Physical models in the education of architectural history

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ABSTRACT: In this article, the authors present the long tradition and common use of physical models in the process of teaching the history of architecture in higher education institutions. The research described in the article is focused on the use of physical models and mock-ups as stimulants during architectural history classes to support lectures and increase the learning capabilities of students. The authors also cover the general use of such models across the history of mankind as the main carrier of the designer's ideas. The presence of these models in public spaces and their artistic values are also touched upon, as well as the models' positive impact on the general sightseeing public. The findings confirmed that both physical and digital models help architecture students to visualise abstractions and space, thus increasing their learning capabilities. The broader public also benefits through the popularisation of models in public spaces.

INTRODUCTION

Although architectural education and the presentation of proposed spatial solutions/projects have been connected with building physical models since at least the 2nd millennium BC (in Sumer and Egypt, as well as in China) [1], the current, innovative methods, particularly 3D modelling with the introduction of virtual reality (VR) and 3D printing make it possible to implement models in architectural education on a previously unknown scale. The creative reuse of existing resources - materials and structures - for the conservation and adaptation of architectural heritage is becoming increasingly important due to the advancing architectural education [2].

Traditionally, the history of architecture was one of the foundations of young architects' education. However, the current discussion on the present role of tradition and knowledge about the historical methods of construction in the education of future engineers is leading the modern academic teaching community to rethink these approaches. The importance of teaching the history of architecture as a tool for the sustainable use of existing resources continues to grow [3].

One of the main elements of teaching the history of architecture is imparting knowledge about architectural forms and styles, and development processes [4], as a basis for developing spatial imagination and knowledge for future creative practice. It is necessary to verify the existing teaching methods, especially in early education [5], and develop new ones [6] to increase students' learning capabilities and design abilities [7][8]. Therefore, this article aims to present the impact of physical models on architectural education in the past and near future.

In July 2019, new standards for architectural education were introduced in Poland, specifying the number of teaching hours for subjects. The introduction of these new regulations has opened up the possibility of modifying the education programme within heritage protection [9]. The changes aimed to professionalise architectural education - each student was to spend at least half of the classes learning architectural design. However, this resulted in the weakening of the classes that support the main design aim, such as the history of architecture.

The current tendency is to omit physical models in education processes due to the popularity of 3D modelling, CAD tools, BIM systems [10][11], HBIM [12][13], including urban scale in the form of geographic information system (GIS) [14] and even direct conservation application [15]. Today, after the Covid-19 pandemic, the role of distance learning is increasing [16]. However, it is not possible to detach the process of architectural education from contact with the existing physical matter of a building object [17][18].

MODELS IN HISTORY - OUTLINE

Models have historically been a common way for a creator to present a complex work. Both in the Middle Ages and the Renaissance, drawing was often a supplement to the model [19]. This concerned not only wooden models (although

it is known that, for example, ship models were also used as a final project), but also competitions for bricklaying or purely artistic works (sculpture, etc). Naturally, making models - as they were cheaper - was the basis of education in craftsman guilds that were managing, but also limiting access to, the profession in Europe from the Middle Ages until the French Revolution.

Physical models are frequently used, alongside the *flat* technical drawings, in the field of architecture to visualise and acquire a fully complementary representation of the designed object during the project phase. The aim is to test the worked-out design in multiple contexts (historical, environmental, sociological, etc) by simulating the reality on the scale. What is more, during some design competitions, models and mock-ups are necessary to present the architectural idea and object in a complex way. One of the most famous uses of this technique is the project for the complementation of the dome in Florence's Santa Maria del Fiore Cathedral, represented by a wooden mock-up, which is still preserved in the Opera del Duomo Museum, Florence, Italy (Figure 1) [20][21]. During the project phase, many models, details and parts of the construction were represented at a scale of 1:1 or at a reduced scale to test them using physical factors or multiple tests to acquire construction simulations, e.g. loads distribution to optimise the design, and deformation and destruction patterns [22].

Figure 1: Interior of the Opera del Duomo Museum in Florence, Italy, with a reconstructed copy of the façade at a 1:1 scale (photograph: Piotr Samól, 2016).

