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D.5.1 Definition of learning methodologies, materials, and delivery tools for ARISE pilot

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Colophon

Publishable executive summary

This report is an exploration of the definition of learning methodologies, materials, delivery tools, and assessment methods focusing on the following four topics: BIM-EPA, Digital Construction, BIM & Sustainability, and Blockchain. Desk research was carried out through academic papers, websites, university curricula and digital platforms. The format of the report presents a section for each of the four topics as well as an introduction and summary. The conclusion of each chapter and the final report includes recommendations for the ARISE project's methodologies, delivery tools, materials, and assessment methods. Our suggestions and recommendations have been put forward based on the popularity of usage in the aforementioned topics found in the desk research.

The main objectives of the research were:

1) to gain an understanding of the existing learning methodologies, materials, delivery tools, and assessment methods of the four key topics this report is focused
2) to put forward recommendations to the ARISE partners for the learning methodologies, materials, delivery tools, and assessment methods of the ARISE platform

The report will also build on the work performed in the report titled Desk research on maturity analysis of digitalisation and sustainable energy skills (3.1).

Contents

Glossary

BIM – Building Information Modelling

BIM-EPA – BIM for Energy Performance Alliance

PBL – Project-Based Learning

GSL – Guided Self Learning

DFD – Design for Disassembly

SRL - Self-Regulated Learning

EBL – Enquiry-based Learned

CPD – Continuous Professional Development

NZEB – Nearly Zero Energy Building

BIMzeED – Education for Near Zero Energy Buildings using BIM (A project funded by Erasmus+)

BIMEET- BIM-based EU-wide Standardized Qualification Framework for achieving Energy Efficiency Training.

NetUBIEP – Network for Using BIM to Increase the Energy Buildings Performance (A project funded by Horizon 2020)

ICT – Information and Communication Technologies

BEM – Building Energy Modelling

1. Introduction

This report explores existing methodologies, materials, and delivery tools. This report aims to provide the initial scoping exercise to establish existing best practices and current resources concerning methodologies, materials, assessment, and delivery tools across current BIM EPA projects and the digital construction, sustainability, and blockchain sectors (Figure 1).

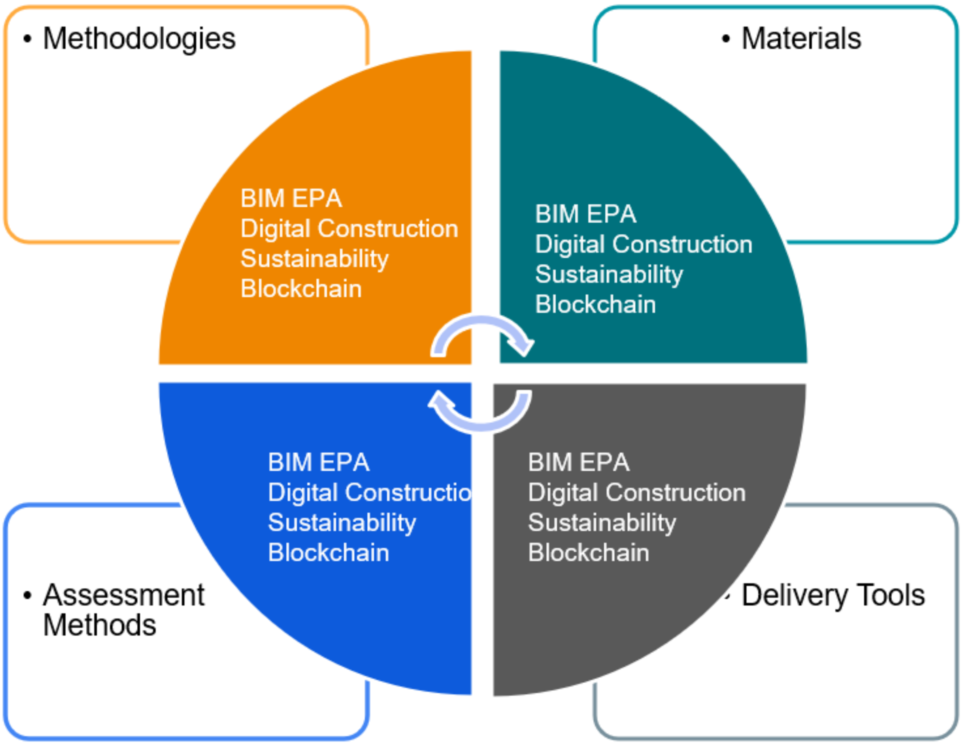

Figure 1 Exploration of existing methodologies, materials, and delivery tools

The report will also build on the work performed in the report titled Desk research on maturity analysis of digitalisation and sustainable energy skills (3.1). The overreaching aim of this process is to establish the Definition of learning methodologies, materials, and delivery tools for ARISE pilot (5.1). However, before this is accomplished, we must establish existing barriers with the aim of developing material that will be cognisant of these training barriers.

1.1. Barriers to Training

Technology is an instrument that helps various companies gain a competitive advantage. Without it, no company will be able to progress fast. However, without the staff capable of operating it, it is of no use (Bajpao & Misra, 2021).

Research to date has highlighted a plethora of reasons explaining hindrances to the construction industry achieving widespread BIM adoption, including resistance to change, initial high cost, as well as a lack of successful real-life examples, awareness of benefits, effective collaboration, and communication, and management support. The authors stress that there must be a clear digital transformation strategy to guide the journey of change. While getting the right technology is important, developing a leadership plan that enables people to fulfil their potential is important.

Apart from the lack of skilled workers, many workers are also highly resistant to change (Bajpao & Misra, 2021). The authors also highlight staff ageing and generation with a paradigm shift among the technology practitioners are still one of the biggest challenges for its adoption. Any proposed change should be managed carefully from a high managerial level, following best practices to ensure effective training for everyone in the team. (Farghaly, et al., 2021). Alemayehu et al. (2021) also highlight resistance to change along with several barriers, including lack of top management support, low awareness of BIM's benefits, staff resistance to change, cultural misfits, and lack of BIM professionals, and lack of access to proper BIM training.

Other barriers included limited in-house expertise in BIM modelling skills which results in additional training costs. This affects the individual practitioners and the organisation, highlighting the need for awareness-raising and up-skilling within the AEC sector. (Georgiadou, 2019). This is coupled with the excessive cost of implementation (software and training), client demand, and resistance to change. Alemayehu et al. (2021), quoting Ku and Taiebat (2011), examined BIM implementation barriers in 31 contracting firms in the United States and identified six major barriers: (1) learning curve and lack of skilled personnel, (2) high implementation cost, (3) stakeholder (e.g., architect, engineer, contractor) reluctance, (4) lack of collaborative processes and modelling standards, (5) interoperability and (6) lack of legal/contractual agreements.

Shojaei et al. (2022) identified key influencing factors to overcome these barriers, which include BIM vision and leadership from management, training on new skills, government support, inter-enterprise structure, corporate culture, corporate strategy, infrastructure, data exchange, construction methods, socioeconomic environment, and technological environment. The authors warn that current information on how construction firms should upskill their workforce is scant. As part of their study, interviewees highlighted that the successful adoption and use of BIM in a company rely on supporting employees to develop the necessary skills and competencies to enable them to engage with BIM technologies.

In adopting industry 4.0 technologies, Demirkesen & Tezel (2021) outlined a series of challenges which include, similar to others outlined above, resistance to change, lack of management support, lack of skilled labour, uncertainties in benefits and gains in terms of labour and workforce, poor knowledge management, cost of training for technology adoption and low technical knowledge of construction professionals. The authors stress that a skilled labour force is necessary for a successful technology transformation.

Meana et al. (2021) summarised the common barriers to BIM implementation under product-related, process-related, and people related. With a focus on people-related, the two areas include new roles and training. The authors add that those who do not use BIM believe that training would be too expensive in terms of time, human resources, and the cost of change. O'Brien et al. (2021) identified the following challenges relating to the uptake of digital training: 1) lack of motivation and time, 2) Stimulate awareness of digital tools, 3) Lack of skills and expertise in SMEs, 4) Fragmented availability of training, 5) New societal and technological career opportunities and 6) Mutual recognition of skills.

The organisations that are most successfully integrating technology are those that are using digital tools to solve specific problems (CITB RESEARCH, 2018). The research paper by the CITB reported that businesses surveyed all felt that they all lack the right data skills or do not have enough people who 'understand' data or know what to do with it. Some common barriers found regarding training and staff included gaps in communication between sites and senior management, which prevent technology from being seen as a tool to solve a problem, and the requirement for a flexible mindset and an understanding of digital tools and data. The report concluded that people need to think creatively about problems and their solutions, understand how to use digital tools, assess which tools to use in which circumstances, and manage the data that flows to and from these tools.

Educators face challenges such as the knowledge base/skills of educators, resources available - both financial and physical - and simple resistance to change by educational institutions and their educators. (Morelli, 2021). Wiit & Kahkonen (2019) highlight several areas which have struggled regarding BIM-enabled education support such as Accreditation, Assessment, Classrooms and technical equipment, example projects, interoperability problems, gap in BIM-related skills between both individual students, teamwork and collaboration, technical support, finding time within educational programmes to include BIM-related education and as no additional time, uncertainty over what to teach and workload. With a focus on education, common barriers included resistance to changing teaching habits established over time, resistance to taking on a new subject in which teachers are not experts, and lack of time and resources (Meana et al., 2021). To attract blue-collar workers and skilled tradespeople to BIMCert, a suggestion was made to reduce the learning scope and content throughout the development and testing of material phase of the project (McAuley, et al., 2021).

On reflection, one can see that the greatest barriers to entry for organisations regarding staff include resistance to change, excessive cost of training staff and software, retention rates, new roles, technical skillsets, motivation access to proper training, and overall demand. The next section will explore existing training mechanisms to overcome these barriers.

2.0 BIM Energy Performance Alliance (BIM-EPA)

To overcome barriers such as lack of knowledge, skills, and competence, depth of understanding of decision-makers, and low ICT literacy, several initiatives focused on BIM were launched in 2018 through the former Horizon 2020 and Erasmus+ projects (McAuley, et al., 2021). Each of the following BIM EPA projects was assessed, focusing on methodologies, materials, delivery tools, assessment methods, and user experience. This section of the report was written with reference to *D.3.1 Report on desk analysis of skills maturity level.* The following table is an introduction to the suite of BIM-EPA projects that were investigated for this report.

