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Integrating BIM Concepts in Academic Education: The Design of Rural Buildings and Landscapes

Antonio Ledda, Andrea De Montis *, Vittorio Serra, Ernesto Usai and Giovanna Calia

Department of Agricultural Sciences, University of Sassari, 07100 Sassari, Italy; antonioledda@uniss.it (A.L.); vserra@uniss.it (V.S.); eusai1@uniss.it (E.U.); giovannacalia@live.it (G.C.)
* Correspondence: andreadm@uniss.it; Tel.: +39-079-229242

Abstract

Building Information Modeling (BIM) concepts are permeating the approach to the design of buildings and landscapes for the architectural, engineering, and construction sectors. Recent regulations require that even medium–small-size public works are managed through BIM-driven design. These circumstances have led to an increase in research on the topic. The expansion of the demand of BIM-skilled professionals urges higher education institutions to re-engineer their design programs. The aim of this paper is to evaluate this academic education transition in the Department of Agricultural Sciences at the University of Sassari, Italy. The method consists of a BIM academic education assessment framework based on ten criteria clustered into three macro-issues. The application of this framework to the assessment of three diploma final theses signals that some actions have been undertaken (i.e., introducing BIM basic concepts in rural building and landscape design, stimulating interest in students, clarifying the dimensions of BIM, and promoting the concept of 3D object design and management), but still, much work must be carried out. The work confirms typical barriers to the implementation of BIM concepts in the core curriculum and the need to mobilize the whole educational ecosystem to achieve satisfactory progress toward effective innovation in contemporary BIM-led design teaching. This work represents the first attempt to evaluate the progress of the Department of Agricultural Sciences, University of Sassari, toward the integration of BIM concepts in its courses and to position this transition in an international panorama.

Keywords: BIM; buildings and landscape design; academic education; maturity level; level of development; student–teacher interaction; transition; innovation

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Received: 2 May 2025
Revised: 20 June 2025
Accepted: 26 June 2025
Published: 28 June 2025

Citation: Ledda, A.; De Montis, A.; Serra, V.; Usai, E.; Calia, G. Integrating BIM Concepts in Academic Education: The Design of Rural Buildings and Landscapes. *Buildings* **2025**, *15*, 2276. https://doi.org/10.3390/buildings15132276

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1. Introduction

The scientific interest for Building Information Modeling (much better known with the acronym BIM) has been expanding in the last decades. According to a query launched on 16 April 2025, over the Scopus database, out of nearly 41,000 documents dealing with Building Information Modeling, almost 16,000 have been published in the last five years. This increasing and urgent focus can be explained, in short, by considering the impacts of BIM on the ways buildings and landscapes are conceived, designed, used, and dismantled/restored. A prominent definition describes BIM as a "a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle" [1–3]. However, BIM has been defined in many ways depending on the context, time, technology, and professional or theorical declination [4]. The emphasis for digitalization has been stressed

in the general context of the Industry 4.0 transition, as well as the need to integrate BIM concepts into the architecture, engineering, and construction (AEC) sectors [5]. Similar general attitudes for digitalization issues have usefully percolated into international and national regulations on the management of public works [6–8]. The evolution of BIM theory and applications unfolds in discourses on methodologies, personnel and organizations, institutions, funding, processes and products, and informatics (hardware and software) as leading enabling technology [9]. The pervasiveness of BIM applications is often described by invoking a dimensional framework where BIM use is implied: early, 2D and 3D modeling, and, subsequently, 4D (construction scheduling), 5D (cost management), 6D (sustainability and energy), and 7D (entire life cycle) variations [10–13]. Other expansions (8D for security, 9D for lean construction, and 10D for industrialization) are under debate [14].

As BIM expanded the range of its implementations, informatic industries provided professionals with a wider spectrum of more powerful hardware solutions empowering the use of a variety of software programs and integrated platforms. In operational terms, BIM software can be defined as a computer program empowering the users with all the functionalities and concepts of BIM. It supports analysts, specialists, and managers in designing an object—single component, entire building, or landscape—through teamwork [15]. The sharing of information is key to BIM software and is enabled through the design of specific data management frameworks, such as the Industry Foundation Classes (IFC) model. Recalling from [16], IFC is an object-oriented data model that is standardized according to the prescriptions of ISO 16739 [17]. The IFC model "allows for a vendor-neutral exchange of BIM data" [16].

Very often quoted applications include Autodesk Revit™ [18–24], Graphisoft ArchiCAD™ [10,18,25,26], Trimble SketchUp™ [24], and ACCA Edificius™ [27]. The selection and orchestration of applications usually correspond to the need to perform multiple analyses and process a variety of datasets in the various sectors of practice. Major software houses design and release flexible programs supporting the analyses and functionalities implied in the n dimensions of BIM. Further specializations are possible through standard integration and communication with existing sectoral software.

BIM is applied mostly to the design and management of buildings [19,28], but it is also increasingly implemented for landscape analysis, planning, and management, through a typical integration with GIS [20,29,30]. Implementations mainly regard urban landscapes and, in expanding ways, rural houses and domains [12,13,31–36]. The applications of BIM to rural domains are multifold: typical variations comprehend Architectural Heritage Building Information Modeling (AHBIM) [31] and Historical Building Information Modeling (HBIM) [25,37]. A domain relatively less practiced is agro-industrial building design, planning, and management. Agro-industrial buildings present complex characteristics, as they are designed to host activities that are conducted by humans and animals at the same time (livestock buildings) and imply the integration into the housing fabric of machinery and systems (food transformation plants). The design, construction, and management of these buildings pose many critical issues, including the elements modulation and coordination, structure, costs and finance, energy, and time sequence.

