements to cover all bigger building permit processes where the use of digital models is getting mandatory.

Figure 1 The global evolution of BIM regulation (Paul, 2018).

The commercial significance of BIM solutions and relating services has increased with the growing sectoral interest. It has been estimated that, currently, the global BIM market is annually growing at a rate of between 11.1 and 16,4% (Fortune, 2023; Market Research Future, 2020; Research and Markets, 2023). Figure 2 portrays the comparison of range for possible development of global BIM market. Accordingly, the estimated trends are proposing the market size ranging between 9.9-11.1 billion USD (2024) and growing then up to 18,5-25,5 billion USD (2030). The market development is demonstrating the constantly growing significance of different BIM-technology service providers and users of those. The existence of such an important market and its development is also reflecting the overall BIM adoption. The adoption of BIM is moving ahead constantly, it is growing and reaching more extensively different players in the real estate and construction (REC) sector.

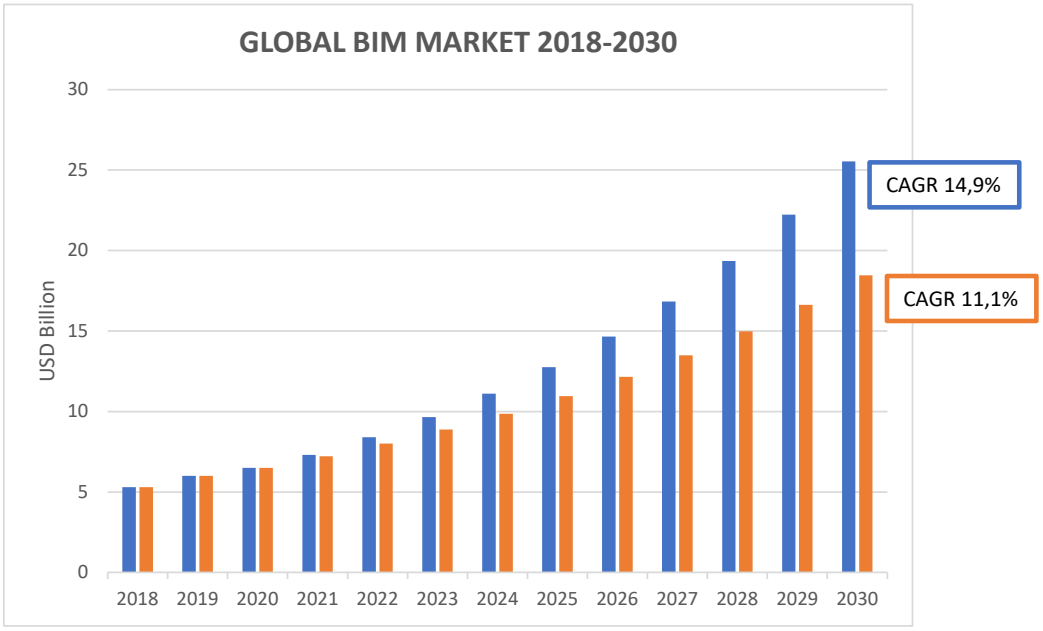

Figure 2. The development of global BIM market 2018-2030. Comparison of two growth estimates. The portrayed two estimates originate from Fortune (2023) and Market Research Future (2020).

Besides appropriate technologies, the wide use of BIM-technologies in construction projects requires substantial changes in skills, attitudes and operational processes. New technological innovations are providing platforms for process re-engineering. National standards have provided first baseline and guidance for common understanding over desirable practices, e.g. COBIM (2012) and BS 1192 (2007). In the long run, international BIM standards shall bring possibilities for more common practices between various regions and nationalities. For this purpose, the first parts of ISO standard 19650 "Managing information over the whole life cycle of a built asset using building information modelling (BIM)" were published in 2019 (ISO, 2019). International standards can provide possibilities for harmonising different national standards.

Nowadays it is widely acknowledged that sound BIM practices are the way to integrate different project partners together for smooth and productive digital model-centric practices. Thus, the engagement of all partners is of prime importance. Their needs are specific ones depending on their roles and contractual obligations. Additionally, long project and product life-cycles set up additional requirements for data management and relating solutions. The spectrum of different BIM tools has grown to include increasingly more specific tools meeting the needs of different partners and their use cases. Practical BIM coordination provides evidence of the different types of digital tools that are needed in construction projects where digitals models are used in an extensive manner. The list of relevant data management and BIM tools used by professional BIM coordinators are listed on the following (Lozinski, 2023):

1. Choosing right Common Data Environment
2. Creating project documents
3. Communication between team members
4. Creating an information database in the model
5. Disciplinary / multidisciplinary coordination
6. Collision management
7. Creating a construction sequence simulation – BIM 4D
8. Tools to assess the information quality in the model
9. Tools for modelling BIM 3D geometry
10. Parametric modelling/programming