Appendix A of this report is the resulting findings of the scoping exercise undertaken to explore each of the BIM-EPA projects. The focus of this scoping exercise was to establish a first-hand user experience of each of the platforms. By signing up for the available modules, we were able to establish what materials, delivery tools, and assessment methods commonly found across each of the platforms. Contact was also made with the point of contact for each of the projects requesting that: the materials currently provided on the platforms are current, and if they can be re-used as part of deliverable 5.2 – Initial production of a selection of learning and assessment materials, and delivery tools.

PROJECT	*DESCRIPTION*
BIMCERT	BIMCert is a project under Horizon 2020, an initiative by the E.U. Research and Innovation programme supporting innovation by demonstrating energy-driven technologies and solutions. The consortium consists of members from Northern Ireland (Belfast Metropolitan Collect and Construction Industry Training Board (CITB NI), Ireland (Technological University Dublin and Future Analytics Consulting), Portugal (CERIS/ Instituto Superior Tecnico), North Macedonia (Institute for Research in Environment, Civil Engineering and Energy (IECE), and Croatia (Energy Institute Hrvoje Pozar (EIHP). The main goal was to develop an efficient training programme to meet real-life industry needs focusing on materials that integrate concepts of sustainability and BIM. The project achieved an e-learning platform consisting of thirty-two “bite-sized” learning modules as a basis for micro-accreditation of knowledge and skills. The accessibility and flexibility of the BIMcert e-learning platform offer the construction industry an opportunity to upskill in their BIM knowledge to collaboratively expertise in support of sustainable energy-efficient construction (McAuley, et al., 2019).
BIMZEED	In response to the current and future needs of the construction industry, the BIMzeED project developed a training program focusing on the area of BIM and nZEB. The project consortium comprised of industry experts and academics from Ireland, Spain, Croatia, and Hungry. BIMzeED’s main goal was to introduce additional learning materials into existing accredited construction programmes or to create new modules/courses focused on BIM & nZEB. To achieve this goal, a framework of twelve multidisciplinary learning modules with learning unit descriptors was developed to increase the understanding and skills of digital tools achieving nearly zero energy buildings. The e-learning platform, with learning plans for specific professional profiles, capitalises on the opportunities environmental protection can offer the construction industry (O'Brien et al., 2021).
BIMEET	BIMEET stands for BIM-based EU-wide Standardized Qualification Framework for achieving Energy Efficiency Training. BIMEET aimed to raise awareness in the construction sector regarding environmental challenges, current and future sustainability scenarios, and energy efficiency targets with a view to delivering informed built environment interventions

	across lifecycle and supply chain underpinned by an effective Europe-wide BIM-based training agenda (Suwal, et al., 2018) The project goals include: 1) to pave the way to a fundamental step-change in delivering systematic, measurable, and effective energy-efficient buildings through BIM training with a view to effectively address European energy and carbon reduction targets; 2) To promote a well-trained world-leading generation of decision-makers, practitioners, and blue collars in BIM for energy efficiency; 3) To establish a world-leading platform for BIM energy efficiency training nurtured by an established community of interest. The project outputs led to the development of a skills matrix related to BIM and energy efficiency, and a training platform contributing to widely disseminating the BIMEET European Qualification Framework to which the skills identified will be recognised in the European market. Both outputs will target blue-collar workers, middle-senior level workers, and governance people (Suwal, et al., 2018).
BIMPLEMENT	The BIMplement project (also financed by the E.U. Horizon 2020 programme) commenced in September 2017. The project consortium comprised of nine partners from five countries: France, the Netherlands, Spain, Lithuania, and Poland. Improving the quality of the construction and renovation process of nearly Zero Energy Building using BIM was the project's main goal in a 36-month programme. To achieve this objective, a methodology for a BIM-enhanced qualification framework was established that described the competencies, skills, and knowledge needed to connect available knowledge to the BIM model, the building process, and the actors involved. A 'BIMplement kit' was developed for companies wishing to up-skill their employees. The proposed principle was to design a 12-one-hour training programme that can be delivered by an employee of a company with expertise in the BIM process and the use of the 'BIMplement kit' pedagogical method (BIMplement, 2017).
BUILDING SMART	BuildingSMART is the worldwide industry body driving digital transformation of the built asset industry (BuildingSMART, 2022). While BuildingSMART does not deliver training directly, a framework and certification of achieved skills are provided. Professional certifications at foundation and practitioner levels can be achieved by taking an online exam based on multiple-choice questions. The framework consists of five learning outcomes for BIM. Recognizing the need for upskilling in BIM and energy performance, BuildingSMART Italy (IBIMI) has developed an additional set of five learning modules focusing on providing knowledge and skills of BIM tools to provide energy performance of buildings in its life cycle. The efficiency of this framework unites two prominent fields (BIM & NZEB) and allows skills to mature progressively, highlighting the impact of the process on the asset and vice versa (BuildingSMART, 2022).

NETUBIEP	NetUBIEP commenced in 2018 following the launch of Horizon 2020. With a project consortium consisting of thirteen partners from Italy, Slovakia, Spain, Lithuania, Croatia, the Netherlands, and Estonia, the main aim was to increase the energy performance of buildings by wide-spreading the use of BIM during the life cycle of the building. To bridge the gap of energy competencies in the construction sector, a BIM Qualification Model was developed comprised of a BIM Training Scheme and BIM Qualification and Certification Scheme focusing on six professional figures: BIM evaluator, BIM facility manager, BIM manager, BIM coordinator, BIM expert, and BIM user. These were identified within four target groups (Public Administrators, Professionals, Technicians, and Owners) to which units of learning outcomes (ULOs) were defined for each group. The BIM training scheme was validated throughout the project through pilot training sessions with more than three thousand people in 7 European countries (netUBIEP, 2018).

Table 1 BIM-EPA Projects (Author,2022)

2.1 BIM-EPA Methodologies

To establish the training methodologies and associate curriculum, the BIMCert consortium undertook a European-wide survey of the industry to ascertain the current level of BIM maturity, knowledge, and understanding within Built Environment practitioners and academia and to establish current standards of sustainable design and construction practice (McAuley, et al., 2019). The results of the survey, combined with results from workshops, were used to establish the training courses that best-matched industry needs. The findings were cross-referenced with a state-of-the-art literature review to produce a rolling Matrix of Concepts and Methodologies aligned to best practice for knowledge transfer. This allowed for a series of Reality Check workshops to take place, which aimed to test the suggested training courses and Matrix of Concepts and Methodologies (McAuley, et al., 2019). BIMCert proposed the following methodologies following the trialling period:

- Problem / Project Based Learning (PBL)
- Guided-Self Learning (GSL)
- Active Learning
- Online Learning / E-Learning
- Multidisciplinary Approach
- Mastery Learning
- Design For Disassembly (DFD)
- Scaffolding Learning
- The Flipped Classroom
- Out-of-classroom education
- Self-regulated learning (SRL)
- Microlearning

A similar approach was adopted by BIMzeED, where extensive research was carried out to identify the knowledge and skills gap for each partner country. In addition to the identified current gaps and future demands of skills the project also recognised the expected benefits of digitalisation skills for the construction sector, the advantages of micro learning units, and the need for internationally recognised micro-credentials (O'Brien, et al., 2021). BIMzeED also utilised Active Learning using the flipped-classroom approach to facilitate a highly engaged collaborative classroom. The terms active learning and experiential learning describe instances in which students actively engage with the information being presented and personalize it by linking it to what they already know (Hammer, 2000). Methodologies such as individual-based, paired, and group activities - in the form of collaborative discussions - were chosen as important features of active learning. Problem Project-Based Learning (PBL), case studies, and enquiry-based learning were also included. PBL is recognized as a capable student-centered pedagogical approach focusing on real-world issues, allowing students to build knowledge and develop critical thinking, creativity, leadership, and communication (Badrinath, et al., 2016). Like BIMCert, the training methodology was categorized into specific micro-learning units presented in several short training modules with a combination of contact and self-study. The flexibility of learning is a key aspect of the BIMzeeD platform, with each learning unit delivered over four sessions, covering the main topic in each session enabling students to balance their working lives. This flexible standardised delivery makes the combination of in-class, online, and on-site training a suitable option for HEIs, VETs, and SMEs. Training material for the modules is delivered in a blended learning format that is supported by an e-Learning platform (O'Brien, et al., 2021). The BIMzeED methodologies are summarised below:

- PBL
- GSL
- Active Learning
- Online Learning / E-Learning
- Multidisciplinary Approach
- Collaborative / Cooperative Learning

- The Flipped Classroom
- SRL
- Microlearning
- Blended Learning
- EBL

The BIMEET methodology involved a combination of applied qualitative and mixed-method research to define the roles and required skills in BIM & energy efficiency based on use-cases, interviews, scientific publications, and social media analysis and scalable heuristic social media analysis (Suwal, et al., 2018).

Results from the background analysis led to:

1) Development of a skills matrix proposing 6-8 specified groups of learning outcomes, which clarify and supplement the required qualifications for each of the selected main category role
2) A mapping of identified skills, qualifications, and accreditation into BIM for energy efficiency
3) Modified BIM4VET platform to build a robust computer-based online and open-access environment
4) Set a Framework and business model to ensure the sustainability of the BIMEET training agenda
5) Development of S-K-C (skills – knowledge – competence) and learning outcomes

Blended Learning is also known as a hybrid method of teaching that integrates online educational materials with traditional instructor-led activities (Panopto, 2022). This has been used in BIMeet, focusing on a multidisciplinary approach by providing training for the following roles: Clients & Clients Advisors, Architectural Designers, Structural Designers, Building Services Designers, Construction Workers, and Maintenance Roles. Blended learning was also found to be a method used by netUBIEP, along with guided self-study. Through BuildingSmart, students can also partake in the learning outcomes and course content by employing guided self-study via e-learning. Where guided self-learning is a common methodology for the BIM-EPA projects, BIMplement offers a different approach to providing instructor-led training. By creating a pedagogical kit named the ‘BIMplement Kit,’ companies can now partake in an upskilling BIM and NZEB training programme delivered by individuals trained in the BIMplement process. The BIMplement training toolkit consisting of twelve one-hour training modules can be used to provide blended learning focusing on blue-collar workers and small enterprises. The training tools were developed to improve the quality of the construction and renovation process of NZEB using BIM.

