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Education of architects in the field of BIM technology

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ABSTRACT: Constant education on how to employ new basic tools in the work of designers is extremely relevant in the design process of the 21st Century. Computer-aided programming (CAP), which is being used in design offices around the world, was until recently, a basic tool of computer-aided design (CAD). However, it only seems to be a substitute for tracing paper. Education on how to replace the technologies associated with 2D CAD drawing is necessary due to the dynamic development of information technology associated with the process of integrated design. Young architects should be educated on how to improve 3D modelling techniques utilising built-in information about materials - iBIM (building information modelling).

Keywords: Architecture, CAD, iBIM, education in building information modelling

INTRODUCTION

Over the past 15 years, 2D computer-aided vector design has managed to take over the hearts and minds of architects from both large and small companies all over the world. 2D computer-aided design is a basic tool, without which no architect is able to work effectively. In order to tie in the architectural design with the structural and infrastructural designs, engage in teleworking, as well as to work as a part of a workgroup, the ability to use 2D computer-aided design is not only needed, but has become the very basis of it. The options for virtual design are increasing day by day thanks to readily accessible tools that allow for 3D design in real time.

Education in the field of the latest advances in information technology in the service of design is crucial to all designers. BIM design can be treated as an expansion of the tools used to work creatively that provides the designer with a list of economic information regarding construction materials, their properties, parameters and, most importantly, their cost. Structural and infrastructural design takes on an entirely new meaning in 3D. Designers can form workgroups, modelling the same element simultaneously, but each working on a different technical aspect. Assuming that the materials used in the modelling process carry with them a set of parameters of characteristic qualities; then, one is able to determine the influence of aesthetic changes on the economic aspects of a building on the go, as well as other things, such as avoiding collisions between structural and infrastructural elements.

The education of an architect or an engineer in the field of 3D iBIM technology is relatively easy and provides substantial benefits in the form of reducing the duration of work and increasing its effectiveness. A 3D model that has been constructed in detail can provide the ability to assess the parameters of a building other than its aesthetic properties, such as its financial expensiveness and energy efficiency. Furthermore, this type of work is highly automated, which reduces the number of design mistakes that are made.

CAD EDUCATION

Douglas Carl Engelbart, an American scientist and inventor, widely known as the creator of the computer mouse, was the precursor of the integrated design process [1]. This visionary, who worked during the Cold War, had a vision of the manner of working with virtual BIM tools that would take place in the future, *...The architect next begins to enter a series of specifications and data - a six-inch slab floor, twelve-inch concrete walls eight feet high within the* *excavation, and so on. When he has finished, the revised scene appears on the screen. A structure is taking shape. He examines it, adjusts it.... The lists grow into an ever more-detailed, interlinked structure, which represents the maturing thought behind the actual design* [2].

In 1963, the program written by Ivan Sutherland - *Sketchpad. A Man-Machine Graphical Communication System*, developed at the MIT Lincoln Laboratories caused a great stir. It featured four viewports and a three-dimensional view, which required a TX-2 computer to operate, which filled an entire room, and needed a then-enormous amount of memory (272 kilobytes). Initially, the technology was used only experimentally to model solids with the use of walls with definable parameters, as well as building and dynamic structures. It took forty years for it to dominate the market and make itself at home in design offices all over the world [3].

In the 1980s, numerous architectural practices that felt the need to adapt to the coming changes and the ongoing digitalisation of the Western World, began implementing computer-aided design (CAD) into their work. This was tied with the abandonment of manual drafting and learning how to use programs allowing their users to draw in a virtual space. It was, then, that the approach to previously acquired knowledge and skills needed to change. The term *refining one's work methods* also took on a different meaning, as the necessary skills to operate these new tools needed to be learnt from scratch. The very process of design had to undergo a thorough redefinition.

