# BIM Adoption in University Teaching Programs – The Swedish Case

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**Abstract – Implementation of BIM in the construction industry relies on sufficient knowledge and skills about BIM in order to gain momentum and success. Thorough understanding of the possibilities as well as challenges related to the application of BIM constitutes essential drivers for the adoption of BIM among all the industry actors throughout the construction process. Thus, there is a need for supply of knowledge and skills about BIM and its implications on the organisation, communication, management, business models etc. in construction. Accordingly, universities play an important role as a knowledge and skills supplier that helps to provide the necessary conditions for the implementation of BIM in the construction industry. This study investigates how the curricula of engineering and architectural teaching programs at Swedish universities and university colleges have responded to the apparent and increasing demand for BIM competences in industry. The study relies on a survey of 10 universities and 8 university colleges that provide engineering and architectural teaching programs at a master's and/or a bachelor's level. The findings show that bachelor's engineering programs at university colleges generally have adopted BIM into the curricula to a somewhat larger extent compared to engineering programs at a master's level. The BIM-adoption in architectural programs is, however, significantly limited. Further, the degree of BIM-adoption differs significantly between the respective teaching programs. Only few universities have adopted BIM as an integrated subject in courses that deal with general construction related issues. The predominant approach is to implement BIM-subjects as discrete teaching modules, i.e. stand-alone courses, rather than as a cross disciplinary aspect implemented in a number of the existing courses. Besides, a considerate mismatch is identified between the technical characteristics of the BIM curricula at universities and the process-oriented approach to BIM represented by the industry. Thus, the universities would benefit from a closer collaboration with the industry in BIM-related matters and they need to take on a strategic approach to BIM at an overall university or program level in order to avoid isolated BIM initiatives at a single course level.**

*Keywords* – BIM-adoption, curricula design, teaching programs, BIM objectives

## I INTRODUCTION

The adoption of Building Information Modeling, BIM, among architects, engineers, contractors and other actors of the construction industry creates an increased need for supply of engineers and architects with profound knowledge and skills about the conception of BIM, how the technology can be used in industry, and not least how BIM can provide a catalyst for change and development of new work processes, business models, roles, services etc. The implementation of BIM in the construction industry constitutes a thorough change process that requires development of innovative solutions as well as sufficient competences for all actors of the construction industry.

The issue of BIM-competence supply constitutes a highly prioritised area for the future BIM development and implementation in the construction industry [1]. Accordingly, university programs that relate to construction must react to and face the increased need for BIM-related competences in industry and integrate BIM-subjects into the existing curricula [2]. Engineering education has been criticised for being too biased in favour of theory and disciplinary knowledge while too little attention has been given additional skills, e.g. personal, interpersonal, and professional skills [3]. The adoption of additional skills and subjects such as BIM and ICT-applications in general must be done without reducing the existing curricula of technical disciplines and still allow for the continuous acquisition of new technical knowledge [4].

BVU*net [5], a Danish non-profit organisation with members from educational institutions involved in construction and architectural teaching programs, states that the on-going development and implementation of BIM in the construction industry to a large extent is run without support or direct involvement from the universities. Thus, the BIM level in terms of competences and curricula adoption at universities is limited in comparison to the level of implementation in the construction industry [5].

The problem statement of this study refers to the scope and characteristics of the prevailing university teaching that relates to BIM and the question about how it corresponds to the requirements and expressed needs in industry.

### *a) Purpose and Objectives*

The purpose of this study is to contribute to the understanding of BIM-adoption in university teaching programs by making a survey of BIM-related courses at universities and university colleges that provide construction related teaching programs. The findings of the survey will be reviewed in light of the BIM-objectives and needs expressed by the industry.

### *b) Delimitations*

The empirical data collection is delimited to Swedish universities and university colleges that provide construction related teaching programs which includes civil engineering programs at the bachelor's (B.C.E.) and the master's (M.C.E.) levels as well as master of architecture (M.Arch.). The study used a somewhat broad definition of BIM and BIM-related subjects and includes courses dealing with e.g. traditional 2D CAD, Geographic Information System, GIS, urban planning modelling, CAD for HVAC-systems, computer supported structural design, and of course, concrete BIM- applications.

