Experimental teaching of computational design tools by intensive workshops

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ABSTRACT: The current development of computational design tools brings new challenges to their timely curricular integration. Nowadays, architectural practice requires a wide range of skills and experiences in this field. However, the current setting of the related courses provides insufficient time to teach students all the required knowledge. This contribution describes an educational experiment tackling this issue by block teaching in two intensive workshops called *Digital Belluš* conducted in the Faculty of Architecture and Design at Slovak University of Technology in Bratislava (FAD-STU), Slovakia. The workshops were named after Slovak well-known modernist architect, founder of the FAD-STU, Emil Belluš. The topic of both workshops was the reinterpretation of the work of this great modernist architect with contemporary computational design tools. The first workshop introduced the entire process of computational design to students in a short time, only in four days. In a similar way, the second workshop provided students with the actual concepts of computational design. The efficiency of block education and the involvement of students in the research were examined and proved. The contribution describes generalisation of the findings and their application in the further education process.

Keywords: Architectural education, block teaching, workshop, computational design, modernism

INTRODUCTION

About sixty years have passed since the release of the first computer-aided design (CAD) software [1]. Together with a rapid development of computational technologies in recent years, these instruments have evolved into various, very specialised tools and gadgets. Currently, there is no software to cover the entire wide range of design requirements. Nowadays CAD software is used almost in every aspect of architectural production - it became the virtual prolongation of the creative human mind. The shift of the economic model of software tools from products to services with regular updates, open-source development and improved on-line communication have made the evolution of these technologies faster than any time before.

Is it even possible to catch up with this rapid development to improve education? The current teaching models are already lagging behind. The current syllabuses of specialised courses provide only an insufficient time to teach all the needed computational skills. Software implementation in other courses is weak because their implementation exerts high pressure on the educators who are supposed to be experts in their own field and simultaneously in cutting-edge software tools. In addition to that, there is a rising gap between these tools and the general knowledge and history of them as the development of theory and teaching methods is becoming slower than technological progress.

METHODS

As higher education teaching methods are developing at a slower pace, the other types of software education emerge rather rapidly. On-line video portals with plenty of tutorials and international lectures proved to be a very powerful source of information replacing several higher education shortcomings. Forums with thousands of discussions, quick response rates and efficient search engines proved to be better than any printed software manual. Open-source platforms provide plug-ins and extensions that can be assembled to new powerful software instruments often replacing the rigid repetitive work. These educative and communication methods were quickly adopted by on-line universities and institutes.

To improve current education, the inspiration was found in lean management often used by production companies, as a university could be compared to a factory in terms of education provision - or by parallel production - to create well-prepared professionals for the job market. Lean management was firstly applied by Toyota manufacture by finding

a delivered value of the final product, eliminating other processes which did not deliver this value. Popular is the following motto by Taiichi Ohno, the founder of the Toyota production system:

> *Costs do not exist to be calculated. Costs exist to be reduced* [2].

Continues improvement of the production process in this approach is achieved by close interaction with every employee. The aim is to quickly develop the product and examine the viability of the production process [3]. The basic lean principles were summarised in the *lean thinking* [4]. These principles are to identify value, map the value stream, create a workflow and establish pull factors, and to add continuous improvements.

In the final product, the delivered education, the motivation of students is necessary for successive learning - the delivered value of the final product. It was identified, that if students have something to create, their motivation to learn rises together with the ability to implement the learned knowledge. To support this motivation even more, the authors of this article introduced them to a compelling topic, gave them the opportunity to work with physical materials in real scale, to be part of the research and to present the outcomes at significant events. Further, they reduced the problems and distractions by establishing the ideal environment providing sufficient time and conditions for concentration needed in their creative work by compressing the entire time of the course to one block of teaching.