For the delivery of WP 5.1, we have engaged with the BIM-EPA partners to explore where we can use existing materials, delivery tools, and methodologies. We currently have engagement from three of the seven partners with permission to use content from BIMCert, BIMzeED, and BIMplement. We have contacted the remaining partners for their input on the existing materials, delivery tools, and assessment methods. The methodologies for each of the BIM-EPA projects are listed in the following table:

Methodologies	**BIMCert**	**BIMzeED**	**BIMplement**	**BIMEET**	**BuildingSmart**	**netUBIEP**
Project / Problem-Based Learning	✓	✓				
Guided Self Learning	✓	✓			✓	✓
Active Learning / Experiential Learning	✓	✓				
Distance Learning / Online Learning / E-Learning	✓	✓		✓	✓	✓
Collaborative / Cooperative Learning		✓				
Multidisciplinary	✓	✓	✓	✓		
Mastery Learning	✓					
Design for Disassembly	✓					

Scaffolding Learning	✓					
Flipped Classroom	✓	✓				
BIM-Integrated Learning Environment			✓			
Out-of-classroom education	✓				✓	
Self-regulated learning	✓	✓				
Enquiry-based learning		✓				
Blended Learning (In-class / on site / online)		✓	✓	✓		✓
Micro-learning	✓	✓				

Table 2 - BIM EPA Methodologies

Upon reviewing the current suite of BIM-EPA platforms, it is evident the most common methodologies found were: PBL, GSL, Active Learning, Online Learning, Blending Learning, and a multidisciplinary approach. Other methodologies such as 'the flipped classroom' and 'scaffolding learning' were both found to be successful in BIMCert and BIMzeED. Both projects have analyzed and selected delivery methodologies in accordance with target groups and designed learning content to be delivered. These are two key areas where ARISE could benefit if adopted. In the next section, the materials and delivery tools are assessed through a review of available academic papers and by signing up to the platforms to harness what is currently in use.

2.2 BIM-EPA Materials & Delivery Tools

To support the developed qualifications and training schemes, the projects prepared training materials that were used in trials. The test involved an analysis of the efficiency of learning and assessment materials as well as the delivery tools. The materials and delivery tools for the BIM-EPA projects were collated via desk research and input from the partners of the projects. Their input can be found in the following tables:

Materials	BIMCert	BIMzeED	BIMplement	BIMEET	BuildingSmart	netUBIEP
Case Studies	✓	✓	✓	✓	✓	✓
Existing Literature	✓	✓	✓	✓	✓	✓
Learning Outcomes	✓	✓	✓	✓	✓	✓
Management / Standards	✓		✓		✓	
Information Flow / Communication		✓				
Technical / Software Skills	✓		✓		✓	✓
Interdisciplinary Knowledge / Teamwork / BIM Related Roles	✓		✓			
Documentation Methods		✓	✓		✓	✓
Research Papers		✓				

Table 3- BIM- EPA Project Materials

Integration of sustainable energy and BIM skills course content can be found throughout several BIM-EPA projects. Each of the BIM-EPA projects prepared training materials that were reviewed in the trialling phase to test the efficiency of the delivery tools and assessment methods. The ARISE project will follow the same process. Firstly, by creating a selection of materials for use in testing and then a finalised catalogue of materials for the final stage of the project. To gain a deeper understanding of how these platforms work, we signed up for each platform and evaluated the user experience while gathering useful information on the materials, delivery tools, and assessment methods. Considering that most of the BIM-EPA projects are completed, materials from active projects were available for a more detailed assessment.

Materials found on BIMzeED and BIMCert follow a similar process of using embedded videos, links to external resources, and presentations prepared that can be downloaded for the course participants. An observation of this delivery is that the use of embedded videos & hyperlinks to external resources may cause issues at a later stage should the links break or the original source has been deleted. To minimize this risk, we propose that all materials be built into the ARISE platform to avoid overusing hyperlinks and embedded videos from other sources. The following table summarises the delivery tools found for the BIM-EPA platforms:

Delivery Tools	**BIMCert**	**BIMzeED**	**BIMplement**	**BIMEET**	**BuildingSmart**	**netUBIEP**
Web-Based Tutorials	✓	✓		✓		
Instructor-Led Tutoring	✓		✓	✓		
Online	✓	✓		✓	✓	✓
Narrative Videos	✓	✓	✓	✓	✓	✓
Review of Existing Literature		✓	✓			
Informal Learning	✓	✓				
Modules	✓	✓	✓	✓	✓	✓
Workshops	✓	✓	✓	✓		✓
Individual Activities	✓	✓				
Group Activities		✓				
Paired Activities		✓				
Digital Library	✓			✓		
BIM Curriculum / Modules	✓	✓				
Case Studies	✓	✓	✓	✓	✓	✓
Segregated-Integrated Approach					✓	

PowerPoint Presentations	✓	✓	✓			✓
Tools			✓			
Flexible Standardised Delivery		✓				
Pre / Post Module Survey		✓				✓
Discussion Forums		✓				✓
Glossaries	✓	✓				
Live Demonstrations of Software and Plugins	✓					✓
Handbook	✓		✓			
Dictionaries						✓
Database of Test Questions						✓
Games						✓

Table 4- BIM-EPA Delivery Tools

As the BIM-EPA platforms are predominately delivered online. It is no surprise to find that the use of narrative videos was one of the most common delivery tools found. All platforms have modularised the learning content specific to what the topic is. Workshops were found to be popular amongst the platforms. While most of the content is delivered online, there is still an opportunity for instructors to provide tutorials. Downloadable exercise files through PowerPoint presentations were found on four of the six platforms. Downloadable content such as exercise files should be made easily accessible if required. In line with Goal 4 of the Sustainable Development Goals, to ensure ARISE produces inclusive and equitable quality education and promotes lifelong learning opportunities for all, the content on the platform should be easily accessible and free to use. The integration of a free model viewer is to be explored to allow users the opportunity to apply the theory of BIM and sustainability in a practical scenario.

The application of Live Demonstration of Software and Plugins were also found across BIMcert and netUBIEP. This is an important addition that could prove beneficial to the ARISE platform. The software applications and tools used for BIM and sustainability/energy efficiency can be complex for novice learners. By signing up for modules provided by the BIM-EPA platform, we could experience how users interacted with the courses, what materials were available, and how they were delivered. In the next section, the use of assessment methods was reviewed for each of the BIM-EPA projects.

2.3 BIM-EPA Assessment Methods

The assessment methods for each of the BIM-EPA projects are listed in the following table:

Assessment Methods	BIMCert	BIMzeED	BIMplement	BIMEET	BuildingSmart	netUBIEP
Quizzes	✓	✓		✓		✓
Exam				✓	✓	✓
Learning Outcome Based Assessment	✓		✓			
Status Reporting						
Group Work		✓				
Problem Solving						
Questionnaire	✓					
Practical				✓		
Crossword		✓				
Karot		✓				
Reflective Study		✓				
Tasks		✓				
Toolkit			✓			

Kahoot	✓					
Pre-Engagement Self-Assessment	✓			✓		✓

Table 5- BIM-EPA Project Assessment Methods

Upon reviewing the assessment methods of the BIM-EPA projects, it is evident that the use of quizzes was the most popular method. Exams were also common across three of the platforms. Users on NetUBIEP were assessed using a hybrid system of both quizzes and exams. To gauge an understanding of the current skill level of students, a pre-engagement self-assessment tool was offered by BIMCert, BIMeet, and netUBIEP. This tool could prove extremely useful if adopted on the ARISE platform to allow users to fast-track the fundamental modules if they are already qualified in that area. It is important to note that not all assessment methodologies were tested during the BIM-EPA projects' duration due to time constraints. Some of the promising methodologies may be subject of testing during the ARISE project.

2.0.4 Summary

The similarities among the BIM-EPA projects indicated that each framework applied the principle of forming matrices of competencies, applicable for professional profiles for specific phases of a project life cycle. Learning Outcomes mapped to specific roles were found to be common in the BIM-EPA projects, which were delivered via micro-modules on an e-Learning platform. It is recommended that a similar approach is adopted for the ARISE platform.

Introducing the concept of micro-learning modules was recognized as a benefit throughout the BIM-EPA projects. Adopting this approach based on learning outcomes catered for specific competencies is recommended for ARISE. Furthermore, the benefits and perspectives of e-learning and GSL encourages learners to progress at their own pace. This, coupled with a micro-accreditation process and a reward system such as certCOIN, is an exciting incentive for professionals to participate in progressing their knowledge and skills of BIM and sustainability. To follow the proposal for materials hosted on the ARISE platform, one area where the content could be improved is by having the course content narrated by a dedicated trainer. Using introductory videos offer an opportunity for an experienced expert in the topic to welcome participants to the course and discuss the learning outcomes & course content. The interactive, social, and learner-centered approach offered by LinkedIn Learning teachers provides a bridge between the content and the end-user.

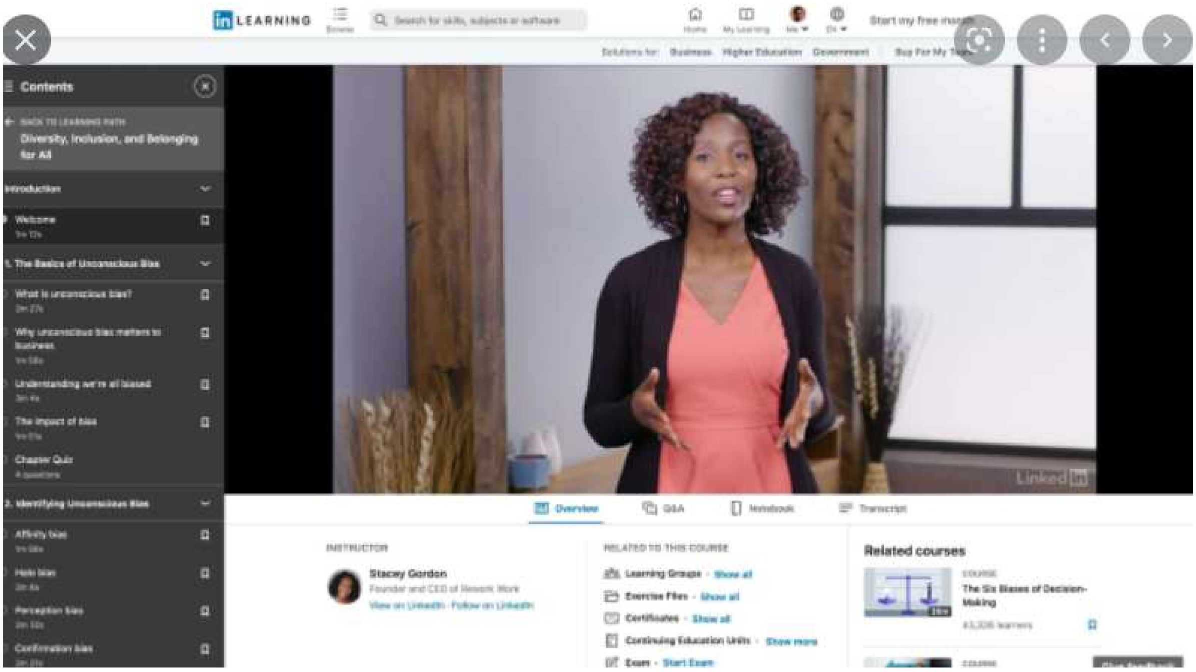

Figure 2 Example of LinkedIn Learning Interface

Like the BIM-EPA projects, LinkedIn Learning modules are completed via a quiz. The final certification is issued once all micro-modules and quizzes are completed. This is where ARISE can introduce monetary rewards in the form of cryptocurrency. BIMzeED presented a learning method assessment divided into two parts – theoretical and practical – in accordance with the nature of competencies. From the investigation of BIM-EPA projects, the assessment methods varied from multiple-choice questions to online exams and voluntary quizzes. The knowledge and skills evaluated through task-based learning via quizzes after each module is an area where ARISE could benefit from.

