International Journal of Engineering Education Vol. 33, No. 2(A), pp. 712–722, 2017
Printed in Great Britain

0949-149X/91 $3.00+0.00

The Implementation of Building Information Modeling Technology in University Teaching: The Case of the Polytechnic University of Madrid*

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The purpose of this research is to analyze the degree of competence in using and understanding Building Information Modeling (BIM), of construction undergraduates at the Polytechnic University of Madrid, from the beginning of their degrees until they get their first jobs. In order to achieve this, a survey was carried out of students from the four Construction Engineering year groups. The analyzed sample comprised 336 students (approximately 25% of all those registered). The results obtained indicate that the level of knowledge about BIM is less than 43% whilst 18% claim that they do not know what it is for. Despite the low percentage of knowledge, there is a high level of motivation, given that more than 98% of those surveyed express an interest in learning how to use it. Meanwhile, the absence of regulations, the lack of development of standard protocols of action and the perceived lack of profitability from using the tool during the period of education contribute towards students putting off learning it.

Keywords: building information modeling; BIM implementation; BIM teaching; curriculum development; construction education

1. Introduction

Less than a decade ago, the concept of Building Information Modeling (BIM) in Spain was confined exclusively to very specific knowledge and research institutions or to companies with important projects abroad. BIM implementation has gained considerable momentum over the past few years. A key factor has been the importance of coordinated government support and leadership[1] as a critical driver for BIM implementation, not only nationwide through the ENISA[2] [1], but also in the creation of international standards [2]. Fortunately, talking about BIM technology in Spain is no longer rare, but we still have a long way to go. It is only to be expected that certain factors, such as for example, the increasing pressure from investors to reduce construction costs, will serve to promote its widespread use [3].

Currently, the process of convergence towards this new technology is gradually becoming standardised [4–6]. Professionals from the construction world accept that it is necessary to use this tool, and numerous companies and architect's offices started to implement it some years ago [7, 8]. Various research projects based on surveys distributed amongst academics and construction professionals working on BIM projects [9, 10] reveal, among other things, three critical barriers to BIM implementation: a lack of BIM standards, a lack of BIM awareness and a fierce resistance to change amongst the majority of its potential users. What is clear is that BIM is changing the way projects are constructed. This emerging practice requires new mindsets and technological know-how in order to achieve significant improvements in building efficiency [11]. Professional, organisational and educational institutions have started to adopt BIM software tools and to adapt their existing delivery systems with the intention of satisfying evolving market requirements [12].

The implementation of this model will imply a revolution in the way many Spanish professionals work, given that they currently only use a few computer programs and learning BIM represents a complicated uphill race for them. That said, the finishing line for the aforementioned race is closer than we would like, since European regulations have set out dates that must be fulfilled [6, 13]. At the present time, the level of implementation in Europe is low and this is partly due to the fact that there is no need to take on projects which make BIM a mandatory requirement. This is reflected in the annual survey that has been carried out since 2011 in the United Kingdom [14], considered to be one of the most advanced examples of the implementation

[1] Spanish Ministry of Public Works' es.BIM Agenda for the promotion of the use of BIM in the professional and educational spheres.
[2] ENISA: National Innovation Company is a public company that is dependent on the Spanish Ministry of Industry, Energy and Tourism.

* Accepted 20 November 2016.

of the BIM methodology in Europe [10]. In fact, the implementation of BIM technology in the field of construction should stimulate the integration of the different roles of all of the players participating in a construction project. This integration will create a balance between all of the interlocutors and result in greater efficiency in the tasks performed between the technicians who, until recently, related to each other as competitors or rivals [7, 15]. Meanwhile, this globalisation process in building activity causes certain previously insurmountable obstacles to disappear, such as standardisation processes, so as to increase stiff competition within the sector, not only with local competitors, but also international ones, which may have developed better capabilities and greater experience in the use of BIM [16].

The purpose of this research is to analyze the degree of competence in using and understanding BIM of construction undergraduates from different year groups at the Polytechnic University of Madrid (Spain). Furthermore, the evolution of the student's competences has been studied from the beginning of their time at university until they get their first job. The results obtained will soon help other universities, companies, professionals and legislators to establish the different timeframes in which this obligation is imposed, by referring to the preparation of future construction technicians who are currently at university.

2. BIM methodology in Spanish university teaching

Despite the commercial interest in the BIM methodology, the academic communities of some countries are acting more conservatively when it comes to its adoption [17, 18]. During the process of adaptation to the European recommendations on the compulsory use of digital systems in the design and bidding processes for building projects financed using public funds for 2016 [13], a parallel initiative to raise the awareness of teachers should have existed at Spanish universities, implementing a series of disciplines resulting in the acquisition of skills and competences necessary to future construction technicians and professionals, not only at an individual level, but also at a collaborative level [19–21]. Furthermore, the economic crisis and the new change to university syllabuses in Europe have led to a significant transformation in degrees, such as that of Technical Architect, with the introduction of the degree in Construction [22], which should have taken the opportunity to increase the aforementioned competences.