Teaching in intensive blocks - workshops are already a well-known method motivating the participants to close team-based co-operation [5] by its professional competitive environment [6], and in a short-time period. The aim was to teach the students to not only rely on training given by tutors, but to ask questions and find information themselves, which will rise the adaptability to new future problems. Involving students in research is another valid and recognised method [7], rising awareness of new problems and enhancing the motivation of students by knowing that their work is meaningfully utilised.

The next principle of lean management is to establish the pull system. The work is pulled only if there is a demand for it. This optimises the resources and creates a stable workflow [3]. In block teaching, the pull system was a given challenging task to students and the scheduled programme of the intensive block. By knowing the aim, which covered the basic knowledge of computational design and its tools for graduates of architecture, the authors did not spend time for teaching other less important details or teaching the issue from an overly wide point of view.

The last principle of lean management is to improve the process by close interaction and communication with employees. To refine the process by people who are making the product. In this case, the authors were closely co-operating with other tutors and students on an equal, friendly level to get feedback quickly and to adapt the tempo and requirements. Concerning communication, they were inspired by on-line models of education. For the on-line conversations with students and between them, they have used Trello [8], an on-line platform for project management. On this platform different communication threads can be created, similar to a small forum for solving software issues. Students were free to ask questions and they could find every information, schedule, recorded video tutorial or lecture on the platform (Figure 1).

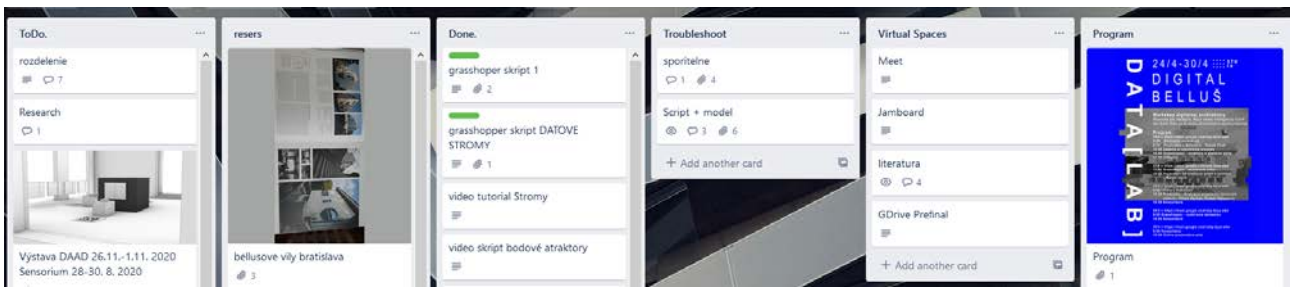


Figure 1: Trello board with multiple threads of communication from a workshop (author: R. Hajtmanek, 2023).

WORKSHOPS

The *Digital Belluš* workshops took place in the Faculty of Architecture and Design at Slovak University of Technology in Bratislava, Slovakia, in 2019 and 2020, and were part of the optional course Digital Architecture focused on computational design tools, mainly on Grasshopper - an algorithmic editor for parametric modelling. The course is normally scheduled as weekly sessions taking two hours, which totals to 26 hours per semester. This time was compressed to four intensive days, eliminating self-study at home, but increasing the concentration and motivation of students.

The students were introduced to a compelling topic, the reinterpretation of Slovak modernism with contemporary computational design tools. The workshops were named after Emil Belluš, a Slovak modernism architect, the founder of Faculty of Architecture and Design in Bratislava, Slovakia [9]. The aim of the workshops was to complement or re-create his great work with new digital techniques. Both four-day workshops additionally motivated students by an opportunity to exhibit their work at significant events, such as the Night of Architecture and the Days of Architecture and Design in Bratislava, Slovakia.

The time schedules of both workshops were similar: discussions and tutorials in the mornings, lectures in the afternoons, and another tutorials or consultations until the evenings. On the last workshop days, students presented and exhibited their work. The workshops were taught together by five tutors and two lecturers.