11. Virtual Reality and Augmented Reality usage
12. Tools to “Gamificate” the project
13. Use of models on site

Development of BIM practices that have sectoral significance takes time and can be characterised as learning process for cultural change. This means the transformation of organisational culture, values and beliefs among employees (Alankarage et al, 2011)

2.2 Project level practices

With project level practices of using BIM our main interest is to look at how extensively BIM is used throughout the lifecycle of construction projects. On the other hand, the understanding over lifecycle of construction projects can be different depending on a partner’s view or the contract in question. For developers and property owners the project lifecycle can start from early drafting/feasibility studies and end up in property demolition (or complete refurbishment for another use). Traditionally, construction companies, particularly with their competitive contracting projects, would see their project lifecycle starting from bid preparation and end up in handover of the constructed product to the client. With increasing demands for sustainability there is growing demand to extend various impact analyses over the use time of built properties.

Research based evidence has shown that BIM is mostly applied in the early stages and less in later stages (Eadie et al, 2013). Historically, the main research, development and innovation (RDI) attention has been on BIM authoring tools for the development of BIM capabilities. BIM authoring tools, i.e. software for modelling by architects and engineers such as ArchiCad, MagiCAD, Revit and Tekla Structures, are of prime importance and these kinds of tools have found their way into the offices of architects, engineering consultants, HVAC engineers, etc. This partly explains the well-established BIM-practices in the early stages of construction.

The use of digital models for communication, collaboration for re-engineering, sustainability analyses, cost estimates, planning, needs of material procurement, site operations, etc., require other, different tools than BIM authoring solutions. Research and development of these tools and relating innovations has increasingly created interest. This can be seen from the rapidly growing number of relevant journal articles - see, e.g., Sepasgozar et al (2022). Figure 3 provides an overview of current BIM practices amongst typical construction project partners. The spectrum of BIM solutions for such needs and new emerging ones is developing rapidly. Different well-established professional tasks are to be transformed into new forms when BIM solutions are fully operationalized (Hardin & McCool, 2015).

When trying to understand the big picture of BIM practices in the REC sector we need to acknowledge the multifaceted nature of construction that is also present in BIM practices. Forerunners with their high-profile showcase projects represent different reality than standard construction project deliveries.

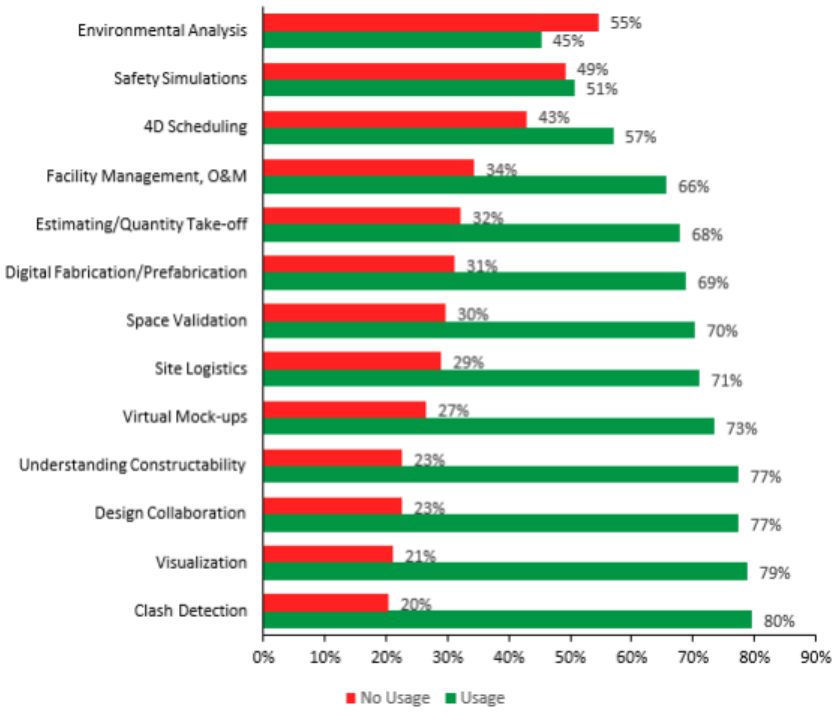

Figure 3. Usage/No Usage distribution of BIM Practices representing various partner companies in construction projects (Nassereddine et al, 2022).

2.3 Practices of different professionals

BIM requirements by clients and governments are resulting in practices where all project data is in digital form. Digital models are used for communication - 2D drawings are still useful but those are printed from digital models and information such as design specifications are increasingly connected to the object of digital models. Thus, all partners of construction projects are gradually enforced to start the adoption of BIM. Recent research results are showing evidence that the use of BIM is steadily getting more common amongst different stakeholders of construction projects (Figure 4).