Consequently, it seems necessary that universities should adopt BIM as an innovative technology in order to enable students to acquire new skills and prepare them for their future activity in a more competitive world [23]. Universities from countries such as the USA, the United Kingdom and Australia have achieved different levels of implementation [24]. However, in Spain, some universities have started to teach BIM on their courses, but in general the implementation of BIM in university teaching is not common. The Polytechnic University of Madrid is in the process of adopting this new tool.

Given the potential of BIM as a set of tools and techniques to facilitate the construction process [25], it is the right time to address aspects which are as important as education [20, 26, 27]. Despite the fact that most Spanish universities are lacking in awareness of the importance of BIM application, it is essential to introduce BIM tools as compulsory or optional subjects at universities [28]. The adaptation process will be "generational" and somewhat similar to the implementation and use of CAD tools some years ago. In order to achieve optimum results, local experimentation and continuous learning ought to play a central role in the implementation of BIM [29]. Furthermore, in order to guarantee an adequate development of competence, it is essential that the motivation for study is boosted by new learning methods [18, 27, 30].

In the specific case of Construction degrees, there is a need for the progressive implementation of the new tools for processing, generating and managing building data throughout its lifecycle, known as BIM. The introduction of virtual models in the teaching of building design and construction makes it possible to manage and share the information relating to a building throughout its entire lifecycle. Consequently, BIM is considered to be a highly effective tool to incorporate in the teaching of architecture and different types of engineering, since it provides a virtual space for information that enables collaboration between students and construction professionals, for the purpose of improving the design, construction, productivity and maintenance of buildings [31].

3. Procedure

This research was carried out by the lecturers who wrote this article with the support of lecturers from the Building Technology and Architectural Constructions and their Control departments on the Building Degree at the Polytechnic University of Madrid.

The period for carrying out the survey spanned from 4 April until 9 May 2016. The surveyed population amounted to 336 Construction undergraduates at the Polytechnic University of Madrid, out of a total of 1510, which represents a percentage of 22.25% of all the students enrolled. The research

Table 1. Questions contained in the survey analyzed in the article

Question 1 Do you know what BIM (Building Information Modeling) is?
Question 2 Do you think that you should learn how to use a BIM application?
Question 3 Which of the following statements describes the reasons that prevent you from learning BIM?
Question 4 Do you have any information concerning BIM courses?
Question 5 Do you think that you will be a BIM user in the coming years?
Question 6 Would you like BIM to be included on your university CV?
Question 7 Do you think that it is important to learn BIM if you want to work outside Spain?
Question 8 In the event that you have knowledge of BIM, have you used or are you a user of any BIM software?
Question 9 How would you assess your own knowledge of the following BIM applications? Revit, ArchiCAD, Bentley BIM, AllPlan, others
Question 10 What do you use BIM for?
Question 11 What led you to use the BIM application?

covers the four compulsory years leading to the attainment of the Technical Architect degree, from those students who have recently started at the university to those completing their degrees. As such, with the intention of performing a balanced analysis of the data, a sample of the students that is as balanced as possible between the four year groups making up the degree course has been studied. As such, 22.32% of those surveyed belong to the first year, 23.89% to the second year, 27.60% to the third year and 26.19% to the fourth and final year. This last group also includes students who are doing their Final Year Project.

All of the students surveyed voluntarily answered both sides of a document containing eleven questions related to their knowledge about the BIM environment. Given the possible duality of results and so as to make better use of the study, it was decided that the survey should be split into two parts depending on the student's knowledge, or lack thereof, about BIM. As such, the first question serves to channel both possible answers. In the event that the student answers this first question positively, or has a minimum notion of this technology, they will go on to immediately answer questions 7–11; all of these questions being about their command and competence in relation to the different existing BIM programs. In the event that the student being surveyed is not a user or has no clear notion of what BIM is, they must answer questions 2-6; which ask them about their motives for this lack of knowledge and the associated reasons. Table 1 reflects the questions contained in the survey that is analyzed in this article.

4. Results

The overall results for question 1 are that 47.02% of the students surveyed know what BIM is. A detailed analysis of the data suggests that less than half of the Construction undergraduates surveyed have clear and concise knowledge of what BIM technology is and what it is used for. Adding together the number of those surveyed who do not know about BIM and those who have simply heard of it, makes a total of 52.98%. If we analyze the results by year group, Fig. 1, we find that 82% of first year students have knowledge of BIM. In this case, the results were distorted by the existence of a pilot experience for the implementation of the BIM methodology in one of the subjects. Based on this, and analyzing only the second, third and fourth years, the data representing a lack of knowledge of BIM would amount to between the 17.56% offered by the overall result, and 20.45%. In other words, one in five students has absolutely no knowledge about one of the possible work tools that they should use when they start working in the construction industry. It can also be deduced from this analysis that the BIM knowledge index gradually increases as students progress through the course. As such, the percentages increase from 31.25% of all second-year students, to 34.41% of third-year students and end up at 43.19% for fourth-year students. In this final year, when theory tells us that we should see the highest percentage of students with skills in the use of this tool with which to tackle the challenges of new professionals, the percentage of students with a clear lack of knowledge or only a simple notion of what BIM is stands at 56.82%.