Below is a summarised table of the findings for the BIM-EPA projects with regards to methodologies, materials, delivery tools, and assessment methods.

METHODOLOGIES	MATERIALS	DELIVERY TOOLS	ASSESSMENT METHODS
Problem / Project-Based Learning	Case Studies	Web-Based Tutorials	Quiz
Guided-Self-Study	Existing Literature	Instructor-led tutoring	Exam
Active Learning	Learning Outcomes	Online	Learning Outcome-Based Assessments
E-Learning / Online Learning	Management / Standards	Narrative Videos	Group Work
Multidisciplinary	Technical / Software Skills	Review of Existing Literature	Questionnaire
Mastery Learning	Interdisciplinary Knowledge	Informal Learning	Crossword
Design For Disassembly	Teamwork / BIM-Related Roles	Modules	Karot
Scaffolding Learning	Documentation Methods	Workshops	Reflective Study
The Flipped Classroom		Individual Activities	Tasks
Out-Of-Classroom Education		PowerPoint Presentations	Toolkit
Self-Regulated Learning		Discussion Forums	Kahoot
Enquiry-Based Learning		Glossaries	
Blended Learning		Live Demonstration of software	
Micro-Learning		Case Studies	
		Digital library	

Table 6 - Summary of BIM-EPA (Author,2022)

This report has reviewed the current landscape of the BIM-EPA projects regarding methodologies, materials, delivery tools, and assessment methods. The user experience of each platform was also reviewed to gauge a better understanding of what is currently on offer for students who are partaking in upskilling their digital and energy skillset. The next section will explore the current pedagogical practices currently in place in the area of digital construction.

2.2 Digital Construction

2.2.2 Digital Construction Methodologies

The BIM process, shaped by a range of technologies and tools, presents a longstanding pedagogical concern for students to not only learn to use software but also evaluate and select the most appropriate use and resource management strategies (Nikolic, et al., 2021). There has been widespread adoption of BIM in the construction industry, but this adoption has been constrained by a lack of adequately educated and trained construction professionals, and their education has tended to lag industry BIM developments (Olowa, et al., 2019).

Adam et al. (2021), quoting Davies et al. (2015), put BIM skills into three categories

- Technical skills: This is the ability to use BIM tool, i.e., the ability to generate three-dimensional (3D) models/animation using specialised computer software; management and maintenance of BIM models, etc
- Soft skills: This refers to an individual's personal quality to have effective interactions and good relationships with other people, i.e., leadership, communication, time management, negotiation, etc
- Discipline-specific skills: This is essential background knowledge of the construction industry before involving BIM

Underwoood et al. (2013) conceptualise the development of BIM education in three progressive stages:

(1) BIM-aware – ensuring that graduates are aware of BIM and the changes it is bringing about.

(2) BIM-focused – students are instructed how to use BIM in the performance of specific tasks; and
(3) BIM-enabled – where learning is embedded in the virtual BIM environment, and BIM acts as a "vehicle" for learning.

The expanding BIM market growth has resulted in the development of new work practices, with roles and responsibilities related to BIM gradually becoming established as professional positions within the construction industry. This development presents multiple challenges. One of the most important is to make sure that construction companies are sufficiently staffed with capable BIM employees who can manage the growing number of BIM-enabled projects (Shuchi, et al., 2020)

Wiit & Kahkonen (2019), through their systematic literature review, reviewed ninety-two papers on BIM education and note that the change brought about by BIM entails moving away from dividing projects between specialist areas and toward integrating work and information flows for whole projects. Advantages of this new, BIM-enabled educational methodology include:

- The BIM environment enables students to apply the abstract concepts they have learned, which has been shown to improve their understanding of engineering concepts.
- BIM provides opportunities for 3D visualisations and interactive, non-verbal simulations enable the communication of complex ideas across different disciplines and cultural-linguistic groups.
- BIM provides an excellent tool for data management and a framework for data-rich information models, which enhance learning experiences.
- BIM enables the simulation of more realistic (and real) project conditions for education.

BIM technology is dynamic, so teaching BIM effectively requires a radical alteration in teaching formats (Shuchi, et al., 2020). To achieve this, digital construction has engaged in several training methodologies, including Problem Project-Based Learning (PBL). The PBL approach is fully supported by the software elements of BIM and is widely used in engineering and construction management education to build the ideal scaffold for student learning for sustainable living (Wu & Luo, 2016). Problem-solving skills through structured training and problem-solving processes are identified as the most powerful principles of learning for classroom instructors. This approach can enable interdisciplinary education, which can motivate motivating students from different AEC subjects (jin, et al., 2019). Nikolic et al. (2021). also advocates this methodology and adds that problem-based and experiential learning has been recognized as valuable approaches to immersing students in realistic scenarios for teaching the complexity and ill-structured nature of BIM-enabled collaboration. The authors add that the problem-based approach carries broader implications for similar initiatives around teaching collaborative BIM, which is an intensive field that should allow students to apply and evaluate BIM strategies that resonate with their experience (Nikolic, et al., 2021).

Other training methodologies examined include Web-based tutorials, which can is a combination of media that allows the user to control, combine, and manipulate different types of mediums of communication such as text, graphics, still images, and interactive features (Guy & Lownes - Jackson, 2013). Web-based tutorials work in tandem with Instructor-led tutoring, which can involve giving step-by-step instructions to students in a virtual or physical class. Instructor-led tutoring has been the most common BIM tutoring approach in AEC degree programs ((Abdirad, & Dossick, 2016)). Design for Disassembly (DFD) could be applied to any of the discussed methodologies as it involves the process of designing products so that they can be easily, cost-effectively, and rapidly taken apart at the end of the product's life so that components can be reused and recycled (Badrinath, et al., 2016).

Clear, understandable, high quality, and up to date resources and software tutorials are invaluable supplements to in-class learning and represent complementary components of BIM-related classes. Apart from using external resources such as global websites and links to certified institutes, companies, organizations related to BIM research and application, it is also necessary to produce in-house resources, such as special-purpose video tutorials. (Isanović & Çolakoğlu, 2020).

Mastery Learning and scaffolding Learning approaches were explored as other possible learning methodologies. Mastery learning requires the students to master a more straightforward subject before moving on to the next, more complex one (Shelbourne, et al., 2017). Guided Self-Study (GSL) is also seen as one of the best ways to facilitate professional development concerning BIM through self-training with continuous peer support and ad-hoc internal workshops (Puolitaival & Forsythe, 2016).

There is evidence that dynamic learning experiences can enhance the learning of collaborative BIM concepts (Becker, et al., 2011). The flipped classroom is an instructional strategy and a type of blended learning that reverses the traditional learning environment by introducing the learning material before class, with classroom time then being used to deepen understanding through discussion with peers and problem-solving activities facilitated by teachers. The application of role-play can also enable the potential user to understand other professionals' roles and therefore provide a greater understanding of the importance of data.

Olatunji (2019), in their paper, discuss Action Research as a philosophy that aid an understanding of how students make meaning of learning in BIM. This approach motivates learners through establishing creative solutions because real-life situations are replicated in learning activities. Olatunji (2019) discuss Constructivist learning as a pedagogy for BIM, which includes learners' active participation in learning by building their perceptions of the real world against personal interpretations of content received. The author also puts forward reflective learning as a BIM teaching tool, as it enables a creative and artistic phenomenon that holds theory and practice together. Other BIM-focused teaching philosophies are authentic learning activities, with the learner generating knowledge cooperatively and collaboratively.

Jin et al. (2018), quoting Zhao et al. (2015), expand on the use of an Integrated Construction Studio as a BIM teaching methodology as it can promote collaborative construction skills through BIM-integrated learning environments by simulating real-world working conditions of the preconstruction phase of a project. The authors developed a multidisciplinary BIM pedagogical approach that focused on software skill training and applying teamwork within a real-world scenario in a BIM interdisciplinary project work. Nikolic et al. (2021) add to this by suggesting that under the BIM paradigm of collaborative working, traditionally taught discipline-specific skills are insufficient, and the emphasis should instead shift to a more complex and flexible set of skills, such as thinking independently, managing ambiguity, solving complex problems, and adapting to changing practices. Wiit & Kahkonen (2019) add to the argument of collaborative BIM-based projects as they share a common trait in that communication and collaboration are enabled by BIM-based communication environments. The authors add that BIM as a learning environment represents a new educational paradigm in which integration, multidisciplinary collaboration, simulation, real-life scenarios, and application of learning concepts are at the heart of the learning process. Shuchi et al. (2020), in their review of BIM education at Australian universities, found that most universities used on-campus teaching mode, followed by group activities, practicals, and workshops. Table 6 provides an overview of some key teaching models applied to the Australian Educational sector.

Teaching mode	Explanation
On-campus	Face-to-face lectures, classes, class discussions
Online	Online learning, webinars, online learning activities
Workshops	Intensive workshops (2-3 days duration), practice-based workshops, group workshops, intensives
Group activities	Team-based learning, tutorials, seminars, presentations
Practical	Computer laboratory, practical learning, problem-based learning, work-based learning, problem-based exercises, problem-based collaborative learning
Private study	Individual study
Studio	Desk critiques, studio work

Table 7- Teaching modes Shuchi et al. (2020)

With an investigation of existing digital construction teaching methodologies, the next section will explore the materials used to deliver them.