	Average Perceived Level of Usage					
BIM Users	Average	A/E	GC/CM	MEP Trades	OR	Owner
Architects/Engineers	3.91	4.36	4.17	3.52	3.71	3.63
Project Engineers	3.51	3.73	3.57	3.26	3.43	3.88
Project Managers	3.00	2.73	2.98	2.94	3.29	3.50
Superintendents	2.75	1.67	2.76	3.10	2.29	3.00
Foremen	2.71	2.17	2.49	3.19	1.80	3.00
Owners/Owner's representatives	2.42	2.11	2.41	2.17	3.00	3.29
Workers	2.35	2.33	2.13	2.81	1.50	2.40
Facility Managers	2.24	1.89	2.21	2.07	2.43	3.29
Project Executives	2.08	1.89	1.92	2.10	2.60	2.71
Inspectors	1.90	1.75	1.89	1.69	2.20	2.40

Figure 4. Stakeholders' reported level of use of BIM by various professionals along the company types they represent. The darker the colour the higher the average level of usage of BIM (Nassereddine et al, 2022).

The practices are still very uneven. Concerning SMEs, a recent study found that 85 per cent of the respondents have no expertise with the BIM packages featured in the survey (Vidalakis et al, 2020). It is concluded that this overall response can be caused by the limited resources (development work, training of employees, SW&HW investments) that SMEs can commit to developing their capacity to use BIM. "Up to 95% of construction, architecture, and civil engineering firms are micro-enterprises or small and medium-sized enterprise (SMES)" (EU, 2023). It is normal to have more than 100 service providers in a standard residential building project (Sorri & al, 2013). Having these kinds of constraints around construction project managers and BIM coordinators it can be very difficult to reach widely spread standardised practices where BIM is used in an extensive manner. This requires cultural transformation that takes time.

3 Towards sector-wide BLE

The purpose of the BIM-enabled Learning Environment (BLE) is to provide a starting point for renewing the educational solutions in the REC sector. A BLE platform prototype has been developed in the Benedict project. BLE platform has been presented in the Benedict report for Intellectual Output 2: BIM-enabled Learning Environment (BLE) – System Architecture and its Implementation.

Three workshops and a questionnaire study were carried out during the Benedict project for exploring views from industry and educational experts (Table 1). World Cafe Method was applied for organising the group work in these workshops. Main points of discussions were documented on flipcharts and discussed and developed further during the latter part of each workshop.

Table 1. Workshops for exploring views from industry and educational experts on the wide use of BIM enabled learning.

Place & Date	Focus	Number of participants	Profiles of participants
Tallinn, 2.6.2022	Opportunities and challenges for BIM-enabled learning	29	Government, industry, training organisations and educational institutions
Tallinn, 17.10.2022	Technical aspects: Online platforms, digital learning resources, online coursework and assessment	22	Academic institutions
Bologna 30.3.2023	Industry, technology, learning & teaching, what's the next?	35	Government, industry, training organisations and educational institutions

In June 2023, an electronic questionnaire survey was carried out to study further the possibilities of BIM-based education (see Appendix for the questionnaire form). Sample size was 139 people from private sector (consultation companies, construction companies, technology providers, real estate/FM) and public sector (educational institutes, research institutes), communal (incl. city councils etc.)). The survey was carried out simultaneously in Finland, Estonia and Italy. Personal invitations were sent to participate in the survey. The response rate was 52% / 73 responses (Figure 5).

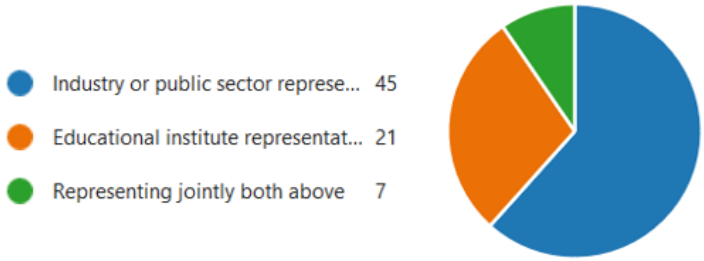

Figure 5. The profile of respondents for the survey on the possibilities of BIM based education.

The following subchapters present the key findings and relating conclusions based on the data received from the workshops and survey presented above.

3.1 Needs in the sector

Workshop data

Figures 6, 7 and 8 present the main data obtained from the workshops. The survey data are to be presented in a scientific paper. However, the following findings present jointly the main findings from all data including the survey.

INDUSTRY	
Opportunities	**Challenges**
To get more competent people	Existing culture(s)
To speed up learning	Different tools and processes
Implementation of more advanced work methods	Lack of common standards
Bring different trades / disciplines together => collaboration	Project life-cycle
Use of real project data	Two sides of open source solutions/software
Feedback from learners to programme developers	Lack of teachers
Site workers	Lack of time/will
	How to unlearn existing practices?

TECHNOLOGY	
Opportunities	**Challenges**
We can define how we use those tools (how to develop what we really need)	Open source tools are limited (IFC.js) how to extend?
Knowledge sharing (students, industry)	Open platforms are vulnerable
Future developments on a flexible platform	Current tools are not developed in collaboration with the end user
Open formats for better interoperability	Upskilling the teacher (technology use)
	Differences how data is defined in a digital vs real world
	How to experiment, awareness of doing things in a lean way.