According to the methods of lean management, the first workshop carried out in 2019 motivated students with a possibility to work with real materials and dimensions of the space around them. The challenging task representing the pulling system was to design new sunshades of the studio in real scale. In this way, the work of Emil Belluš could be complemented with new digitally fabricated interior elements. (Figure 2a and Figure 2b).

Students also took part in a solar research project, helping to develop scripts for solar radiation analysis. The workshop was open for everyone, and was attended by 16 course students and four voluntary students in addition. The students were divided into four groups to create competitive environment. This also simplified communication with them in regard to continuous regulation and improvement of the teaching process according to the lean management methods. The communication was further simplified and intensified by daily coffee meetings with discussions about the students' projects and using the on-line platform Trello.

None of the students had experience with the computational or algorithmic tool Grasshopper, digital fabrication or theoretical knowledge in the field. The aim was not only to teach Grasshopper to students, but to make them understand the strategies and theory of computational design, to have the general and contextual knowledge about the topic. During the workshop, the three theoretical lectures were attended by students, and one by a computational design theorist, guest professor Imrich Vaško (Figure 2c).

a) b) c)

Figure 2: a) students worked with space around them, designing new sunshades to the studio window; b) digital fabrication of sunshades with laser-cutting; and c) theoretical lecture in the studio (author: R. Hajtmanek, 2023).

The second workshop in 2020 was carried out in the beginning of the pandemic, thus it was completely on-line. The pandemic complicated the teaching, but active communication with students was preserved by discussions during on-line coffee sessions and with the Trello platform. Nevertheless, the model of teaching was similar to the first workshop. The workshop lasted four days, the motivation of students was ignited through an opportunity to work with artificial intelligence as part of a university research project.

The task was to recreate with the help of AI chosen buildings of Emil Belluš, to revive and reinterpret his patterns of work. The students worked with artificial neural networks [10], which allowed to learn the relations between the internal properties of the chosen building, such as its circulation, programmatic organisation with its final form. Artificial neural networks then extrapolated these relations on new inputs, creating new forms. These new forms were comparable with the original artworks used for machine learning.

The second workshop was focused mainly on AI as a cutting-edge tool and was attended by seven students from the previous workshop. The main purpose was to examine the preparation of the students for completely new problems and different approaches to design. The outcomes of the workshop were then exhibited during the events of the Days of Architecture and Design in Bratislava, and the Night of Architecture.

RESULTS

In comparison to the previous, standard model of weekly short sessions and assignments for self-study, the block teaching with mentioned enhancements proved to be noticeably more efficient. With the standard, previously used methods, more time had to be spent for issues with software as students forgot some procedures after a week pause.

In the block of teaching, students learned skills in a tutorial and they immediately implemented them in their design, which led to deeper memorisation. They learned them not only as abstract procedures, but as practically utilised processes. Another aspect of block teaching was the reinforced communication between the students. They troubleshot a lot of issues themselves in groups faster than they would with the help of a tutor. The on-line platform Trello with all

recorded video tutorials and lectures proved to be very helpful when the pandemic broke out, repeating of certain parts of tutorials was not needed as students found them on-line.

Also, the spared time enabled to teach the theoretical knowledge, which led to a better understanding of computational design issues in the wider context. Students managed to go through the entire process of computational design from first conceptual thinking and geometry studies, through scripting and digitalisation of these concepts to their digital fabrication and testing of their designs. Although self-study at home was limited by the time schedule of the workshop, students learned more in this short amount of time, thus the costs were reduced and benefits increased.

Motivation enhancements together with the form of teaching in blocks led to a higher engagement of students. By the regular weekly sessions, students were not especially engaged with the topic, they hardly presented their outcomes on the exhibitions. On the other hand, in block teaching, their concentration was fully focused, which led to successful outcomes, motivating them even more. The students have built a relation with their designs giving them a reason to present their work. In the exhibition they additionally learned how to professionally install and illuminate their work (Figure 3).