2.2.3 Materials

Abdirad & Dossick (2016) endorse the use of Case Studies as tools to enable students to learn and think about real-world challenges and solutions as well as standards and conventions in BIM implementation. Jin et al. (2019) also recommended the development of prototypes with more case studies addressing the role of BIM in enhancing lean construction and sustainable practice. The authors add that with the division of BIM content into learner-defined modules, smaller chunks, and more focused topics, a student, can grasp a more effective way of learning than having all students learn everything together. The use of real projects makes educational exercises much more meaningful. Students understand and adopt new BIM concepts more easily when their meaning and application in real-life examples are demonstrated to them. Using real-life examples also allowed exposure to different tasks and roles in a project which helped students reveal their different interests in various BIM areas. (Isanović & Çolakoğlu, 2020).

Materials in the form of BIM Execution Planning have helped in managing and understanding the lifecycles of projects. This form of documentation provides a platform for all project participants to communicate smoothly and collaboratively, which greatly contributed to avoiding mistakes (Zhang, et al., 2019)

Jin et al. (2019) recommend several future directions through their scientometric analysis, which include investigating differences in the benefits and barriers of applying BIM between fast-track projects and traditional Design and build projects and how best to integrate the information workflow and interoperability in construction waste reduction. Other areas suggested include linking BIM to other digital technologies, interoperability between different BIM tools, and how best to showcase or demonstrate the impacts of BIM on off-site construction projects and lean construction. Nikolic et al. (2021) suggest prioritizing the quality of an information delivery process rather than a final product, which can help students learn collaboration techniques and strategies informed by BIM standards. Shuchi et al. (2020) also highlight the importance of having construction practitioners with interdisciplinary knowledge and software skills in multiple domains and fields to handle various categories of BIM use on BIM-enabled projects.

Shuchi et al. (2020), quoting a study by Wu et al., suggested thirty-four industry job requirements that material should be developed to meet, such as problem-solving, teamwork, communication, and management, ranked in the top five – all BIM related. Content analysis of all BIM related subjects revealed that some focus predominantly on the skills to identify, apply and describe the basic knowledge of BIM principles, maturity levels and drivers, while others prioritise improving technical skills, documentation methods, and BIM execution plans etc. (Shuchi, et al., 2020) The challenge in many countries appears to be in taking this further, to fully prepare students for the digital world in which they will operate and to provide them with the BIM skills that their industry will demand in the future (Morelli, 2021). The authors also stress that it is important for BIM-ready graduates to understand the nature of BIM-related roles performed by professionals in other fields and disciplines – and the impact that their decisions have on projects overall.

BIM education requires training on developing content and interacting in a modelling environment. BIM education in construction management is highest when they can develop their software skills in addition to their social skill, as both are not mutually exclusive (Olatunji, 2019). Below is a summary of materials and delivery tools found in delivering digital construction through learning. The next section will focus on which assessment methods are used in practice for digital construction.

2.2.4 Assessment Methods

Assessment design is the key to how the system triggers incredible insights in both the learner and the educator. Students are motivated if their assessment tasks relate to real-life problems, and they can use the skill during their study at work and vice versa (Olatunji, 2019). A growing body of research suggests that teaching students in experiential learning environments supported by continuous assessment and improvement methods can advance problem-solving and decision-making skills. (Nikolic, et al., 2021). Informal group work can also enhance student collaborative work as learning should be collaboration-based. Zhang et al. (2019) emphasizes four evaluation methods: a questionnaire survey of self-reported student problem-solving skills; problem-solving in Technology-Rich Environments; peer evaluation; and manual grading of student submissions and presentations. Shuchi et al. (2020), in Table 7, details the preferred assessment methods for the utilisation of BIM tools for modelling and documentation, ranging from presentations to model-based project assessments.

The development of various skills usually means a higher rate of assessment types, which, in turn, may influence the motivation to finish the course (Puust, et al., 2019)

Assessment type	Content analysis
Presentation	Oral presentations, class presentations, portfolio showcases, oral pitches, group presentations
Quiz	Class quizzes, individual quizzes, tests
Exam assignments	Examinations, theory examinations Continuous assessments, learning outcome-based assessments, case-studies, problem-solving reports, self-reflection reports, personal reviews, Microsoft Excel assignments, SPACE GASS assignments, peer review assignments, written assignments, tender assignments, concept designs, energy analysis reports
BIM report	Reports (application of software tools), group BIM reports, 1000-word reports (BIM role and opportunities), BIM technical reports, BIM implementation plans, BIM business cases
Group assessments	Individual team contributions, group-based case studies, virtual construction and collaboration, workshop exercises
Professional activities	Workplace projects, practical projects, industry field studies, month-long onsite activities, facilities management handovers
Practical/model-based/project assessment	Laboratory activities, design projects, capstone projects, model development, use of BIM applications, extraction of technical documentation from BIM models, practical applications, CAD Revit tests, Revit detail studies, nD BIM modelling, clash detection, construction simulations, quantity extractions, 2D+ 3D graphical representations, 3D BIM model analysis, group projects, model-based construction detailing and documentation, digital models

Table 8- Assessment Types

They conclude that learners are keen to use BIM tools if there are opportunities for them to achieve satisfactory learning outcomes as they navigate the value that BIM adds to their learning processes. Such values include timesaving, collaboration, visualization, tool integration and the capacity of BIM to help them achieve target assessment objectives – for example, accuracy and process simulation (Olatunji, 2019).

2.2.5 Summary

In this section, digital construction pedagogical methods were investigated to understand what methodologies, materials, delivery tools, and assessment methods are currently used in industry and academia. Like, the BIM-EPA platforms, there has been a strong uptake of adopting PBL, GSL, Active Learning, Online / E-Learning, and the 'the flipped classroom' in digital construction. Both areas also endorse the use of case studies to enable students to think about real-world challenges. (Abdirad & Dossick, 2016). Implementing case studies using the latest environmental data, the ARISE platform can prosper from this choice of material, allowing users to adopt problem-solving skills while enhancing their skills in the digital construction field. Unsurprisingly, the use of online learning tools through narrative videos and modules was common in the digital construction sector. Creating an e-learning platform that may be delivered by an instructor or self-taught should be both considered for ARISE. Pre-recorded lecturers or even live software demonstrations could prove to be beneficial in allowing a student-lecturer connection. One of the key assessment methods found in the digital construction field was using model-based assessments. Strong consideration will need to be taken to discuss this validity for the ARISE platform. Accessibility to specific BIM tools can be difficult for companies and students who do not currently have the opportunity to use them. If model-based content and/or assessment is to be utilised on ARISE, a solution will need to be implemented to allow all users can undertake the training with access to the tools and materials that the partners put forward. Commonalities between the BIM-EPA platforms and digital construction are quizzes, exams, and learning outcome-based assessments. These assessment methods should be put forward for inclusion on the ARISE platform.

This report up until this point has reviewed the current landscape of the BIM-EPA projects and Digital Construction concerning methodologies, materials, delivery tools, and assessment methods. In the table below, a summary has been presented of the findings throughout the digital construction sector. The next section will explore the current pedagogical practices in BIM & Sustainability.

METHODOLOGIES	MATERIALS	DELIVERY TOOLS	ASSESSMENT METHODS
Problem / Project Based Learning	Case Studies	Web-based tutorials	Continuous Assessment
Mastery Learning	Information Flow / Communication	Workshops	Questionnaire
Guided Self-Study	Problem Solving	Group Activities	Peer Evaluation
Action Research	Technical / Software Skills	Integrated Construction Studio	Quizzes
Multidisciplinary Bim	BIM Execution Plan	HyFLEX	Professional Activities
Design For Disassembly	Interoperability	Instructor-led tutoring	Status Reporting (Energy Reporting)
Scaffolding Learning	Management / Standards	Online	Learning Outcome-Based Assessments
Flipped Classroom	Documentation Methods	Narrative Videos	Model-Based Assessments
Constructivist Learning	Interdisciplinary Knowledge / Teamwork / BIM Related Roles		Group Work
			Presentations
			Exams
			Practical

Table 9- Summary of Digital Construction (Author, 2022)

2.3 BIM & Sustainability

Sustainability is defined as the 'use of natural products and energy in a way that does not harm the environment and 'the ability to continue or be continued for a long time (Oxford, 2020). The foundations of sustainability comprise three core dimensions: economic, environmental, and social. Human sustainability is also the fundamental principle that groups these together (Goodland, 2002).

BIM offers the AEC industry many benefits, including cost and resource savings, greater efficiency, improved communications and coordination, more opportunities for prefabrication, and higher quality results (Zutec, 2021).

The Climate Crisis is a huge concern for humanity and, without action, will result in mass droughts, flooding, and extreme heatwaves across the globe. Currently, buildings are the largest energy consumer in Europe with a frightful energy consumption of 40%. To achieve the targets set in the EU Directive on Energy Performance of Buildings, sustainability must become a core focus to educators and firms in the construction industry. Investments in energy efficiency from governments are a necessity to meet the 2050 targets (EU, 2020).

BIM is an approach that can be used to achieve sustainability in construction. BIM can rapidly produce energy outputs that enable design teams to analyse and compare the most cost-effective, energy-efficient options. BIM software now includes lifecycle cost and lifecycle assessment technology, allowing project teams to be better informed during the decision-making process (Vasquez and Shealy, 2014). BIM can accurately demonstrate the airflow, sunlight, and surrounding environment to ensure the quality of the atmosphere inside; application in water systems and materials can be modelled and analysed with the precise quantification to reduce material wastage (Hosein et a., 2017). Kim (2014) expects the growing need for professionals with specific training in sustainable building practices to increase significantly over the next decade as the importance of accelerating sustainability in a built environment has been well recognized worldwide. However, if BIM and sustainability are to be fully adopted, we must develop a skilled and equipped workforce. The green economy must now deliver a better-skilled workforce and reduce labour market shortages by increasing participation in training.

2.3.3 Sustainability Methodologies

Kim (2014) proposes a teaching model, with the sequence of the approach, the tool needed to implement each step, and the deliverable produced because of each one illustrated in figure 3.