Once the degree of BIM knowledge has been determined by those surveyed, they are asked whether they consider it appropriate to learn a BIM application. Fig. 2 shows the results with regard to this question. The results are clear: nine out of ten students surveyed see a clear need to learn BIM tools. These results are reinforced by the fact that almost 11% believe that this learning process, if not immediate, should take place in the near future. This reality results in a figure of more than 98% of the total, which demonstrates a high level of student motivation. Carrying out a study detailed by year group, and cross-referencing data, it is observed that, despite the existence of greater knowledge of BIM applications in the initial years, it is in the final two years, the third and fourth years, where a greater awareness of their use can be detected. This could be due either to the imminent entry of

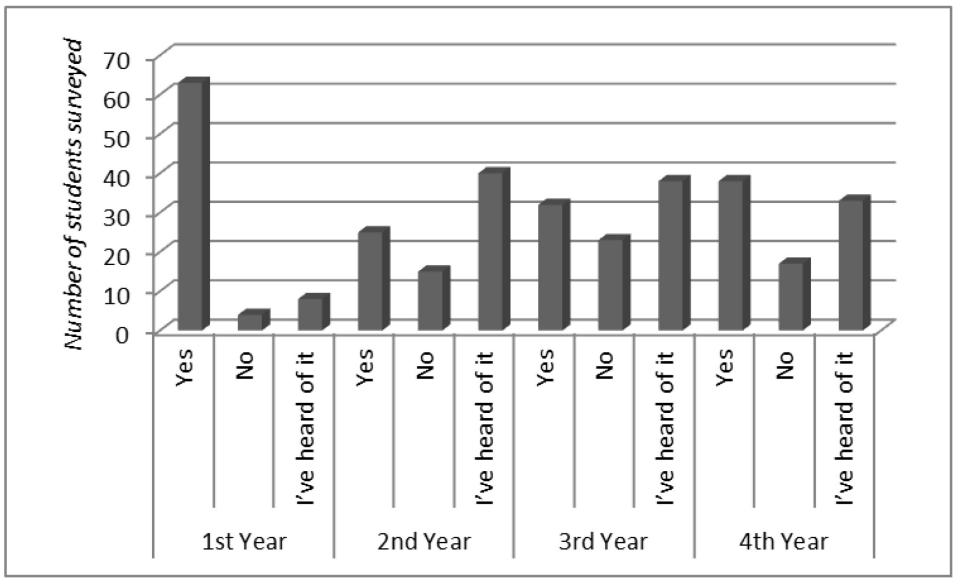

Fig. 1. Distribution of results by year group for question 1: "Do you know what BIM is?".

those surveyed in the job market or the urgent need to be able to use them correctly. Meanwhile, despite the high level of knowledge concerning BIM programs amongst first-year students, their belief that they should learn how to use them is lower than in subsequent years. This could be due to the lack of information about the potential of this kind of programs, or to poor preparation in certain important topics such as, for example, the level of construction know-how.

In the case of those surveyed with little or no BIM knowledge, the survey sought to find out first-hand the reasons why this kind of student, belonging to the Construction department, did not think it appropriate to acquire some knowledge about the BIM environment, particularly when taking into account the high probability that its use will be compulsory in bids for public works [6]. Fig. 3 shows the overall results extracted from the third question. Analysis of the data reveals that more than half of the students asked state that they do not have enough time to acquire basic BIM skills. The figures increase significantly for third and fourth-year students. This circumstance is mainly due to the high teaching load which Construction degree students must endure. The figures studied attract particular attention given that, just as we have seen previously, only 1.4% of the students believe that they will not use it in the future, thereby demonstrating the existence of an extremely high level of awareness concerning the need to use it. This need could be partially met if, throughout the different years, certain curricular subjects were adapted to the BIM environment with the resulting "time saving" for the majority of students in learning BIM.

