Integrating BIM in Industrial Engineering programs. A new strategy model

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Abstract: The implementation of the BIM in the AEC sector, both in companies and in academic institutions, is taking place mainly through the knowledge and handling of the software that makes its implementation possible. There are several public and private initiatives that provide professionals with workshops, courses, degree programs and even master’s programmes oriented towards knowledge of the BIM methodology. These are aimed at all types of professionals, from qualified technicians to unskilled labour. In order to achieve a truly successful implementation of BIM, it is important not to focus only on the technological perspective, but to base it on the human aspects involved in the methodology. Working the skills is as important, if not the most, as using the tools. It is the attitude of the professionals that will determine a successful integration. This paper brings together research works on the state of higher education in Spain in industrial engineering programmes related to BIM and the required competencies. Educational guides and also the needs of the sector are reviewed. New roles and skills demanded are also analysed. The implementation strategies and academic barriers found when integrating BIM methodology in higher education are studied in depth. Finally, the paper presents a model proposal that includes the main lines of work to integrate BIM so that the training of future graduates will be effective for the sector.

Keywords: BIM, Higher education, Industrial Engineering, BIM roles and competencies, Effective integration strategy.

1. Introduction

The Building Information Modelling (BIM) methodology is a response to the need for modernization and digitalization of the Architecture, Engineering and Construction (AEC) sector. It is a collaborative work methodology based on the existence of a single digital model in construction projects, buildings or infrastructures, which is shared by the different participating agents, for their management, throughout the entire life cycle.

This remarkable transformation of the sector implies, among other consequences, that higher education is aligned with the new professional demands that will appear in the market. Therefore, it is the responsibility of the universities to train new profiles adapted to the new requirements, both in terms of knowledge and skills. The BIM methodology is not only a necessity for professionals in the sector,
but also a teaching and pedagogical tool that can allow the acquisition and encourage the work of reinforcing certain competencies of the teaching guides of subjects with BIM content.

The integration of the BIM in recent years is being chaotic and asymmetric and where the technical aspect is playing an important role without taking into account the cultural dimension of this methodology. Therefore, there is a lack of evidence of the importance of considering cultural and emotional aspects in the implementation of BIM methodology in the training of present and future professionals. Working the skills is as important, if not the most, as using the tools. The paper presents a model proposal that includes the main lines of work to integrate BIM so that the training of future graduates will be effective for the sector.

2. Research methodology

The line of research followed has been based on knowing the state of the implementation of BIM in higher education in Spain, focusing the information on industrial engineering programs; knowing the implementation strategies followed both at national and international level, looking for support in successful cases that could sustain the proposal for implementation; knowing the barriers that higher education has found at an international level to achieve successfully implement the BIM methodology; learning about the competencies that are taught in higher education in industrial engineering programs in Spain; and knowing the competences that the sector demands from new professionals who develop their work in the field of this methodology.

We have sought to establish a basic knowledge of the methodology so that it could be understood in its entirety, and then to focus the search for information on aspects related to education and training in BIM, following the basic research pillars mentioned above. In this sense, an attempt has been made to contextualize the situation of BIM at the national and international level by seeking reference points in the most advanced countries in its implementation.

2.1. BIM in the national and international context

Various papers and documents referring to the implementation of the BIM methodology have been found in different schools and universities in Spain. Its inclusion in the different curricula has been carried out from different platforms. The approach to the issue has been carried out through transversal workshops, such as at the University of Alicante [1], integrative workshops at the University of Seville [2] and immersion training programs for teachers at the Polytechnic School of Cuenca [3], the inclusion of the fundamentals of the BIM methodology in undergraduate subjects [4], the inclusion of the BIM methodology in construction masters [5], specific masters on BIM (Polytechnic University of Madrid, International University of La Rioja, University of Granada,...), development of own degrees (University of Oviedo, University of Seville,...), etc. All of them having as a common denominator the technical and technological aspect of the implementation of the methodology.