The integration of BIM into the AEC industry and professional practice shows a pattern of situations worldwide, with leading (such as the USA, the UK, and Sweden) and latecomer (including France and Italy) countries [38,39]. The intensity of the coupling of BIM into practice is often measured by means of two frameworks. The first one, introduced by [40], is the maturity model, unfolding in levels ranging from 0 for CAD applications through 1 for stand-alone 2D and 3D modeling, 2 for collaborative BIM, and finally to level 3 for the so-called iBIM with integrated and interoperable data. The maturity model is key to understanding the transition from CAD to BIM models and corresponding software

applications [15]. The second gauging system consists of the level of development (LOD), which describes the intensity of implementation, or the model itself, with respect to the information conveyed [41]. LOD's figures are as follows: 100 for the basic form (standing for shape, size, and location), 200 for the generic form, 300 for specific form, 350 for actual model of the product including its form, and 400 meant as 350 but including fixing, assembly details, and information.

Despite the positive effects expected and promised on the efficiency of the variety of processes characterizing the AEC sectors, the actual integration and daily use of BIM at a reasonable maturity intensity and level of development is hindered by skepticism on the profitability of BIM for specific construction sub-sectors [42] and recurring bottlenecks. The major barriers reported include scarce attitude to change in professional routines, a lack of standardization and institutionalization of BIM, and the high cost of technological innovation and education/training of staff [10].

As for overcoming the poor institutionalization, nowadays, the use of BIM for managing the design of public works over certain threshold cost values is mandatory in many countries [8]. As for the cultural transition, the higher demand of BIM-skilled professionals for the AEC sectors has been pushing many universities to re-address their AEC management programs [43]. The transition implies a wide spectrum of actions pertaining to the entire academic ensemble: teachers and staff, students, governance, funding, and infrastructure [44]. The restructuring of the curriculum of higher education institutions is not homogeneous worldwide [45]. Some universities have been introducing BIM concept coverage from the very early stages of undergraduate programs [46–48]. Others have reworked their graduate programs (master's and PhD levels) [49]. And some others have introduced approaches to BIM in the diploma final thesis [50]. The engineering of existing programs is multiform, as it implies initial (i.e., the integration of existing courses), moderate (i.e., the introduction of completely new single modules), and strong shifts (i.e., the launching of an entire new program) [51,52]. Academic courses on BIM capabilities can be introductory (for a BIM modeler), intermediate (for a BIM analyst), and advanced (for a BIM manager) [53]. They can be taught in traditional ways or through online sessions [3,39].

This academic renovation does not proceed by itself and needs to be strongly supported and continuously steered. Major common criticalities and bottlenecks include "lack of skilled teachers, lack of student interest, no room for BIM course in the curriculum, lack of faculty interest or willingness to teach BIM, no requirements of BIM in the accreditation of the professional boards, unclear and inconsistent expectation of BIM skills on [. . .] graduates, lack of textbooks, tutorials, or models" [24]. In broader terms, other reported barriers regard "conceptual issues (lack of understanding of the process), technical issues (difficulties to use the required tools), and environmental issues (circumstances of the learning environment)" [54]. Sometimes, BIM introduction is hindered by typical misconceptions (i.e., BIM is just another drawing tool, or BIM limits creativity) [46]. To overcome these criticalities, universities are engaged in cyclical assessments of course quality, students' learning behaviors, and teachers' satisfaction [44,47,55].

In Italy, BIM adoption is substantially mandatory as planned [56], while BIM concept integration in academic education proceeds between good practice and critical lags [39]. With respect to the design of agro-industrial buildings, the Department of Agricultural Sciences at the University of Sassari, Italy (now on identified as DAS-UniSS) is approaching the preliminary stages of the transition to a BIM issues-informed curriculum. Personnel and staff are willing to investigate the main strategies to master this transition; so, research work is needed to position current experiences in a broader context and plan future courses of action.

With respect to these background issues, the aim of this paper is the critical presentation and discussion of the integration of BIM concepts in the academic curriculum of the Department of Agricultural Sciences of the University of Sassari, Italy. We describe the status of the integration by stressing the main bottlenecks to the transition from CAD-based to BIM-based design academic education and focus on the characterization of three educational experiences developed during the editing of three diploma final theses on the design of agricultural buildings using BIM. To do so, we calibrated a BIM academic education assessment framework able to gauge the educational experiences with respect to ten criteria grouped into three macro-issues (basics, implementation, and learning interaction). The use of this framework allows for the positioning of educational experiences in the panorama of international studies on and practice of the BIM concepts-led renovation of academic education.

We calibrate our work by developing on the following research questions (RQs) corresponding to the three macro-issues. RQ1 focuses on the basics of BIM concept education: sector of application, type of educational program, and software adopted. RQ2 regards the implementation of the quality and intensity of integration of BIM concepts and recalls operative issues such as BIM dimensions, maturity, development, and barriers. RQ3 is pedagogic, refers to the quality of the learning experience, and invokes questions concerning students' and instructors' BIM principles background and type of interaction.

The argument of this paper unfolds as follows: In the next section, we present the methodology, consisting of an assessment framework including criteria broadly accepted in the scientific literature on the transition to the integration of BIM-driven design concepts in academic education. In the third section on the results, we describe three educational experiences and apply the assessment framework to their characterization. In the fourth section, we discuss the results obtained with respect to the research questions and present the conclusions of this work.

2. BIM Academic Education Assessment Framework

The methodology adopted in this paper is inspired by the scientific literature presented in the introduction and consists of a criteria-based assessment framework able to appreciate academic education experiences related to the integration of BIM in the student curriculum. This framework is useful to compare the educational experiences under evaluation to the worldwide panorama of educational transitions to a BIM-based curriculum in AEC academic programs. The criteria included in the assessment framework are reported in Table 1. Criteria are grouped by macro-issue and listed by code; a description explaining the meaning and rationale; the entry consisting in an operational codified expression of evaluation attribute, qualitative intensity level, or quantitative score; and reference to papers citing the specific criterion. We selected the criteria from the scientific literature on BIM concepts and definitions and the assessment frameworks concerning the transition of academic education to BIM issues-driven design, construction, and management. We have developed inductively our assessment framework; we proceeded bottom–up by first considering the criteria and secondly grouping them into macro-issues.