LEARNERS	
Opportunities	**Challenges**
Attractive interactivity	Students' background knowledge
Playing with real stuff	BIM & AEC content
Enhances creativity	1st/2nd year students?
Integration between studies and industry	No room to fit the module in one's study programmes
Collaboration	Open (access) tools not necessarily the ones used in industry
Communication	Availability of good facilitators
Visualisation	Does step 1 output add value to the process or as an input to step 2
Have a better idea what the output should be	Are Learning Outcomes valuable to graduates?
Groups, mixed learning from each other	
Platform to work with other disciplines outside our faculty	

TEACHING	
Opportunities	**Challenges**
Real life experience	Open software
Educators developing software	Knowledge of staff (teachers)
Feedback from teachers and students	Hardware
Openness	Real life experience
Maintaining database	Different classification systems
Different software	Moodle – no access for everybody
Group work on specific tasks	Big student groups
Need for BIM specialist (workers)	Students' previous knowledge
Scaling real problems to different levels	Different tools (no open!)
Vocational schools	Different students (MSc, BSc, continuing education)
	Lend software from companies
	Quick development

Figure 6. Data from workshop on opportunities and challenges of BIM-based education.

ONLINE PLATFORMS		
Opportunities	**Challenges**	**Common Understanding**
Measuring learning outcomes	Limited infrastructure, facilities, resources (access to internet, privacy aspects)	Students do not know themselves – extra motivation
Collaboration (study group, institutions, countries)	To enable live collaboration	F2F -> same opportunities
Freedom to learn (no need to travel, no time constraint)	Limitations to use webspace	Qualitative framework: how to change teaching philosophy
Evaluating learning / teaching efficiency	Travel (for some) to access internet	
Cost effectiveness (students -> online study program)		
Customized teaching (learning path)		

COURSEWORK AND ASSESSMENT		
Opportunities	**Challenges**	**Common Understanding**
Coursework	New proper coordination (organisation)	Opportunities:
Interdisciplinary-based courses (diverse groups of experts)	Skill development	• Online platform
Assessment	Practicalities	• Interdisciplinary
Students:	Disadvantage for disabled - technical	
• Continuous assessment	Assessment: technical equipment:	• Assessments of courses and students
• Peer assessment	• Students don't have	Challenges:
• Group assessment	• cheating	• Capable coordination
Course:		• Address people with disabilities
• Student feedback		• Equipment for assessment
• Happiness index		• How to manage practicalities
• Scatter plot of teacher assessment		• Cheating in examinations
• Assess the outcomes		
• Text mining		

DIGITAL LEARNING RESOURCES (DLR)		
Opportunities	**Challenges**	**Common Understanding**
Customized learning	Compatibility (follow open standards)	Stakeholders profiling and mapping (Design Thinking)
Scalable	DLR require also maintenance	Establish intent and aims
Flexible	Online examination difficult	Activities -> materials -> assignments
Traditional learning materials:	Availability of resources (platforms, money for developing content)	Assessment and reflection
• Videos	Infrastructure before learning resources?	Improvement opportunities
• Open materials / libraries	Digital competencies of learners	
• Scientific articles	Availability of educators	
Multi-modality of materials	Mobile-based	
Outside experts	Digital infrastructure can be very poor	
Mentoring	Not too many have items	
Global competitiveness	IT resources of students	
Employability	Challenge of introducing DLR	

Figure 7. Data from workshop on technical aspects of BIM-based education.

	Theme 1 Industry	Theme 2 Technology	Theme 3 Learning & teaching	Theme 4 What's the next?
Group	What professions can benefit most from BIM based education & training?	How can we obtain digital models of good quality for educational needs?	What would engage and motivate you to partecipate BIM based education?	What would be BIM based course or educational module that would create wide interest and enthusiasm?
1	Construction workers, On-site managers of construction project, Firemen, Engineers and Surveyors	Software development for free Apps, Digital Twinning, collaboration of physical and digital model	Realization of 3D modelling (user friendly and free); Skills necessary to enter in the industry	To develop a project in all its phases (lifecycle of a project); The 8th dimension of BIM that manages safety
2	Designers, Architects, Technical site manager e Construction manager	Collaborations with the world of work	Needs on construction site, Participation in public tenders, Collaborative planning	Learning a new BIM design tool; Costs; Times
3	Contracting authorities (Project Managers); Construction companies (Site managers, Project Manager), Contractors; Construction Manager and Safety Coordinator	By clearly and consciously defining information requirements; by developing workflows for model approval and validation; by defining information requirements and strategies at the single project, asset and organisational level	Work requirements, Public procurement partecipation, Collaborative design	BIM for contracting authorities (drafting information specifications; OGI assessment and PGI drafting) + (coordination processes and model validation); Open BIM and related topics (bsDD, ECB, IDS, IDM)
4	Architects, Engineers, Surveyors; Vocational level (on-site workers, cleaners, etc.); Client professions; Authorities (building permit auth.); Small (companies)!	"Good" is not necessarily complete (reduced complexity); Public data (ie. Estonia…); Materials produced by students with courses; QA process needs to be in place, if production will be		
5	Engineers; Architects; Project Manager/Facility Management	Information Sharing, Information Integration, Open data	Increasing organisational skills; understanding conceptual and managerial aspects	Life cycle assessment
6	Engineers, Architects; BIM manager/coordinator; Health and Safety Coordinator during the Design Phase (HSCDP)/Health and Safety Coordinator during the Execution Phase (HSCEP)	Starting from simple but comprehensive models and moving towards more complex models; Introducing BM courses within the university curriculum from the first year	The practical side: software use and development into reality	A course that explains BIM at 360 degrees: starting with a solid theoretical basis and then focusing on the use of software that showcases the potential of the methodology

