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PAPER

Embedding Building Information Modelling in the Construction Area: A Case within an Undergraduate Civil Engineering Program

Alexandre Almeida Del Savio[1], **Katerina Galantini Velarde**[2](✉), **Ana Felicita Luna Torres**[1], **Jose Roberto Salinas Saavedra**[1], **Mónica Alejandra Vergara Olivera**[1]

[1]Faculty of Engineering, Universidad de Lima, Lima, Peru

[2]Faculty of Architecture, Universidad de Lima, Lima, Peru

kgalanti@ulima.edu.pe

ABSTRACT

Undergraduate programs face the challenge of staying up-to-date by responding to globalization, internationalization, and regionalization processes. Civil engineering programs should meet the requirements of the Architecture, Engineering, Construction, and Operation (AECO) industry. Building Information Modelling (BIM) is a methodology that involves shared digital representations of built assets to facilitate design, construction, and operation processes within the construction knowledge field. The present research describes a methodology with six mechanisms to develop and consolidate BIM-related competencies within the construction area from an undergraduate civil engineering program. It also explores students' perceptions about the subjects within this area and their relationship with the training and reinforcement of the competencies. The study follows a descriptive scope with an action research design. The principal result is the methodology, which has six mechanisms: (1) BIM implementation into topics and syllabi; (2) use of collaborative platforms; (3) professor training programs; (4) establishment of student organizations; (5) development of a BIM application project; and (6) area and subject meetings. The validation process, which included professors, enrollment, employability and research rates, and the curricular proposal and students' perceptions, revealed that the mechanisms could effectively support the development and reinforcement of BIM-related competencies.

KEYWORDS

undergraduate curriculum, civil engineering, competency-based curriculum, construction area, Building Information Modelling (BIM), Architecture, Engineering, Construction, and Operation (AECO), Virtual Design and Construction (VDC)

1 INTRODUCTION

Undergraduate programs face the challenge of staying up-to-date by responding to globalization, internationalization, and regionalization processes, as these

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determine multinational quality standards [1]. Competency-based curricula are the foundation of higher education programs since they prepare future professionals to build knowledge while adapting to the permanent cycle of contextual changes [2]. Therefore, they enhance lifelong learning (LL), the process throughout life to address every individual's learning needs [3]. Competency-based curricula prepare students to practice a dynamic combination of knowledge, skills, attitudes, and values, allowing them to face the emerging challenges of their professional environment [4]. Furthermore, they actively contribute to achieving the 17 Sustainable Development Goals (SDGs) [5].

In the context of engineering programs, curricula should be aligned with the requirements of the Architecture, Engineering, Construction, and Operation (AECO) industry. Thus, they should introduce new technologies, workflows, and methodologies that the Fourth Industrial Revolution, or Industry 4.0, has brought [6], considering the multidisciplinary nature and variety of stakeholders participating in the projects. Traditional construction methods do not provide this work environment, as AECO project organizations are fragmented into subgroups, including owners, designers, and contractors, who may work as independent entities [7].

An example is Building Information Modelling (BIM), which implies processes supported by shared digital representations of built assets that facilitate design, construction, and operation based on reliable data for decision-making [8]. BIM utilizes graphic and non-graphic information to create, manage, and operate digital representations [9]. Due to the collaborative processes involved in this methodology, BIM has been embraced for project management by the AECO industry since the mid-2000s, enabling the improvement of construction efficiency [10]. Moreover, its application is expanding as it helps in organizing interdependencies among stakeholders in design, construction, operation, and maintenance processes. Governments endorse this growing trend, as the methodology has become essential in public projects [11]. Consequently, the demand for AECO professionals with BIM-related competencies has surged significantly.

A BIM professional is expected to conceive, design, project, plan, develop, analyze, coordinate, integrate, and manage multidisciplinary projects within the AECO industry. BIM provides an advantageous environment for developing both generic and specific competencies required within this industry [3]. A BIM professional should be trained not only in organizing and prioritizing tasks and using programming languages, but also in generic competencies such as leadership, innovation, and mentoring [12]. Similarly, critical and systematic thinking, which enable the deployment of the aforementioned competencies in both collaborative and individual work environments, are also essential. Therefore, teamwork, effective communication, and other generic competencies are enhanced [13] since BIM is a collaborative methodology involving the coordination of project stakeholders [14]. Furthermore, BIM also supports the development of problem-resolution competencies, which are applied within the context of a project and, consequently, allow the development of work plans considering the contributions of peers [15].

BIM also promotes the use of Information and Communication Technologies (ICT), software, and Common Data Environment (CDE) management because it relies on these tools to integrate a project's information based on technical knowledge. Project management is also enhanced since the application of technical, contractual, economic, and financial concepts is necessary for project development. Furthermore, design, coordination, and planning are also emphasized. As a result, BIM can effectively be integrated through a competency-based curriculum [3]. This assertion is reinforced by the increasing adoption of BIM within the AECO industry, which has led to its incorporation in higher education programs [16].

BIM has evolved, integrating different dimensions into its methodology. Beginning with the primary spatial dimensions (width, height, and depth) in 3D BIM models, a fourth dimension was quickly added, incorporating the variable "time," which refers to the planning or scheduling of a project, as a dimension in 4D BIM models. Later, a fifth dimension, corresponding to the variable "cost," was added, resulting in 5D BIM models. After that, six and seven dimensions were included, which answer the "sustainability" and "facility management" variables, respectively. The products are 6D and 7D BIM models [17].

Nevertheless, BIM adoption in undergraduate programs has primarily focused on software operations and skill applications [18]. In essence, the changes implemented involve transitioning from pedagogical tools in 2D design to 3D visualization. This shift is attributed to the potential of 3D BIM models in comprehending areas such as design fundamentals, building technology, programming, and modeling concepts [19, 20]. Students initially learn the fundamentals of 3D BIM models to develop the necessary skills and grasp the concepts essential for understanding the advanced dimensions of BIM [12]. Consequently, without comprehensive implementation, students may not effectively acquire BIM-related knowledge and skills in a progressive manner [21].

However, the BIM adoption should also integrate from the 4D to the 7D to support the development and reinforcement of generic competencies, such as communication and teamwork, that are put into practice when different project stakeholders work in collaboration to coordinate inputs and improve the quality of the delivered project [19]. Hence, higher education plans should fully integrate these BIM dimensions throughout the curriculum [22, 23]. Additionally, civil engineering students have reported expecting to work in management positions in AECO industry companies, where various technical and soft skills, or specific and generic competencies, are required, such as leadership and people management [24].

In a parallel scenario, within civil engineering programs, traditionally, training in the construction field has been one of the main components worldwide [25]. This training involves preparing students for the planning, management, and implementation of construction projects, and it introduces them to the processes and techniques used in the AECO industry. It also includes training in preventing labor risks, cost management, construction equipment and machinery, project evaluation, and personnel selection and management [26]. Furthermore, construction field topics, such as construction materials, concrete design, steel design, construction systems' design and planning, scheduling, and cost estimating, are of deep interest among civil engineering students since they consider them an important part of their learning experience [27, 28].

Thus, it is necessary to include training in the construction field throughout the curriculum to meet the requirements of the AECO industry and keep students motivated during their formative years. The approach to traditional construction concepts should promote critical and systematic thinking so that students can identify future opportunities for improvement [14]. In this regard, BIM offers a suitable framework as it enhances the quality of projects while fostering a collaborative problem-solving environment [3]. Moreover, students exhibit a positive attitude towards learning BIM, which can further strengthen their motivation to learn [29].

To this day, studies have reported BIM-related experiences developed along the undergraduate curriculum. However, these studies are primarily focused on different types of BIM implementations: on individual subjects, collaborative subjects, final projects, or to complement the subject's content [30]. In each scenario, BIM is partially integrated throughout the undergraduate curriculum. Consequently, there is still a gap in the literature that needs to be explored to comprehend the transversal implementation of BIM throughout an undergraduate civil engineering curriculum and the necessary assessment methods to ensure the effectiveness of this process. In this context, a methodology for incorporating BIM into an undergraduate civil engineering program has been established within the framework of a competency-based curriculum [3]. This methodology has been successfully executed at a Peruvian higher education institution. The current study delves into how this implementation has been executed within the construction knowledge domain, which is crucial in the civil engineering training process. The primary outcome of this study is a functional methodology that can be replicated in other undergraduate civil engineering programs.