The first macro-issue consists of basic characteristics and includes three criteria: CR1 describes the focus of the case study, CR2 illustrates the level of academic education, and CR3 reports on the software program used. The second one regards implementation and comprehends four criteria: CR4 pertains to the dimension(s) of the application developed, CR5 the maturity, CR6 the LOD, and CR7 the barriers to BIM concept understanding. The third macro-issue is about learning interaction and groups three criteria: CR8 is about students' background on BIM concepts and the practice of design or BIM software, CR9 on teacher training on BIM issues and software, and CR10 on student–teacher interaction.

Table 1. BIM academic education assessment framework structure with macro-issues and criteria by code, description, score, and scientific references.

Macro-Issues	Code	Criteria	Description	Entry	References
Basics	CR1	Focus	Sector of application	Rural building, rural landscape, or rural building and landscape	[19,20,28–30]
	CR2	Level	Educational level	Undergraduate final thesis or graduate final thesis	[46–50]
	CR3	Software	BIM software used	Autodesk Revit, Graphisoft ArchiCAD, etc.	[10,18–26]
Implementation	CR4	Dimension	Dimension of the BIM application	2D, 3D, . . ., nD BIM	[10–13]
	CR5	Maturity	Level of maturity of BIM adoption	0, 1, 2, 3	[40]
	CR6	Development	Level of development of BIM adoption	100, 200, 300, 350, 400	[41]
	CR7	Barrier	Educational barriers of BIM integration into academic curriculum	Conceptual, technical, and environmental	[24,54]
Learning interaction	CR8	Student's background	Student background education on BIM concepts	No background, basic, or advanced	[47]
	CR9	Teacher's training	Teacher's training on BIM concepts	No experience, 2 years, 5 years, or more than 5 years	[57]
	CR10	Student–teacher interaction	Type of interaction between teacher and student	Autonomous, semi-autonomous, or teacher dependent	[43,53]

The rationale of the assessment exercise is sketched through the methodological workflow presented in Figure 1.

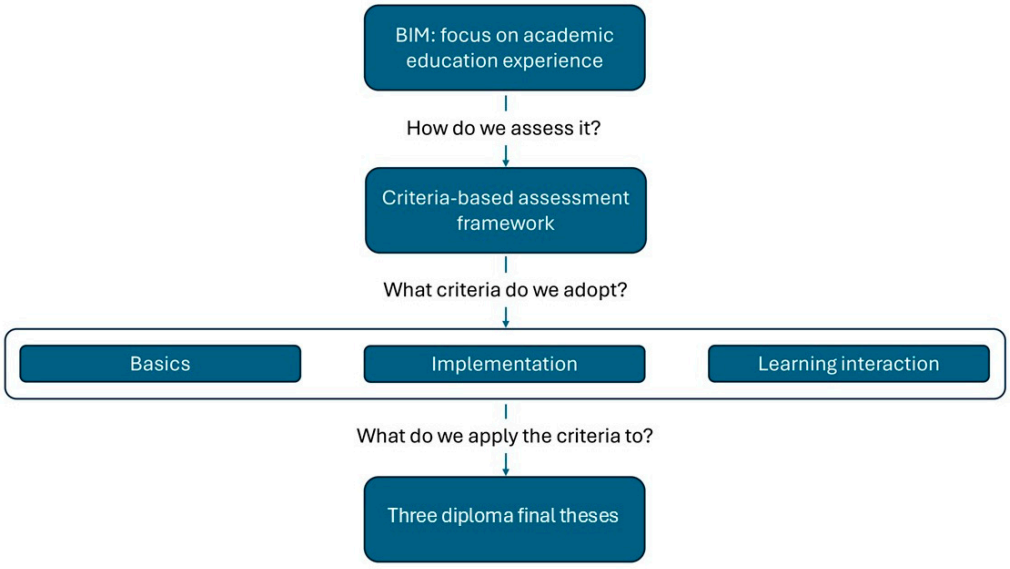


Figure 1. Methodological workflow. Elaboration by the authors.

The rationale implies a sequence of three major phases. A general interest in the assessment of academic education toward a BIM concepts-driven curriculum motivates the

design of an assessment framework based on criteria clustered into three macro-issues and applied to the case of three diploma final theses.

In Table 2, an operational explanation clarifies how the entry values reported in Table 1 are assigned.

Table 2. BIM academic education assessment framework: entry score attribution operational explanation.

Code	Criteria	Entry	Operational Explanation
CR1	Focus	Rural building, rural landscape, or rural building and landscape	Focus of the exercise on rural building, rural landscape, or both (one out of three alternative entries)
CR2	Level	Undergraduate final thesis or graduate final thesis	Level of the academic program, where the thesis was developed: undergraduate or graduate (one out of two alternative entries)
CR3	Software	Autodesk Revit, Graphisoft ArchiCAD, etc.	Name of software house and program (one out of many alternative entries)
CR4	Dimension	2D, 3D, . . ., nD BIM	Dimensions of the application: 2D for bidimensional CAD, 3D for three-dimensional modeling CAD-BIM, 4D for construction scheduling BIM, 5D for cost management BIM, 6D for sustainability and energy BIM, 7D for entire life-cycle BIM, 8D for security BIM, 9D for lean construction BIM, and 10D for industrialization BIM (one out of nine alternative entries)
CR5	Maturity	0, 1, 2, 3	Maturity of the application: 0 for CAD, 1 for stand-alone 2D and 3D modeling, 2 for collaborative BIM, and 3 for iBIM with integration and interoperability (one out of four alternative entries)
CR6	Development	100, 200, 300, 350, 400	Level of development: 100 for the basic form (standing for shape, size, and location), 200 for the generic form, 300 for specific form, 350 for actual model of product including its form, and 400 being like 350 with fixing, assembly details, and information (one out of five alternative entries)
CR7	Barrier	Conceptual, technical, and environmental	Type of barrier: conceptual for a lack of understanding of the process, technical for difficulties to use the required tools, and environmental for circumstances of the learning environment (one out of three alternative entries)
CR8	Student's background	No background, basic, or advanced	Background exposure to BIM concepts: no background for a lack of previous exposure to BIM concepts, basic for starting exposure to the basic concepts of stand-alone BIM concepts, and advanced for complete exposure to integrated, interactive, and interoperable BIM concepts (one out of three alternative entries)
CR9	Teacher's training	No training, 2 years, 5 years, or more than 5 years	Time period of instructor's training: no training for lack of training, 2 years for 2 years of training, and more than 5 years for more than 5 years training (one out of three alternative entries)
CR10	Student–teacher interaction	Autonomous, semi-autonomous, or teacher dependent	Type of interaction between teacher and student: autonomous for a very autonomous and proactive student and minimal coaching over BIM concepts and application, semi-autonomous for a moderately autonomous student and some need of coaching over BIM concepts and application, and teacher dependent for a non-autonomous student and continuous need of coaching over BIM concepts and application (one out of three alternative entries)