Education paid off, however. These changes significantly influenced the speed with which architects were able to work. Repetitively used elements could be copied and modified in an astoundingly short time. The precision of technical drawings increased. There are no limitations associated with scale in the virtual space of the *drafting board*, and the structure or element that is being designed can be zoomed in indefinitely. The time invested into learning how to work with the new software saw a return rate several times larger in the case of later designs, which could be drawn faster. The computer significantly influenced the quality and clarity of design documentation. Any mistakes could be erased in a matter of moments, without the need to scratch the ink from the transparency, while any mistakenly removed item could be brought back with the speed equal to that of the bits of information calculated through a computer's central processing unit. However, this technology served only to replace the physical drawing board with its virtual equivalent, and designs were in fact still developed just as before, line by line, pixel by pixel.

BIM EDUCATION

The changes brought on by education in the design methodology based on building information modelling (BIM) are much more profound. They require a different manner of thinking about a building and about the design process itself. A design revolution has started. Instead of producing flat drawings, the designer constructs a virtual 3D model, as well as an entire database of information about a building, the structure of its lifecycle and the manner of its use. With the aid of structures, surfaces and objects - the attributes, layouts and mutual interrelations, which are established by the designer - they can generate intelligent buildings.

However, many designers do not use even half of the available features of these programs, because they do not know about the options that they provide. Thus, education in the field of the latest technologies is extremely important to the architectural profession. To learn and master the new tools provided by software that allow the construction of a three-dimensional virtual reality is imperative in order to fully make use of its potential. The software engine calculates every change made on any of the drawings on its own and redefines all of the other views in moments, automatically ensuring the integrity of the design. The designers, meanwhile, can give in to the passion of design. The science of forming spaces in BIM systems directly on the monitors of computers is not limited to the construction of the virtual shapes of the elements of which a building's partitions, surfaces or dynamic blocks are made. It is a form of design which integrates all design professions. Based on a database of the model, the central processing unit can generate not only schedules and quantity tables of surface areas of walls, floors or report on the quantity of construction materials needed to build them, but it also allows simulations to be performed of energy and heat expenditure, the need for fresh air at the design stage, as well as controlling the entire lifecycle of the building, from its construction to the point of its demolition and recycling.

Thanks to the IFC databases (Industry Foundation Classes) generated during a model's development, cooperation between the design branches of architecture, civil, electrical and sanitary engineering is made possible [4] (IFC-SPF - is a text file format defined by the ISO 10303-21 standard - *STEP-File*, it has the extension **.ifc*. It is the most commonly used file format, readable by the largest number of programs). The modelling of a building through group network-based cooperation with specialists of one's own choosing from all over the world and a full interdisciplinary synchronisation allows the introduction of any possible changes and the continuous perfecting of buildings, making it possible to eliminate weak points and save large amounts of time and money. Learning about the possibility of virtually exchanging information with third-party applications allows virtual analyses to be performed. Such applications can determine the weak points of a building that increase its energy consumption, generate its energy performance report or conduct a sunlight exposure analysis, determine its influence on surrounding areas and ascertain the impact of wind on high-rise buildings.

According to the NBS National BIM Report 2016, a study developed in Great Britain, the awareness of the existence of BIM technologies among specialists is nearly complete [5]. In 2010, it was reported that 58% of respondents were aware of it, while in 2013, 95% of respondents were not only aware of the existence of BIM, but also knew the basics of its operation. The British government has introduced legislation that enforces the implementation of BIM standard design for every architectural practice or architect who wishes to take part in a state-organised tender from the year 2016 onwards. Mastering this type of software has become a necessity for independent British architects and architectural practices. It is also known from the statistics provided that 95% of architectural practices declared that they will introduce the standards of BIM methodology into their offices in the next five years, while 54% of respondents had already implemented the system and had been using it in their design process [6]. In this case, the investment in education was a form of ensuring the survival of architectural practices. However, in the absence of an obligatory requirement of mastering the operation of new methods of work, the position of practices utilising slower and less effective design methods would be quickly checked by the market. Stephen Mordue, a representative of the Royal Institute of British Architects and the manager of the BIM2050 project, claims that the key to an effective education in the field of technology is a culture of integration [7]. These words, uttered in the context of integrating the team associated with a design, perfectly describe the very concept of BIM. According to him, the five main barriers to the implementation of BIM on a wide scale are:

- the lack of client demand for advanced design documentation;
- the lack of a substantial influence of BIM on the development of a practice;
- the fact that designs on which a practice is already working on are deemed as too small;
- the lack of an employee qualified in the operation of BIM software within a practice;
- the problems associated with interdisciplinary coordination.

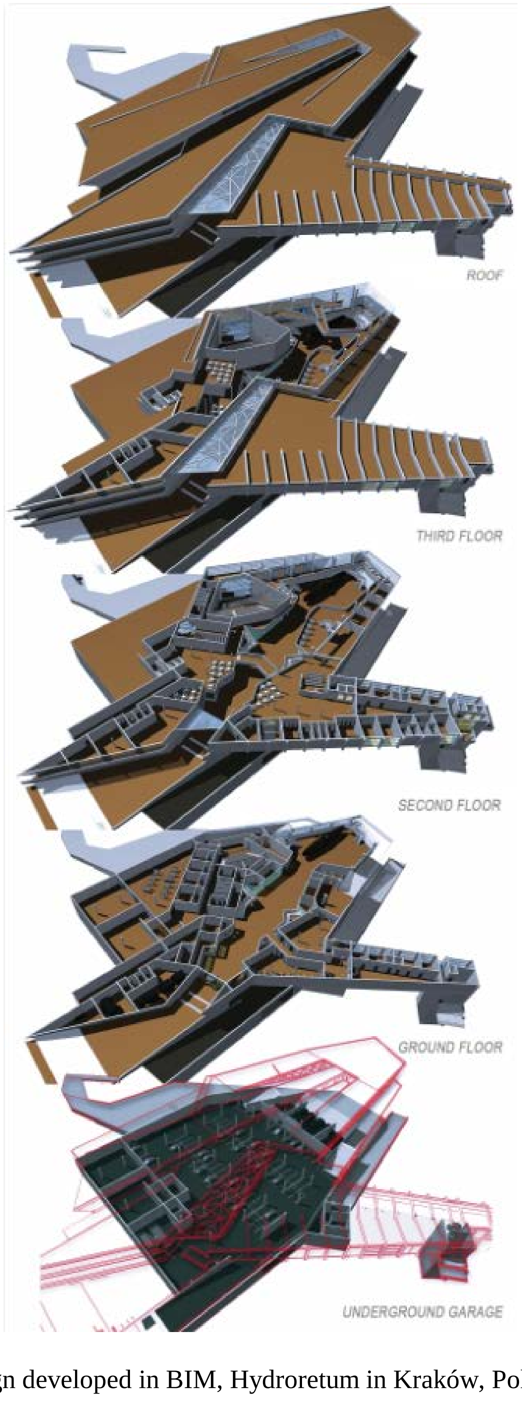

Figure 1: Conceptual design developed in BIM, Hydroretum in Kraków, Poland (author: M. Jamroży).

Over the course of the study reported by Hamil, the approach of designers to the concept of learning and mastering new methods of work was measured [5]. 93% of the participants of the study responded that adapting a practice to the implementation of BIM entails a redefinition and change of time-honoured practices, changes to habits and a formalisation of the flow of tasks and procedures.

The majority of respondents claimed that this was a difficult and time-consuming process. At the same time, 66% of respondents were of the opinion that the time devoted to learning how to use this new tool was a good investment in oneself. The participants of the study confirmed their awareness of the fact that contractors are soon going to require design documentation in the BIM standard and that going through the learning process will become inevitable. 52% of respondents stated that using BIM software increases the pace of work in a practice, while only 4% claimed that there is no need to implement a new standard of work. It is interesting that only one-fifth of the persons with a negative attitude towards BIM do not work using BIM, while only 4% are persons who already design using it. It can be observed on the basis of this study that the British, forced by law to change the design environment as it were, are inclined to look on the bright side of the situation rather than seeing it as a needless complication and a futile attempt at changing old habits.