1.1 Goals and research question

This study describes the methodology for integrating BIM-related competencies into the construction area of an undergraduate civil engineering program. Additionally, it investigates students' perceptions of the subjects in this area, and their impact on developing and strengthening these competencies to assess the effectiveness of the methodology. The study addresses the following research questions:

- How can BIM-related competencies be developed and consolidated within the construction area through an undergraduate civil engineering program?
- What are students' perceptions of the construction area's teaching-learning methodology and its impact on developing and reinforcing BIM-related competencies?

The present study uses the Gradual Implementation Research Competencies (GIRC) Program as a conceptual framework. This GIRC Program allows students to develop and reinforce research competencies gradually and across disciplines [4]. It also builds upon the research conducted by [3], which outlines a methodology and a proposal to integrate BIM throughout an undergraduate competency-based civil engineering curriculum. This study specifically concentrates on implementing this proposal within the construction area. The paper is structured into the following sections: conceptual framework, methods, results and discussion, and conclusions.

2 CONCEPTUAL FRAMEWORK

The following section addresses the relationship between the construction area and the two main topics developed throughout the present study: BIM and competencies.

2.1 Construction area and BIM

BIM has been adopted within the construction industry in different countries, with more emphasis in the last two decades [31]. Some of the benefits of its implementation for infrastructure projects include visualization of the entire construction process, coordination between different disciplines to avoid interference issues, simulation of the project's and construction's activities, and the generation of non-graphical information such as budgets, schedules, and energy or structural analysis [32]. Among these benefits, detecting errors and incompatibilities between specialties is a major advantage, leading to significant savings in construction costs [33]. One of the biggest challenges within AECO projects is interoperability between specialties [34]. A study conducted in the United States by the National Institute of Standards and Technology (NIST) found that the cost of interoperability problems between systems can reach $15 trillion annually [35].

Despite these advantages, establishing BIM in the construction industry has not been easy since it requires time and training [33]. However, with the launch of BIM policies and regulations regarding the presentation of AECO projects, such as ISO 19650, BIM adoption policies have been established by countries such as Singapore, Finland, Korea, the USA, the UK, Australia [36], Brazil, Chile, and Peru. These adoption policies have raised the need to develop projects using BIM efficiently. According to [37], experiences have shown that, although project teams try to integrate BIM, the learning curve is very steep because of the following challenges: time and cost needed for hiring or training people in BIM; protection for ownership and management of data; legal or contract issues; cost of hardware and software; compatibility issues between software; and a lack of businesses' desire to adopt BIM [38].

While there are challenges in adopting BIM for AECO projects, the construction industry is persistently developing strategies to implement it into this methodology. Due to the increasing demand for BIM in the industry, integration into the civil engineering curriculum is essential. This integration will enable students to enhance their competitiveness in their future professional endeavors. Moreover, incorporating BIM into civil engineering courses helps students grasp the various processes and stages of an AECO project, such as modeling, visualization, design, construction, operation, and information exchange [39].

BIM can also lead to more hands-on experiences that may benefit students as they enter the workforce [40]. Using real cases helps them comprehend the limitations of current processes within the field and seek solutions within the classroom environment [41]. Moreover, students believe that receiving BIM training enables them to develop a more substantial acquisition process of generic competencies essential for training competent professionals in the AECO industry [3].

Furthermore, [42] found that existing educational studies primarily concentrated on construction-related topics, such as visual and interactive displays. This indicates that construction subjects hold significant potential for incorporating BIM, as the associated tools offer a digital and interactive platform that enhances students' comprehension. Moreover, AECO companies anticipate that graduates pursuing construction-related professions possess knowledge of BIM tools and procedures, particularly in constructability areas, underscoring the critical necessity of educating students in this approach.

In the undergraduate civil engineering program to which this study belongs, Computer-Aided Design (CAD) and BIM software are utilized to teach design and construction processes. Real projects serve as case studies. BIM enhances the didactic nature of the class, making it easier for students to learn about construction elements and develop generic competencies [43]. The study of BIM methodology is advanced through BIM application projects, providing students with opportunities to explore cutting-edge technologies and methodologies in the AECO industry.

2.2 Construction area and competencies

A competency-based training approach is a proposal that begins with meaningful learning and is also focused on comprehensive human development [44].

Competencies should be directed towards the specific subjects of a discipline and their practical applications in the professional field [45]. Therefore, training processes should include the development of generic competencies to produce competent professionals for the AECO industry [46, 47].

[3] determined eight competencies, both generic and specific, to be trained within an undergraduate civil engineering BIM curriculum. These competencies include: ethics and leadership; teamwork; research; innovation; design, coordination, and planning; ICT, software, and technologies; project management; and engineering knowledge. Some of these competencies are developed within the construction area of the current study. Table 1 demonstrates how the construction area aims to enhance and reinforce the following generic and specific competencies: teamwork, research, innovation, design, coordination, and planning; ICT; software; technology; and engineering knowledge.

Table 1. Proposal of development of generic and specific competencies in the construction area

Semester	Topic	Generic Competency				Specific Competency			
		Ethics and Leadership*	Teamwork	Research	Innovation	Design, Coordination and Planning	ICT, Software and Technology	Project Management*	Engineering Knowledge
III	Graphical Engineering		X	X		X	X		
IV	Building Information Modelling I		X	X		X	X		X
V	Building Information Modelling II		X	X	X	X	X		X
	Construction Technology I		X	X	X	X	X		X
	Environmental Engineering		X	X	X	X			X
VI	Construction Technology II		X	X	X	X	X		X
	Sanitary Engineering		X	X	X	X	X		X
VII	Electromechanical Engineering		X	X	X	X	X		X
X	Sustainable Infrastructures			X	X	X			X

Notes: *Ethics and leadership, as well as project management, are integral aspects of the civil engineering program. Although they also involve BIM, their application mainly relates to their specific domains within other areas of civil engineering. Therefore, since they are not directly focused on the construction area, this paper will not explore them further.

3 METHODS

The following section details the context in which this research was conducted. It also explains the design, participants, and data collection and analysis techniques.

3.1 Context

The study was conducted within the construction area of an undergraduate civil engineering program at a private Peruvian higher education institution. The proposal involved designing, implementing, and assessing a methodology with six mechanisms to ensure the transversal development and reinforcement of BIM-related generic and specific competencies [4] according to the specific curricular design proposed by the program to which this study belongs. The mechanisms mentioned above include: (1) BIM implementation into topics and syllabi; (2) use of collaborative platforms for class activities; (3) professor training programs; (4) establishment of student organizations; (5) development of a BIM application project; and (6) area and subject meetings.

Furthermore, to assess the success of the implemented mechanisms, a validation process was conducted using data concerning the key stakeholders of the program, including freshmen, graduates, students, and professors. A survey was carried out to investigate students' perceptions of the construction area subjects and their impact on the development and enhancement of BIM-related competencies.

3.2 Design and participants

This study adopts a descriptive scope as its aim is to establish and elucidate a methodology with specific mechanisms to integrate BIM across the construction area in an undergraduate civil engineering curriculum. Therefore, in terms of design, this study is classified as action research as it involves demonstrating and assessing the feasibility of a proposed idea within a particular context. The research and intervention were conducted concurrently to generate and apply knowledge simultaneously [48]. The outcome of this study is the proposal of a methodology.

The study includes 1041 undergraduate civil engineering students from a Peruvian private higher education institution. These students are divided into ten levels based on their curriculum semesters. This group has experienced the adoption of the methodology described above.

As for the sample related to the surveys, it consists of 59 students who have successfully completed all subjects in the construction area. Therefore, non-probability sampling was utilized, specifically judgment sampling, as the sample was intentionally selected based on the established technical criteria [49]. At a 95% confidence level, this corresponds to a margin of error of 12.40%.