## II METHOD

The survey of the BIM-related teaching at Swedish universities relies basically on a manual, hands-on, examination of the curricula of all engineering and architectural teaching programs. Thus, the survey was done manually, supplemented with the use of internet search functions, by exploring the homepages of all Swedish universities, semester by semester, identifying courses that potentially could include BIM-related subjects. The learning objectives of all the identified courses that included BIM-related teaching aspects were analysed and documented.

Of course, a manual and partly subjective survey like this is likely to include mistakes. For example, courses that actually include BIM-aspects could be neglected if the title of the course did not indicate an obvious relation to BIM. Especially courses in which BIM provides an integrated learning objective rather than a main topic in itself could be ignored.

In order to validate that all BIM-related courses were covered in the survey, the list of all identified BIM-courses was sent by mail to all the study leaders of the respective teaching programs. All in all, the preliminary list of BIM-related courses was sent to 44 study leaders of which 9 replied with comments, corrections and supplementary information about their courses.

In this study, only universities and university colleges with teaching programs that relate to construction were considered. The survey included architectural schools as well as civil engineering programs at a bachelor's and master's levels. All in all, 10 universities and 8 university colleges with construction related teaching programs were identified and included in the survey. These educational institutions represented a total of 35 different teaching programs, which all together represented 92 courses with syllabuses that relate to BIM-subjects.

To critically review the relevance of the BIM-contents in engineering and architectural teaching, the curricula were to be analysed in light of the BIM-objectives expressed by the construction industry. This study decided to use a recently (in 2013) published strategic research agenda [1], initiated by IQ Samhällsbyggnad, IQS, [6] with support from OpenBIM [7] and Bygginnovationen [8], as the reference for the BIM-objectives and needs in industry. The agenda maps the current BIM-status in industry, describes BIM-objectives and identifies important areas of future research and development with regards to the further application and implementation of BIM in the construction industry.

IQS is an independent, non-profit, member funded, organisation that works as an integrating hub between research, industry and politics in matters that relate to all aspects of the build environment. IQS has about 130 members representing public institutions, building clients, real estate owners, contractors, consultants etc.

IQS put together a project team with members from industry and universities to work with the agenda. A reference group and a steering committee were assembled to support the project team. Altogether, 20 members of IQS were represented in the project team, reference group and the steering committee. Besides, during the work process the agenda has been presented and critically discussed at three public workshops with representatives from academia, industry, trade organisations, institutional organisations etc. The agenda was financially supported by Vinnova, [9], the Swedish Governmental Agency for Innovation Systems.

The argument for choosing this particular research agenda as a reference in this study is principally twofold. First, the agenda is produced and published in parallel with the empirical data collection of this study, i.e. the timing is perfect. Besides, the broad representation of the main stakeholders from industry, universities, authorities, trade organisations etc. provides a comprehensive, thorough and validated basis for the agenda.

## III About the Swedish System of Higher Education

The system of higher education in Sweden differentiates between universities and university colleges. The universities are research-oriented and are certified to award bachelor, master and doctor degrees in all academic fields. University colleges, on the other hand, are more into applied sciences and have a primary focus on the bachelor degrees. University colleges can, however, apply to the government for the entitlement to grant master's and doctor degrees in limited and specific fields. [10, 11].