Figure 8. Data from workshop on industry, technology, learning & teaching, what's the next for BIM based education?

General views

As a starting point for the workshops and survey, the BLE was presented as a game changer for education in the REC sector. This is naturally a bold hypothetical vision, but the received responses are rather encouraging. Numerous potential and multifaceted opportunities were identified. Whether the attention was on industry, technology, teaching or learners' viewpoints, it was possible to identify and see plenty of opportunities. Likewise, it was the case with technical viewpoints: online platforms, coursework and assessment, and digital learning resources worked also well as thinking frameworks for identifying numerous opportunities. The following brings up certain opportunities that are in a weighty manner present in the workshop and survey data.

Connection with reality. The used digital models can provide a clear link to the reality they originate (at least partly) from a certain case project or industrial context that can be explained in the learning events. This can be valuable in different ways: making courses more interesting and motivating, connecting industry and educators, presenting industry proven ways and solutions.

Collaboration between different professionals. An open online environment enables collaboration between different organisations and even countries. Collaboration can be simulated and experienced for learning purposes with digital models used in a digital working environment.

Customised teaching. Meaningful, flexible (dynamic) learning paths where progress of learning is monitored with the aid of digital learning environments.

Better feedback. With a comprehensively digitalised teaching (digital models, learning environments, communication and assessment) communication between learners, teachers and other possible involved parties can be more systematic and instant than in the case of traditional teaching solutions.

Open format. This was seen both as a challenge and an opportunity. Open format is not dependent on licensing agreements and therefore offers a cost-effective solution for small companies to attend and for developing countries to organise training.

Learners' background knowledge. This was also seen both as a challenge and an opportunity. Diverse learners enrich the learning experience, however, designing the environment to support diverse learners is challenging.

Use cases for BIM-based education

After completing the last more specific workshops and survey it is now possible to name some use cases for BIM-based education which are clearly creating interests amongst experts that provided their responses.

- More than 20% of the responses cited use cases related to **construction-phase** Building Information Modelling (BIM).
- The **inventory of existing facilities, as-built and record models** emerged in over 10% of the responses. Overall, 17 % of the respondents mentioned some sort of use for the purposes of facilities management and operation.
- 10% of the responses highlighted the presence of **design information analysis and simulation**-related use cases.
- **Design coordination**-related use cases garnered less than 5% of the responses. This figure is notably modest due to its historical role as one of the primary applications for building information models, as it primarily entails accurate geometry without exhaustive data requirements.
- Other thematic use cases that were mentioned include **visualization** and **obtaining building permits**.

In addition to the interest in various BIM use cases, it needs to be noted that the BLE solution was seen as applicable and attractive widely across the industry, public and education sectors, and useful in various roles in the organisations.

3.2 Challenges

As a sector wide implementation, the BLE solution is still a hypothetical opportunity. It is possible to see numerous opportunities and potential benefits but challenges are also numerous. Obviously, the development path towards fully implemented BLE is long but there are already now applicable technologies available and thus for having the first wider used solutions in place should not be too difficult to reach. The BLE prototype, its first pilot courses and their implementations are evidence of the possible quick wins and door opening using those for reaching the next level.

The notable challenges that were identified included:

- How to get digital models that are well suitable to teaching?
- What is the value of the learning outcomes?
- Digital competences of learners and teachers
- Useful pedagogical solutions and competences are not known (-> good facilitators)
- Existing culture(s) and attitudes in industry and amongst teachers
- Lack of time/will amongst teachers

- Vulnerability and data safety of platforms
- Arrangement and collaboration with private software and hardware vendors (impartiality)

4 BLE solutions for sector-wide impact

The BLE platform and its prototype were designed to meet the requirements of sector-wide use not only in a single country but also internationally.