3. Method Application: Educational Experiences and Results

In this section, the assessment framework is applied to the appreciation of three academic educational living case studies. The section is split into two sub-sections, the first one presenting the educational experiences and the second one reporting on the results.

3.1. The Educational Experiences

The University of Sassari (UniSS) is an Italian middle-size (around 13,000 students) university located in the north of Sardinia, a major island of Italy. The region has another larger academy, the University of Cagliari (UniCA), located in the capital city in the south. In Sardinia, UniSS is the only academy with a large agricultural department, while UniCA is the only academy with a large engineering department. Both the universities have an architectural department. The Department of Agricultural Sciences (DAS) is a major research and teaching body of UniSS and includes a Section of Territorial Engineering (STE) dealing with the application of engineering principles to agricultural systems (land, landscapes, building, and infrastructures). STE hosts a research group—including the authors of this paper—focusing on rural buildings and landscape (RBL) analysis and design. This group deals with transitioning planning and design education from a traditional CAD-based curriculum to a BIM-based curriculum. The DAS runs various undergraduate and graduate programs and a PhD school in agricultural and forestry sciences. These programs include courses on CAD (elective modules) and the analysis and design of RBL (compulsory modules). In the last five years, the restructuring of programs has not permitted the institution of new courses dedicated to BIM concepts and application due to environmental barriers, mostly consisting of a lack of didactic space (i.e., credit hours) and general teachers' skepticism on the usefulness of including BIM concepts in the learning outcomes of university programs in agricultural sciences and forestry at UniSS. So, these contents are being integrated into the educational syllabus and coursework of the existing modules. The RBL research group is projecting a proposal of post-graduate program (level II masters' program for entry candidates holding a five-year academic diploma), where two modules discuss BIM concepts for the design of RBL. A relatively larger space is granted for covering BIM concepts during the drafting of the final diploma thesis. In this respect, exemplary educational experiences are described in the subsequent paragraphs.

3.1.1. The Design of a Winery

The first thesis, Final Thesis 1 (FT1), titled "Designing a winery with BIM: building requirements and impact on the landscape" focused on the use of BIM for the design of a new middle-size (312,000 bottles per year) winery in southern Sardinia, Italy [58]. It was the voluntary output of a mandatory traineeship for the three-year undergraduate program in Viticulture, Enology and Food Technologies. During the traineeship in an architectural studio at the beginning of 2020 (during the early stages of the COVID-19 pandemic), the candidate worked on BIM issues for several dimensions, with a focus on the entire life cycle of the building, in the perspective of a collaborative study. BIM was used to design the building per se and the relation between building and landscape. The candidate used ACCA Edificius™ (educational release), software with powerful 3D modeling and rendering features [59]. In Figure 2, some screenshots of the project are reported.

The winery is designed to be partially underground, a typical solution for hosting the wine-fining section of the building. COR-TEN shading was designed to follow mainstream options adopted in other well-known cases (see Foster's Bodega Portia, in Burgos, Spain [60]) with the attempt to reduce the impact over local landscapes. Spaces are tailored to host and maximize the efficiency of the sequence of processes and activities (reception, transformation, fining, stock, and sending to the market). The teaching–learning interaction

was characterized by the very proactive behavior of the student, who carried out the tasks in a substantially autonomous way. The candidate had previous exposure to BIM concepts and winery design in a course on buildings for the enological industry during the first semester of the third year. The instructor had experience mostly of 2D CAD modeling and early 3D BIM modeling.