There are about 50 national institutions of higher education in Sweden, from Luleå University of Technology in the north part of Sweden down to Malmö University in the very south. 16 of those are full universities and 30 are university colleges. 11 of those university colleges have the rights to grant master and/or doctor degrees in specific fields. All higher education is offered by public sector institutions or by independent education providers that have been grated degree-awarding powers by the Swedish Government. 14 of the 16 universities are public sector universities and, consequently, 2 are independent universities. The distribution between public sector and independent university colleges is more equally distributes. 20 university colleges are public and 10 are independent. All higher education, at public sector as well as independent institutions, is free of charge for Swedish citizens and for citizens of the EU/EEA countries including Switzerland. [12]

## IV Distribution of BIM-subjects in Teaching Programs

The 35 different teaching programs included in this study were represented by 4 Master of Architecture (M.Arch.), 6 Master of Civil Engineering (M.C.E.) and 23 Bachelor engineering programs (B.C.E.). Two master programs represent a combined education that qualifies for a double exam in architecttture as well as in civil engineering.

When mapping the total number of BIM-related ECTS-credits (European Credit Transfer and Accumulation System) [13], it immediately becomes obvious that the vast majority of BIM-related ECTS-credits are presented by B.C.E. programs. The bullet list below shows the percentage of the number of BIM-related ECTS-credits for each teaching program in relation to the total number of BIM-related ECTS-credits (640 credits) for all the 35 teaching programs at a national level.

- M.Arch. 5% (34 of 640 credits)
- M.Arch. + M.C.E. 8% (50 of 640 credits)
- M.C.E. 17% (109 of 640 credits)
- B.C.E. 70% (448 of 640 credits)

One immediate observation when looking at the distribution of BIM-related ECTS-credits above is of course the significant differences between the M.Arch. and the B.C.E. programs. Thus, 70% of all BIM-related ECTS-credits are produced in a B.C.E. program and only 5% in an architectural program. Consequently, it seems correct to conclude that BIM-related subjects are not very well adopted in architectural programs in comparison to B.C.E. programs. However, the adoption of BIM must also be analysed considering the total number of programs and courses in the various teaching programs. The actual adoption of BIM-related ECTS-credits in the curricula of the various teaching programs compared to the total number ECTS-credits in each type of program show a more balanced distribution. The bullet list below show the percentage of BIM-related ECTS-credits in relation to the total number of ECTS-credits for each type of teaching program:

- M.Arch. 3% (34of 1 200 credits)
- M.Arch. + M.C.E. 8% (50 of 600 credits)
- M.C.E. 9% (109 of 1 440 credits)
- B.C.E. 11% (448 of 3 960 credits)

The figures above indicate that the implementtation of BIM-related subjects in the curricula in B.C.E., M.C.E. and the M.Arch. + M.C.E. programs are at a more or less similar level and that the BIM-adoption in M.Arch. programs is limited. Besides, a minor difference can be identified when comparing the percentage of BIM-related ECTS-credits at universities and at university colleges, regardless of the type of program. University colleges have an average of 13% of BIM-related ECTS-credits. The same figure for universities is 8%. Thus, it seems that university colleges are ahead of the universities in terms of the level of BIM-adoption.

Another aspect identified in the analysis is the significant variance in the level of BIM-adoption of the various educational institutions as well as the teaching programs. The survey shows that the level of BIM-related courses at a university differs from the top level of 90 ECTS-credits, at the Luleå Technical University, down to the lowest possible level of 0 ECTS-credits at Umeå University. It should in this context, however, be mentioned that the total construction related ECTS-credits is more than the double at Luleå Technical University in comparison to Umeå University (1 020 compared to 480 ECTS-credits).

The same significant differences are recorded when looking at the level of BIM-adoption at the respective teaching programs. The Bachelor program of Building Engineering at Malmö University shows the highest adoption of BIM in its curriculum. In this particular program, as much as 39% of the total ECTS-credits, i.e. 70 out of a total 180 ECTS-credits, include BIM-related subjects. The average percentage of BIM-related ECTS-credits related to the total number of ECTS-credits of all programs is 10%.

## IV BIM-RELATED SUBJECTS IN UNIVERSITY CURRICULA

The second question raised in this survey is that of the conformity between the BIM-subjects taught in the existing university curricula and the BIM-objectives inquired by industry. The question answers to the degree of relevance of the teaching subjects at universities and aim at indicating the needs for the future BIM-adoption in university teaching programs.