Winstanley and Fraser from Lean BIM Strategies Limited described the process of implementing BIM technologies and have identified the practical benefits of programmed education and the implementation of these solutions in everyday design practice [8]. They have further organised the benefits associated with modern design technology into a hierarchy, ranging from those that are most important in the everyday design process, as well as aspects which are fundamental in the long term.

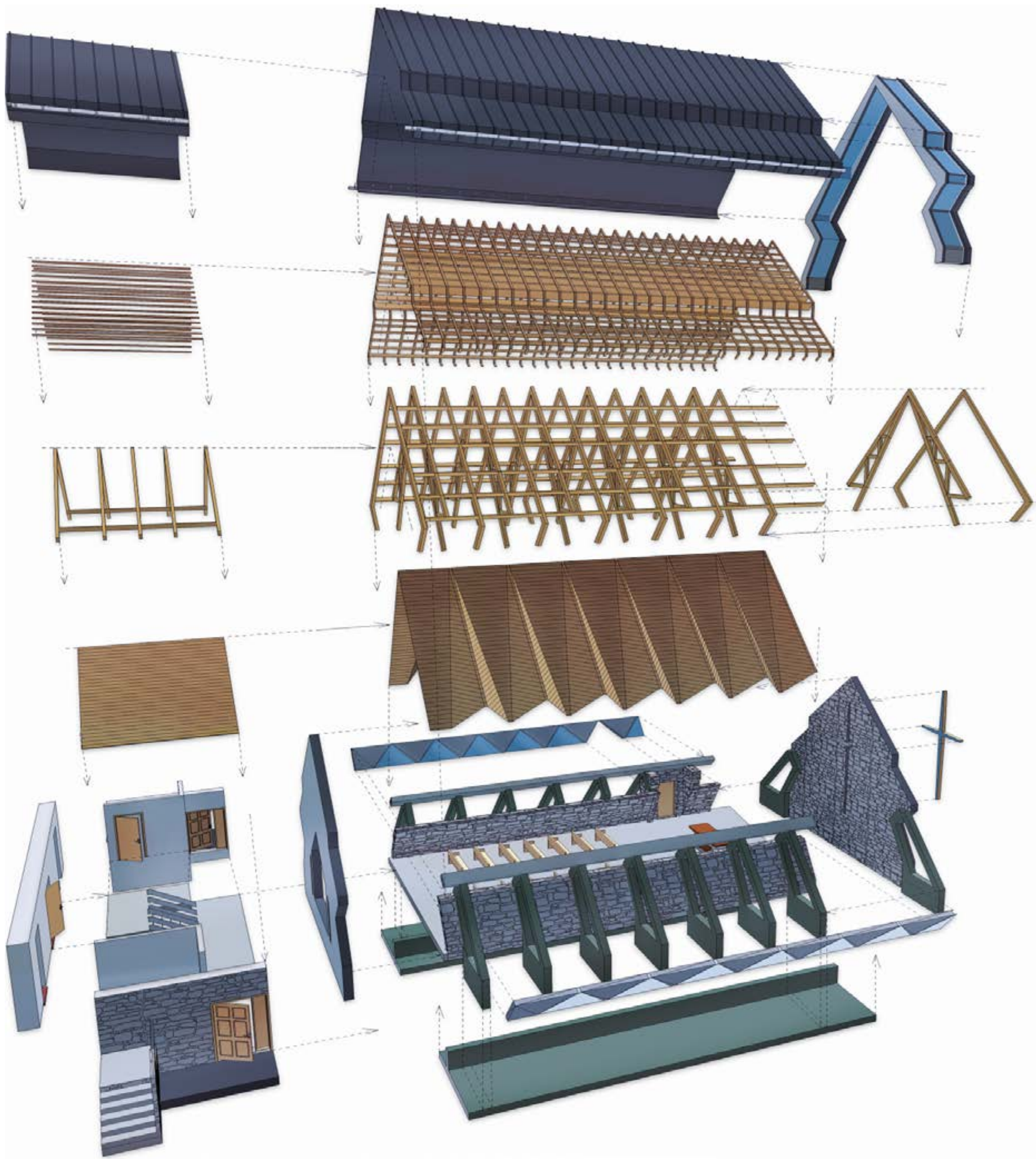

Figure 2: The picture shows Roman Catholic Chapel in Polańczyk, Poland implemented in BIM (author: M. Jamroży).

At the very top of the pyramid were elements like fast 3D modelling, photorealistic visualisations, renderings and animations, the possibility of virtual walkthroughs or use in expanded reality. Below them were elements that influenced the entirety of office and group work, such as good collaboration, the coordination of the creative process, ease of communication and the outstandingly important ability to detect collisions. At the base of the pyramid, there were also qualities without which the development of a practice and the management of a design would not be possible; namely, exchanging data and information, the planning and management of the design process, control of expenditures, orders and construction time. Thanks to the carrying out of such an analysis, one is provided with a picture of the education in the operation of programs and implementing BIM technologies that can revolutionise the system of design in the 21st Century. Investing in education is needed, because it provides human resources that are knowledgeable not only in the basics of theory, but that are also able to work in a modern manner. An educated architect becomes a manager responsible for the carrying out of a construction project, having complete control over it during the entirety of the project's development cycle, beginning at the conceptual design stage, going through the technical design stage, cost control and cooperation at the construction site, to the coordination of the entire team involved in the process [9].