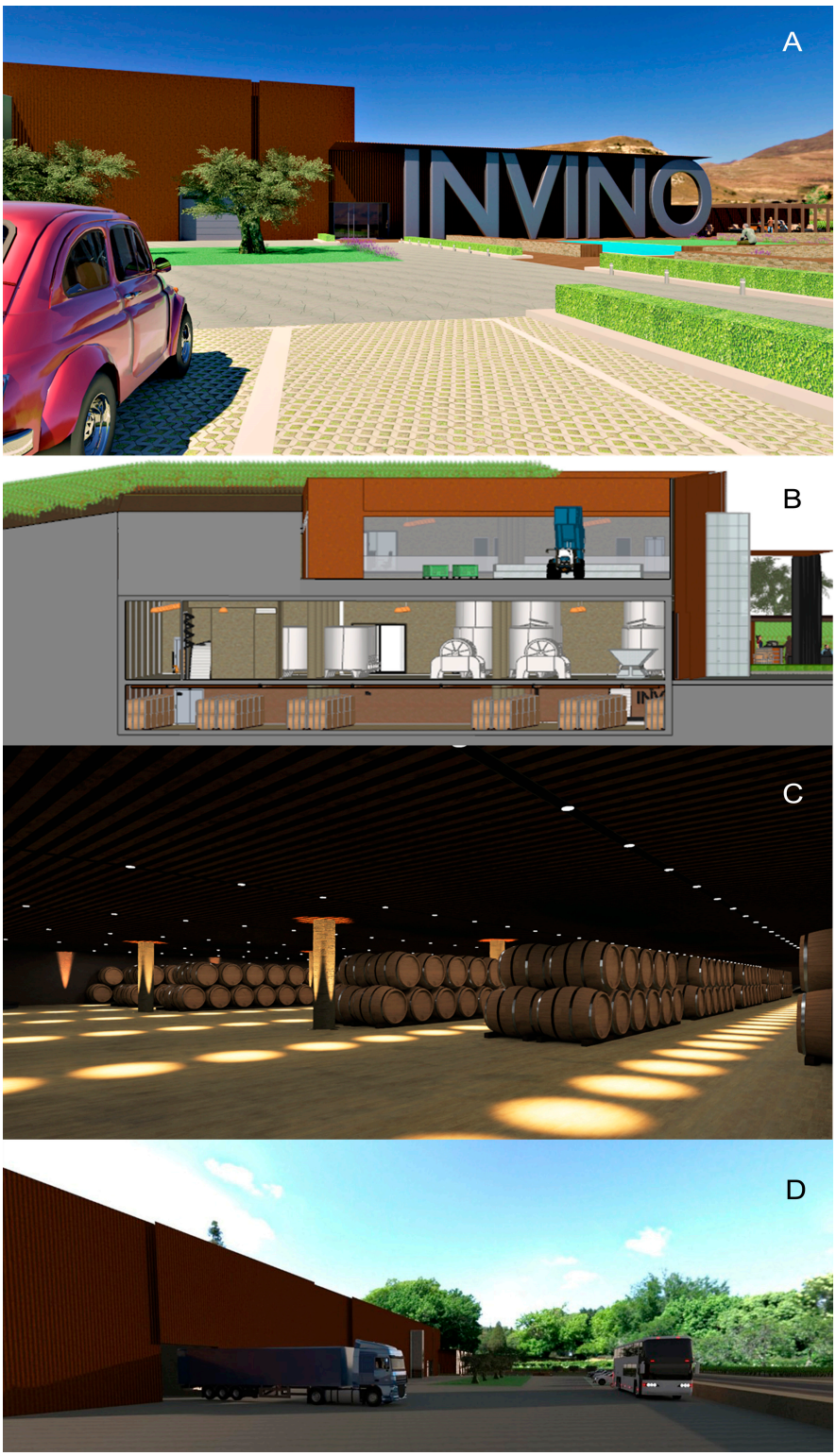


Figure 2. Screenshots of the winery project designed with ACCA Edificius™ [58]: (**A**) view of the entrance, (**B**) section of the building, (**C**) view of the wine fining space, and (**D**) view of the logistic area from the North. These images are courtesy of Alessio Tiddia.

3.1.2. The Design of a Livestock Barn

The second thesis, Final Thesis 2 (FT2), titled "BIM for the design of livestock buildings: theoretical issues and an application" focused on the advantages and disadvantages of BIM application to the design of a new barn for dairy cattle in southern Sardinia, Italy [61]. It was the mandatory final dissertation of a master's graduate two-year program in Zootechnic Production Sciences. FT2 starts with a literature review on the evolution and the pros and cons of BIM and presents critically an application to a zootechnic building. The candidate was able to identify some typical strengths (i.e., less errors and less costs) and weaknesses (i.e., a lack of libraries of building solutions for the design of barns). BIM was used mostly to design the building per se, with a focus for the steel frame structure. The candidate used ACCA Edificius™ (educational release), software with powerful 3D modeling and rendering features [59]. In Figure 3, some screenshots of the project in the software framework are reported.

The building is designed to host the milk production processes regarding 90 cows managed in six 12 m × 10 m internal boxes (in brown) and six external paddocks (in grey) connected to the boxes with an open gate in the 1.20 m tall wall boundary. Spaces are designed according to a modular framework mastered through the software function "magnetic grid 2D". According to animal welfare concepts, boxes are dimensioned with 8 sqm per individual and a feeding lane with 0.75 m per individual. The structure comprises four steel portals with HE 300 M pillars and IPE 300 beams, seven reticular A-shape beams in the main barn, and wooden elements in the auxiliary buildings. The teaching–learning interaction was characterized by the very proactive behavior of the student, who carried out the tasks in a substantially autonomous way. The candidate had previous exposure to 2D CAD concepts and barn design in a graduate course on the design of zootechnic buildings during the first semester of the second year. The instructor had experience mostly of 2D CAD modeling and early 3D BIM modeling.

3.1.3. The Design of a Honey House

The third thesis, Final Thesis 3 (FT3), titled "Honey house in Sardinia: an approach to the design with SketchUp", focused on the use of BIM for designing an hypothetic conversion of an existing rural building into a honey house in northern Sardinia, Italy [62]. It was the voluntary output of a mandatory traineeship for the three-year undergraduate program in Agricultural Sciences and Technologies. During the traineeship in an agronomic studio in 2022–2023, the student worked through BIM issues mostly for 3D dimensions, with a focus on texturing. BIM was mainly used to design the building per se. The candidate used SketchUp 2021 Pro™, software with powerful 3D modeling and rendering features [63]. In Figure 4, some screenshots of the project are reported.

The concept of the building is related to the architectonic shape of the simple existent rural building. Texturing is managed to stress the use of stone structural walls and roof cover with tiles. Spaces are tailored to host and maximize the efficiency of the sequence of processes and activities (reception, garderobe, processing, stock, and sending to the market). The teaching–learning interaction was characterized by the very proactive behavior of the student, who conducted the tasks in an autonomous way. The candidate had previous exposure to BIM concepts in courses on rural buildings and topography and CAD. The instructors had experience mostly of 2D CAD modeling and early 3D BIM modeling.