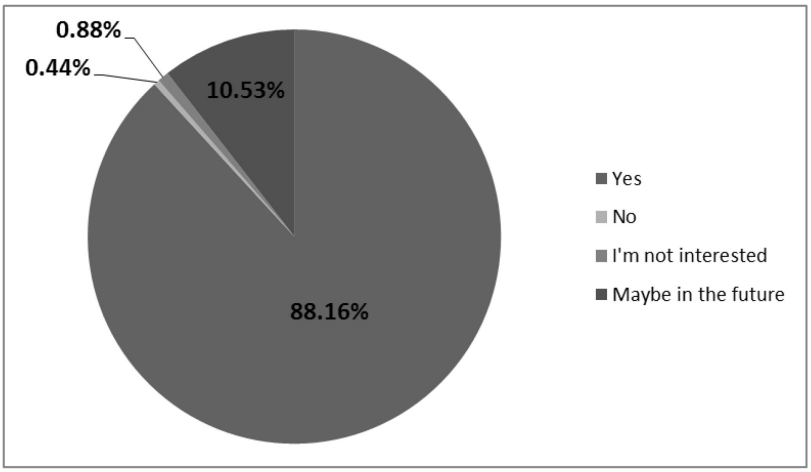

Fig. 2. Overall results for question 2: "Do you think that you should learn how to use a BIM application?" (Percentage of students surveyed).

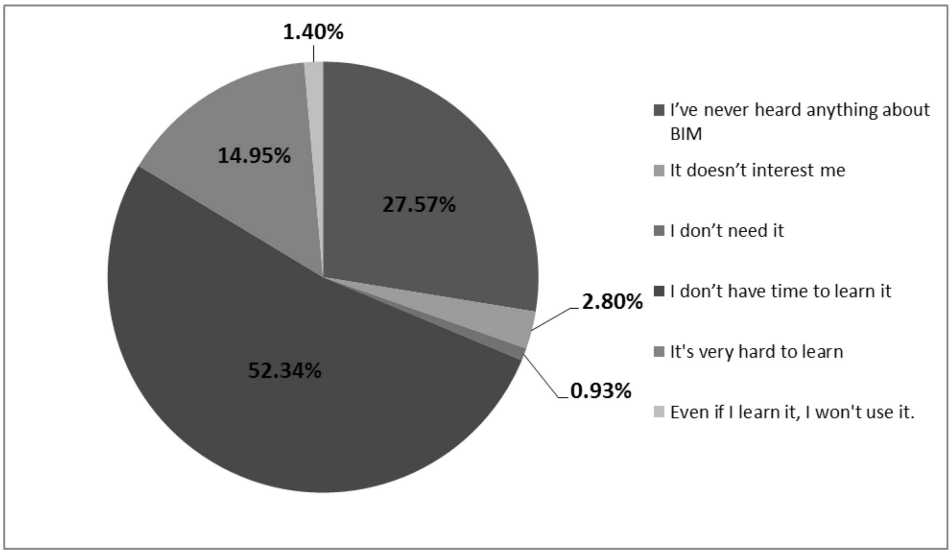

Fig. 3. Overall results for question 3: Which of the following statements describes the reasons that prevent you from learning BIM?" (Percentage of students surveyed).

The absence of BIM on the academic curriculum of the Construction degree is one of the reasons why the majority of students interested in acquiring the aforementioned knowledge attend specific extracurricular courses. This situation was what prompted the drafting of the fourth question on the survey. The responses obtained from the different year groups are very similar. Almost half of those surveyed, 47.09%, were unaware of the existence of external courses, which shows a lack of interest in this respect but, on the other hand, 45.15% view the high cost of these courses as an obstacle, preventing them from enrolling. Once again, this demonstrates that were there a change to the syllabus of certain subjects with the intention of adapting them to the BIM environment, cost would no longer be a barrier to learning. Finally, from the answers analysed, it can be deduced that the vast majority of students have a clear idea that BIM is not a passing trend and that it will probably coexist alongside computer-aided design programs. Once again, the data shows us the high level of awareness that exists among students when acquiring skills in the use and management of this work tool. The fifth question seeks to determine the current forecast of each student with regard to the speed of BIM "self-implementation". Fig. 4 shows the graphs associated to the four year groups surveyed. During the first three years, the students are clear about the need to adapt to learn about and use BIM tools in the medium term (three years). This feeling increases with each year of the degree course. It is in the final year, when the need transforms into an obligation ahead of their imminent entry in the construction job market. The perception of these students is clear: they are aware of their lack of BIM skills and the fact that they have been poorly prepared in this area. The complete lack of knowledge about the need to use BIM technology also attracts particular attention, especially amongst first-year students. Almost one in three students surveyed states that they do not know whether they will really need to learn these kinds of tools. This data shows the scarce information that exists about this kind of professional tools among Construction undergraduates.

The sixth question is the last of this first block. It asks the students about their desire to see BIM tools included in the subjects offered on the Construction degree course. The results are common to all of the year groups and present a clear trend. It is observed that the vast majority, almost 91%, would be in favour of implementing such a change. Another of the consequences that may be extracted from the research is that with each successive year of the course, the number of students who would either not be interested or who are indifferent to this situation rises. This fact gradually increases from 6.06% in the first year, to 13.72%. Obviously, final year students know that they can no longer enjoy the possible benefits of incorporating BIM in their subjects and as such their only wish is to be able to acquire the skills by means of an extracurricular course.