3.3 Data collection and analysis

Documental analysis was carried out to describe the mechanisms designed, implemented, and assessed to develop and consolidate BIM-related competencies within the construction area of an undergraduate civil engineering program.

Other cases where BIM has been applied in subjects related to civil engineering, architecture, or similar fields were analyzed. The syllabi were compared with the requirements of the AECO industry and students' preferences. Additionally, studies related to BIM application within the AECO industry and professional development were consulted, as presented in Table 2.

Table 2. Literature review regarding BIM implementation in curricula worldwide

Country	Author	Entity	BIM Implementation
Malaysia	[50], [51]	Universiti Teknologi Mara	Slow implementation of BIM in the syllabus.
Romania	[52]	Brasov University	No strategy for BIM implementation in the syllabus. Self-taught education.
Nigeria	[53]	Lagos University	No BIM implementation in universities. One has an introductory course.
		Federal University of Technology	
South Korea	[54]	University A, University B and University C	Basic BIM courses.
Costa Rica	[55]	Instituto Tecnológico de Costa Rica	Not many BIM professionals.
Croatia	[56]	Universidad de Zagrev	Plans to adopt BIM in superior education.
Slovakia		Universidad de Košice	
Chile	[57]	53% of Chilean universities	Slow implementation of BIM in the syllabus. Focused on technical skills.
Peru	[58]	Universidad de Lima	Transversal integration of BIM in the syllabus.
	[59]	Universidad Católica del Perú	BIM elective subject
	[60]	Universidad Peruana de Ciencias Aplicadas	One mandatory BIM subject.
	[61]	Universidad Tecnológica del Perú	One mandatory BIM subject and BIM certifications.

As for students' perceptions about the teaching-learning methodology within the construction area and their relationship with the development and reinforcement of BIM-related competencies, a survey using a 5-point Likert scale was proposed. It comprised 23 closed questions, with values ranging from 1, 'strongly disagree,' to 5, 'strongly agree.' These questions were organized into two (2) sections: Subject Design, which consisted of ten (10) questions, and Teaching-Learning Methodology, which comprised thirteen (13) questions. Table 3 displays the questions developed for each section.

Table 3. Survey questions for each section

Section	No	Question
Subject Design	1	The contents of the course are up-to-date and useful for your professional training.
	2	The application of BIM methodology has contributed to developing your teamwork capacity.
	3	The BIM software used allowed me to understand the discipline-specific concepts.
	4	The collaborative cloud platform allowed the coordinated information handling through an online environment.
	5	The collaborative cloud platform was easily accessible.
	6	The collaborative cloud platform helped develop the deliverables for the project.
	7	The university provided different supports (licenses, software, books) that allowed me to fulfill the development of my project.
	8	Project-based learning methodology supported by digital tools helped me to understand theoretical concepts in a practical way.
	9	The hours allocated to the course were appropriate.
	10	Project-based learning methodology would be beneficial for other topics within the civil engineering curriculum.

(Continued)

Table 3. Survey questions for each section *(Continued)*

Section	No	Question
Teaching-Learning Methodology	1	It helped develop the Ethics and leadership competency.
	2	It helped develop the Teamwork competency.
	3	It helped develop the Research competency.
	4	It helped develop the Innovation competency.
	5	It helped develop the Design, coordination and planning competency.
	6	It helped develop the Information and Communication Technologies, software and technology competency.
	7	It helped develop the Project management competency.
	8	It helped develop the Engineering knowledge competency.
	9	It motivated me to learn.
	10	It motivated me to prepare myself before classes so that I could participate in their development.
	11	It motivated me to work as a team.
	12	It motivated me to meet the learning objectives of the topic.
	13	It motivated me to apply the obtained theoretical knowledge in practice.

For the survey application, students were organized into three groups based on the main knowledge fields of the construction area: BIM, construction technology, and installations in infrastructure. Informed consent was obtained from all participants prior to the survey being conducted. The survey was administered using Google Forms.

Finally, the acquired information was appropriately coded for data processing using Microsoft Excel, as recommended by the literature. The values and evidence documented were saved for analysis and evaluation [62]. The data allowed for the exploration of students' perceptions towards the subjects while pinpointing opportunities for enhancing the teaching-learning methodology, with a focus on the implementation of BIM.

4 RESULTS AND DISCUSSION

The following text is organized into two sections. The first section describes the methodology, which consists of six mechanisms designed and implemented within the construction area to properly integrate BIM throughout the curriculum. Each mechanism is developed in a subsection. The second section focuses on the validation and assessment of the applied mechanisms.

4.1 Mechanisms

BIM implementation into topics and syllabi: BIM implementation aligns with the interrelationship matrix and the corresponding proficiency levels established by [4], which were matched with the general topics covered within the construction area in this study, as illustrated in Table 4 and recommended by [45]. These topics encompass Graphical Engineering, Building Information Modelling I, Building Information Modelling II, Construction Technology I, Construction Technology II, Environmental Engineering, Sanitary Engineering, Electromechanical Engineering, and Sustainable Infrastructure.

Further engineering topics such as project management, structures, surveying, geotechnics, and hydraulics, among others, were not included because they are covered in other specialized areas within the undergraduate civil engineering program.

Table 4. Interrelationship matrix with proficiency levels between topics and generic and specific competencies from the construction area

Semester	Topic	Generic Competency			
		Ethics and Leadership	Teamwork	Research	Innovation
III	Graphical Engineering		P	P	
IV	Building Information Modelling I		R	R	
V	Building Information Modelling II		R	B	P
	Construction Technology I		R	B	P
	Environmental Engineering		R	B	P
VI	Construction Technology II		B	B	R
	Sanitary Engineering		B	B	R
VII	Electromechanical Engineering		B	A	B
X	Sustainable Infrastructures			S	S
Semester	**Topic**	**Specific Competency**			
		Design, Coordination and Planning	**ICT, Software and Technology**	**Project Management**	**Engineering Knowledge**
III	Graphical Engineering	P	P		
IV	Building Information Modelling I	R	R		P
V	Building Information Modelling II	R	R		R
	Construction Technology I	R	R		R
	Environmental Engineering	R			R
VI	Construction Technology II	B	B		B
	Sanitary Engineering	B	B		B
VII	Electromechanical Engineering	A	B		B
X	Sustainable Infrastructures	S			S

**Notes:* P = Pre-formal, R = Receptive, B = Basic, A = Autonomous, S = Strategic.

Regarding the generic competencies, teamwork was developed between semesters III and VII. Students are expected to use BIM software and collaborative platforms in the form of cloud-based solutions managed by the AECO industry, enabling students to work in collaborative environments. The research competency is developed across the curriculum until reaching the strategic level in semester X [4], involving the completion of practical tasks [63], in which research methodologies are encouraged to explore current construction issues associated with the application of BIM. The development of this competency is also supported by the use of collaborative platforms, which facilitate the sharing of novel information among students. From semester V to X, the innovation competency is trained through activities that involve implementing, applying, and designing new technologies.

When it comes to specific competencies, design, coordination, and planning are enhanced through various BIM software that aid in teaching and learning discipline-specific content like design, budgets, and schedules. This teaching-learning process is intertwined with ICT, software, and technology competency, which is also trained from semesters III to VII. Additionally, starting from semester IV, the development of engineering knowledge competency commences as students begin to identify structural elements at a pre-formal level, progressing to understanding the economic, social, and environmental aspects of efficient infrastructure at a strategic level, which is achieved by semester X.

After the matrix above was established, the syllabi were adapted, considering the BIM topics and related software that needed to be included. This process took the BIM dimensions as a reference: 3D, 4D, 5D, and 6D [17]. As the students' progress within the construction area, they learn about the different BIM dimensions that are aligned to the different stages of a construction project: geometric construction of projects for the 3D dimension, schedule management for the 4D dimension, cost management for the 5D dimension, and sustainability analysis and building performance for the 6D dimension. The 5D initiates within the construction area but is further complemented with cost-related subjects, such as construction project management.