GENERAL PRESENCE OF MODELS IN PUBLIC SPACES

Besides the academic and professional applications, models are frequently used in public spaces to educate and visualise the past shape of the city, spatial problems and unfinished concepts or allow the visitor to touch the duplicate shape of an untouchable object (e.g. extremely valuable statue of Michelangelo, shown in Figure 2). A series of architectural landmarks were also constructed as scale models dedicated to blind people, to visualise the shape and describe elements using typographic lettering.

Figure 2: Laser-scanned and 3D printed representation to allow visitors to interact with elements of Michelangelo's Moses sculpture built into the tomb of Pope Julius II located in the Church of San Pietro in Vincoli in Rome, Italy [23] (photograph: Szymon Kowalski, 2022).

Two more examples of models in public places are shown in Figure 3 and Figure 4.

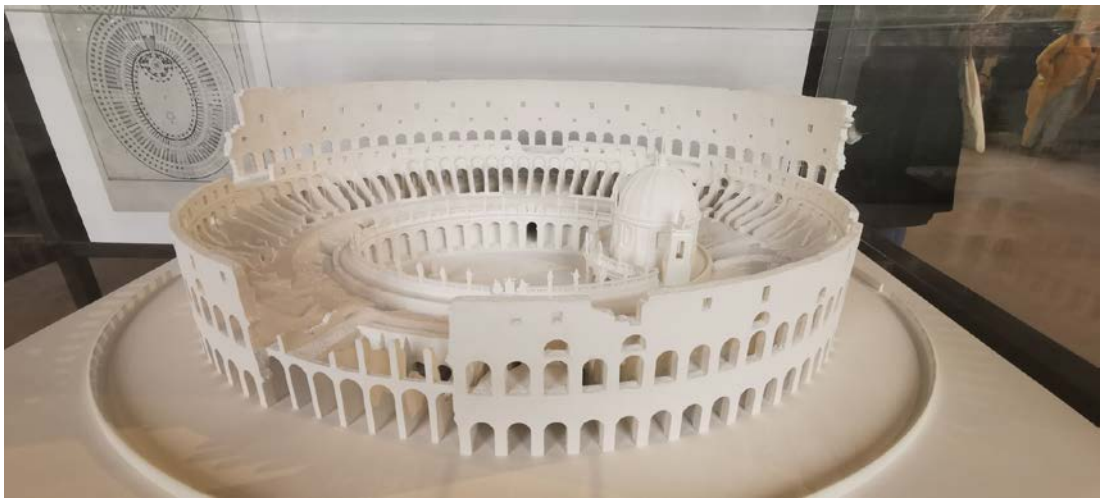

Figure 3: Model of unrealised concept of Martyr's Church within the adapted Colosseum, Rome, Italy designed by Carlo Fontana [24] (photograph: Szymon Kowalski, 2022).

Figure 4: Bronze urban model of the city Malmö, Sweden in the 18th Century, with the perimeter of the fortifications. Displayed at the Malmö Castle (photograph: Szymon Kowalski, 2022).

With the popularisation of new technologies, such as 3D printing using multiple materials, such as polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polyethylene terephthalate glycol (PETG), and other types of plastics [25], ceramics, concrete [26] and even metal [27], new possibilities have emerged to speed up the process of creating such objects which dramatically increased the accuracy due to CAD drawings.

METHODOLOGY

In previously published articles, the authors focused on the use of digital models and VR in the teaching processes of the same classes [28][29]. The finding of that study led the authors to investigate a much more traditional way of teaching with the same connecting point, which is the idea of the model as a representation of reality.

In the study outlined in this article, the main methodology was to present models during coherent lectures and exercises. To acquire statistical data on the use and true impact of the models during the educational process, the authors formulated a questionnaire and distributed it to students of the present study cycle - who are no longer learning remotely, and to the previous group, whose whole study cycle was unfortunately remote. The authors also analysed a drawing exercise and observed students during the exercises to collect data on the students' ability to transfer the spatial solutions presented in the models onto their drawings. Besides the questionnaire, the authors arranged in-depth interviews with students to collect additional data about the students' perceptions regarding the problem.

RESEARCH

According to the long tradition of the Faculty of Architecture at Gdańsk University of Technology, creating scale models was one of the exercises during the History of Architecture subject, pushing students to learn history by making

models, which also verified the knowledge of construction. Through this approach, to this day, the Faculty has collected many high-quality didactic resources, some even perceived as a form of heritage, regarding the former education process, dating back to 1945. Academic teachers of the architectural history subjects still use the models, both traditional and recently 3D printed ones, to stimulate students' learning capabilities and explain all of the peculiarities of the presented objects, which are later repeated by the students in drawing exercises.