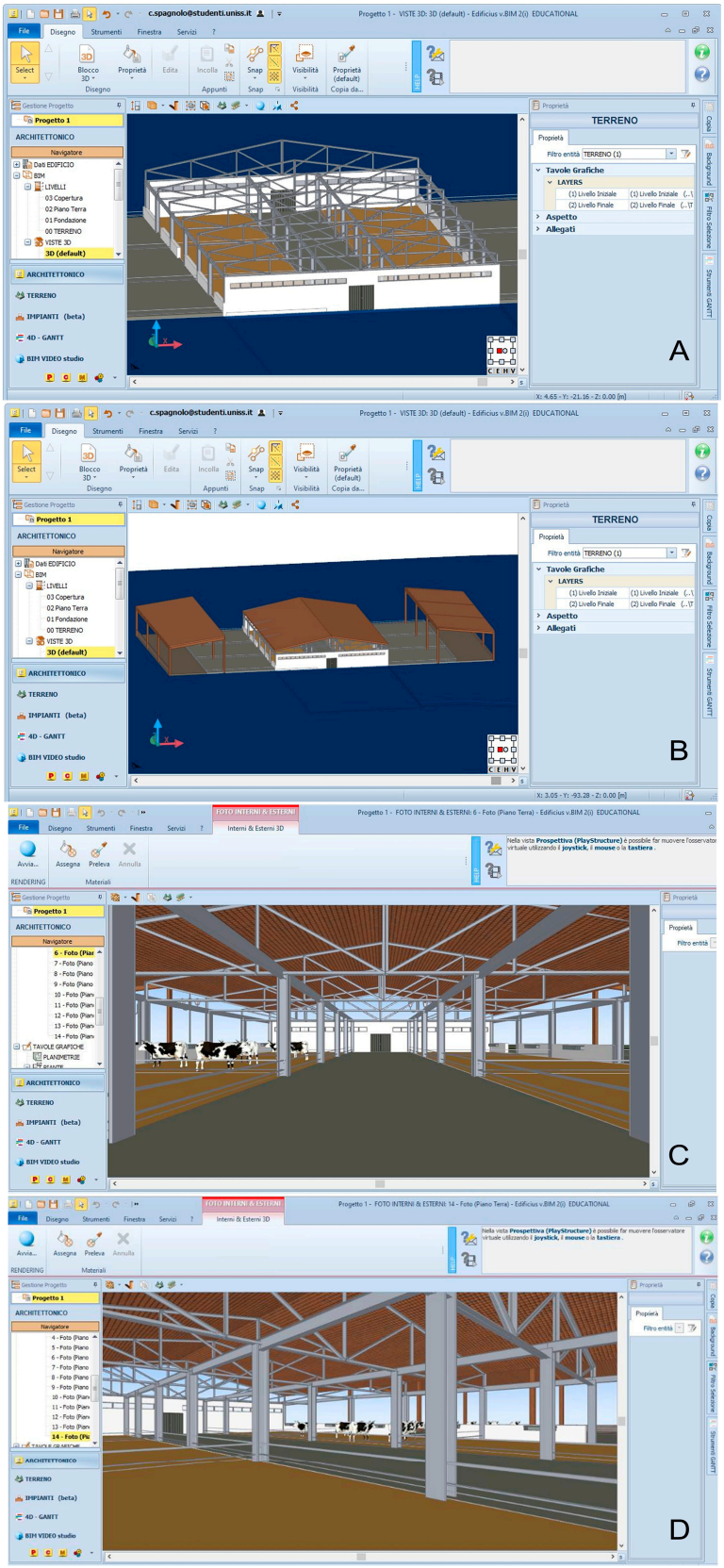


Figure 3. Screenshots of the livestock barn project designed with ACCA Edificius™ [61]: (**A**) prospective view of the steel A-shape structures, (**B**) view of the entire farm, (**C**) prospective view of the steel structure, and (**D**) prospective view of the cattle box and service lane. These images are courtesy of Claudia Spagnolo.