The information models developed within the construction area topics are later used in the topics of other areas of the civil engineering program, fostering collaboration throughout the curriculum, as suggested by [16]. Table 5 presents the topics where BIM has been implemented within the construction area and the corresponding software used. It also illustrates the interrelationship between the topics and BIM dimensions, along with a proposal for BIM software and platforms.

Table 5. Interrelationship matrix between topics BIM dimensions with a BIM software and platform proposal

Semester	Topic	BIM Dimension	BIM Software and Platforms					
			Revit Architecture	Revit Structure	Revit MEP	Civil 3D	Navisworks	BIM 360
III	Graphical Engineering	3D	X					X
IV	Building Information Modelling I	3D	X	X				X
V	Building Information Modelling II	3D/4D/5D	X	X				X
	Construction Technology I	3D/4D	X			X	X	X
	Environmental Engineering	6D	X		X			X
VI	Construction Technology II	3D/4D/5D	X	X		X	X	X
	Sanitary Engineering	3D	X		X			X
VII	Electromechanical Engineering	3D	X		X			X
X	Sustainable Infrastructures	6D	X		X			X

Later, the main contents regarding each topic were determined following the proposed BIM dimensions, as shown in Table 6. The construction area uses BIM 3D, a valuable tool for teaching and learning about construction elements and processes through models and information. Additionally, it is supported by BIM 4D, which enables the understanding of the planning and organization of these processes. Concerning BIM 5D, students are introduced to the topic of project costs visually, allowing them to connect geometric and numerical concepts associated with investment. Finally, BIM 6D introduces sustainability and energy efficiency concepts into the model in the environmental engineering and sustainable infrastructure topics [64].

Table 6. Topics and contents for BIM implementation in the construction area

Topic	Content	BIM Dimension
Graphical Engineering	Introduction to the architectural preliminary project	3D
	3D Modelling	
Building Information Modelling I	Representation of 3D elements	3D
	Start of architectural project	
	Architectural project development	
	Structural drawing reading	
	Start of structural projects	
	Structural project development (foundation)	
	Structural project development (structural elements)	
	Use of Common Data Environment	
	Quantities	
Building Information Modelling II	Project–Structural and Civil Engineering	3D/4D/5D
	Project of reinforced concrete structures (foundation)	
	Project of reinforced concrete structures (columns and plates)	
	Project of reinforced concrete structures (beams)	
	Quantities of structural elements	
	Reinforced concrete structure projects	
	Structural steel project (structural elements)	
	Structural steel project (details and quantities)	
Construction Technology I	Provisional works, safety and health, preliminary works	3D/4D
	Earthworks	
	Foundations and reinforced concrete elements	
	Formwork, placement of concrete on site and reinforcing steel	
	Wood formwork and masonry units	
	Construction planning	
	Finishes in construction	
Environmental Engineering	Environmental impact study	6D
	Surrounding definitions	
	Use of weather data and thermal block	

(Continued)

Table 6. Topics and contents for BIM implementation in the construction area *(Continued)*

Topic	Content	BIM Dimension
Construction Technology II	Origin and formation of Soils	3D/4D/5D
	Surface Foundations and Deep Foundations, soil as a building material	
	Slopes and excavations, buried and retaining structures	
	Earthworks	
	Longitudinal profile and cross sections	
	Analysis and interpretation of the most important parameters in an EMS	
	Quarrying	
	Equipment for civil works, conditions that affect performance	
	Equipment	
	Heavy machinery yields	
	Dams	
	Tunnels	
	Bridges	
	Pre-drilled systems	
	Prefabricated systems	
Sanitary Engineering	Drawing preparation and reading	3D
	Cold water system	
	Hot water system	
	Impulsion equipment for the supply of water in buildings, classification, types	
	Fire system	
	Wastewater disposal	
	Drawing preparation and reading of drainage installations	
	Rainwater Collection and Evacuation Systems	
	Installation of drainage to public networks	
Electromechanical Engineering	Electrical installations drawings	3D
	Unifilar diagram and selection of conductors	
Sustainable Infrastructures	Environmental sustainability analysis of buildings	6D
	Building Energy Model (BEM)	
	Definition of construction systems	
	Ventilation and Refrigeration	
	The link between BIM and BEM models	
	Energy cost analysis	
	Building performance improvement	

Use of collaborative platforms for class activities: ICT is a fundamental pillar within higher education, as the new generation of students are digital natives. They are related to the success of the teaching-learning processes since they include benefits such as interactivity [65], flexibility [66], and easier access to information [67]. Thus, as part of the BIM implementation, the professors also used collaborative platforms to properly monitor students' performance within the classroom environment throughout the semester. These platforms permitted storing the evolution of each student's process, facilitating the assessment and personalization of the learning process [68]. Additionally, the platforms provided digital support that promoted peer learning by allowing the sharing of knowledge, ideas, and experiences [69] while promoting debate.

Therefore, these platforms helped to develop and reinforce the generic competency of teamwork from the pre-formal to the basic proficiency level, as well as the specific competency of ICT, software, and technology from the pre-formal to the basic level.

Professor training programs: To train students in BIM methodology, it was necessary to have professors with advanced knowledge in this area since they are the managers of this change, as reported by [43, 70]. Since launching the civil engineering program this study belongs to in 2017, training programs have been designed to prepare the professors' staff to use BIM methodology and software. Some examples of the training programs that were developed are presented in Table 7.

Table 7. BIM professor training programs

Program
Module I: Introduction to BIM Methodology, using Autodesk Revit Architecture Tools
Module II: Using the Autodesk Revit Architecture Tool: Terrain Modelling, Materials
Module III: Using Autodesk Revit Architecture tools, 2D model, 3D model, 4D model, 5D model, print formats
Basic AutoCAD
Revit Structure: Structure Modelling
3D Modelling Applied to Courses
BIM Modelling applied to a Civil Engineering Program
BIM 360 Platform
Energy analysis in BIM models

The first three modules shown in Table 5 provide an introduction to BIM. These modules may use Revit Architecture tools, encompassing 2D, 3D, 4D, and 5D modeling, terrain modeling, materials, and print formats. They serve as the initial exposure to BIM for educators with limited BIM knowledge. The Basic AutoCAD program covers the fundamentals of computer-aided drawing and modeling. Subsequently, a Revit Structure program is recommended, focusing on structural elements and information generation. The following program may entail applying BIM principles to civil engineering topics and utilizing collaborative work platforms. Lastly, an energy analysis program equips individuals with the skills to ensure project quality and sustainability.

Establishment of student organizations: Student organizations are groups of students managed as autonomous non-profit organizations. Within these organizations, students take on various roles, including president, coordinator, and manager [71]. Encouraging group training in research and developing generic competencies such as teamwork and effective communication through student interactions is recommended [72, 73]. Therefore, student organizations can help strengthen the generic and specific competencies outlined in this study.

The students of the civil engineering program proposed a BIM student club: *Círculo de Estudios* Building Information Modelling (CEBIM), under the supervision of professors from the Construction Area. The objectives of this organization were to encourage students to research national and international benchmarks of BIM methodology, study BIM methodology, promote research about the implementation of BIM within different engineering fields, and explore the impact of the methodology on society.

To achieve this, CEBIM, with the guidance of professors, developed activities involving students from various universities and institutions in Peru. Some examples of these activities, which were organized and included the participation of the members, are shown in Table 8.

Table 8. Activities developed by the CEBIM

Activity	Type
"Getting to know civil engineering student organizations"	Launch event
"Importance of programing in civil engineering"	Presentation and workshop
"Importance of the ISO 19650 series for construction"	Presentation and workshop
"Importance of the standardization of BIM plan in Peru"	Presentation and workshop
"Bim projects planning according to the ISO 19650"	Presentation and workshop
"BIM management for engineering development"	Presentation and workshop
CEBIM meetings	Weekly meetings
"First BIM Peru Student Symposium"	Symposium
"Getting to know civil engineering student organizations"	Launch event
CEBIM meetings	Weekly meetings

As seen in Table 6, CEBIM has hosted a launch event every year to present the activities and objectives of their organization, aiming to attract more members. Additionally, the students held weekly meetings throughout the semester with all the members. During these meetings, they organized integration activities, shared information about BIM and related technologies, and informed members about the research or modeling teams they could join.