This survey examined the expressed learning objectives in terms of knowledge, skills and attitudes of all the 92 courses that were identified as being BIM-related in one way or another. The learning objectives were categorised into four overlapping groups:

1. Aggregation levels: Construction (single project related issues) and Urban Planning and Landscaping (areal planning, GIS related issues)
2. Modelling levels: 3D or 2D and, syllabuses including 3D and 2D
3. Teaching subjects: Drawings (rendering of drawings from the model), Visualisation (communication and rendering etc.), IFC (information exchange between software platforms), Construction Management (4D, 5D, model validation, clash detection etc.) and Business Strategies (business opportunities, implementation and change processes, new roles and responsibilities etc.).
4. Construction process: Architectural Design (general aesthetic and functional design), Structural Design (structural engineering, MEP etc.), Construction (production related issues construction management) and Real Estate Management (Facilities Management, operation and maintenance etc.)

The first issue of aggregation level shows the distribution of courses that deal with single project of buildings and constructions of all kinds in comparison to urban planning and landscaping, i.e. primarily GIS-related issues. The study finds that 86% of the BIM-related ECTS-credits concern construction of buildings and consequently, only 14% relate to issues of urban planning and landscaping (GIS). The study does, however, not take into account the total number of courses and ECTS-credits in the respective categories of teaching programs.

Most BIM-related ECTS-credits include 3D-modeling (66%), while courses that are delimited to 2D-modeling represent 22% of the total number of ECTS-credits. The remaining 12% are represented by courses that include both 3D- and 2D-modeling.

The mapping of subjects being represented in the identified BIM-courses is interesting in compareson to the competence needs expressed by the industry. The study found the following distribution of ECTS-credits (% of the total BIM-related ECTS-credits) between the five categories of teaching subjects described above:

- Drawings (generation of drawings) 51%
- Visualisation (communication, rendering) 32%
- IFC (data exchange) 9%
- Construction Management (4D, 5D, etc.) 7%
- Business Strategies (implementation etc.) 1%

Obviously, more than 50% of the BIM-related ECTS-credits include learning objectives about generating architectural and engineering drawings from the 3D (and 2D) models. It is of course an important BIM-feature to be able to quickly update all drawings when changes are made to the model. However, the importance and representation of this aspect in the curricula must be considered overrated in relation to other BIM-objectives. Thus, despite the transformation into 3D-modeling (66+12% of all BIM ECTS-credits), the prevailing BIM-adoption in university teaching still rests upon the CAD-tradition and the conception that paper drawings provide the information platform in construction.

It is also worth noting that only 1% of the ECTS-credits, i.e. one single course, have matters of business strategies in relation to the implementation of BIM as its principal learning objectives. This crucial aspect of BIM-integration in existing as well as new processes, new forms of collaboration, new roles and responsibilities, new ways of communication etc., is clearly underrepresented in the university curricula.

The fourth issue relates to learning objectives that connect to the various phases of the construction process. The study shows the following distribution of ECTS-credits (% of the total BIM-related ECTS-credits) between the phases of the construction process described above:

- Architectural design 62%
- Structural design 14%
- Construction 18%
- Real estate management 6%

According to the figures above, the learning objectives that somehow relate to architectural design (62%) constitute the vast majority of the total BIM ECTS-credits. In this context architectural design includes all teaching activities dealing with general model generation. The design phase is, in this study, divided into architectural and structural design in order to illustrate the strong dominance for the architectural aspects of design in relation to structural design. The findings correspond to the previous observations of teaching subjects according to which the generation of drawings (51%) and visualisation (32%), by far provided the most prominent BIM-subjects.

Obviously, the adoption of BIM in the university teaching programs follows the successive progression from the initial design phase(s), through the phase of construction and on to the finishing phase of real estate management.