The level of BIM training provided by various higher education institutions is improving year by year worldwide, with universities increasing the offer of courses in this area. A growing number of countries report that their educational institutions are already providing some form of BIM training. However, analyses in countries such as Australia, Canada and the United Kingdom have indicated that educators face many challenges in integrating BIM into the curriculum. These include the challenges of incorporating additional learning materials into already crowded curricula or converting theoretical subjects into multi-disciplinary subjects with smaller, team-based groups of students.

On the other hand, BIM education is moving in the right direction, driven by higher education institutions in the different countries, thus improving the connection between the education system and the industry. This coordination will help to meet the needs of the industry. It will provide a skilled workforce with the required BIM collaboration skills.

There are many degree programs that support the AEC sector, including Civil Engineering, Architecture, Architectural Engineering, Construction Engineering and Construction Management [6]. However, it is remarkable that very few of them have incorporated BIM content into their curricula. The challenge is that most universities do not understand what skills are needed in the construction sector.
One of the most successful proposals is to gradually cover most topics from the undergraduate level to later graduate courses and where the development of BIM skills will be carried out in a progressive and incremental way. However, it should be noted that it is not possible to cover all subjects, mainly due to time constraints. It is understood that some of them may be suitable for integration of BIM into other courses where teaching can be done in classrooms that enable teamwork [8]. The implementation of Project Based Learning (PBL), to provide students with the opportunity to work in groups and therefore have the possibility of practicing aspects of collaborative work, is shown as an effective solution [9]. In any case, the options for incorporating the BIM into higher education go through four routes recognized by researchers [10]: a) teach BIM through courses or workshops, b) introduce a new BIM-focused degree, c) restructure an existing degree program to include the BIM methodology, d) integrate BIM into the curricula of an existing AEC degree.

2.2. Barriers to BIM integration

Many problems were found in the implementation of BIM in the AEC sector due to the different barriers that prevent the effective adoption of the BIM methodology [11]. Some of these barriers are quite simple to remove, while others might be considered impossible to mitigate. There are numerous studies available in the literature to identify these barriers to adoption of BIM in the construction industry in different countries. For a better understanding and comprehension of the barriers, an in-depth analysis of the barriers encountered at the time of implementation should be carried out. All identified barriers can be grouped into three relevant categories (table 1): product-related, process-related and people-related.

| PRODUCT | PROCESS | PERSONS |
|---------|---------|---------|
| • interoperability | • changing work processes | • new roles |
| • different views of the BIM | • risks inherent in the use of a single model | • training |
| • poor user-friendliness | • legal issues | |
| | • personal and particular interests of the agents involved | |
| | • initial costs | |

But the difficulties in implementing BIM are not only practical but also educational. It is necessary to distinguish between barriers and obstacles in the implementation of BIM in both directions. In any case, the main problems that teachers may find when implementing BIM training in their curricula are concentrated in

- How to fit the new topics into an already saturated curriculum.
- Resistance to changing teaching habits established over time.
- Resistance to taking on a new subject in which teachers are not experts or to retraining in a field in which they are unfamilar.
- Finding an overwhelming feeling when trying to keep up with rapidly changing technologies.
- Lack of time available for teachers to prepare to handle and teach the multitude of software packages available in each of the topics covered with BIM.
- Lack of resources to convert theoretical courses into multidisciplinary practical classes/workshops that require fewer students.

2.3. BIM roles and competencies in demand

The adoption of the BIM in AEC sector companies is generating the emergence of new roles and relationships among participating members of development teams [12]. Roles do not define a new discipline; they are not a position but responsibilities for certain actions that must be carried out
throughout the project's life cycle. One person may perform more than one role and a role may be performed by more than one person. Roles can be carried out by existing people within a team when they are trained to do so. When adopting BIM, it is essential that people are adequately trained in the use of the new methodology so that they can contribute to the changing work environment. It is important to keep in mind that training is an essential part of the process for successful BIM implementation. All members involved should be experts in the use of BIM in relation to their specific field and assigned role.