An example of a major event that involved collaboration with the AECO industry took place in 2021. CEBIM organized its inaugural large-scale event, the BIM Peru Student Symposium, with other Peruvian universities. The symposium featured the involvement of professionals from the AECO industry who shared their experiences.

Development of a BIM application project: The BIM application project was developed by students as an integral part of the construction area curriculum. Students utilized BIM methodology and tools to collaborate on a project that included a research exercise [63]. The assignment required the application of concepts learned throughout the semester to analyze and propose improvements for a construction project. This project departed from previous studies by incorporating BIM into its development.

This BIM application project was a group activity developed throughout the entire semester, integrating knowledge from various topics within the construction area, in a practical manner. The project's core focused on contributing to and achieving the United Nations' SDGs, specifically SDG 9: Industries, Innovation, and Infrastructure. The objective of this SDG is to construct resilient infrastructure and minimize the environmental impact of construction [74].

The BIM application project aims to enhance research skills such as defining objectives and scope, managing bibliographic sources, identifying problems, conducting state-of-the-art research, and mastering writing and citation, all within the realm of BIM contents. In this project, the generic competencies of teamwork and research were trained from a pre-formal level, aligning with the Graphic Engineering topics from semester III. The topics within the construction area elevated the proficiency level and initiated the development and reinforcement of the competency of innovation. Specific competencies such as design, coordination and planning, ICT, software, and technology were emphasized [3].

Furthermore, students could present these BIM application projects at a civil engineering program event called Research Expo, where the best research proposals from all program subjects were showcased [63]. Table 9 indicates that in 2020, 18 projects were displayed at the Research Expo, with 10 of them falling under topics related to the construction area. In 2021, five projects from the area were exhibited out of 12 in total, and in 2022, there were three out of 10.

Table 9. Construction Area exhibited projects at the Research Expo from 2020 to 2022

Topic	2020			2021			2022		
	Exhibited	From the Area	Area Winner	Exhibited	From the Area	Area Winner	Exhibited	From the Area	Area Winner
Graphical Engineering					1			1	1
Concrete Technology		2			2			1	
Building Information Modelling II		2			1	1			
Construction Technology I		1							
Environmental Engineering		1							
Materials Technology		2							
Construction Technology II		1				1			
Sanitary Engineering		1			1				
Electromechanical Engineering								1	
Total	18	10	0	12	5	2	10	3	1

The results of developing and reinforcing generic and specific competencies within the construction area may be supported by the number of research projects awarded from the Researc Expo, as also shown in Table 7.

Additionally, students were able to present their BIM application projects at external student contests. For instance, Sanitary Engineering projects were showcased at Cities: Vision 030, organized by the sustainability center of the *Universidad de Lima* with the backing of the United Nations system in Peru. One of the projects, titled "MEP Project of a multi-family building that uses artificial wetlands for wastewater treatment in streams", took third place.

Area and subject meetings: To coordinate all efforts related to BIM implementation within the construction area, weekly meetings are conducted for professors, with an average attendance of 90%. These one-hour sessions cover various topics such as general coordination of the civil engineering program, enhancement plans, and strategies for BIM integration across the program. Specifically, strategies include utilizing the latest software version, new tools, shortcuts, and enhancements; fostering collaborative work through project application; enhancing assessments through collaborative environments; and utilizing new tools for the CDE.

4.2 Validation

Curriculum proposal: The methodology described earlier was designed to align with the civil engineering program at a Peruvian higher education institution. This methodology was validated through an indexed publication detailing the curricular design [3]. The design encompasses an admission profile, graduation profile, academic areas, study plan, curriculum, teaching and learning methods, assessment methods, technology and infrastructure, and profiles of professors. The construction area is specifically one of the academic areas outlined.

Thus, the methodology with the six mechanisms described was designed as part of the curricular proposal. Therefore, it needed to be validated at an institutional level through several stages. First, the methodology was approved by the Academic Committee of the civil engineering program. Second, it was reviewed by the Engineering Faculty. Later, it was submitted to the *Dirección Universitaria de Servicios Académicos y Registro* (DUSAR) and, finally, to the Chancellorship for final approval. Additionally, the curricular proposal was validated by the *Superintendencia Nacional de Educación Superior Universitaria* (SUNEDU), the national body that regulates higher education and ensures its quality in Peru.

Professors' participation: To effectively implement BIM within the construction field, participation in BIM training programs for professors was encouraged. These programs enabled the professors to recognize the advantages of BIM methodology and tools in construction education. Initially, the programs covered the fundamentals of BIM and later delved into specific topics of interest for the professors. This approach helped address concerns expressed by the faculty regarding the perceived complexity of using BIM software, leading to an increase in attendance as the civil engineering program progressed. It was crucial for the faculty to gain practical experience with BIM, and these programs offered support and boosted their confidence in utilizing the technology [43, 70].

Furthermore, the attendance was high, as presented in Table 10. The table also indicates that, of the professors who attended all nine training programs, on average, 100% successfully completed the programs.

Table 10. Professors' attendance to BIM training programs

Program	Professors Invited	Professors Attending	Professors with an Approving Grade
Module I: Introduction to BIM Methodology, using Autodesk Revit Architecture Tools	6	5	5
Module II: Using the Autodesk Revit Architecture Tool: Terrain Modelling, Materials	5	5	5
Module III: Using Autodesk Revit architecture tools, 2D model, 3D model, 4D model, 5D model, print formats	4	4	4
Basic AutoCAD	5	5	5
Revit Structure: Structure Modelling	6	6	6
3D Modelling Applied to Courses	6	5	5
BIM Modelling applied to a Civil Engineering Program	10	8	8
BIM 360 Platform	13	13	13
Energy analysis in BIM models	13	11	11

New students' enrollment: Regarding new students, specifically freshmen, the numbers indicate a high acceptance rate within the context. Figure 1 illustrates the growth in the number of students enrolled in the civil engineering program annually from 2017 to 2023.

A distinguishing feature suggested by the civil engineering program in this study is the integration of BIM throughout the curriculum. This inclusion attracts new students to enroll, as BIM offers a novel approach to learning [41]. Additionally, a swift transition into the workforce is a key attraction for potential students and professionals, given that BIM expertise is currently in high demand in the AECO industry [75].

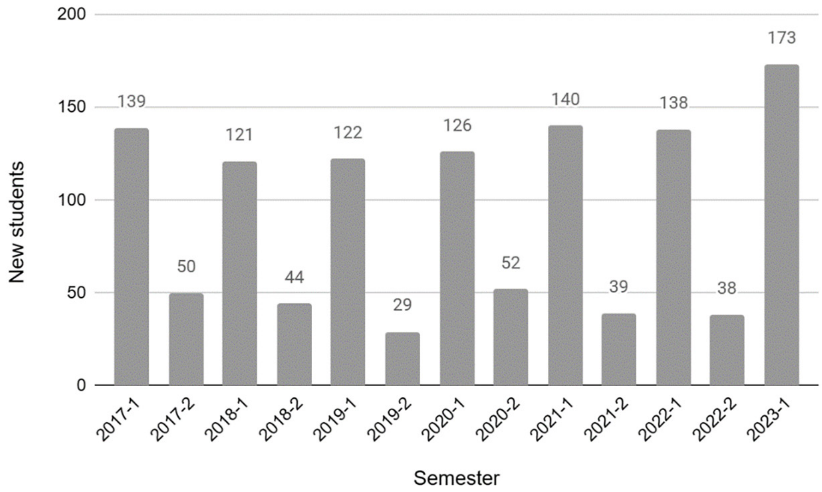

Fig. 1. Number of new students per semester enrolled in the civil engineering program

Figure 1 illustrates the number of students accepted into the program by semester. Typically, the first half of the year sees a higher influx of new students enrolling in the program, resulting in a significant disparity in the number of new freshmen between the first and second semesters. Using the first semester of each year as a benchmark, in 2017, the civil engineering program with a focus on BIM was introduced, garnering significant interest and leading to 139 new students joining the program. In 2018, enrollment slightly decreased, but numbers saw a rapid increase in 2019, continuing through 2020 and 2021, despite reports indicating a decline in participation in higher education programs during the years of the COVID-19 pandemic [76]. The surge in numbers could be attributed to the flexibility offered by online environments, the interactive nature of digital tools, the customization of teaching-learning processes, and the ease of information sharing, facilitated by collaborative methodologies and platforms that enabled remote learning in higher education to be more accessible to potential students [77]. The peak enrollment figure corresponds to the 2023-1 semester, as in-person classes resumed, supporting pedagogical goals, social interaction, and engagement in blended learning [78].