The seventh question is the first in the block which is aimed at those students who have certain notions of BIM. It asks them about whether they consider the fact of possessing certain BIM skills to be important in the event of needing to look for a job abroad. The data in Fig. 5 attracts particular attention, since it is in the first year when the largest percentage of students surveyed consider a command of the BIM environment to be positive when

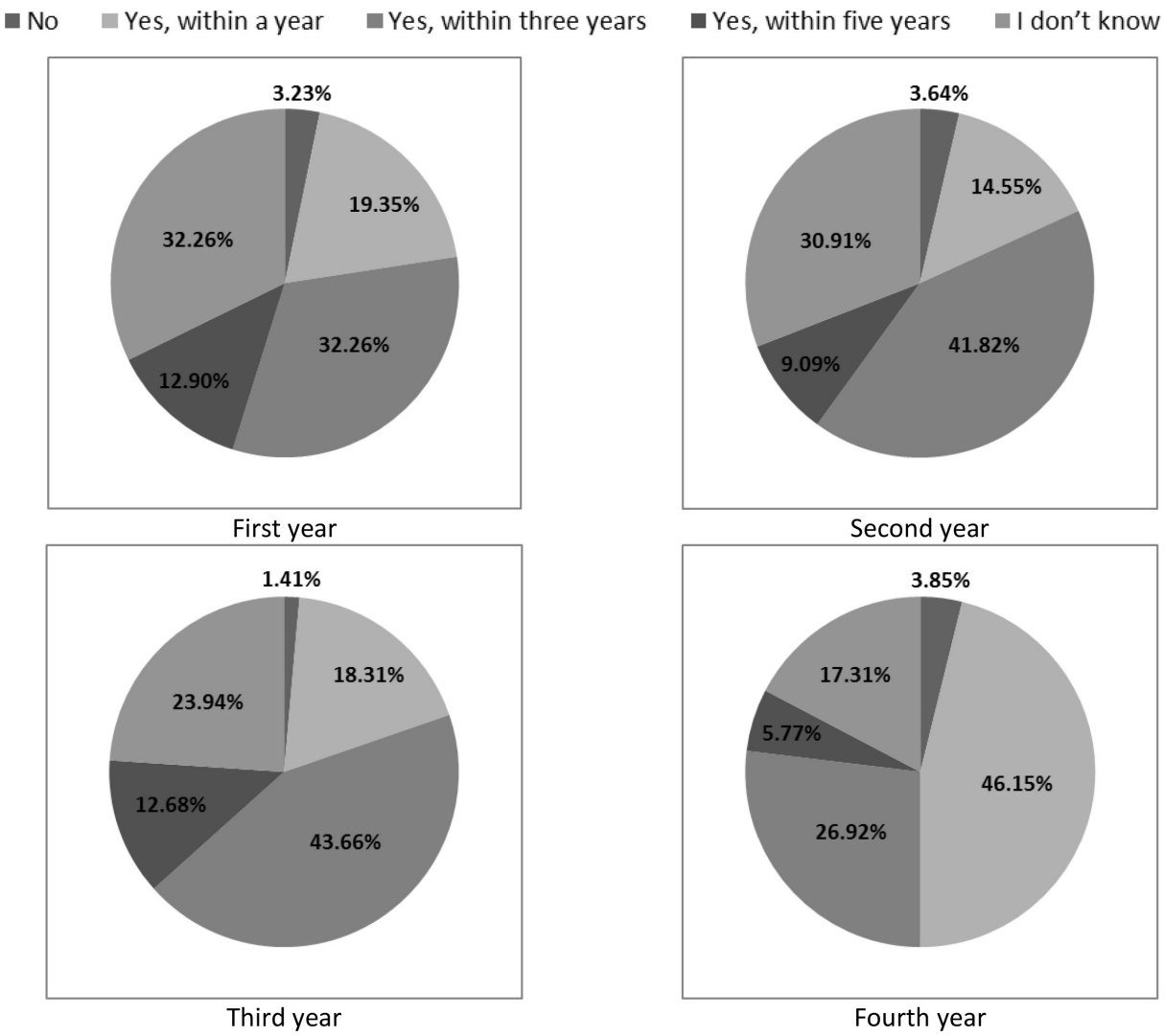

Fig. 4. Results per year group for question 5: "Do you think that you will be a BIM user in the coming years?" (Percentage of students surveyed for each year group).