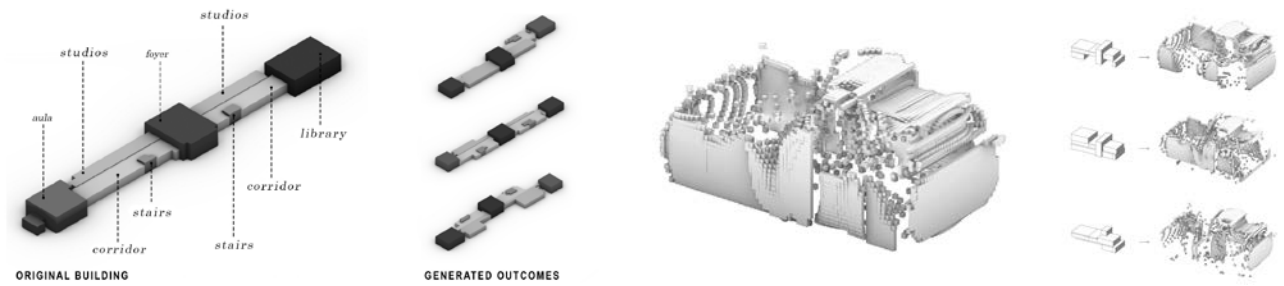
Figure 3: Installation of the workshop outcomes in the exhibition Night of Architecture 2019 (author: M. Uhrík, 2023).

Both workshops were strictly planned with a time schedule for tutorials, lectures and consultations. Despite that, as the authors communicated and closely co-operated with students according to the lean management formula, they had to limit the set-up requirements throughout the first workshop. In usual education, some students are getting meaningful outcomes faster, which results in the demotivation of the weaker ones, as they lose the virtual competition.

Working in groups and constantly regulating the process led to similar quality results in each group. The comparable quality of the outcomes enabled healthy competitiveness between the groups. The previous aim was to create the sunshades in full-scale, each in size four cubic meters. In the end, by getting feedback from students, the authors limited the set-up requirements to 1:2 scale, sunshades in the size of one cubic meter each. By regulating the requirements, students were not demotivated by unsuccessful results.

The second workshop was attended by students from the first workshop. Their preparation for new tools was surprisingly high as they achieved a complex layering of few artificial neural networks together. The unexpected success of the students led the authors to increasing the requirements by adding another neural network to generate even more detailed results. By increasing the difficulty, based on the feedback, the workshop was still enjoyed by students. The students were not bored by simple not challenging tasks. Additionally, generating more complicated results helped in the research project [11] (Figure 4).

Because of the pandemic, the digital fabrication in the university campus was not possible. Despite that, the outcomes of the workshop were exhibited in the on-line version of the Days of Architecture and Design in Bratislava as interactive 3D models on the related Web site [12].



a) b)

Figure 4: a) outcomes of a neural networks learning programme of the Faculty of Architecture and Design (authors: D. Takáč, M. Kuchar and A. Maté, 2020); and b) outcomes of neural networks learning - the form of the House of Oarsmen (authors: M. Pajerský and A. Mravík, 2020).

DISCUSSION

The efficiency of the used methods could be argued in a way that the workshop was only attended by a very hardworking class of students, but the positive outcomes were already proved by the subsequent workshops with the similar formula, attended by other participants.

Another argument against block teaching could be that as students attended the workshop, they were missing other subjects. This issue is currently solved by delicate time planning and agreements with pedagogues from other courses. The workshops were announced in the beginning of each semester thus students could manage their time in advance. Despite that, students missed some parts of the tutorials or lectures of the workshops. The active communication between students and recorded tutorials and lectures overcame this issue without difficulties. The workload on educators during the workshop days was higher than usual but this approach to teaching was for them less routine and thus more engaging. Additionally, the successful outcomes helped in their research projects and spared their time from the weekly sessions.