These numbers are also a result of proper dissemination and visibility of the program, which is supported by strategic alliances with major international and national organizations from industry and the state, such as the Global Resilience Institute, the Stanford Center for Professional Development, the Peruvian Ministry of Economy and Finance, the *Instituto Nacional de Defensa Civil*, and *the Instituto Nacional de Calidad*, among others.

Graduates' employability: From the first, second, and third cohorts of graduate students (totaling 84 bachelor's degree recipients) who completed their studies in

December 2021, July 2022, and December 2022, 67% (56 bachelor's degree recipients) are currently employed within two years of graduation.

From the first group of students (29 bachelors) who completed their studies in December 2021 and graduated in July 2022, 76% (22 bachelors) are employed. Similarly, from the second group of students who completed their studies in July 2022 and graduated in December 2022, 62% (18 bachelors) are employed. Lastly, from the third group who completed their studies in December 2022 and graduated in July 2023, 62% (16 students) are employed. These percentages are illustrated in Figure 2.

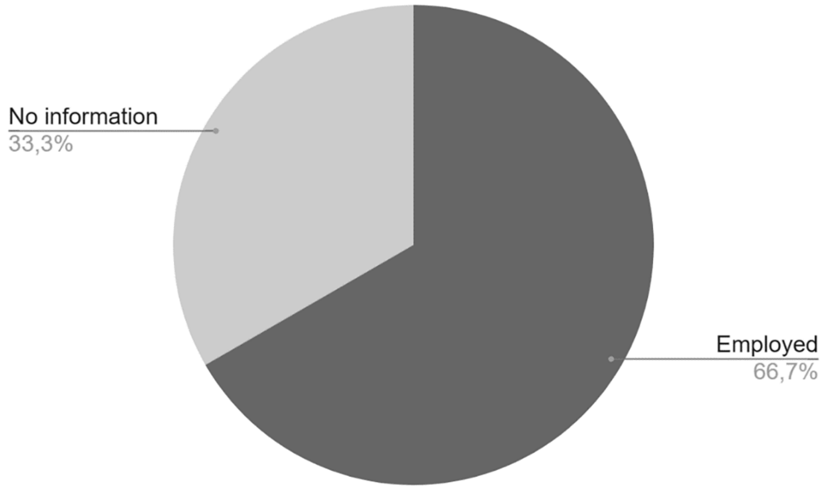

Fig. 2. Percentage of employed bachelors (December 2021, July 2022 and December 2022) from the civil engineering program

Furthermore, of the 67% employed, 61% (34 bachelors) are employed in BIM-related roles, as shown in Figure 3. Some of the most common roles are BIM modeler, BIM assistant, BIM coordinator, and BIM manager, which highlights the AECO industry's demand for BIM professionals. These positions involve daily tasks such as creating and updating BIM and as-built models, providing project-specific information, communicating with stakeholders, coordinating across disciplines, identifying clashes, overseeing on-site activities, and producing construction-related documentation directly from BIM models.

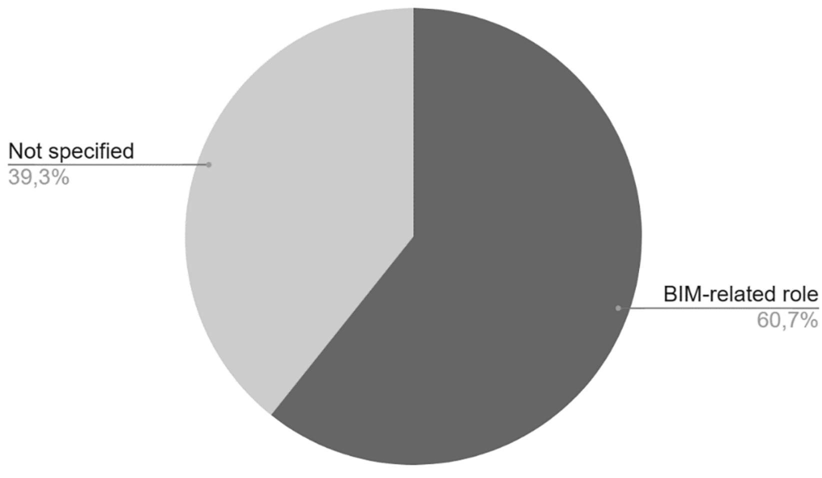

Fig. 3. Percentage of employed bachelors in BIM-related roles (December 2021, July 2022 and December 2022)

Finally, the employment rates reveal a positive reception for the labor market and recognition within the group of stakeholders, as the employers are transnational, international, and national enterprises of the AECO industry. Therefore, embedding BIM in the curriculum prepares students for a complex and changing workforce, as universities seek to contribute positively to labor outcomes by providing students with experiences as close to the "real world" as possible [79, 80].

Research results: The civil engineering program is dedicated to conducting impactful research. Students are actively engaged in the GIRC Program [4] from the early stages of their education. Consequently, they undertake their final degree project as a research paper eligible for publication in an indexed journal. Out of 16 graduates who have presented their final degree project, nine (56%) have successfully authored and published research papers. The topics explored include the utilization of BIM models for construction optimization, Virtual Design and Construction (VDC) [81], and time and process optimization, underscoring the significance of BIM in the construction sector.

As for the professors, they also conduct research. Within the *Laboratorio de Simulación*, they develop projects on topics such as BIM norms, photogrammetry, artificial intelligence, virtual reality, and augmented reality, all related to applications in BIM. Several research papers out of the these research topics have been published in indexed journals.

Students' perceptions: A survey was conducted to explore students' perceptions about BIM implementation within the construction area and its relationship with developing and reinforcing competencies. The questionnaire was divided into two sections: Subject Design and Teaching-Learning Methodology.

In the statement regarding the utility and relevance of the presented content, which is related to BIM, for their professional training, 49.2% of the total surveyed students strongly agreed with it, 42.4% agreed, and 3.4% were undecided. None of the students disagreed, and only 5.1% strongly disagreed, as shown in Figure 4. This could be explained by the students' awareness of BIM's expansion and growth within the AECO industry [16].

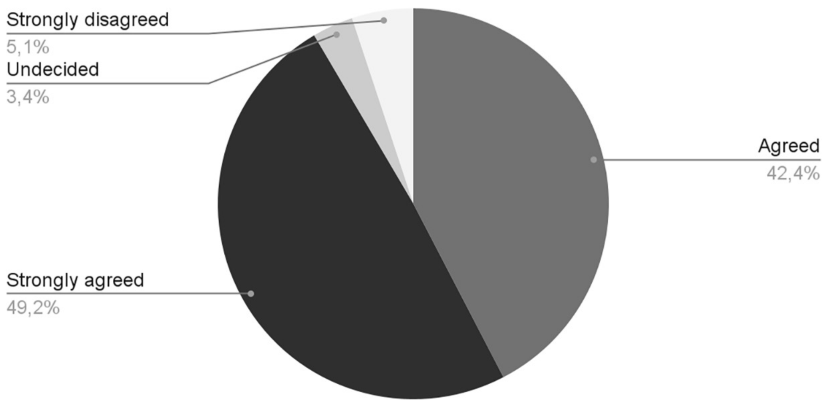

Fig. 4. Students' perceptions upon the utility and actuality of the presented content within the construction area subject

Figure 5 presents the results regarding whether the application of the BIM methodology has contributed to the development of students' teamwork competency. 42.4% of the surveyed students strongly agreed with this statement, 44.1% agreed, and 6.8% were undecided. Since BIM is a collaborative methodology that involves stakeholder coordination, teamwork, and effective communication are promoted [14].