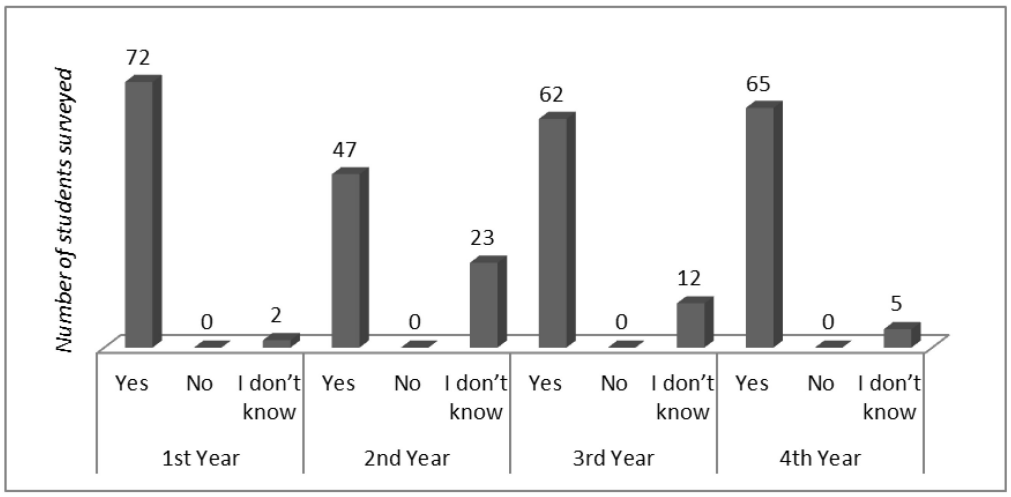

Fig. 5. Results per year group for question 7: "Do you think that it is important to learn BIM if you want to work outside Spain".

Table 2. Overall results for questions 8 and 9: "In the event that you have knowledge of BIM, have you used or are you a user of any BIM software?" and "How would you assess your own knowledge of the following BIM applications?" (percentage of students surveyed).

		Level of expertise				
	Users	Very basic Knowledge	Novice	Intermediate	Advanced	Expert
Revit	63.10	26.06	50.30	15.15	8.48	0
ArchiCAD	5.35	78.23	13.71	4.84	2.42	0.81
Bentley BIM	1.07	97.39	1.74	0.87	0	0
Allplan	2.14	95.76	4.24	0	0	0
Other	4.28	82.98	5.32	5.32	6.38	0
None	24.06			–		

job hunting abroad, with a figure of 97.30%. In other words, virtually all students responded affirmatively to this question. In the second year, 67.14% of students consider learning BIM to be positive for potential job hunting outside Spain, but the degree of uncertainty towards this issue now rises to 32.86%. This data gradually decreases throughout the rest of the degree course until the final year in which the level of indecision in the need for BIM stands at 7.14% of students, the percentage of students who consider learning BIM skills to be positive standing at 92.86%. With regard to the overall results for the four year groups, it is possible to deduce the Construction undergraduates' belief that, if their objective is to apply for a job related to these studies abroad, then they inevitably need to be able to demonstrate professional skills in the BIM area.

The eighth question of the survey is related to the type of software used by those students currently using some kind of BIM tool. There are currently lots of BIM programs which compete with each other to provide the best services to architects and engineers. The students are not asked which BIM software is the best, but rather which is the most commonly used amongst students. Table 2 shows the overall data for the BIM software used. The students surveyed mainly assert that Revit is the principal BIM program. The huge success of this computer package may be due to the fact that Autodesk offers free educational licences to students, educators and educational institutions worldwide. ArchiCAD is the second most commonly used software, but at a considerable distance. Finally, knowledge of the remaining BIM software is practically residual. The majority of students have not even heard of any other software apart from Revit or AllPlan.

The ninth question is directly related to the previous one. It asks the students about their level of competence in using the BIM software with which they are familiar. In order to measure this, they are asked to choose between five possible answers ranging from very basic knowledge, to novice, intermediate and advanced levels; before reaching a level of expert competence. The results reflected in Table 2 demonstrate that with extracurricular learning, none of the students have achieved an expert level in using the BIM environment. What is more, the biggest percentage of students represents those who exhibit basic or very basic skills. In the case of Revit, this percentage stands at 76.36% of its users, this being the most favourable figure of all those obtained, since the other BIM applications stand at more than 90%. Another of the conclusions extracted from the answers to question 9 is that it is among the fourth year students where the best percentages with regards to the use of BIM software are obtained, reaching figures of close to 25% in terms of intermediate and advanced users in the case of Revit.

The tenth question seeks to ascertain which kind of use Construction undergraduates make of their BIM software. Certain studies[3] record as many as 25 different uses for the different phases of a project, from the conceptual idea, through to its execution, and even for defining the sustainability processes derived from the lifecycle of the different materials used. This question seeks to consolidate this kind of use and tries to identify the basic needs which can be met by Construction undergraduates when carrying out their projects. Fig. 6 offers the partial data for each of the year groups. All of them reflect the use of BIM programs as being predominantly for generating architectural plans, followed by structural plans. Amongst final year users, the frequency of use appears to be somehow related to the stages of an architectural project. This course of action is due, principally, to this type of student having greater knowledge about the construction process.