Even today, one can observe the establishment of the government project Construction 2025: Industrial Strategy for Construction, which is aimed at improving the position of Great Britain on the construction market of Europe, as well as on the global one [10]. Standing at the brink of such profound changes, which are already becoming visible in neighbouring countries, Poland, despite the lack of official legal regulations, not wishing to stand out in terms of not meeting Western European standards, is forced to adapt the technology to its domestic conditions. Otherwise, Polish designers may find themselves in a situation in which they will not be able to compete with the modern model of design, not only formally, but perhaps first and foremost, in terms of speed, precision and scope of the designs that they develop. Over a period of a couple of years, this could lead to a lack of the ability to participate in international tenders for both design and construction work [11].

In the land near the Vistula River, numerous architects have already given BIM standard technologies a try. However, when the time comes to deliver design materials to specialist designers, architects are forced to *take a step back*, converting the intelligent 3D model into flat, 2D CAD drawings, forgoing the databases that have been generated. Specialists from many other disciplines that participate in developing construction designs do not see the need to design in a multi-dimensional space (4, 5, 6D). However, Poland is gradually arriving at a point in time when new generations of designers brought up during the age of information technology are going to enter the market and sanitary and electrical engineering designs made entirely in the three-dimensional space of a model developed by an architect are going to become the norm. Designs are going to achieve a level of precision and real-world compatibility previously only encountered at the construction site, and most collisions and other problems are going to be foreseeable at the design stage [12]. The education of specialist engineers in the field of 3D design is also profoundly important.

CONCLUSION

By observing the rapid changes in the British market, one can see that education in the field of BIM methodologies and their implementation in Poland is likely to be the most profitable in the case of small practices, which have the capacity to quickly adapt to new market conditions, especially, in light of the growing requirements in terms of the scope of design documentation. It is certain that the benefits of designing in accordance with BIM methodology are substantial enough that even the expense associated with implementing a new style of design seem not to be that great, as they guarantee the preservation of an appropriate level of competitiveness in the design market in the future.