Only 3.4% disagreed, and 3.4% strongly disagreed. Furthermore, concerning the statement about the utility of BIM software for understanding theoretical construction concepts, which is linked to engineering knowledge competency, 40.7% of the total surveyed students strongly agreed, and 47.5% agreed. BIM models facilitate the comprehension of areas such as design fundamentals, building technology, programming, and modeling concepts [12]. Only 5.1% were undecided, 1.7% disagreed, and 5.1% strongly disagreed, as illustrated in Figure 6.

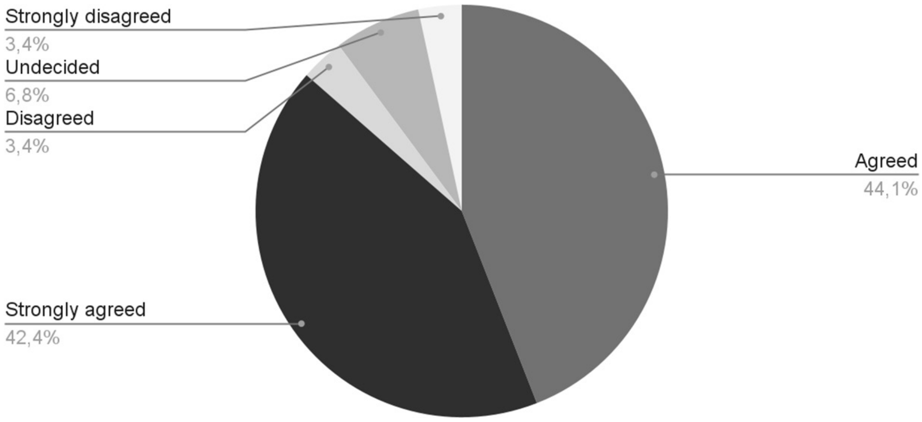

Fig. 5. Students' perceptions upon BIM contribution to the development of teamwork competency

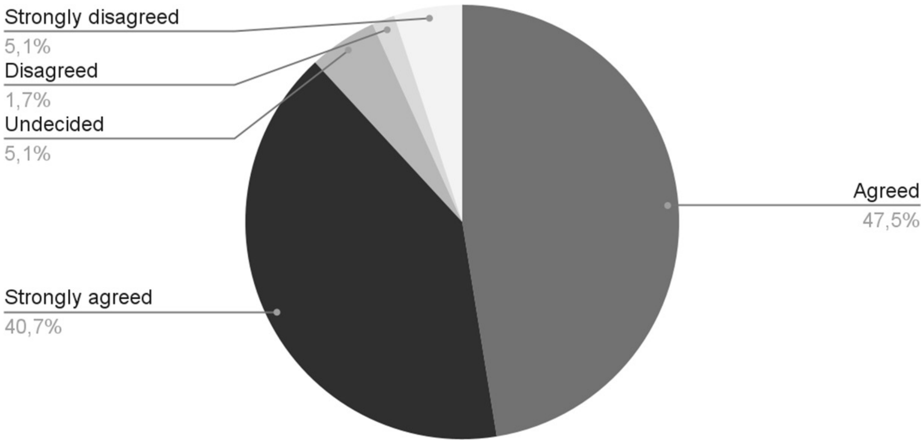

Fig. 6. Students' perceptions of the utility of BIM software to the development of engineering knowledge competency

In this study, 47.5% of the surveyed students strongly agreed with the idea that project-based learning (PrBL) supported by digital tools helped them understand theoretical concepts practically, while 40.7% agreed that PrBL supports learning experiences, enabling students to engage with real-world problems [46]. Only 5.1% were undecided, 1.7% disagreed, and 3.4% strongly disagreed. Additionally, 57.6% of the surveyed students strongly agreed, and 33.9% agreed that implementing PrBL in other subjects from the civil engineering program would enhance the learning process. Only 3.4% disagreed with this statement, no students disagreed, and 5.1% strongly disagreed.

About students' perceptions of the development and reinforcement of generic and specific competencies within the construction area, Figure 7 shows the results.

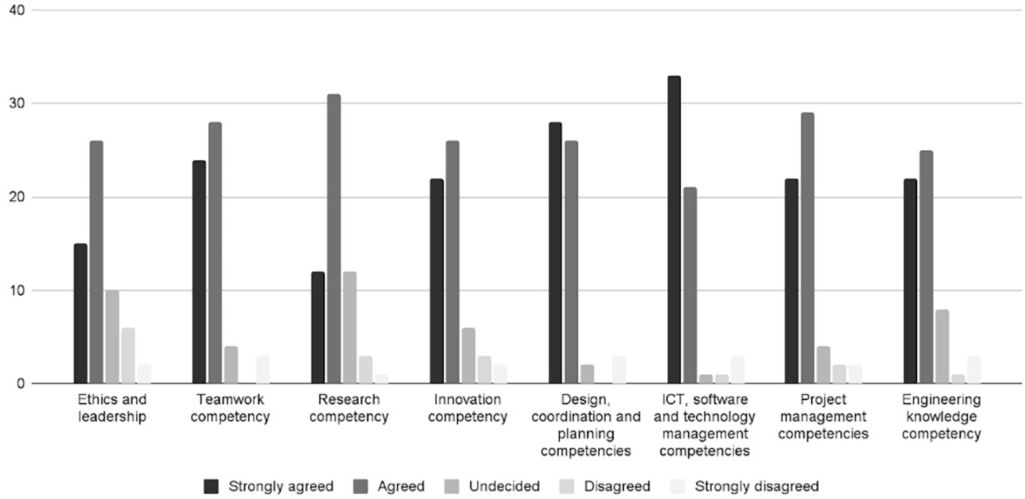

Fig. 7. Students' perceptions of competencies development and reinforcement within the construction area

Regarding the generic competencies of ethics and leadership, 25.4% of the surveyed students strongly agreed, and 44.1% agreed that the teaching-learning methodology helped them to develop and reinforce these competencies. In comparison, 16.9% were undecided, 10.2% disagreed, and only 3.4% strongly disagreed. BIM supports the training of generic competencies in leadership and mentoring [12]. Furthermore, 40.7% of the surveyed students strongly agreed about teamwork competency, and 47.5% agreed that BIM encourages a collaborative work environment [14]. Only 6.8% were undecided, none of the students disagreed, and 5.1% strongly disagreed.

Additionally, 20.3% of the surveyed students strongly agreed, 52.5% agreed, 20.3% were undecided, 5.1% disagreed, and only 1.7% strongly disagreed that the teaching-learning methodology supported the training of the research competency since research is encouraged for proposing solutions to significant problems related to constructive processes [46]. Finally, 37.3% of them strongly agreed, 44.1% agreed, 10.2% were undecided, 5.1% disagreed, and only 3.4% strongly disagreed that it helped them develop and reinforce the innovation competency. BIM promotes critical and systematic thinking so that students may recognize opportunities for improvement [14].

Regarding the specific competencies, 47.5% of the surveyed students strongly agreed, 44.1% agreed, 3.4% were undecided, none disagreed, and 5.1% strongly disagreed with the statement that the teaching-learning methodology helped them develop the design, coordination, and planning competencies. Certainly, BIM facilitates design, construction, and operation processes [8]. Moreover, 55.9% of all students strongly agreed, 35.6% agreed, 1.7% were undecided, and 5.1% strongly disagreed that it helped them to train the ICT, software, and technology management competency since BIM relies on graphic and non-graphic information to compose digital representations [9].