Most companies that do not use BIM believe that training would be too expensive in terms of time and human resources [13]. Furthermore, they understand that the issue of training is the biggest obstacle to the adoption of BIM in companies due to the costs of change, since decisions are made mainly based on the business perspective of making profits. The AEC sector has generally not been very interested in investment due, among other reasons, to the lack of studies on the subject showing the potential financial benefit of BIM. There is also a usual resistance to change. Many architects are aware of and satisfied with their current design tools and work processes and are sceptical of the benefits of this new technology. This means that some stakeholders are not interested in learning how to use the tools associated with BIM. And this is where academic training plays a major role.

To do so, it is essential to identify the new roles that are emerging in the construction sector as a result of the job opportunities offered by the BIM methodology and that are developed in the construction process. Habits, behaviour and persistence of the corporate culture are often underestimated when BIM is introduced into the way a company operates. Working with BIM requires employees to develop different skills and a change in mindset. The new activities that are generated can be added to the existing job description, but they certainly lead to new production and management roles. In fact, today's professionals themselves do not agree on exactly what each BIM role does, and companies generate their own roles. They do this based on generic standards, although it should not be forgotten that there is usually a traditional role structure in place before the BIM. BIM roles have to fit into the pre-BIM role structure, which is not always easy to do.

In order to identify training needs, the measurement of skills must be complemented by their degree of usefulness. To this end, the assessment of competencies must be carried out from a dual perspective: the importance or relevance that they have to the world of work, and the satisfaction with those competencies. The most valued competencies are theoretical, practical, cognitive, personal management, instrumental, interpersonal and attitude and professional ethics skills.

3. Proposal model

The integration strategy proposed in this paper is based on establishing, as a first step, an implementation model that can be complemented with future initiatives. These potential actions will be, in a second phase, based on changes to curricula and the incorporation of specific topics or postgraduate courses on BIM methodology.

This model aims to launch a BIM Implementation Plan (BIP) integrating subjects from the four courses of the degree with the challenge of not changing their syllabuses, desired competences and expected learning outcomes, but with a teaching load that reinforces the BIM skills that each subject contains in its guide. Considering BIM as an essential skill [14] implies that it should be taught early in engineering school as a central component of a student's ability to communicate graphic information. BIM can significantly improve the planning quality and efficiency, not only for conventionally but also for additively manufactured building components [15].

The analysis and study of national and international cases provided the basis for the design of the implementation model that will be proposed, helping to define the strategy to be followed. The integration of BIM information, to cover all the BIM concepts throughout the different courses, will be done gradually by suggesting a progressively development of the student in the acquisition of BIM competences. It will be important to define the skills and abilities that the student must acquire throughout the process, as well as the knowledge that will be progressively taught, so that at the end of the Plan, the success of the integration of the BIM methodology achieve can be evaluated. In any case,
the fundamental characteristic of work in everything related to the BIM environment, and which should be encouraged in each participant, will be the maintenance of an unequivocal attitude of multidisciplinary collaboration supported by project-based learning. This will require collecting information from both students and teachers at the outset, analysing this information and assessing the effectiveness of the implementation.

This model of progressivity in academic integration will overcome the current lack of training of teaching staff in BIM methodology and technology, which is also one of the main pillars of the implementation of the methodology. Six main backbones have been considered to carry out the proposed implementation of the BIM methodology:

- The academic commitment of the different areas involved in the BIM methodology Implementation Plan is necessary, so that transversality is reinforced by cooperation between all the teachers who will teach the subjects with BIM content. Similarly, explicit support from the management is required to motivate the teaching staff.
- Likewise, coordination of resources is required, basically at the application level, which will allow the structured development of the proposed contents throughout the process, as those subjects must be provided with the necessary material resources.
- Specific training of teachers must be carried out so that they can be sufficiently competent in the methodological teaching proposed. This section is not only limited to the knowledge of materials and tools specific to BIM technology, but also to the methods and practices that make them competent in the application of the strategy.
- It is necessary to offer students an incentive scenario that reinforces their motivation to participate, throughout the different courses of the degree, in an integrated project that replicates as faithfully as possible a real construction project.
- From the very first moment, surveys must be established for the evaluation and monitoring of the BIM Implementation Project, which will be compared with similar data collected from students currently studying the subjects that will be involved.
- The continuous and rapid development of the BIM methodology and the technology requires for its implementation makes it necessary to establish an observatory of practical implementation experiences in other universities. This will allow for the updating and feedback of the implementation project itself, so that it can serve as a reference for possible adaptations and improvements of the integration methodology. The creation of a BIM technical commission (BIM Board) is considered appropriate and essential to coordinate the implementation and to guide possible new paths.

The BIM Implementation Plan is designed as an extra-academic, transversal and voluntary participation activity in which, as a final objective, the participants will be able to live, as main actors, the experience of developing a constructive project in a real way by applying the BIM methodology. At the end of the whole process, those students who have proposed it will also have the knowledge and material necessary for the development of a Final Degree Project (FDP).

To help promote the skills of a collaborative environment, which is the basis of the BIM methodological concept, it is proposed to create a "BIM Classroom" (figure 1) in which participation is extended to all students, including first-year students. The proposal is based on the subjects of the Mechanical Engineering Degree of the University of Oviedo. This will facilitate their integration into the work in progress by enabling active participation from the outset, so that their possible contributions can serve as individual motivation and stimulation of the whole team. The more advanced the student is in the courses, the more active their participation will be. With this approach, it was decided to consider BIM not as a specific subject or topic, but as a basic communication skill among future graduates.
The BIM Implementation Plan is also designed as an activity supported by play-based learning techniques. The application of game-based learning strategies to education is intended to help students achieve the motivation to become involved in the activities of a subject. It is understood that the generation of BIM competitions should be carried out through the involvement of external professionals in the process. These new teammates may participate as co-tutors of the projects. This dynamic may
activate the participative stimulus. The possibility of contacting or participating in a team that contacts professionals in the sector from the earliest stages of academic life should be another incentive for student participation in the Plan. Participation can also be encouraged by the establishment of a credit validation programme.

The BIM Implementation Plan is based on the creation of an inter-area BIM Commission that coordinates from the beginning the subjects to be taught and the distribution of the work areas (designs, calculations, planning, costs, ...) and the roles that each of the participants will assume. To this end, it will be necessary to take into account the progressive incorporation of knowledge and skills of the students participating in the work teams, since the complete cycle of the BIM Implementation Plan will not be completed until the fourth year of implementation.

4. Conclusions

All of the above assumptions have led to the following final conclusions:

- The adoption of the BIM methodology in the teaching projects of Spanish universities is not yet very significant, especially when compared to Central European countries, being almost irrelevant in the Spanish Schools of Industrial Engineering. It is the Schools of Architecture, Building Engineering and Civil Engineering that are leading this process. This low implementation of the BIM methodology shows a great lack of knowledge on the part of teachers that must be solved through coordinated actions that allow their involvement in the process as subjects inexorably necessary for their success.

- Successful experiences in implementing the BIM methodology at the international level are based on three key factors: awareness of all actors in the educational system to BIM; implementation of gradual teaching of the concepts and incremental learning of BIM competencies through project-based learning methods; and training of students according to market expectations.

- The heterogeneity of curricula, in general, and their assignment of competencies in subjects related to the BIM, in particular, demonstrates a significant gap in the focus of skill needs and demands within the world of work. Interpersonal skills must be an essential key focus in a methodology that acquires a high degree of awareness in collaborative and multidisciplinary processes. The integration of the BIM methodology must be used as a vehicle tool that not only transfers knowledge to students, but also helps to fully develop the expected skills which, on the other hand, in most cases are already part of the syllabuses.