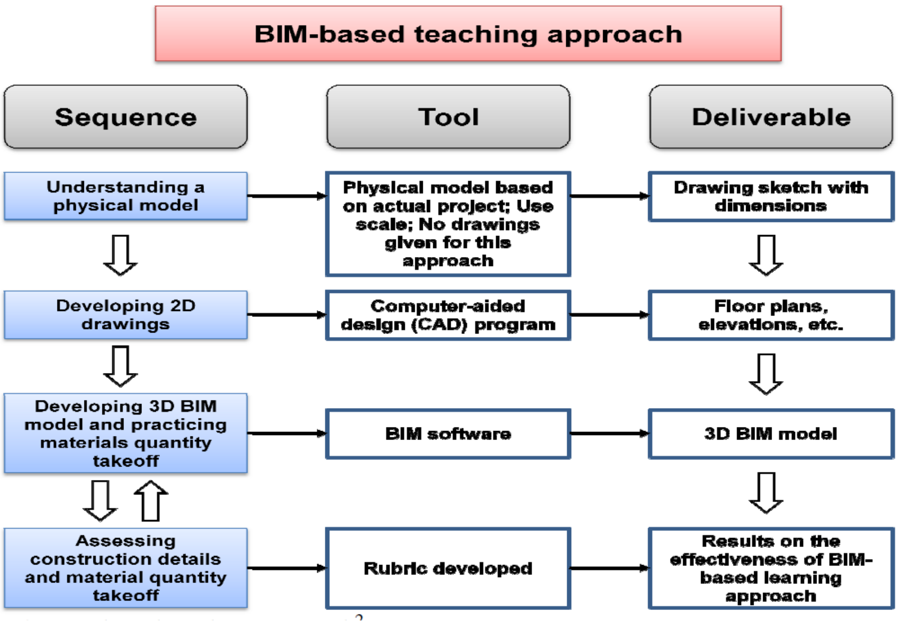

Figure 3: BIM-Based Teaching approach

The authors have expanded this model into a teaching framework for sustainability and project-based course, with the first 5 weeks devoted to the foundations and effects of green resources such as building materials, building forms, and building systems, on the green buildings. The next six weeks (18 hours) are hands-on laboratory-based work. In the second six weeks, the applications and techniques of BIM technology are studied through experiments that create the BIM model and closely simulate the effects of green resources on the building projects. The last five weeks (15 hours) are hands-on project-based work to understand the relationships between BIM technology and the sustainability environment. While the course length is impractical for the ARISE project, there are possible modules that may be of interest to assist with creating the proposed curriculum. The course layout can is illustrated in figure 4.

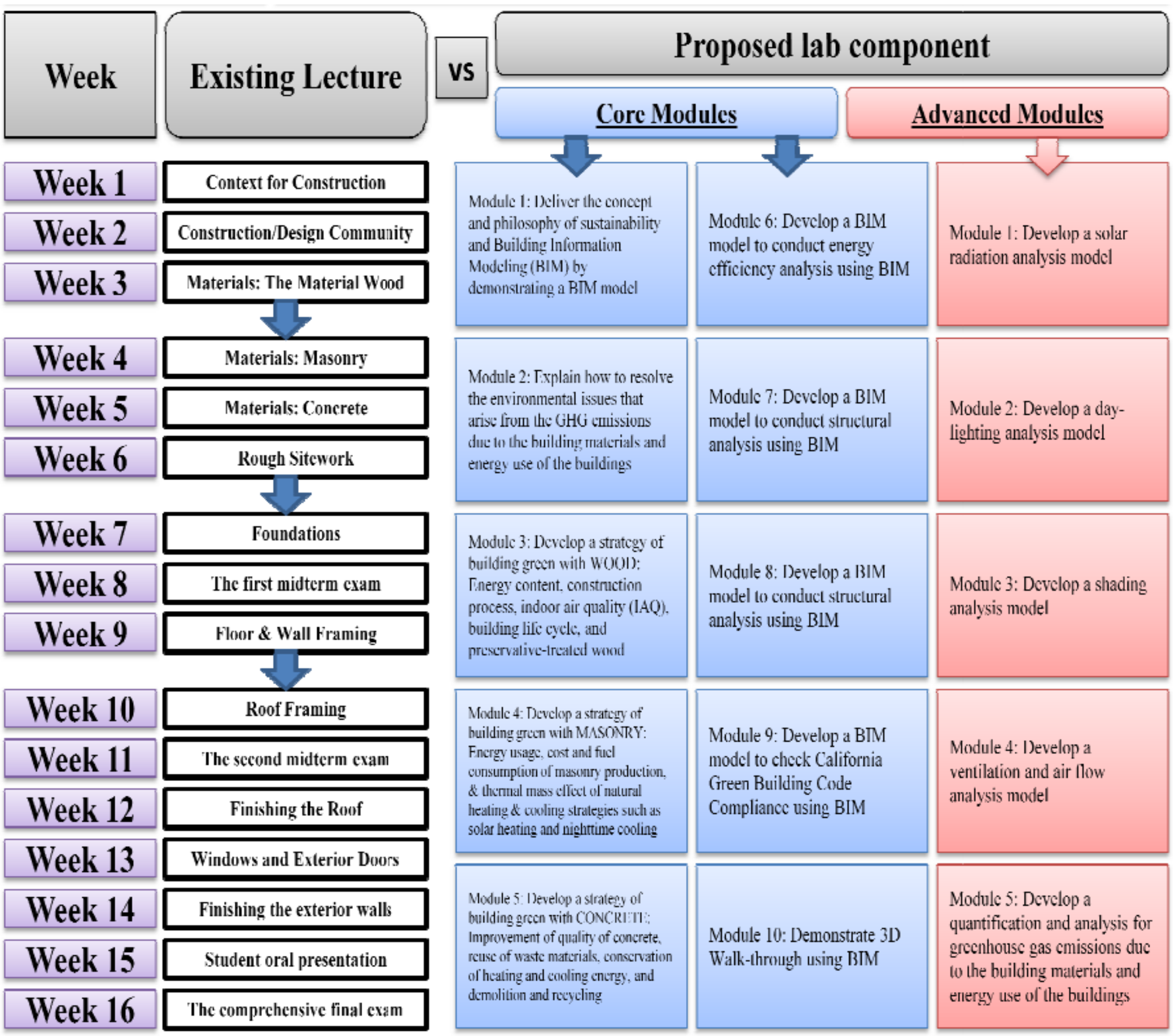

Figure 4: Expanded BIM-based teaching approach

In previous work, the BIM-EPA partners had confirmed, with measurable results, the advantages of BIM as an improved enabler for higher levels of sustainable energy in buildings compared to traditional methods (McAuley, et al., 2021)By incorporating PBL as the central teaching and learning technique, the students who partook in the trials could better understand building energy consumption. Shen, Jensen, Wentz, and Fischer (2012) also explored teaching sustainable Design using BIM and project-based simulation. The project was divided into four modules where students learned how to use BIM modelling tools (Autodesk Revit) and analyse the energy consumption of the case study building (Autodesk Ecotect). The final module introduced a real-world scenario allowing the students to take the skills and knowledge acquired at the earlier stages of the programme to conduct various what-if design analyses. The course content on how to use the software was taught using in-class tutorials, exercises, assignments, and short tutorials on YouTube. Video tutorials proved to be a valuable resource enabling students to learn at their own pace (Shen, et al., 2012). The assessment methods of this programme included quizzes, assignments, graded homework, and presentations to provide students with frequent assessments of student learning. Shen et al. (2012) conclude that the results of their survey of students that BIM integrated with building energy software using project-based learning provided a good pedagogical and suitable technical platform for teaching sustainability in a building design and construction class.

PBL was also adopted by Sanchez, Gonzalez, Paz, and Flores (2020) in using BIM for sustainable development education. Students were introduced to green BIM topics, the building industry's status, and sustainable development via existing literature and workshops. The deliverable of most importance was the creation and assessment of a BIM model demonstrating sustainable developments. To measure the evaluation of the education for sustainable development (ESD), an exit survey was conducted online to assess students' knowledge of BIM and sustainable development. One of the findings from the survey indicated that BIM integrated with PBL was beneficial in understanding sustainability and green building concepts (Sanchez, et al., 2020). This is supported by Wu and Luo (2016), who state that project-based learning allows students to build knowledge and develop critical thinking and creativity. Combining education and industry needs, they stress that traditional lecture-based pedagogical models are no longer efficient in meeting the skills demand in communication, teamwork, collaboration, and the ability to solve solutions in real-world scenarios. The role of the instructor is also transformed through PBL, becoming a mentor or an expert consultant rather than the point of authority (Wu & Luo, 2016). Leite (2016) suggests that PBL can be coupled with corporative learning to deliver BIM Modules, given that students typically work on course projects collaboratively in small groups.

LEED (Leadership in Energy and Environmental Design) is a voluntary rating system certifying sustainable construction. The efforts of LEED are concentrated on improving five key areas: energy efficiency, indoor environmental quality, materials selection, sustainable site development, and water savings (Contributor, 2010). Regarding LEED, Luoa and Wub (2015) report that integrating BIM and LEED can demonstrate the possibilities of using BIM as a sustainable design decision-making tool and performing certain LEED calculations with BIM-based information. In their paper, Alwan et al (2015) detailed how, through BIM-generated data, such software can be used to inform a number, although not all, of the credit items involved in the LEED assessment. They noted that this was encouraging for a rapid assessment approach compared to the conventional approach, as the constraints involved a 48-hour international BIM design competition. Figure 6 illustrates in bold the key LEED criteria achieved through BIM in the design competition.

LEED topic	LEED prerequisites (R) and credit items
Sustainable sites	Construction activity pollution prevention (R)
	Site selection
	Development density and community connectivity
	Brownfield redevelopment
	Public transportation access
	Bicycle storage and changing rooms
	Low-emitting/fuel-efficient vehicles
	Alternative parking capacity
	Protect or restore habitat
	Maximise open space
	Stormwater (quantity control)
	Stormwater (quality control)
	Heat island effect (non-roof; roof)
	Light pollution reduction
Water efficiency	Water use reduction (R)
	Water-efficient landscaping
	Innovative wastewater technologies
	Water use reduction
Energy and atmosphere	Fundamental commissioning of building energy systems (R)
	Minimum energy performance (R)
	Fundamental refrigerant management (R)
	Optimise energy performance
	On-site renewable energy
	Enhanced commissioning
	Enhanced refrigerant management
	Measurement and verification
	Green power
Materials and resources	**Storage and collection of recyclables (R)**
	Maintain existing walls, floors and roof
	Maintain existing interior non-structural
	Construction waste management
	Materials reuse
	Recycled content
Indoor environmental quality	Minimum indoor air quality performance (R)
	Environmental tobacco smoke control (R)
	Increased ventilation
	Outdoor air delivery monitoring
	Construction indoor air quality management plan (during construction, before occupancy)
	Low-emitting materials (adhesives and sealants, paints and coatings, flooring systems, composite wood and agrifibre
	Indoor chemical and pollutant source control
	Controllability of systems (lighting, thermal comfort)
	Thermal comfort (design, verification)
	Daylight and views
Innovation in design	Innovation in design
	LEED-accredited professional
Regional priority	Regional priority

Figure 6 LEED Prerequisites and Credit Items (Alwan et al, 2015)

The definition of Knowledge Management is 'process of organizing, creating, using, and sharing collective knowledge' (Guru, 2022). In the U.K, a combination of Project-Based Learning and Knowledge Transfer Partnership (KTP) is an advantageous method of creating a bridge between the education system and industry (Rathnayake & Coates, 2016). Through KTP high quality, and up to date materials allow universities and industry to collaborate in developing the future of the industry by sharing knowledge. Similarly, Kivits and Furneaux (2013) discuss how BIM enables sustainability and asset management through collaboration of sharing information.

