INTRODUCTION

Digital media are used extensively in architectural education at universities and colleges worldwide. They are used in the process of design, for boosting collaboration and presenting architectural concepts and buildings. A range of software and plug-ins are available in today's market, which help architects at different stages in the process of design, opening up new possibilities to present and actualize ideas in architecture.

Using digital methods for design purposes raises new issues in the domain of architect education. On the one hand, there is the issue of how ‘traditional’ architectural knowledge can be passed on and how new digital possibilities can be included in the process of design. On the other, there is also the issue of the essential knowhow needed for employing digital methods adequately in architectural design. This issue is even more topical today since this software has become both simpler and more complex. Therefore, it is inevitable to rethink an architect’s ‘basic’ competencies and question the position of these professionals in relation to the ‘digital machinery’ dominating the market.

DIGITAL DESIGN AND NON-STANDARD ARCHITECTURE

Digital methods offer a range of possibilities, from 3D modeling to parametric design to visualizing architectural concepts. Using digital tools helps develop creativity and generate new forms, shapes and their interrelations. Simultaneously, architectural design has become highly complex and too often the technical development of the construction industry today does not allow the actualization of non-standard architectural design, which is architectural design characterized by higher degrees of complexity (Bekiroglu, 2010; Kolarevic, Klinger, 2008). Finding the right measure in terms of complexity and appropriateness of digital design and the possibility to make the construction of such structures efficient.

ARCHITECTURAL SCALE MODEL IN DIGITAL AGE – DESIGN PROCESS, REPRESENTATION AND MANUFACTURING

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Abstract. The topic of this paper is the concept and outcomes of the new syllabus of the course Visualization and Modeling. The aim of the course is to introduce students to digital and analog methods of design, visualization and fabrication. In order for students to acquire such complex matter more efficiently, the classes are held in the form of a five-day workshop. Topics to be covered in the workshop are selected based on their character, which is meant to bear a resemblance to that of architectural design, scaled down to match the scope and goals of the workshop.

Keywords. Architectural education; analog-digital tools; design process; digital fabrication; modeling.
and feasible represents a highly complex set of issues that must be included in and make an integral part of student education.

The problem characterizing the actualization of new non-standard forms today is the lack of standards and norms in terms of their construction using traditional building materials, such as concrete, wood and steel (Teunissen, 2010). The currently used norms have standardized those structural forms and systems as confirmed by experiments and practice, and any structure departing from these norms in terms of structural properties represents a challenge and asks for a new approach to problem solving. Interdisciplinary research combining the efforts of architects, structural engineers and building material technologists is needed to define new standards, classify forms and shapes, analyze the impact and action of stress, optimize forms and structures, examine connections between various members, and also examine non-standard structures making a great number of real-scale models (Kolarevic, 2003).

The first step in this process is student education. In working with students, it is necessary to present critically the benefits and drawbacks of digital design methods; also, students must be given the opportunity to design structures digitally and produce models on their own, and so gain first-hand experience of the complexity of these issues. This process requires combining traditional architectural knowledge with that of digital design (Jones, 1970; Lawson, 2006).

A program has been designed at the Faculty of Architecture and Civil Engineering in Banja Luka in an effort to introduce new methods of teaching digital design. The program is still in the phase of evaluation, continuous modification and improvement. This paper presents the results accomplished so far, which have been quite satisfactory. The program combines simultaneously the teaching of geometry, mathematics, programming and digital design methods.

In the course of two semesters early in their undergraduate studies, students are taught the fundamentals of higher mathematics. The course covers topics related to spatial configuration (vector mathematics, transformation matrices and parametric curves and surfaces), and students are required to solve related problems. In parallel with this course, students attend a course in structural geometry, where they analyze geometric bodies, spatial configuration and relations between different bodies in a given space, and use analog methods to solve various problems of spatial geometry (intersections of lines and planes, conditions of orthogonality, planar cross-sections of polyhedra and non-polyhedra, different projection methods). One of the objectives of this course is enhancing students' spatial thinking and competencies and connecting their previous knowledge of mathematics with actual cases of architectural design. The third part of this program takes place in the third semester, when students are introduced to programming using the programming language Visual Basic and are taught a course in visualization and modeling, offered in the form of a workshop, which synthesizes the previously acquired fundamentals. The workshop is the students' first encounter with digital methods and collaboration, and as part of the set task they are asked to solve a number of analog and digital problems. By the end of the workshop, the students have produced a digitally designed prefabricated object, which they are also required to present. This paper describes the workshop program in detail. The workshop is succeeded by courses focusing on free-form and parametric modeling.