## V BIM-SUBJECTS IN TEACHING VS. BIM-OBJECTIVES IN INDUSTRY

In order to critically review the relevance of the BIM-adoption in university teaching programs, the current BIM-curricula are compared to the BIM-objectives expressed by the construction industry. As mentioned in the Method section, the Strategic Research Agenda [1], SRA, for Building Information Modeling, established by IQ Samhällsbyggnad [6] will represent the BIM-objectives pronounced by the industry.

The SRA agenda provides a comprehensive review of the current BIM-situation as well as future objectives and visions for BIM-development. All in all, three areas are pointed out as being the most prominent for the future research and development:

- BIM Standards and regulations
- BIM-applications
- Supply of BIM-competences

The call for supply of BIM-competences is in line with the argument raised in this study, i.e. the need for universities and other educational institutions to provide sufficient and relevant knowledge and skills about BIM and its implications for the construction industry. Further, the continuous establishment of common standards, processes and formats provide an important basis for the future development and implementation of BIM in the construction industry.

The area of BIM-applications, which in this study provides the basis for the comparative analysis between BIM-adoption in university programs and BIM-objectives in industry, includes the three sub-aspects of “BIM and process renewal”, “BIM and real estate information” and, “BIM implementation”. Altogether, a number of key issues and BIM-objectives that cover all phases of construction were emphasised in this context, e.g.:

- Process renewal
- Urban planning
- Design
- Production
- Industrial processes
- Real estate management
- Modeling the existing stock
- Implementation and change processes
- New forms of cooperation, incentives, contracts
- New business models, value chain
- New roles and responsibilities

The areas of BIM-applications included a large number of specific BIM-objectives such as visualisation, quantity take-off, light analysis, energy analysis, clash detection, simulations etc.

Two immediate observations can be made when reviewing the expressed BIM-areas and objectives in light of the BIM-adoption in university curricula. First, the industry expresses a wider scope of application, including in all phases of construction, with specific emphasis on the areas of urban planning and the real estate management. According to this survey, the predominant BIM-applications in the curricula of the teaching programs relate to design (architectural design, 62%, and engineering design, 14%), while urban planning and real estate management appear to be more or less neglected in the BIM-curricula of today.

Secondly, the learning objectives of BIM courses typically have a primary focus on discrete features, i.e. generation of drawings, visualisation, etc. Besides, BIM-courses appear to be designed as standalone silos, i.e. isolated from courses dealing with other subjects of disciplinary knowledge. Thus, the nature of BIM as an integrator, connecting the various processes and the information flow between the actors involved, is not prevalent in the university curricula. Industry, on the other hand, pronounce the importance of change and process renewal with focus on new business models, forms of collaboration, communication, integrated value chains, etc.

Thus, there is a gap between the BIM curricula of the universities and the BIM-objectives expressed by industry.

## VI CONCLUSION

The study finds that all construction related teaching programs, only with few exceptions, have adopted BIM in their respective curricula. Engineering Bachelor programs at university colleges have the highest general representation of BIM-subjects in the curricula. The BIM-adoption in architectural schools is, however, significantly limited.

Further, the degree of BIM-adoption differs significantly between the respective teaching programs, which can be explained by different adoption strategies applied by the universities. Only few universities have adopted BIM as an integrated subject in courses that deal with general construction related issues. The predominant approach is however to implement BIM-subjects as discrete teaching modules, i.e. stand-alone courses, in which BIM is regarded a technical tool rather than a facilitator for process integration and organisational development.

Thus, there is a considerate discrepancy between the technically oriented BIM curricula at the universities and the more process and change oriented approach to BIM represented by the industry. Besides, the industry emphasises the importance of BIM-implementation in urban planning and real estate management, which currently is more or less neglected in university curricula. The study concludes that the industry, primarily represented by large consultancies and contractors, is driving the BIM-movement and is ahead of the universities in terms of BIM awareness, maturity and competences.

Accordingly, the universities would benefit from a closer collaboration with the industry on BIM-related matters. Besides, the universities need to establish a strategic approach to BIM at an overall university or program level in order to integrate BIM as a cross-disciplinary subject in the curricula and avoid discrete BIM initiatives in stand-alone courses.

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