Several MSc courses in the UK and Ireland offer modules in BIM. The University of the West of England has a module titled Low/Zero-Impact Buildings which assesses the role of BIM in designing and operating comfortable buildings that significantly reduce or eliminate energy use. The University of Liverpool's MSc in BIM has a BIM-Enabled Sustainable Design module. The University of Salford also offers a Sustainable Design Theory and Practice module, which aims to provide critical awareness and appreciation of sustainable urban and building Design to develop sustainable communities. The TU Dublin MSc in Applied BIM and Management can also offer BIM modules for sustainability with Revit and IES capabilities. This is only a quick snapshot of the industry.

As established, BIM can rapidly produce energy outputs that are now being used to meet international energy standards such as LEED. A few teaching models and curriculum criteria have been discussed in this section which has enabled, primarily through PBL, the opportunity for students to analyse models and alter design criteria to target future life cycle costing implications. Several universities are now offering standalone modules in this area, with Autodesk also capitalising on this skills gap by providing online accreditation courses. The following tables summarise the methodologies, materials, delivery tools, and assessment methods found in the literature review of BIM and Sustainability.

METHODOLOGIES	MATERIALS	DELIVERY TOOLS	ASSESSMENT METHODS
Problem / project based learning	Case Studies	Web-based tutorials	Quizzes
Guided self study	Existing Literature	Instructor-led tutoring	Exams
Active learning	Learning Outcomes	Online	Continuous Assessment
Distance learning / online learning / e-learning	Management / Standards	Narrative Videos	Status Reporting
Collaborative / cooperative learning	Problem Solving	Review of Existing Literature	Group Work
Multi-disciplinary bim	Technical / Software Skills	Informal Learning	Problem Solving
Bim-integrated learning environment	Interdisciplinary Knowledge / Teamwork / BIM Related Roles	Modules	Model-Based Assessment
Experiential learning	Interoperability	Workshops	Presentations
	Knowledge Transfer Partnership (KTP)	Group Activities	Homework / Assignments
		Integrated Construction Studio	Graded Assessment
		BIM and Sustainability Module	Exit Surveys
		BIM Curriculum / Modules	
		Personal Learning Environments (PLEs)	
		Segregated-Integrative Approach	

Table 10- Summary of Sustainability (Author, 2022)

2.3.4 Summary

This section reviewed the methodologies, materials, delivery tools and assessment methods of BIM & Sustainability. By examining the three fields of BIM-EPA, Digital Construction, and BIM & Sustainability, we can see a picture developing of the commonalities in each area. Like the aforementioned sectors, the most common methodologies include PBL, GSL, Active Learning, and E-Learning. Collaboration and Multidisciplinary BIM were found to be also common across Digital Construction and Sustainability. While this methodology is the closest one would get to work in the construction sector, careful consideration should be taken if the ARISE platform can offer learning material to suit this methodology. Case studies, learning outcomes, standards, problem-solving, and teamwork were again found to be popular learning materials amongst the BIM & Sustainability academics and industry experts. Like the concern mentioned in the summary of the previous chapter, the issues of access to software for enhancing technical skills in sustainability and energy efficiency using BIM tools.

Interoperability of tools will need to be also considered as this is a major talking point in the use of BIM & Sustainability tools and collaboration with other software vendors. BIM & Sustainability tools from a novice user's perspective are difficult to comprehend, particularly for students and industry users who aren't specialised in this field. A recommendation for this is to have an industry expert(s) in both fields of BIM & Sustainability provide training for the selection of modules related to this area. This is where instructor-led learning, web-based tutorials, live software demonstrations, and narrative videos could prove beneficial. Both BIMCert and BIM & Sustainability have examples of providing modules specific to BIM and Sustainability. This is recommended to bring forward into the ARISE project to discuss the integration of both key areas, as well as foundation level modules to discuss the topics separately. Assessment methods such as quizzes, exams, learning-based assessments and group work are commonalities across this report.

Two assessment methods not discussed to this point found in sustainability are Energy Reporting and Energy Model-Based Assessments. If the learning content goes to the extent of providing narrative videos, instructor-led tutoring, case studies, or software demonstrations of specific BIM and/or Building Energy Modelling (BEM) tools. If students are to be assessed using these, consideration should be taken for the following: Will the students have access to relevant tools? How much content will be provided to give students a strong understanding of the tools? How will the assessments be graded? If feedback is provided, who is providing the feedback, and how detailed will the feedback be? Who is responsible for keeping the materials updated? While these questions might be heavily focused on the materials and delivery tools, the answers will provide our work package to progress into subsequent work packages of providing a selection of materials. In the next section, the scope of the research will venture slightly outside of the built environment to discuss the pedagogical methods being utilised by the blockchain sector. This diversion is to set the basis for the correlation of methodological methods and tools with the blockchain platform within *WP4 - Development of the ARISE platform autonomy – e-ngine.*

2.4 Blockchain

As described by IBM, Blockchain is *"a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network. An asset can be tangible (a house, car, cash, land) or intangible (intellectual property, patents, copyrights, branding). Virtually anything of value can be tracked and traded on a blockchain network, reducing risk and cutting costs for all involved."* (IBM, 2022). At its core, Blockchain is cryptographically secured using crypto algorithms serving as a distributed ledger that is shared rather than owned by a single party (EuroMoney, 2022).

As an emerging technology that is quickly spreading, the ability to understand blockchain technologies is difficult (Çulha, 2021). In response to this challenge, efficient learning mechanisms were adopted to tackle complex topics. These were project-based learning, team-based learning, active learning, and competition-based learning. The use of competition and project-based learning incentivised students to take an active role in comprehending blockchain concepts to win competitions. By adopting an active learning approach, the students also benefited from collaboration with classmates, teachers, and available materials found online and in books. An observation of the methodology from Çulha (2021) is that project-based learning is best suited for teams of three people with three competitions, each making up the overall semester grade.

Project-based learning was also integrated into courses dedicated to teaching Blockchain at two different universities: Bryant University and Bentley University, by Mentzer et al. (2020). As well as project-based learning, the courses were designed to include self-regulated learning and peer feedback to enhance the students' understanding of Blockchain. At the beginning of the projects, students were offered a choice of writing a research paper or a group-based activity on a programming project.

Several courses in Ireland offer modules in Blockchain and/or Emerging Technologies. The National College of Ireland and Atlantic Technological University both provide part-time online courses for a Level 7 NFQ Certification in Emerging Technologies. Dundalk Institute of Technology also offers a Level 8 NFQ Certificate in Blockchain and Distributed Ledger Technology and a Level 6 NFQ Certificate in Fundamentals of Blockchain. Dublin Business School holds a Diploma in Blockchain, which is delivered online. Assessment methods are broken down through a mixture of formative, summative assessments, scenario-based group work, and a final exam. City Colleges, in their diploma in Blockchain, Bitcoin, and NFTs, assess students through project-based assignments. In 2019, the first MSc in Blockchain (Distributed Ledger Technology) in Ireland was launched. The course is part-time and can be completed online over two years.

Online courses in Blockchain can also be found on EDx, Linkedin Learning, and Udemy. The courses range from foundational, introductory courses to more advanced topics beyond the basics and how blockchains will change business. All three platforms follow a similar structure of providing learning outcomes, modularized narrative videos, supplementary reading material, and downloadable content. Users are assessed via uploaded homework assignments and quizzes.

METHODOLOGIES	MATERIALS	DELIVERY TOOLS	ASSESSMENT METHODS
Problem / Project Based Learning	Case Studies	Web-based tutorials	Quizzes
Guided Self Study	Existing Literature	Instructor-led tutoring	Exams
Active Learning	Learning Outcomes	Online	Questionnaire
Distance Learning / Online Learning / E-Learning	Management / Standards	Narrative Videos	Peer Evaluation
Action Research	Problem Solving	Review of Existing Literature	Group Work
Competition-Based Learning	Technical / Software Skills	Informal Learning	Problem Solving
Out-Of-Classroom Education	Information Flow / Communication	Modules	Homework / Assignments
Self-Regulated Learning	Internet Searcher	Workshops	Graded Assessment
	Research Papers	Individual Activities	
		Research Papers	
		Tournaments	
		Pre / Post Module Survey	
		Live Demonstrations of Software and Plugins	

Table 11- Summary of Blockchain (Author, 2022)

3.0 Summary / Conclusion

This report explored existing methodologies, materials, and delivery tools across current BIM EPA projects and the digital construction, sustainability, and blockchain sectors. Most found across the four sectors where the adoption of project / problem-based learning, guided self-learning, active learning, and distance / online / e-learning. PBL was recognised as an effective student-centered pedagogical approach concerning the four sectors. By all accounts, this seems like a key methodology used throughout the literature and is a strong enabler in a student's learning outcomes, as it encourages them to interact with the material. For experienced pratctitioners, relating and comparing to traditional method of work (based on CAD or 2D drawings and calculations) was proven as a successful teaching approach for BIM tools delivery. PBL both lends to mastery and scaffolding levels, as it encourages the student to interact with the curriculum and, based on the platform, interact with the lecturer to discuss their findings. Delivery tools such as narrative videos / interactive videos can incorporate elements of PBL and ask the user to solve a PBL equation before access to the next part, or case studies can ask questions based on the read content for the user to answer. A possibility of incorporating this into the ARISE platform could include a section after each webinar / interactive video where the student is asked to solve a problem before advancing in the course.

Guided self-study is an important aspect of any learning experience and encourages students to explore and learn for themselves. This is an important element of mastery learning, especially if digital badging is used, as the students will need to master different levels before moving to the next. Active Learning may be viable if a live lecture is incorporated into the ARISE platform. This will create an environment for an active learning space between the lecturer and student. The following tables summarise the findings from the literature review of existing methodologies, materials, delivery tools, and assessment methods of the four sectors.