**VISUALIZATION AND MODELING**
The course entitled Visualization and Modeling was introduced in the architecture curriculum at the Banja Luka Faculty of Architecture and Civil Engineering after the old curriculum was modified to comply with the recommendations of the Bologna Declaration. In this course students are familiarized with digital and analog methods of visualization, modeling and presentation, and they master digital techniques used in contemporary architectural practice and design.
In order to make the acquisition of the subject matter interesting for students and allow them to express themselves creatively, each year the workshop sets a new theme to achieve the objectives of the course Visualization and Modeling. In October 2009, the first workshop entitled ‘doghouse’[1] was held, whose accomplishments and the satisfaction of both the students and professors led to the decision to organize the workshop the next year as well, entitled ‘box3’[2].

**METHODOLOGY**

Since this course is the first opportunity for students to learn about digital methods of design and presentation, teaching in the form of a workshop has proved ideal. In the workshop, students focus on a single topic over a time span of five days, and owing to intensive teacher support they are in a position to experience the complete process of digital design, from the first sketches to fabrication. In the workshop analog and digital methods alternate, and the main goal is connecting the knowledge students already have with the subject matter of digital design they are presented there (Table 1). The method used in the workshop is ‘learning by doing,’ which spurs student interaction, leads to constant reconsideration of the concept and learning based on the know-how mastered in the previous stages (Drake, 1978).

The workshop lasts five days and each day focuses on a different topic. It is held at the very beginning of the third semester, and as students do not have sufficient basic knowledge of complex building design, the topics selected for the workshop are simple in terms of use, compounded by adequate levels of difficulty in terms of structural and architectural design. The topics covered in the workshops held to date are ‘doghouse’ and ‘box’ (packaging box).

At the start, students are divided into three groups. The method used by the first group to deal with the design problem is sketching; the second group uses analog modeling; and the third digital modeling (CAD). Each group employs each of the three design methods. This approach allows students to opt for the method they personally find the most suitable for further design. Putting different methods into interaction is seen as highly beneficial by the students, as they are encouraged to analyse and improve their projects using different methods.
THE STRUCTURE OF THE WORKSHOP
Irrespective of the topic selected, the workshop is structured per day. Depending on the special character of the topic covered (doghouse, box), minimal changes can only take place. The individual days are organized so as to cover the following topics:
1. Analog sketching and interim design modeling.
2. Digital modeling and design.
4. Voxelisation.
5. Fabrication, presentation of work and the closing exhibition.

The topics covered are put in an order that allows students to become familiar with the design process gradually, through a balanced use of analog and digital design methods, phasing in the subject matter they are supposed to acquire (Figure 1). Each stage of the workshop has its own goals, but the order is nonetheless sufficiently flexible, as it stays in tune with the students’ capabilities.

The process of analog freehand sketching enables students to visualize their imaginary project for the first time. This is the fastest way to analyze form and function and to generate alternative solutions in the conceptual phase of project. At this stage students may choose from a range of materials (cardboard, paper, styrofoam, clay) and cutting tools. After the form analysis, in parallel with their drafts, students create meshes of their first spatial models. The topic selected typically seems unchallenging at the beginning of the workshop, but what makes it really challenging is modeling an interim design, i.e. developing the concept to create a mesh to be actualized using a two-dimensional material (taking into consideration the thickness and properties of the selected material).

At this stage students must also be careful so as to optimize both the structure and the use or quantity of material to be expended. This task requires the transformation of a three-dimensional model to a planimetric drawing and vice versa. It also develops the student’s ability to handle spatial transformation and allows hands-on application of the knowledge of geometry students gained in the previous semester. The materials planned for the final models are also used to make the interim ones, so students can respond immediately by eliminating any perceivable mistakes and become aware of and consider the problems arising in the process of assembling the model (Figure 2).

**Digital modeling and design**
The second phase is the digital 3D modeling and design of the concept. Out of a myriad of 3D software available in the market, the workshop authors have decided to use Google SketchUp. This software is very easy to use for modeling 3D objects, and it also...
The objective of this phase of the workshop is digital 3D modeling and possibly modifications to the analog design, which is most often inspired by new digital possibilities. Namely, when creating an analog design, students are quite often not skilled and patient enough to actualize their ideas, or they do not know how to materialize them using the set material. Thus, digital design offers a different kind of modeling, where ideas can be put into practice ‘more easily’. After mastering digital modeling, students often get new ideas and substantially change their initial designs, or they are so excited by the new methods that they start the whole project over again, reanalyze the form digitally, etc.

**Comic books**

During this stage of the workshop students are asked to draw a comic book which should contain the object they have designed (Figure 5). The comic book focuses on the spatial configuration of the object and ways to simplify form by stressing the right elements. After an introductory lecture on the structure, elements (Ditschke, Krouchova, Stein, 2009; Dittmar, 2008) and digitalization of the comic book, the students are asked to produce three-image strips on the set topic (University Campus, Banja Luka City hidden charms, etc.). The students digitalize their freehand drawings, which are then colored (the final stage of the production) in the Photoshop.
Voxelization

The principal idea behind this phase is ‘changing’ the dimensions and use of the designed object. The project is given a new dimension at this stage – that of an architectural object (Figure 6, Figure 7). Voxelization – the multiplication of discrete elements – leads to the creation of a new spatial structure, where the project is seen from a completely different perspective. The form of a complex object is reduced to its basic elements, it is materialized in a different manner (solidity, transparency), and becomes practically unrecognizable in the new environment. This phase is possible only in a virtual environment, so students use the SketchUp to transform, group, animate, etc. their objects.