The main aims of the history of architecture subjects are to teach students the recognition and analysis of historical architecture, including functions (monasteries, churches, castles, tenements housing, etc), construction solutions and multiple details, alongside the periodisation and dating of objects, as specified in the Subject Chart for History of Polish Architecture I (*Karta Przedmiotu dla Kursu Historia Architektury Polskiej I*, A:01648 2021/2022) [30].

The main topic of the research presented in this article is measuring the impact of using a model in architectural education during the History of Polish Architecture classes, which were the topic of one-year observation and deep analysis of students learning capabilities, as well as direct questionnaires regarding the general use of models as a didactic tool for architectural education. The stimulation covered different topics, from churches through public buildings to the process of development of city fortifications and castles, which was archived by presenting models to support the lectures. Multiple drawing exercises were done to measure the efficiency of that practice. During the task, the students were required to draw the desired theme during 1.5-hour classes using the spatial solutions presented during the lectures and physical models, which were evaluated by the teacher.

One specific task focused on the transfer of similar spatial solutions between different architectural objects. Around 1948, students from the Faculty of Architecture built a model of St Peter and Paul's Church - a Gothic hall temple that was partially demolished during WWII [31]. In 1959, there several models were made to stimulate and support the conducted lecture covering the topic of hall churches (Figure 5).

Figure 5: Multiple physical models, including gypsum, representing a section of St Peter and Paul's Church in Gdańsk at a 1:50 scale, made in 1959, and used during the History of Polish Architecture classes to stimulate and support the conducted lecture covering the topic of hall churches (photograph: Szymon Kowalski, 2021).

The students' work, besides its documentary value, has been serving as an example in the analysis of Gothic construction systems, along with a model of the Church of St John in Toruń [32] (from *ca.* 1970). Both of them allow students to see and analyse the objects, which are complex structures created over a lengthy construction process.

An awareness of the multi-generational work of many historical monuments (which is completely different from the current practice) may give the engineers-to-be valuable experience. The choice of such an approach resulted in solving the problem of mindless copying of solutions, instead it required rethinking the adaptation of general spatial similarities within different historical objects. During the preparatory phase of the exercise, the lecturer gave a description of spatial solutions and differences, with greater attention devoted to the vaults, which slightly differ in those two examples.

RESULTS

The research confirmed that 3D models are effective didactic tools to increase the students' learning capabilities by recognising multiple factors. The models were found interesting and intriguing by the students and described as a *piece of art* for their complexity and form of physical expression. The authors also focused on bronze models, (e.g. showing the complete shape of a church) in historical public spaces, which were also found interesting not only by the architecture students, but also by passers-by, who usually stop when walking by to admire, interact with and learn from the model. What is more, these kinds of models with tactile writing system descriptions should be reflected in the form of physical objects at an appropriate scale to allow people with disabilities to visualise the object by touching them, so it is strongly recommended that they be placed in public spaces.

The following questions were put forward to students:

1) Do you think models/mock-ups generally help to teach the history of architecture?
2) Do you think models/mock-ups help you personally to learn the history of architecture?
3) Do you think the cross-sectional model of the Church of St Peter and Paul's in Gdańsk, which served as a similar example, helped you in the drawing task that covered the Church of St John in Toruń?
4) Do you think creating a model/mock-up of, e.g. a church will positively influence its understanding, in particular its spatial relations and construction details?

Figure 6 below includes the responses in percentages:

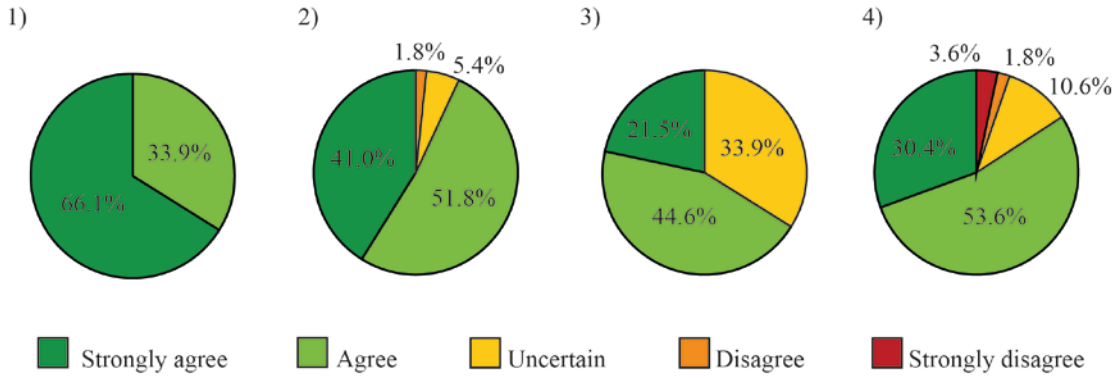

Figure 6: Some of the students' responses to the questionnaire.

Based on the data collected from the questionnaires and interviews, more than 75% of the students believe that knowledge of both European and Polish history of architecture will be useful in their later professional careers, and it is generally perceived as an interesting academic subject. The overwhelming majority of the students claim that models help directly in the process of architectural education, and they generally like to construct models using the most popular materials such as cardboard, balsa wood, paper and gypsum, and find it very time-consuming.

During the in-depth analysis and interview of the Gothic transformation classes, the authors discovered that the model of a section of the Gothic church was extremely influential during the drawing exercises and led to better drawing outcomes. The most important feature, as recognised by the students, was to see and understand the concept of a section of the medieval church that stimulates the spatial imagination, as it cannot be seen in reality. Other important results were complementing the knowledge shortcomings about the space that accommodates the roof truss and visualising the vaults from the top, as access to these spaces is limited in the churches, and only a few of the students have ever been there.

Students pointed out that it was particularly helpful to visualise:

- cross-section through the vaults;
- cross-section through the wall and Gothic window;
- relationship between the arcade and vaults, especially at the embedding of the vaults;
- Gothic roof truss.

Furthermore, the models play a key role in education not only during architecture history classes, but also in such subjects as architectural and urban design, which also strongly focus on the use of this form of expression, mostly focusing on the design presentation and development of architectural form.

DISCUSSION

The presented research showed that one of the best solutions for architectural education, knowledge transfer and architecture history is the approach of *learning by doing* where students are pushed to construct physical mock-ups and models of their architectural and urban designs, as well as historical objects to verify projects and consolidate knowledge.

Another finding of the research was that students do not fully understand historical concepts and nomenclature, even during the brief description in the lecture. The authors observed that some of the students were not interested in the analysis of the object, but only in the end result and still hoped to receive a good grade, which caused them to try to simply copy the solution of the presented, different church. Even when using multiple didactic tools, which unfortunately cannot be successfully applied to all students, some of them were simply not interested in the learning process, and the use of highly effective solutions, didactic tools and methods could simply be ineffective due to the recalcitrant character of certain individuals.

Moreover, not only physical models were perceived as helpful, but also 3D models in digital environments are expected to be similarly helpful. Modelling, for example, a church in a 3D environment, using software, such as Sketchup, Rhinoceros, 3Ds Max or similar, would probably increase the knowledge of similar architectural objects. There is also greater interest among the students in creating historical models in digital modelling classes, where such experience gained during the process can be helpful in future careers, where advanced modelling skills as perceived as a strong advantage in the recruiting process.

The digital process of model-making can also be applied to the technique of model printing, which is also seen by the students as a very interesting activity, and a *futuristic* solution. It is recommended to research the topic of teaching architectural history supported by 3D model creating, editing and printing in more depth. Besides the process of 3D printing, the traditional method of creating mock-ups is also needed and cannot be suspended as an architectural academic activity due to the convergent idea of constructing the building and constructing the model by processing similar materials to archive the design goal, but represented in scale. Times and techniques change, but the role of models in architecture does not diminish; on the opposite, it seems to be increasing as one of the main languages of architecture that should be performed in all stages of study.

CONCLUSIONS

The presented research confirmed that both physical and digital models can be good teaching tools, which can help to visualise abstractions and space, and effectively increase the learning capabilities, not only for architectural students, but also for the broader public through the popularisation of models in public spaces. The time-consuming process of producing models forces the creator to spend more time recognising shapes, details and spatial solutions resulting in a better understanding of the object. Even observing a physical model of the object almost always results in curiosity and admiration of the object, again supporting the transfer of knowledge.

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