Methodologies	BIM-EPA	Digital Cons	Sustainability	Blockchain
Project / Problem-Based Learning	✓	✓	✓	✓
Guided Self Learning	✓	✓	✓	✓
Active Learning	✓	✓	✓	✓
Distance Learning / Online Learning / E-Learning	✓	✓	✓	✓
Collaborative / Cooperative Learning		✓	✓	
Multidisciplinary		✓	✓	
Action Research		✓		✓
Mastery Learning	✓	✓		
Design for Disassembly	✓	✓		
Scaffolding Learning	✓	✓		
Flipped Classroom	✓	✓		
Constructivist Learning		✓		
BIM-Integrated Learning Environment		✓	✓	
Competition-based Learning				✓
Out-of-classroom education	✓			✓
Self-regulated learning	✓			✓
Enquiry-based learning	✓			

Blended Learning (In-class / on site / online)	✓			
Micro-learning	✓	✓		
Role Play		✓		

Table 12 – Summary of Methodologies

Materials	BIM-EPA	Digital Const	Sustainability	Blockchain
Case Studies	✓	✓	✓	✓
Existing Literature	✓	✓	✓	✓
Learning Outcomes	✓	✓	✓	✓
Management / Standards	✓	✓	✓	✓
Problem Solving		✓	✓	✓
Information Flow / Communication	✓	✓		✓
Technical / Software Skills		✓	✓	✓
Interdisciplinary Knowledge / Teamwork / BIM Related Roles		✓	✓	
Interoperability		✓	✓	
BIM Execution Plan	✓	✓		
Documentation Methods		✓		

Knowledge Transfer Partnerships (KTP)			✓	
Internet Searches				✓
Research Papers		✓		✓

Table 13- Summary of Materials

Delivery Tools	BIM-EPA	Digital Const	Sustainability	Blockchain
Web-Based Tutorials	✓	✓	✓	✓
Instructor-Led Tutoring	✓	✓	✓	✓
Online	✓	✓	✓	✓
Narrative Videos	✓	✓	✓	✓
Review of Existing Literature	✓	✓	✓	✓
Informal Learning	✓	✓	✓	✓
Modules	✓	✓	✓	✓
Workshops	✓	✓	✓	✓
Individual Activities	✓	✓	✓	✓
Group Activities		✓	✓	✓
Paired Activities	✓			
Integrated Construction Studio		✓	✓	
Research Papers	✓			✓
HyFlex		✓		
BIM and Sustainability /	✓		✓	

Energy Efficiency Module				
BIM Curriculum / Modules	✓	✓	✓	
Personal Learning Environments (PLE's)			✓	
Segregated-Integrated Approach			✓	
PowerPoint Presentations	✓			
Tools	✓			
Tournaments				✓
Flexible Standardised Delivery	✓	✓		
Pre / Post Module Survey	✓	✓	✓	✓
Discussion Forums	✓	✓		
Glossaries	✓	✓		
Live Demonstrations of Software and Plugins	✓	✓	✓	✓

Table 14- Summary of Delivery Tools

Assessment Methods	**BIM-EPA**	**Digital Const**	**Sustainability**	**Blockchain**
Quizzes	✓	✓	✓	✓
Exam	✓	✓	✓	✓

Learning Outcome Based Assessment	✓	✓	✓	
Status Reporting		✓	✓	
Group Work	✓	✓	✓	✓
Problem Solving		✓	✓	✓
Questionnaire	✓	✓	✓	✓
Practical		✓		
Crossword	✓			
Karot	✓			
Reflective Study	✓			
Tasks	✓			
Toolkit	✓			
Kahoot	✓			
Pre-Engagement Self-Assessment	✓			
Peer Evaluation		✓		✓
Model-Based Assessments		✓	✓	
Presentations		✓	✓	
Homework / Assignments			✓	✓
Graded Assessment			✓	✓
Exit Surveys	✓		✓	
Professional Activities		✓		

Table 15- Summary of Assessment Methods

The report has provided an understanding of the most popular methodologies, materials, delivery tools, and assessment methods across four sectors. As the platform will be online, the primary methodology would involve a scaffolded learning environment guided by a series of instructor-led live lectures. This could be complemented through PBL, DFD, and self-guided learning, which would create the active learning environment suggested in the results. However, as explained earlier, this may prove difficult due to the nature of the project, and a more blended approach could be adopted. This could include a combination of narrative videos and live lectures, which would assist in reducing the requirement of a lecturer and put more focus on the student doing self-guided learning through PBL and DFD before they advance to the next digital badge. Despite not being voiced, other options include delivering the module through interactive videos that require elements of PBL before the student has deemed a pass. This could be complemented through self-guided learning suggestions at the end of each digital badge.

In tables 11-14, the methodologies, materials, delivery tools, and assessment methods were mapped against the four key areas we explored in this report. The lists are quite extensive, as displayed in the previous sections. To clarify our key findings, we have adopted a filtering process for any of the methodologies, materials, delivery tools, and assessment methods found across two or more sectors. Below, as presented in Figure 7, we have reduced our key findings to a more concise list. This may be further reduced in subsequent revisions of this report based on feedback from the partners. Future work for this work package will be cross-referenced with Work Packages 3 deliverable recognition framework for sustainable energy skills leveraged by BIM (3.2) and Work Package 4 Initial materials, requirements, and features (4.1) report. A final gap analysis will also be presented with the findings of this report to put forward the recommendation for the methodologies, materials, delivery tools, and assessment methods for the ARISE agility e-tools. The following findings of the gap analysis report will inform discussions with the partners. Feedback and comments from the session at the Skopje partner meeting will inform our work package of our next steps and will allow conclusions and recommendations to be put forward based on the outcome of the proceedings.

Existing Methodologies, Materials, Delivery Tools and Assessment Methods in BIM-EPA, Digital Construction, Sustainability & Blockchain

Methodologies	Materials	Delivery Tools	Assessment Methods
- Problem / Project-Based Learning	- Case Studies	- Web-based tutorials	- Quizzes
-Guided-Self Study	- Videos	-Instructor-led tutoring	-Exam
-Active Learning	-Existing Literature	-Online	-Learning Outcome Based Assessments
-Distance Learning / Online Learning / E-Learning	-Learning Outcomes	-Narrative Videos	- Continuous Assessment
-Collaborative / Cooperative Learning	-Management / Standards	-Review of Existing Literature	-Status Reporting
- Multidisciplinary Learning	-Problem Solving	- Informal Learning	-Group Work
-Action Research	- Information / Flow Communication	-Modules	-Problem Solving
-Mastery Learning	-Technical / Software Skills	-Workshops	-Questionaires
-Design for Disassembly	-interdisciplinary Knowledge / Teamwork / BIM Related Roles	-Group Activites	-Peer Evaluation
-Scaffolding Learning	-Scaffolding Learning	-Integrated Construction Studio	-Model Based Assessments
- The Flipped Classroom	- Interoperability	- BIM & Sustainability Modules	-Presentations
			- Homework / Assignments

Figure 7 -Gap Analysis of Summary (Author,2022)

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awakening | relevant | innovative | scalable | equitable

Appendix A: Scoping Exercise of BIM-EPA Platforms

BIM EPA Project	Methodologies	Materials & Delivery Tools	Assessement Methods	Are these materials current? (Y/N)	Can we have permission to use materials? (Y/N)	Who is the point of contact for this project?
BIMCert	1) Development of "bite sized" training packages (modules) in the follow a digital mirco-accreditation process 2) Testing of micro modules concept in trials for the following units: BIM Fundamentals, BIM Principles, Digital Skills, Intro to Low Energy Building Construction.	*Case studies* *Web-based tutorials* *Narrative Videos*	*Quiz* *Learning Outcome Based Assesments* *Exam*	Yes	YES	erebelo@belfastmet.ac.uk
BIMzeED	1) Background analysis on BIM and nZEB through literature review, implementation of BIM and NZEB in partner countries, BIM training courses, current status of training skills and report on gap analysis and roadmap plan 2) Design of an integrated BIM and NZEB skills framework 3) Development of a framework consisting of 12 multidisciplinary learning uints	*The material emcopasse powerpoint presentations on BIM and nZEB and some videos.*	*Quiz* *Crossword* *Karot* *reflective study* *Tasks*	Y	Y	larissa.derosso@ace-cae.eu
BIMEET	1) Delivery of module for 'BIM for energy efficiency,training, education, expertise and best practice 2)Methodology to identify roles, skills and training needs in the field of BIM of energy efficiency 3) Application of qualitative and mixed-method research to define the roles and required skills in the area of BIM & energy efficiency 4) Creation of a BIMEET Learning Outcomes framework based on: 1) identification of roles and responsibilites in the construction process and 2) the formulation of learning outcomes (LOs) 5) Result of 6-8 specified groups of learning outcomes for the 6 main categories: client & client advisors, architectural design roles, structural design roles, building services design roles, construction work roles, and maintenance work roles.	*Case studies* *Web-based tutorials* *Narrative Videos*	*Quiz* *Learning Outcome Based Assesments* *Exam*			sylvain.kubicki@list.lu
BIMplement	1) BIMplement developed a BIM-enhanced Qualification Framework that described the competences, skills and knowledge needed in order to connect available knowledge to: the BIM-model, the building process and the actors involved. The results were applied in 49 experimental sites in which training interventions were tested in practice leading to upskilling 710 white collars and 752 blue collars	*Tools* *A set of Learning Outcomes*	*A toolkit of short training modules on BIM implementation*	Yes	Yes, downloadable from BIMplement website Several competences are already replicated in WP3 of ARISE. Including elements of the work on maturity modelling	Narjisse Ben Moussa (nbenmoussa@ville-emploi.asso.fr)
Building Smart	1) BuildingSmart does not deliver training but provides a global learning framework and certification of achieved skills, by taking an online exam, based on a multiple chuce selection. BuildingSmart provides two levels of Professional Certification in BIM - Foundation and Practioner	*Case studies* *Web-based tutorials* *Narrative Videos*	*Quiz* *Learning Outcome Based Assesments* *Exam*			Anna Moreno Presidenza IBIMI <presidenza@ibimi.it>
netUBIEP	specfic BIM related competences 2) Creation of a three-dimensional matrix considering the three variables: target group, construction phases and competences was then developed 3) Development of a BIM Qualification Model composed by a BIM Training Scheme and a BIM Qualification and Certification Scheme, which was adapted to the buildingSMART qualification	*Unit of Learning Outcomes*	*Learning Outcome Based Assesments* *Exam* *Training materials*			Anna Moreno Presidenza IBIMI <presidenza@ibimi.it>
NEWCOM	1) Development of new training schemes with clear competence descriptions on the base of units of learning outcomes (ULOs) 2) Developmnet of the NEWCOM competence database for the Europe-wide comparability of aquired skills.	*Tools for recognition and storing of Unit of Learning Outcomes*	*N/A*	N/A	Yes for using the functionality in WP3 a	Jan Cromwijk

Figure 8 Scoping Exercise of BIM-EPA Projects (Author,2022)