4.1 BLE platform

The BLE platform presents infrastructure for a systemic solution of BIM-enabled learning. The vision is that BIM centric education shall be a game changer for education and training in the real estate and construction sector. This would address educational institutes and teachers in different levels from vocational schools to high education institutes and private training providers. Education of qualified professionals is the main object of BLE operations. This can target all different professionals in the REC sector: city planners, land surveyors, architects, mechanical and structural engineers, HVAC engineers, electrical engineers, project managers, building inspectors, site workers, etc.

The top-level structuring of the BLE platform has been designed to satisfy successfully various functional and technical requirements and additional requirements that were identified during the creation of BLE. A leading principle of importance was to take advantage of existing proven IT-technologies and to avoid large scale technology development. The main objective for the development of BLE platform prototype is to provide solution that can demonstrate possibilities of digitalisation for renewing the education of the REC professionals (Figure 9).

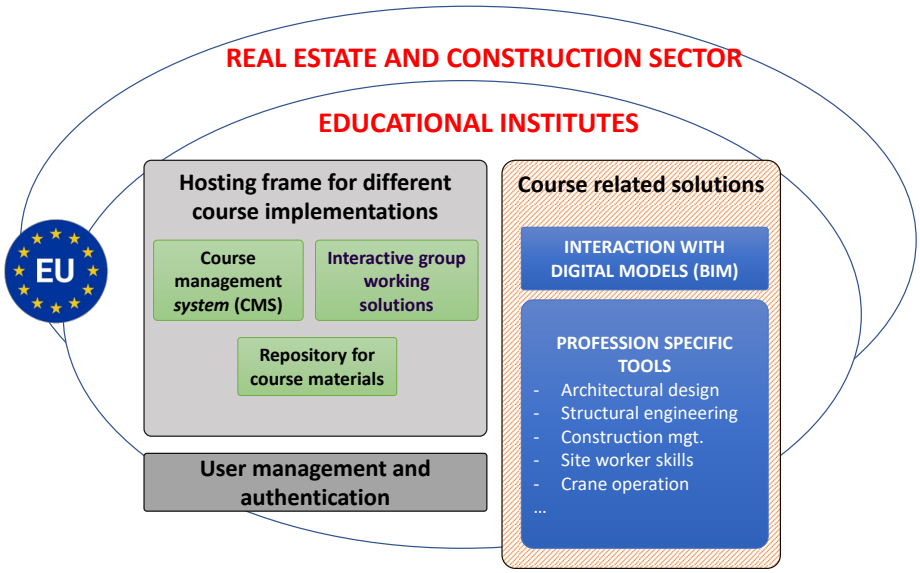

Figure 9. The top-level structure of BLE platform.

Creation of generic possibilities for exploitation is one of the requirements that was considered thoroughly when the BLE platform structuring, and later its IT solution were developed:

- *Educational platform for the REC sector*: Generic solution for renewing educational services in a sector-wide manner. This to meet different professions in the REC sector.
- *Scalability*: number of students, duration of teaching modules/courses, content (models, supporting materials), generally scalability is only limited by the used IT infrastructure (hardware

and software)

- *Openness towards different pedagogical approaches*: BLE is not built around any specific pedagogical approach.
- *Various educational institutes*: From vocational schools to universities. Continuing education as a special case where private course organisers and training companies can be service providers.
- *Regional independency*: educational organizers and service providers can locate in different regions and countries.
- *Vendor independence*. Use of open-source software solutions, based on principles of openBIM
- *Creation of low-cost possibilities*. This was recognised to be of prime importance for various educational needs in different regions and countries. The open-source software solutions workable in standard computer environments meet this target.