Finally, the eleventh question seeks to pinpoint the motives of those surveyed for starting to learn about and use BIM tools. Fig. 7 reflects the overall results for all year groups. The most common response, representing 44.55%, shows that the stu-

[3] Uses of BIM. Source: Pennsylvania State University—"The BIM Project Execution Planning Guide".

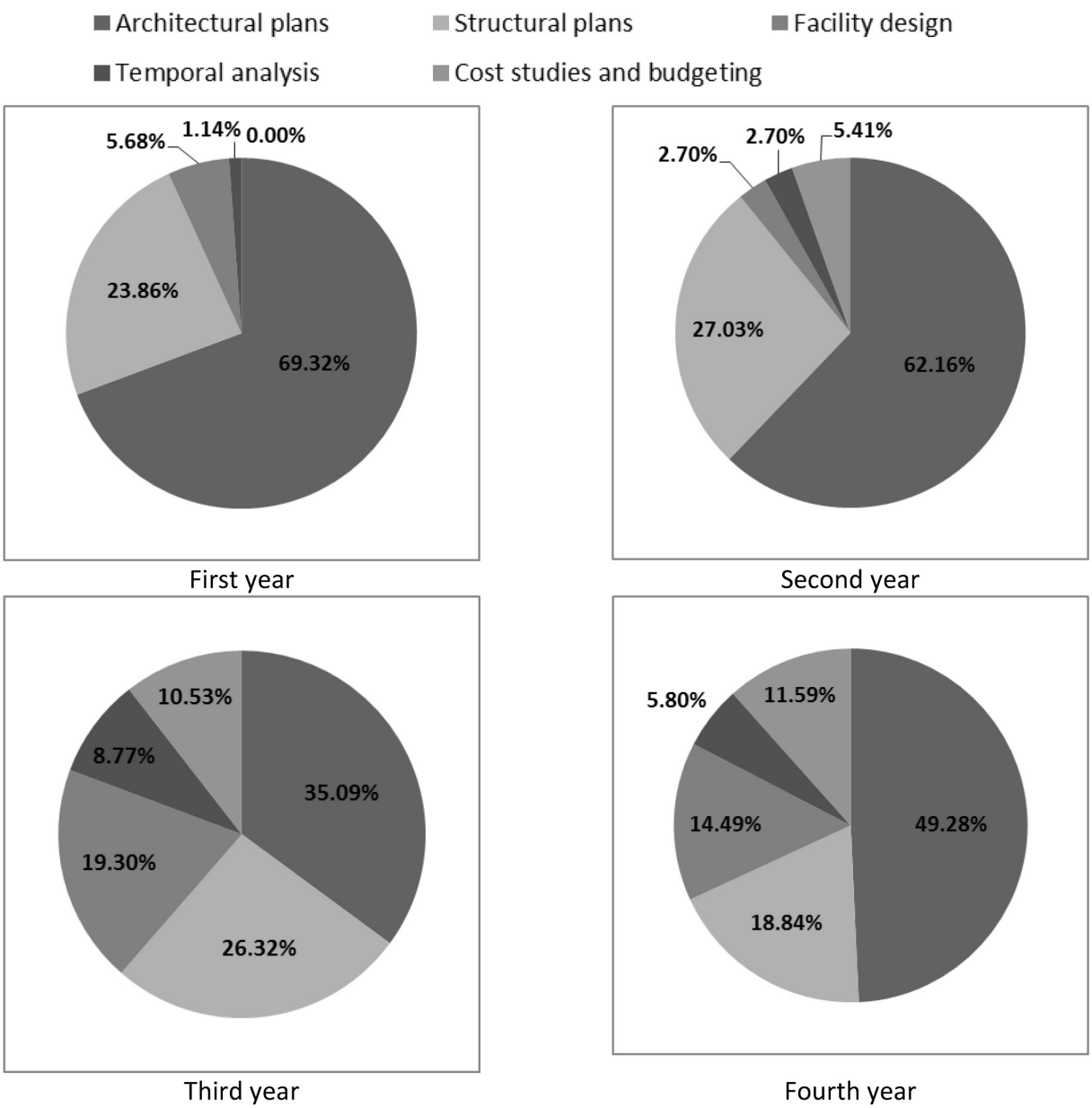

Fig. 6. Partial results per year group for question 10: "What do you use BIM for?" (Percentage of students surveyed per year group).

dents have sought to anticipate the possible compulsory use of BIM. This reason came before the simple wish to be up-to-date or the possible need to learn it for a hypothetical job search. Once again, the answers obtained show the high level of motivation of these students in the face of the challenge of the compulsory use of a tool which barely features, if at all, in degree course subjects. Analyzing the results by year group, the data from first-year students is that which most closely resembles the overall results. In the second and third years, a need to be up-to-date often overrides any possible future challenges, whilst in the final year, in light of their imminent entry into the job market, the obligation to try and anticipate the compulsory use of BIM sets the maximum figures of all those surveyed at 63.01%.