The Digital Architecture course is optional and thus most of the students were interested in the topic. Nevertheless, students with less motivation were supported in individual groups. Close interaction with students revealed some inconsistences in work which were projected into their final evaluation.

It is difficult to assume if block teaching will be equally meaningful in other courses with a larger time load or with different knowledge than computational design tools to teach. Nevertheless, the application of block teaching in optional courses with a shorter teaching time load is viable. From the authors' experiences, the weekly sessions in such a short and insufficient time lead only to a lack of interest and motivation among students caused by the repetitive tasks.

CONCLUSIONS

The new development of the educational process should answer the new challenges. Technical universities should provide graduates with extensive software skills that prepare them for more computerised and informatised professions. Despite that, time and pedagogic capacities are insufficient. Only few pedagogues are supposed to provide hundreds of students with high quality software education. Also, students are already overloaded with other significant subjects. Education has to be more automated and at the same time customised to masses of students. On-line education with recorded lectures and tutorials utilising on-line management platforms similar to Trello or Teams should help to solve the pedagogic capacity issues.

With insufficient time to teach the vast area of knowledge, it is required that the educator is a good manager. The use of lean management proved to be a successful way to find how and what is relevant to teach. Expecting that motivation to learn will rise through the implementation of software skills in predefined challenging tasks with rewards and continual close interactions with students led to successful results. Students understood deeper the practical application of the techniques.

The gap in software education and technological progress leads to an already globally visible lack of architects' interest in technology, computational approaches and hard data analysis. It is often represented by post-digital collages visually similar to post-modern artworks but created in basic drafting and photography manipulating software tools [13].

How will these techniques bring more sustainable, environment-friendly and efficient buildings able to tackle future society problems is not clear. If this gap will not be closed by new forms of education, bringing technology again closer to architects, the benefits of computational design will be attainable to very specialised professions. Architects may then become obsolete.

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BIOGRAPHIES

Martin Uhrík graduated from the Academy of Fine Arts at Bratislava, Slovakia, in 2001 and completed his PhD studies at the Faculty of Architecture at Slovak University of Technology in Bratislava (FA-STU), Slovakia, in 2006. He was a visiting scholar in the School of Architecture and Conservation, Columbia University, and has been working with several internationally acclaimed institutions. He is the author of the book Digital Architecture. He works as a teacher in the Institute of Ecological and Experimental Architecture of the Faculty of Architecture and Design, STU, teaching in the computational digital studio Data[LAB]. The practice is based on research of architecture and its overlaps into other fields of study. The scope of his work is broad, and consists of lecturing, research, publishing, architectural design, industrial design and computer-driven design.

Roman Hajtmanek graduated from the Faculty of Architecture at Slovak University of Technology in Bratislava (FA-STU), in 2016, and from the University of Applied Arts in Vienna, Austria, in 2018, gaining his Master's degrees in architecture. In 2019, he finished his doctoral studies in the Faculty of Architecture and Design (FAD) at the STU, receiving his PhD degree. His work has been issued in several publications, and he has participated in various competitions and group exhibitions. He has worked for several architectural studios based in Vienna and Bratislava. Currently, he is a researcher in the FAD, focused on experimental applications of virtual reality and machine learning in architectural domain. He teaches in the Institute of Ecological and Experimental Architecture, and at the computational design studio Data[LAB].

Alexander Kupko graduated from the Faculty of Architecture and Design at Slovak University of Technology in Bratislava (FAD-STU) in the field of architecture in 2020. He is currently a PhD student at the FAD-STU. He teaches in the Institute of Ecological and Experimental Architecture, and in the computational design studio Data[LAB]. His work focuses on parametric design, fabrication, manufacturing, virtual and augmented reality, and 3D modelling. His doctoral studies are focused on the topic of breaking the barriers in education and intuitive using of computational tools in the creative process. Currently, he is also part of the light design and digital art studio CTRL space.