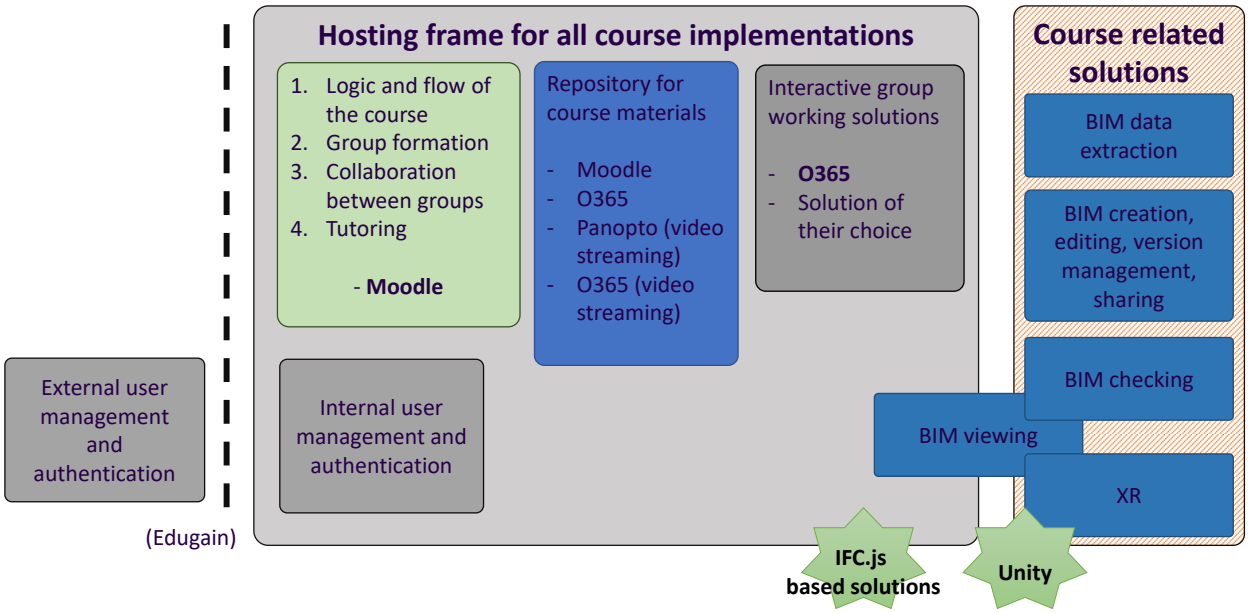

Figure 10. The IT architecture of BLE platform.

4.2 BLE open learning resources

Open learning resources are seen as an important solution for having sector wide impacts. Open learning resources (OLR) stand here for *learning, teaching and research materials in any format and medium that are useful for teaching, learning, and assessing and for research purposes.*

Structure of BLE open learning resources

The needs of BLE users – learners, teachers, system administrators – consist in having the availability of data, reports, pieces of information concerning architecture – engineering systems. The technical data and information concerning design, development and installation of the building and its project management allow BLE users to take advantage of the Building Information Model for various educational needs. For example, construction management students will need a set of case studies to be tested with practical exercises and the Open Learning Resources will be supplied as actual case studies - each case study consisting of a building or facility that has been designed and engineered in industry or in previous courses. Learning experiences using these will greatly enhance BIM-enabled learning where BIM-based workflows will provide immersive learning and training opportunities. BIM-enabled learning can use a

virtual platform, a web site and repository, where all BIM models, examples and data can be stored and used. This creates a BIM-enabled Learning Environment, the BLE. The BLE provides the learning environment or web platform specifically designed to support this type of learning. Key resources for the use of the BLE include the Open Learning Resources (OLR) (Table 2).

Table 2. BLE open Learning Resources.

OLR	Examples	File format
Descriptions of projects	project objectives; site description and analysis; media concerning the site; building overall concept description; statement of work (sow); building systems reports, drawings and calculation	.docx; .xlsx; .pdf; .dwg; dxf; xml; mp4; JPG
Technical BIM models	BIM objects; BIM model	.ifc
Project Plans	architecture and envelope layout; structure layout; MEP systems layout, construction process. bills of quantities; budgets; schedules; resource estimation, procurement documentation concerning materials, products, components and other supplies; safety plans	docx; .xlsx; .pdf; .dwg; dxf; xml; mp4; JPG

UNIBO server for OLR

Different open learning resources are available for all registered users via server developed in the Benedict project (Figure 11). The registered users have personal accounts:

- guest / anonymous: most limited accounts
- activated / students: can navigate and download data
- content creator / teachers: can create and upload data
- administrator: privileges for all wide changes

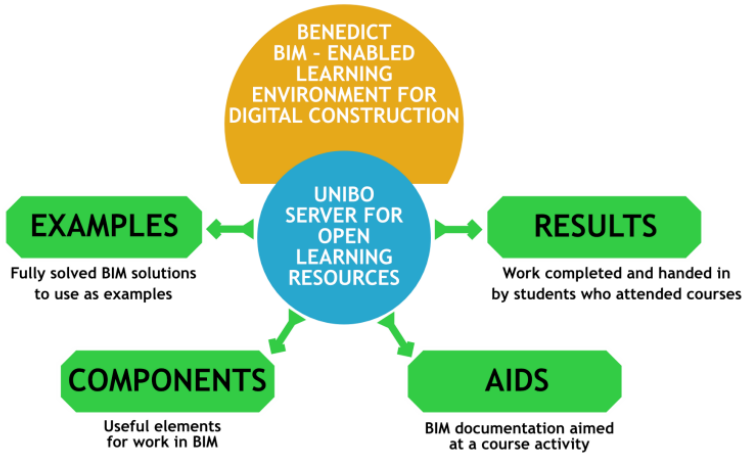

Figure 11. Server solution for sharing different open learning resources.

BLE OLR taxonomy

In the management of extensive data repositories, it is important to utilize the annotation of data with metadata, rather than relying solely on location-based data management. Through the use of user-set metadata, the organization of data becomes more versatile and convenient, compared to a file location-based file management system.

Regarding BIM files, the following metadata describing the contents of the models has been identified and proposed for use.

Table 3. BLE open learning resources taxonomy.