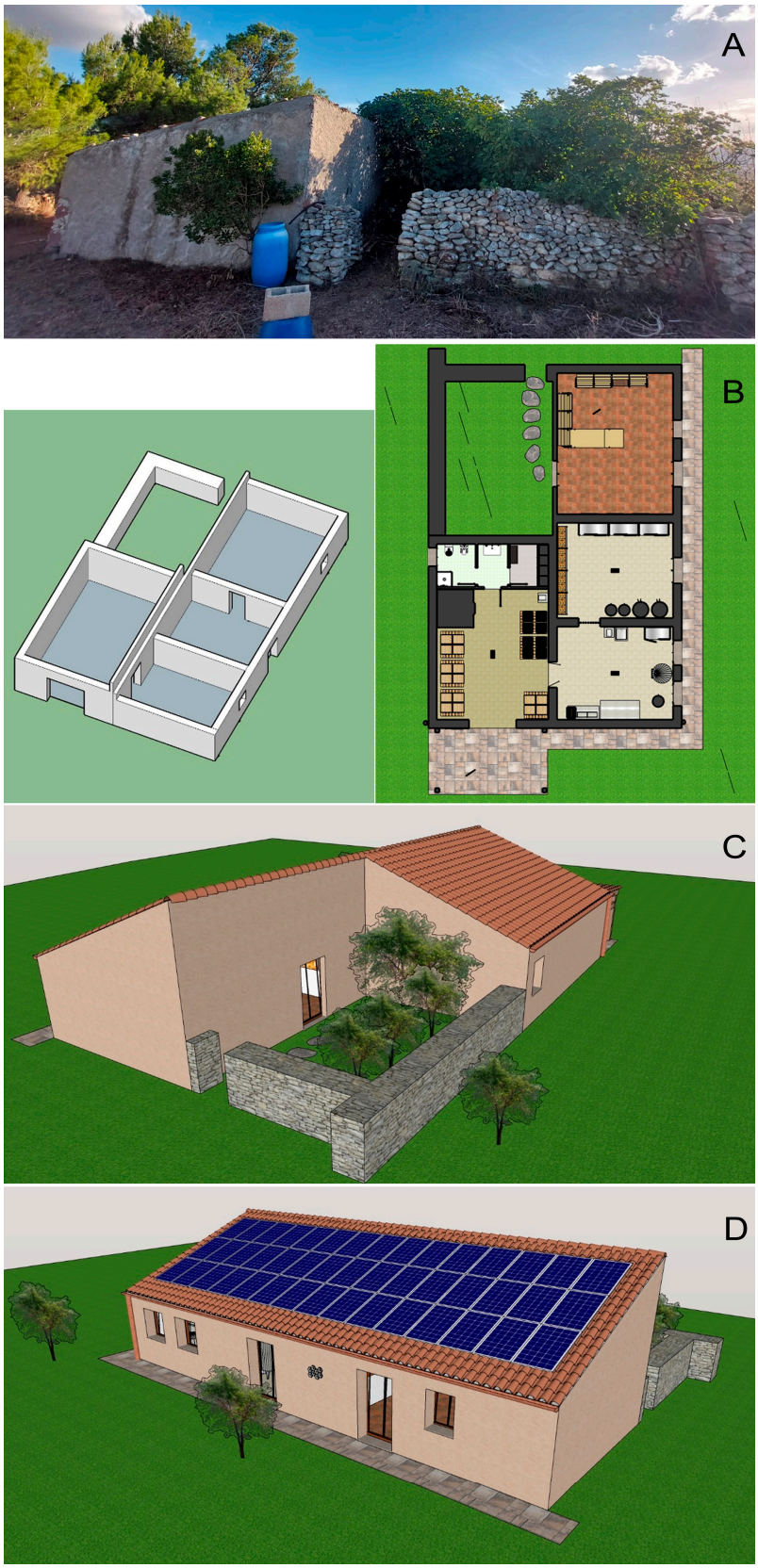


Figure 4. Screenshots of the honey house project designed with SketchUp Pro™ [62]: (**A**) the existing rural building (photo by Maria Vittoria Brundu, courtesy), (**B**) left 3D view of the internal spaces, (**B**) right ground-level layout, and (**C**,**D**) 3D prospective views with texturing effects. These images are courtesy of Maria Vittoria Brundu.

3.2. Results

The application of the BIM academic education assessment framework reported in Table 1 yields the results reported in Table 3.

Table 3. Application of the BIM academic education assessment framework to the evaluation of the three final theses (FTs).

Macro-Issues	Code	Criteria	FT1	FT2	FT3
Basics	CR1	Focus	Rural building and landscape	Rural building	Rural building
	CR2	Level	Undergraduate	Graduate	Undergraduate
	CR3	Software	ACCA Edificius™	ACCA Edificius™	SketchUp 2021 Pro™
Implementation	CR4	Dimension	3D	4D	3D
	CR5	Maturity	1	1	1
	CR6	Development	300 (specific form)	300 (specific form)	300 (specific form)
	CR7	Barrier	Environmental	Technical	Technical
Learning interaction	CR8	Student's background	Basic	Basic	Basic
	CR9	Teacher's training	2 years	2 years	5 years
	CR10	Student–teacher interaction	Autonomous	Autonomous	Autonomous

As for the basic macro-issues, in one case (FT1), BIM was applied to the design of both the building per se and the binomial building–landscape. In the other two cases, apart from a limited description of external spaces, the focus was mostly on the building as a stand-alone object. Two learning experiences (FT1 and FT3) were carried out in an undergraduate program: an encouraging sign of the interest of the students from the early stages of academic education. The software used was ACCA Edificius™, educational release, in two learning experiences (FT1 and 2), while SketchUp Pro™ was used in one educational experience. In this case, the student used the proprietary license acquired by the Laboratory of Rural Buildings and Landscapes, DAS. The students used the software programs quoted, as the instructors and tutors had the required competencies and skills to master the corresponding concepts, routines, and commands.

With respect to the implementation macro-issue, FT1 and FT3 were worked out in a three-dimensional framework, while FT2 was realized in 4D, with a focus on the scheduling of the building process (i.e., the sequence of the operations regarding the structural skeleton). The maturity level of all the FTs scores 1, as BIM 3D concepts were invoked and applied mostly from the perspective of a single expert (collaborative work was always recalled only in theoretical terms). All the FTs were developed according to a score equal to 300, as the elaboration always led to the drafting of buildings with a specific form and function. The barriers to the introduction and use of BIM concepts into the learning experience were environmental for FT1 (no spare credit hours for BIM application to the design of rural buildings in the undergraduate program), and technical for FT2 and FT3 (lack of predefined solutions for rural buildings).

As for the learning interaction macro-issues, student background was basic for all the FTs because of the very limited or absent exposure to BIM concepts during regular courses. Teachers had experienced BIM concept for 2 years for FT1 and FT2 and for 5 years for FT3. The attitude of the students for BIM concept implementation was very good: with minimum coaching on introductory concepts, they were autonomous in the use of the software and application of the principles.

4. Discussion and Conclusions

In this section, we discuss the results with respect to the RQs formulated in the introduction.

As for RQ1 on the basic characteristics of the introduction of BIM concepts into academic education, the educational experiences were developed at the end of the academic experience (three years undergraduate and two years graduate programs) with a focus mostly on rural buildings per se, in line with other experiences worldwide [12,13,32,34–36]. In one case (winery design), the student was able to master rendering features on the relation between building and landscape with interesting lighting effects and vegetation shaping with predefined libraries. In two cases, the educational release of a BIM software program was used with powerful yet limited characteristics, and in one (FT3 on honey house design), the full version of professional software was implemented. The adoption of Trimble SketchUp™ and ACCA Edificius™ is documented [24,27].