5. Analysis and discussion

Education as it is currently understood is closely linked to communication, leading to wider dissemination of information. Virtual spaces have become a very important part of our education system which has contributed towards a broader vision of the problems and solutions. Furthermore, due to the globalisation of building activity, where the large construction companies compete at an international level, this exchange of information between the different parties participating in the design and

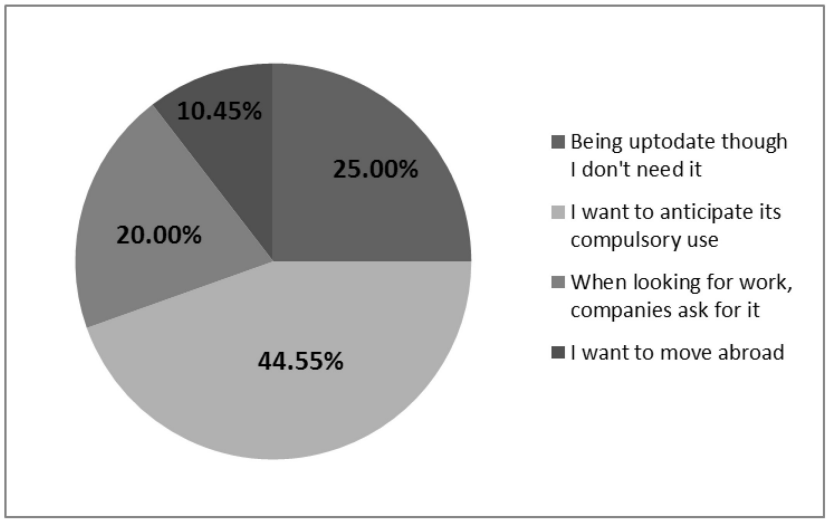

Fig. 7. Overall results for question 11: "What led you to use the BIM application?" (Percentage of students surveyed).

construction of a building is of utmost importance for obtaining a successful result.

One of the virtual reality applications is Building Information Modeling (BIM). The introduction of virtual models in building design and construction courses makes it possible to manage and share information concerning a building throughout its entire lifecycle. Consequently, BIM is considered to be a highly efficient tool to be included in architecture and various engineering courses, given that it provides a virtual space for information that enables collaboration between students and construction professionals, for the purpose of improving the design, construction, productivity and maintenance of buildings.

However, despite the commercial interest in this tool, the academic communities of some countries are acting more conservatively when it comes to its adoption.

It seems necessary that universities should incorporate BIM as an innovative technology in order to enable students to acquire new skills and prepare them for their future activity in a more competitive world. Universities in countries such as the USA, the United Kingdom and Australia have achieved different levels of implementation. However, in Spain, some universities have started to introduce BIM tools in their syllabuses. The Polytechnic University of Madrid is in the process of incorporating this new tool; as such the objective of this research is to ascertain the level of knowledge, motivations and BIM use of university students. Furthermore, the evolution of their skills was analyzed from starting university until entering the job market.

However, the fact that there is a high percentage of students with no knowledge of BIM and that approximately half of the students surveyed do not know how they can go about learning it, highlights that it is not a tool that has been implemented in universities. Implementation in countries such as the USA, Finland, Sweden, Norway, Denmark, the Netherlands and the United Kingdom, where the legislation in force makes using BIM compulsory in public works projects, has led to the inclusion of BIM technology in the university curriculum and to its subsequent application to the job market.

The current reality is that companies in the construction sector, educational institutions and organisations have started to adopt BIM software tools and to adapt their existing delivery systems with the intention of satisfying market requirements. This is, perhaps, the reason why the vast majority state that they will be BIM users in less than three years, this period being reduced to a year in the case of final year degree students. In other words, it is increasingly perceived as a necessity, but for the future rather than the present day.

6. Conclusions

- The results indicate that the level of BIM knowledge is lower than 43%, and 18% of the students surveyed stated that they did not know what it was. Despite the low percentage of knowledge, there is a high degree of motivation, given that over 98% expressed an interest in learning how to use it. This information is relevant, since in order to ensure an adequate development of competence, it is essential that the student's motivation is high.
- The main obstacle to students learning BIM skills by themselves is said to be a lack of time (almost 40% of those surveyed), despite the perception of it being a simple tool to use at a basic level (only 10% see it as something difficult to learn).

- Students are increasingly understanding the BIM concept to be a future need but they do not perceive it as something that they require now.
- There is no doubt that the lack of regulations in this area in Spain, the lack of development of standard protocols of action and the perceived lack of profitability from using the tool during the period of education contribute towards students putting off learning it.

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