Information Category	Value Type	Values	Description
Model Language	Text	English, Finnish, Estonian, Italian	The language(s) used in the model to describe the content
Building Type	Text	Office, Teaching, Care, Residential	Property used to describe the dominant function/use case for the facility
Discipline	Text	Urban, Architecture, Landscape, Interior Design, Structural Engineering, Building Services Engineering (HVAC and MEP), Construction Engineering, Facility Maintenance	The model discipline prepared by or for the purpose of the given discipline.
Program	Text	Small, Medium, Large	Reflecting on the size of the building, relative to its building type.
Model Categorization	Text	Mass, Room/Space/Zone, and Element models	The type of model content
Life-Cycle Stage	Text	Strategic Planning, Brief, Programming, Schematic Design, Preliminary Design, Design Development, Detailed Design, Pre-Construction, Construction, Commissioning, Hand-Over, Use, Renovation, Disassembly, Demolition	The stage of the model prepare in or for
Model Use	Text	Gather, Generate, Analyze, Communicate, Realize	Penn state classification for BIM uses
Model Maturity	Text	Initial, Defined, Managed, Integrated, Optimized	The mature of the model in any specific stage.
Geometry Maturity	Text	Symbolic, Generic, Detailed, Fabrication	Average accuracy of geometry in the model.
Model Information Reliability	Text	Preliminary, Proposed, Coordinated, As-Built	The state of the information in the model, its reliability with respect to itself and others in the process
Content Classification	Text	CCI, Uniclass, Masterformat, TALO2000, TATE Yleisnimi	Classification system(s) used for identifying model objects.

Metadata needs to be managed and updated by the OLR administrator. More information for maintaining and updating described metadata needs to be collected from the users.

Metadata scope needs to be extended also for other project data beyond BIM files in the future.

5 The channels for reaching sector-wide BLE impacts

Various directions of action and communication are needed for having sector-wide BLE impacts for education and training of professionals. These include:

- Media appearances for
  - making BLE approach known as key solution for the development of REC sector to the next level
  - creating awareness of new business possibilities that can originate from BLE for start-ups and existing service providers (educational IT solutions, training services).
- Educational authorities and ministries for creating presence of BLE in educational targets and policies.
- International and national research, development and innovation (RDI) funding bodies for setting up projects and programmes enabling BLE further advancements.
- Individual schools and educational institutes of different levels for widening pilots and having direct impacts on course solutions.
- Professional associations together with their training services.

6 Discussion

Development and implementation of BIM-enabled learning impactfully for the REC sector is a complicated long-term effort. The BLE platform prototype is an achievement that can be used as a stepping-stone for moving ahead with additional BLE experiments amongst vocational schools, higher educational institutions and training companies. The technical solution needs further development and maintenance to be planned, organised and realised.

The received feedback from BLE pilots together with the data obtained from workshops and survey are very encouraging. The BLE concept, the developed BLE platform and the BLE vision have all been well received. This is indicating that right choices have been made and the path is open for further development. It is possible that new educational innovations can arise when education is to be built extensively around digital building models. These can mean new kinds of educational experiences where logic of learning is moved drastically toward problem-based learning as a collaborative effort. This is just one descriptive example and there can be plenty of other exciting new breakthroughs.

The identified needs in the REC sector seem to be very multifaceted depending upon respondent's role and background organisation. However, it is possible to recognise some guiding patterns from the obtained data. It is worth noting that most responses seem to be around thinking about use of BIM in professional work. When looking at BLE and its possibilities broadly one should not limit thinking on the use of BIM for professional duties in construction projects but to think of BIM possibilities to renew and enhance of any educational work.

7 Conclusions

The BLE platform and its IT prototype present a novel solution for advancing BIM-enabled learning for the REC sector. The BLE platform prototype was planned and developed to be an open, low-cost, flexible, scalable and robust solution for different needs of the REC sector. Basically, the sector-wide use and exploitation have already been seen as design criteria at the beginning of BLE platform development.

The completed exploratory studies (workshops, survey, feedback from pilots) are showing evidence that the BLE concept and BLE platform as its practical instance are creating working possibilities for renewing education in the REC sector. The sectoral renewing of education can be seen as a transitional change. This is a very demanding, complex and long-term effort. However, this transition is worth targeting since it can be highly beneficial in terms of education effectiveness, employment of new educational possibilities for varying needs of different individuals for the development of their professional skills and for meeting the different growing demands for the REC sector.

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APPENDIX: Survey questionnaire

BIM based education/training in the operations of my organisation

Respondent profile:

Theme 1 Organizations: What professionals, degree programs or training courses can benefit most from BIM based education & training in our organization?
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•
•
Theme 2 Technology What type of digital models are needed for our educational needs?
•
•
•
Theme 3 Learning & teaching What would engage and motivate you to participate BIM based education?
•
•
•
Theme 4 Attractiveness of BIM based education What would be BIM based course or educational module that would create wide interest and enthusiasm?
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•
Theme 5 What's next What would you like to see happening next to realise the benefits of BIM based education?
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