Fabrication, presentation of the works and the exhibition opening

In the last stage of the workshop students prepare two-dimensional CAD drawings for fabrication (the drawings are used to differentiate between the two different functions of the laser cutter, cutting and
At the end, the students complete their projects by presenting all of their work on a poster, assembling their meshes and participating in the organization and mounting of the exhibition (Figure 9, Figure 10). Since time is short and the subject matter that needs to be acquired broad, this type of intensive work that students engage in during the workshop helps them to develop a sense of teamwork and collaboration. Students are also additionally motivated by the prospects of the closing exhibition. The experience to date has shown students develop excellent collaboration during the workshop, and the web support, used for student experience exchange and for storing the individual phases of the project, helps a great deal in developing students’ creativity.
THE WORKSHOP AS SEEN BY THE STUDENTS

After an intensive workshop, there are always a couple of questions to answer. Have the program of the workshop and the teachers’ expectations been fulfilled? What exactly and how much of the new subject matter have the students been able to acquire in such a short time, and are students capable of mastering new principles of digital design over such a short period? Based on the students’ accomplishments, it may be concluded this kind of ‘introduction’ into digital design has proved highly successful. Namely, while learning, students often need teacher support, and workshops are perfect for providing this kind of intensive contact. The teacher-student cooperation is at a very good level, because there is direct contact and knowledge transfer between them; at the same time, information exchange between students themselves is also faster and more immediate.

Over a period of five days students have a chance to learn about various digital formats, which serves as encouragement for future individual knowledge upgrade. The methodology used in the workshop entails alternating lectures with hands-on work, and new topics and tools used in practical work (analog-digital) are introduced daily.
The outcomes and benefits of the workshop are seen in the ensuing semesters. According to teachers who do design courses in the third semester, the results are visible as early as the very beginning of the semester, especially in terms of modeling. However, the benefits of this manner of structuring the courses and subject matter taught is primarily important in the sense of continuous, gradual, and targeted study of contemporary architecture, which requires the knowledge of the overall process, ‘from the design concept to its fabrication’; the division of the workshop into stages is also a good demonstration of the various stages in the process of architectural design.

On the other hand, there is also the question if the students’ expectations are fulfilled. The remarks the students put on their posters and their opinions quoted below in this paper give an answer to this question:

‘When I think about the previous five days, what fascinates me is the fact that so much can be learned in a short period of time. The first day I arrived I was faced with a blank piece of paper, unresponsive, unknown software, new tasks and a demanding pace of work. But the path from the idea to its realization was more than interesting; positive energy, laughter, and enthusiasm made the strenuous and demanding work interesting and exciting, and the daily exposure to new, unfamiliar things made the time spent at work short and fulfilling.’ (student: Jelena Marić)

‘In one of his lectures the Dean quoted Albert Einstein, who once said that not even God plays at dice, and we obeyed... We did not play, we dallied with ideas... In what way? We started with purpose... There were all sorts of ideas, somewhat comical, but gosh, is finding true purpose not the most difficult thing of all? Not just for a box, but for anything we try to do in life... After that we played with shape, and then we moved on to design... and, finally, on to the final treatment. There was everything there: a real decathlon, a competition without a winner, because we were all equally good... It was a somewhat strange decathlon, one characterized by team spirit, collective deprivation of sleep, occasional hangovers... sharing grub... the kind of decathlon one no longer finds, not even in the Olympics...’ (student: David Latinović)

CONCLUSION
The new trends in the field of architecture propelled by the use of digital media for design and prefabrication of individual parts of buildings (non-standard architecture) raise new issues regarding student education. The process of design of non-standard buildings is connected with digital methods, the possibility to fabricate individual building parts, creating connections between them, and the process of manufacturing. Thus, mastering this subject matter requires the integration of various fields (structural engineering, geometry, technology, materials, etc.) and a new reconsideration of the curriculum traditionally taught in schools of architecture.

The workshop described in this paper represents a model of integrated teaching of digital design. At the same time, it offers students an introductory course in the field of digital design. This concept focuses on the physical architectural scale model and digital methods of design and presentation, and its greatest benefit lies in the intensive cooperation established between the students and teachers. The consecutive application of analog and digital methods of work make the design process a complete cycle, while developing student competencies in a way that will make them competitive in terms of the trends and tendencies in today's architectural market.

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REFERENCES