In a time of increased pressure being exerted by highly developed countries, the day approaches when interdisciplinary design in accordance with BIM methodology is going to replace virtual drawing boards completely - forever changing the way of thinking about shaping modern architecture. Over the next couple of years, designers are going to experience a repetition of the scenario familiar to them from the time when 2D CAD technologies were first starting to be implemented. It was thought of by a mere handful 15 years ago, only to become a staple of the reality of most design practices, something they cannot live without in the digital world of today. It is time to prepare for the coming changes. It is time for education in the field of BIM.

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BIOGRAPHIES

Magdalena Jagiełło-Kowalczyk, MSc Arch., PhD, DSc, has been a Professor at Cracow University of Technology (CUT), Kraków, Poland, since 2014. She was born in Kraków and graduated from the Faculty of Architecture at CUT. She wrote her doctoral thesis, entitled *Shaping Residential Areas of an Ecological Character* (Kształtowanie osiedli mieszkaniowych o charakterze ekologicznym) under the supervision of Professor Wacław Seruga. She obtained the title of DSc in 2013 on the basis of her habilitation monograph entitled *Environmental Coordination in the Formation of Sustainable Housing Developments* (Koordynacja środowiskowa w kształtowaniu zrównoważonych inwestycji mieszkaniowych). Her field of interest includes matters related to the concepts of *green architecture*, which form the constituent parts of the concept of sustainable design. She is the author and co-author of many publications in the form of books, monographs and papers in scientific journals, as well as numerous presentations at conferences, sessions and seminars. Along with Prof. Seruga, she has been, the co-editor of the annual, bilingual, scientific publication *Środowisko Mieszkaniowe - Housing Environment.* She has been associated with this journal since 2003, in addition to being the Chief Editor of the architectural scientific journal *Archivolta*. She is the co-author of the Web sites of the aforementioned publications. She participates in KBN (Polish Research Committee) grants and international projects co-financed by the EU, as well as in research conducted by the Chair of the Residential Environment at CUT, with separate independent tasks. She is the organiser and co-organiser of conferences, seminars and scientific sessions, workshops, architectural competitions, students' designs exhibitions and post-competition exhibitions. Prof. Jagiełło-Kowalczyk is the author and co-author of numerous designs of residential and commercial buildings, as well as interior designs of homes and offices. Since 2005, she has been the scientific supervisor of the GROW Students' Scientific Club, operating alongside the Chair of the Residential Environment of the Institute of Urban Design at the Faculty of Architecture, CUT. Since September 2016, she has been Director of the Institute of Urban Design at the Faculty of Architecture, CUT. As an author of lectures, curricula and didactic materials, she is in charge of the implementation of curricula based on integrated design using building information modelling (BIM).

Mr Maciej Jamroży graduated a MSc Arch from the Faculty of Architecture at Cracow University of Technology, Kraków, Poland, majoring in Architecture and Urban Design (2010) and Landscape Architecture (2009). Also, he completed a postgraduate Marketing and European MBA Management Studies course at the Economic University in Kraków (2012). Since 2015, he has been a member of the Regional Chamber of Architects of Małopolska and a member of the Board of the Rzeszów Branch of the Society of Polish Architects (SARP). He has been issued with an unlimited design license in architecture (MPOIA 052/2013). He is currently the CEO and owner of the URBAN PROJECT Sp. z o.o. design company. He has obtained professional experience while working in Polish and European design studios/companies. He is a member of the Communal Architectural and Urban Committees, and is the co-organiser of the Architect's Advisory Zone at the International Rzeszów Trade Fair. As part of the process of writing his doctoral thesis, he delivers lectures and conducts academic design courses with students on practical design and carries out construction projects in Poland. He is the Technical Editor of the architectural scientific journal *Archivolta* (2015). Mr Jamroży specialises in parametric design and BIM. He is a founding member of the EXPO Cluster and takes part in conferences, trade fairs, exhibitions, and is involved in education, promoting events and knowledge associated with construction technologies.