Regarding the development and reinforcement of project management competency, 37.3% of the surveyed students strongly agreed that the teaching-learning methodology supported it, 49.2% agreed, 6.8% were undecided, and 3.4% disagreed and strongly disagreed. BIM has been adopted by the AECO industry specifically for project management [10]. Finally, 37.3% of the surveyed students strongly agreed, 42.4% agreed, 13.6% were undecided, 1.7% disagreed, and 5.1% strongly disagreed that the methodology enabled the training of engineering knowledge competency.

Indeed, BIM tools provide a digital and interactive environment that helps in understanding construction processes [42].

Students' motivation was also measured, as shown in Figure 8. Regarding whether the subjects motivated students to learn, 39.0% strongly agreed, 47.5% agreed, 5.1% were undecided, 1.7% disagreed, and 6.8% strongly disagreed. Concerning whether the subjects motivated students to prepare before the classes to participate in their development, 28.8% strongly agreed, 40.7% agreed, 18.6% were undecided, 6.8% disagreed, and only 5.1% strongly disagreed. This may be because construction field topics that interest civil engineering students are considered [27].

When asking students whether subjects motivated them to work as a team, 47.5% strongly agreed, 35.6% agreed, 10.2% were undecided, no one disagreed, and only 6.8% strongly disagreed. Furthermore, 42.4% strongly agreed that the subjects motivated them to meet the learning objectives, 45.8% agreed, 5.1% were undecided, none disagreed, and 6.8% strongly disagreed. Finally, regarding whether the subjects motivated students to apply theoretical knowledge in practice, 44.1% strongly agreed, 40.7% agreed, 8.5% were undecided, 1.7% disagreed, and 5.1% strongly disagreed.

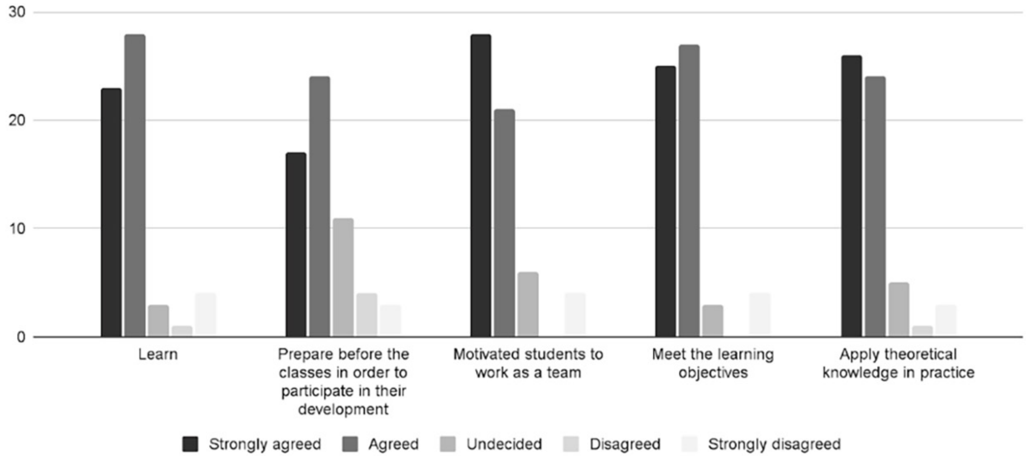

Fig. 8. Students' motivation upon the teaching-learning methodology within the construction area

5 CONCLUSIONS

In the context of developing and solidifying BIM-related competencies in the construction area within an undergraduate civil engineering program, six mechanisms were designed and implemented: (1) integration of BIM into topics and syllabi; (2) use of collaborative platforms for class activities; (3) professor training programs; (4) establishment of student organizations; (5) development of a BIM application project; and (6) area and subject meetings. The integration of BIM into topics and the corresponding syllabi required significant effort from the faculty to ensure that BIM-related competencies were incorporated across the curriculum, aligning with civil engineering discipline-specific contents effectively. The validation process, involving professors, enrollment rates, employability, and research outcomes, as well as the curriculum proposal and students' feedback, demonstrated that the implemented mechanisms effectively supported the development and enhancement of BIM-related competencies.

Challenges in effectively implementing BIM within the construction area include the issue of collaboration among university authorities, faculty, professors, and other stakeholders. The reluctance to embrace change is a common limitation within higher education institutions. Providing BIM training for professors has proven to be crucial, as they must acquire competencies that were not part of their academic and professional training, including ICT, software and technology management, teamwork, research, and innovation. Additionally, collaborative efforts have been essential, as professors' expertise and confidence in their knowledge directly impact students' learning and development.

Regarding the students, they mostly agreed that the teaching-learning methodology within the construction area helps them to develop and reinforce both generic and specific competencies. 69.5% perceived that it supports the ethics and leadership competency, 88.2% the teamwork competency, 72.8% the research competency, and 81.4% the innovation competency. As for the specific competencies, 91.6% thought the methodology supports the design, coordination, and planning competency; 91.5%, the ICT, software, and technology management competency; 86.5%, the project management competency; and 79.7%, the engineering knowledge competency.

In this context, acquiring knowledge of BIM as an undergraduate student can have a substantial impact on the student's employability. In fact, within the sample analyzed in this study, 61% of the students who are currently employed work in positions and environments related to BIM. Given that the AECO industry has been rapidly embracing BIM methodology to enhance project development, the demand for professionals equipped with BIM expertise is expected to increase significantly in the labor market in the coming years.

In addition, it should be noted that students showed great curiosity upon their initial exposure to BIM in the early stages of the program. They believed that it would help them enhance their 3D perception and apply it to construction-related subjects. As the program progressed, professors observed that students who had a solid understanding of BIM found it easier to grasp construction concepts. This is because BIM offers robust 3D visualization tools that are seamlessly integrated with 4D time simulation.

Therefore, it would be most valuable for future studies to measure graduates' perceptions to analyze if their BIM training has granted them advantages compared to their peers without this knowledge. Additionally, applying quantitative research techniques, such as a survey, and qualitative ones, such as interviews or focus groups, to the employers of graduated students may provide invaluable insights about the impact of embedding BIM in the construction area within an undergraduate civil engineering curriculum. It would also be necessary to explore BIM implementation within other training areas of civil engineering programs, such as structures, surveying, geotechnics, and project management.

6 ACKNOWLEDGMENT

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7 DECLARATION OF INTEREST STATEMENT

The authors reported no potential conflict of interest.

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9 AUTHORS

Alexandre Almeida Del Savio has a Ph.D. in Civil Engineering from the Pontifical Catholic University of Rio de Janeiro, a mentor certificate in Virtual Design and Construction (VDC) from Stanford University, and over 22 years of experience. He is a Researcher and Full Professor of the Civil Engineering Department and Head of the Scientific Research Institute at *Universidad de Lima*. He is particularly interested in VDC, BIM, Integrating Project Delivery (IPD), Integrated Concurrent Engineering (ICE), Project Production Management (PPM), civil engineering competency-based curriculum, Project-Based Learning (PBL), construction automation and industrialization, construction technology, transportation, computer vision, artificial intelligence, and machine learning.

Katerina Galantini Velarde is a Doctoral Candidate in Higher Education by Universidad de Palermo. She is a Master in Education by *Universidad Femenina del Sagrado Corazón* and architect by *Universidad de Lima.* She is a professor for the Architecture Faculty and a researcher for the Scientific Research Institute at the *Universidad de Lima,* Peru. Her research interests include undergraduate research training, undergraduate curriculum design and management, engineering and design pedagogy, and formative assessment (E-mail: kgalanti@ulima.edu.pe).

Ana Felicita Luna Torres is a Doctoral Candidate in Science and Civil Engineering at the *Universidad Nacional de Ingeniería*. She is a civil engineer and Master in Civil Engineering. She is a professor and researcher at *Universidad de Lima.*

Jose Roberto Salinas Saavedra is a Master in Construction Management by *Universidad Peruana de Ciencias Aplicadas* and *Universidad Politécnica de Catalunya Barcelona*. He is a civil engineer, professor and researcher at Universidad de Lima.

Mónica Alejandra Vergara Olivera is a Master's in Project Management student at *Universidad ESAN*. She is an architect, researcher and a teaching assistant at *Universidad de Lima.*