With respect to RQ2 on the quality and intensity of the BIM concepts conveyed into the educational experience, the results testify that BIM concept adoption patterns compatible with the barriers are usually reported in the case of early stages of transition from CAD- to BIM-driven design academic programs for the AEC sectors [10,42]. As a confirmation of a general criticality [24], one of the main obstacles reported is the lack of space (i.e., no credit hours available) in the educational course scheme for teaching BIM-led design issues at the DAS, University of Sassari. This limitation is being overcome by a progressive shift toward BIM concept teaching, a restructuring of existing courses or proposing new courses on drawing and design of rural buildings [51,52], and specific work on drafting the final diploma thesis [50]. In the case of FTs, the relatively higher freedom with respect to the regular teaching schedule has allowed for a satisfactory intensity of application, maturity, and development of BIM concepts. Given the educational engineering local circumstances (i.e., BIM concepts do not inform design issues in a sufficient number of courses on structure, energy, finance, etc.), 3D and 4D BIM implementations can be welcomed as a success but are a signature of a still limited use of the instruments, with respect to the potential of the approaches to nD BIM variances. This confirms the evidence reported for latecomer countries in BIM academic education [38,39]. The level of maturity equal to 1 (i.e., 3D BIM concept applied by an individual designer with no collaboration with other specialists) can be explained with the usual path walked by students while drafting their final thesis in a context that simulates professional working environments. Similar observations hold for the level of development, which does not score more than 300, since the design was addressed with a general approach to the definition of size, built volumes, and surface areas, without any need to delve into the description of the details. These limitations can be generally attributed to the physiological minor emphasis for building design in Italian departments of agricultural sciences, with respect to departments of engineering or architectural sciences. Another important limitation is the weak connection with live practice of BIM concepts by students in ongoing projects. As signaled in other contexts [5], stronger relations between academy and AEC industry are prerequisites for the effective integration of operative BIM concepts into academic education at the DAS-UniSS.

As for RQ3 on the quality of learning experience, the students were enthusiastic about the proposal and successive use of BIM concepts applied to the design of rural productive buildings. This was appreciated, notwithstanding their relatively scarce exposure to BIM issues and instruments before they began to work on the final thesis [47]. This was also due to the attitude of the teachers, who started from limited experience of BIM applications but rather extensive experience of the design of rural buildings. This awareness led to a soft coaching by the instructors over BIM principles and the specifics of software program commands during the cyclic sessions of revisions [57]. The learning behavior of the students

was very proactive, as the candidates were always able to move autonomously, receiving comments and elaborating alternative solutions between one revision and another [43].

The systematic evaluation of the transition to BIM-informed education at the DAS-UniSS has revealed that some actions have been undertaken, but much work still must be carried out. Immediate strategies can be undertaken to improve the existing opportunities to teach BIM concepts in the academic curriculum at the DAS: integrating the existing design courses, expanding new pilot courses, designing a new post lauream master's course including modules on BIM application, and making structural the offer of theses concerning the design of RBL with BIM. In the longer run, strong academic educational shifts—implying a systematic revision of entire programs and the introduction of new courses totally on BIM-driven design—require commitment by the complex AEC education ecosystem, including the university community (governance, students, teachers, and technicians), software houses, industries, and design and planning agencies. In close future times, the educational market will be demanding more skills related to BIM specialists, analysts, and managers. Subsequent research work should be directed to overcome the bottlenecks and orchestrate a stakeholders' convergence to feasible standards of life-long learning outcomes.

The assessment framework proposed and applied in this exercise represents a possible BIM academic education measurement system, but it could be confronted and integrated with the concepts related to long-lasting and established schemes, such as the BIM competency framework [64] and the Technology Acceptance Models [65]. In addition, our framework has been designed and applied without the proper tests and validations using experts. This can undermine the robustness, neutrality, and transferability of the method. Similarly, other strategies are needed to improve the scoring and appreciate the instructor evaluation in a fair, standardized, and acceptable way. It is also evident that the analysis can benefit from evaluator feedback and inter-rater agreement measures. Future works will be addressed in this direction.

Building design education presents well-known limitations in university departments of agricultural sciences, with respect to the other departments of architecture and engineering. RBL design is an expanding niche but still absorbs a minority share of the whole projects for AEC sectors. Further research on the role of departments of agricultural sciences in Italy and worldwide is needed to verify the feasibility of courses of actions including, for instance, joint endeavors under the coordination of polytechnic schools.

Author Contributions: Conceptualization, A.D.M.; methodology, A.D.M. and A.L.; software, A.L., V.S., E.U. and G.C.; validation, A.L., V.S., E.U. and G.C.; formal analysis, A.D.M. and A.L.; investigation, A.D.M. and A.L.; resources, V.S., E.U. and G.C.; data curation, V.S., E.U. and G.C.; writing—original draft preparation, A.D.M.; writing—review and editing, A.D.M. and A.L.; visualization, A.L., V.S. and E.U.; supervision, A.D.M. All authors have read and agreed to the published version of the manuscript.

Funding: Andrea De Montis and Antonio Ledda are supported by the Agritech National Research Center (CN00000022, Concession Decree 1032 of 17/06/2022) and the National Biodiversity Future Center—NBFC (CN00000033, Concession Decree 1034 of 17/06/2022 adopted by the Italian Ministry of University and Research, CUP J83C22000870007), as well as the European Union Next-GenerationEU, Projects funded under the National Recovery and Resilience Plan (NRRP; Piano Nazionale di Ripresa e Resilienza), and Mission 4 Component 2 Investment 1.4. This manuscript reflects only the authors' views and opinions, and neither the European Union nor the European Commission can be considered responsible for them.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Acknowledgments: The Authors thank Alessio Tiddia, Claudia Spagnolo, and Maria Vittoria Brundu for allowing the use of the materials of their final diploma theses, under proper citation in the text.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Abbreviations

The following abbreviations are used in this manuscript:

AHBIM	Architectural Heritage Building Information Modeling
AEC	Architecture, Engineering, and Construction
BIM	Building Information Modeling
CAD	Computer-Aided Design
CR	Criterion
DAS	Department of Agricultural Sciences
FT	Final Thesis
GIS	Geographic Information System
HBIM	Historical Building Information Modeling
LOD	Level Of Development
RBL	Rural Buildings and Landscape
STE	Section of Territorial Engineering
UniCA	University of Cagliari
UniSS	University of Sassari

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