- The need to manage change becomes evident. Approaches to implement BIM methodology in the university must be strategic, firstly, and operational, secondly. Among other objectives, the aim is to minimize the effect of graduates’ perception of the differences between the academic and working world as being enormous after completing their studies and beginning their professional careers in the AEC sector. There is no doubt that there are still opportunity frameworks that can mitigate the delay in the full incorporation of BIM in the University. This should not prevent an implementation plan such as the one proposed in this paper from being put in place an effective, solid manner and with institutional commitment.

- Six necessary conditions have been identified without which the implementation of the BIM methodology will not achieve the expected success in the medium term: academic commitment, coordination of available resources, specific teacher training, student incentives, self-evaluation of the process and monitoring of other implementations. The objective is to replicate the real needs of the construction industry so that graduates finish their studies with a high understanding of the work carried out under BIM methodology.

References

[1] Piedecausa-García B, Pérez-Sánchez VR and Mora-García RT 2017 Empleo de metodologías BIM en asignaturas de construcción en el Grado de Arquitectura Técnica EUBIM 2017:
[2] Nieto E, Rico F, Antón D and Moyano JJ 2017 Metodología BIM en el grado de edificación: modelo de taller en la asignatura Expresión Gráfica de Tecnologías Building & Management 1 pp 37–47

[3] Cañizares JM, Alfaro J, Valverde D, Martínez JA and Pérez P 2017 Experiencia docente de integración de metodología BIM para el concurso BIM Valladolid 2016 EUBIM 2017: Congreso Internacional BIM / 6º Encuentro de Usuarios BIM pp 86–95

[4] Valverde D, Cañizares JM, Márquez D, Pérez, P and Peso R 2016 Implementación BIM en la Escuela Politécnica de Cuenca. Experiencia piloto en Proyectos Técnicos 2015-2016 EUBIM 2016: Congreso Internacional BIM / 5º Encuentro de Usuarios BIM pp 34–45

[5] Cos-Gayon F 2016 Experiencia de implantación de metodología BIM en el plan de estudios del Máster Universitario de Edificación de la UPV EUBIM 2016: Congreso Internacional BIM / 5º Encuentro de Usuarios BIM pp 13–22

[6] Abbas A, Ud Din Z and Farooqui, R 2016 Integration of BIM in construction management education: an overview of Pakistani Engineering universities Procedia Engineering 145 pp 151 – 157.

[7] Sacks R and Pikas E 2013 Building information modeling education for construction engineering and management I: Industry requirements, state of the art, and gap analysis Journal of Construction Engineering and Management 139 (11)

[8] Yan, Wei. 2010 Teaching Building Information Modeling at Undergraduate and Graduate Levels Proceedings of Conference of Education and Research in Computer Aided Architectural Design in Europe Zurich pp 91–99

[9] Ahmed A, McGough D and Austin S 2013 Integration of BIM in Higher Education: Case Study of the Adoption of BIM into Coventry University's Department of Civil Engineering, Architecture and Building Sustainable Building and Construction Conference (SB13) Coventry University pp 394–403

[10] Ghosh A, Parrish K and Chasey A 2013 From BIM to collaboration: A proposed integrated construction curriculum American Society for Engineering Education (ASEE) Annual Conference pp 618.1–618.9

[11] Mandhar M and Mandhar M 2013 Biming the architectural curricula – integrating building information modelling (BIM) in architectural education International Journal of Architecture 1 (1) pp 1–20

[12] Gu N and London K 2010 Understanding and facilitating BIM adoption in the AEC industry Automation in Construction 19 (8) pp 988–999

[13] Yan H and Demian P 2008 Benefits and barriers of building information modelling Proc. 12th Int. Conf. on Computing in Civil and Building Engineering Beijing

[14] Sacks R and Barak R 2009 Teaching Building Information Modeling as an Integral Part of Freshman Year Civil Engineering Education Journal of Professional Issues in Engineering Education and Practice 136 (1) pp 30–38

[15] Paolini A, Kollmannsberger S and Rank E 2019 Additive manufacturing in construction: A review on processes, applications, and digital planning methods Additive Manufacturing 30