Improvements to the STEAM-based teaching of architectural drawing

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ABSTRACT: The author of this article presents a systemic approach to improving the teaching of architectural drawing courses for engineers in the 21st Century. In this era of rapid development of digital technologies, the traditional teaching structure should be redefined to a purpose-oriented dynamic model. The existing, generally accepted teaching models have already proved successfully based on the practice-oriented STEAM programme, which integrates science, technology, engineering, art and mathematics. The systemic approach proposed in the article is a step forward in the teaching model strongly focusing on the open structure of the model necessary for its future development in this changing environment. The usefulness of the proposed model for the improvement of teaching architectural drawing has been analysed along with the syllabus of the Architectural Drawing course in the Faculty of Architecture at Gdańsk University of Technology, Gdańsk, Poland. The results of on-line teaching during the Covid-19 pandemic restrictions were processed by data analysis. The usefulness of the proposed model in different areas of engineering education is discussed in this article.

INTRODUCTION

Architectural drawing is a basic skill in the field of architecture [1], as well as many engineering and technology fields, such as product design, urban design, civil engineering and cinematography [2]. Knowledge of the appropriate drawing technique improves effectiveness in many technical design areas. It is a supporting skill for visual forms of communication, which are perceived as essential for the engineering profession [3]. Architectural drawing enables technical tasks; however, some modern trends seem to present sketching as an out-of-date, incomplete and unsatisfactory format in which to present a design [4]. But the domination of digital technology also carries a risk for the development of design ideas [5]. The clear historical connotations of design and freehand drawing studies show that the drawing skill improves how people think about the structure, shape and surroundings [6]. This provides a tremendous advantage in achieving better design outcomes. This is how designers present their ideas and communicate within the design workflow. Moreover, the proportions designers create are important for aesthetics, where architectural drawing provides accurate depictions for practice. Freehand drawing, as a work of art, carries energy that moves human sensitivity. The integrity of this skill was defined by Frascari:

> *Architectural drawings are representations that facilitate understanding of buildings, conditions, processes and events in human world-making, in other words they are the interactive and generative mapping of architectural cosmopoiesis. Cosmopoiesis can be described as* world-making. *In ways of World making the philosopher Nelson Goodman observes that a* world *is not only a physical universe, but also the cultural artefact, the systems of organization and meanings created by a group of people at any one time* [7].

In modern times, the times of dynamically developing technology, freehand drawing is constantly evolving and used with hybrid techniques, where the traditional approach is combined with photographic techniques and computer-aided design (CAD) [8]. Therefore, the possibility of developing other techniques depends on the acquired basic skill. Even though computer skills are mainstream, architectural drawing is a foundation for design education, and the teaching process should develop along with growing challenges.

BACKGROUND

Laseau, who redefined the visual thinking that uses the products of vision-seeing, imaging and drawing, sees the essence of drawing as a norm of interpersonal communication [9]. Diagrams and conceptual sketches are the integral part of the design-thinking process [10] and the building design process [11]. Architectural drawing can be considered as a precursor for developing a sense of aesthetics for future designers, often presented as an interactive tool in the architectural design process [12]. However, one of the most important things is to define the teaching model. Allen presented a comparison of different models of teaching techniques combining the conventional model with a technical teaching model developed towards an advanced *second studio* model [13]. The aim was to present each activity as fully

architectural rather than just technical, to exercise the student's imagination in creating solutions, and to ensure that the work which students complete drive the lectures. This model, however, turned out to be very time-consuming and difficult to apply due to the constraints within architectural design courses. The above premises indicate the potential for improving drawing education and confirm the drive for changes [14]. Mastering architectural drawing is a skill to improve the design workflow. This is the basic term to define the reorganised model. The architectural drawing teaching context, including complementary knowledge, teaching and the field of application in the organisational structure of architectural drawing in design education in the Faculty of Architecture at Gdańsk University of Technology (FA-GUT), Gdańsk, Poland, is presented in Figure 1.

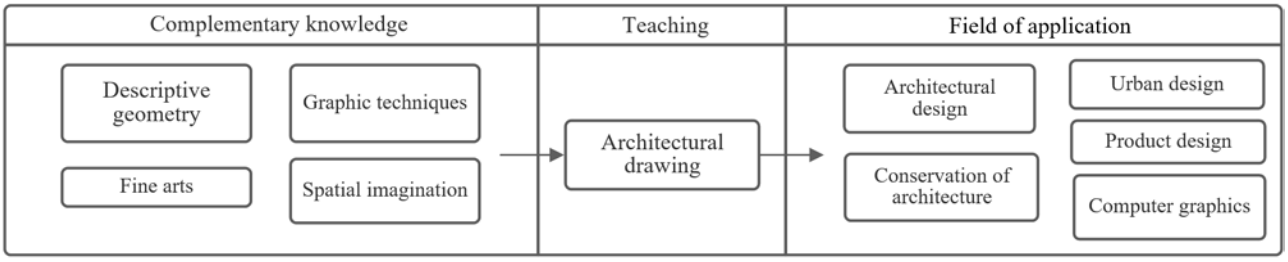


Figure 1: Organisational structure for architectural drawing in design education at the FA-GUT (Author: M. Gerigk).

Here, one can see that architectural drawing relies on complementary knowledge and has an impact on other fields of education. The initially developed manual skills find their practical application in subjects taught in parallel, such as descriptive geometry, graphic techniques and fine arts, through shaping proportions and ending with the aesthetics of graphic representation. It is a milestone to become more effective in individual or group practice courses that require constant drawing and improve communication between the teacher and student. The beneficiary effect of this practice, is evident in courses for architectural design [15][16], urban design, architectural history [17][18], product design and computer graphics.

The way of thinking presented above highlights the tremendous influence of architectural drawing in relation to engineering education in the design field as knowledge of architectural drawing is an integrator that allows practical skills to be developed. The presented research background prompts questions about whether the current teaching model is sufficient; what improvements are possible to achieve better graduate performance; and how the current model can be improved so that it can be managed remotely.

There is a great variety of drawing schools in the international higher education sphere. When comparing drawing courses, the typical teaching model usually consists in the implementation of a set of independent exercises arranged in ascending order towards more difficult tasks. In Poland, at some universities, such as Warsaw University of Technology [19] or Cracow University of Technology [6][20], the teaching is more focussed on geometry, details, greenery or human body shapes. Some approaches have the strict aim to teach drawing in a simplified technical style, such as in the Drawing Gym course for engineers at the University College London (UCL) in Great Britain [21]. At Monash University in Melbourne, Australia [22], as well as at the College of Architecture, Art and Planning at Cornell University, New York, USA [23], the drawing courses are problem-solving oriented, where the analytical approach is introduced as part of the provided knowledge. The drawing course at the Beuth University of Applied Sciences Berlin, Germany [24] is developed according to the teaching structure with distinguished spatial outdoor study drawings, as well as tutorials in digital image processing.

FREEHAND ARCHITECTURAL DRAWING BASIC COURSE AT THE FA-GUT

The Architectural Drawing course model at the FA-GUT is conducted in the first year of engineering studies. The course is a block set of exercises presented in Figure 2 in the form of four stages of the complete course.

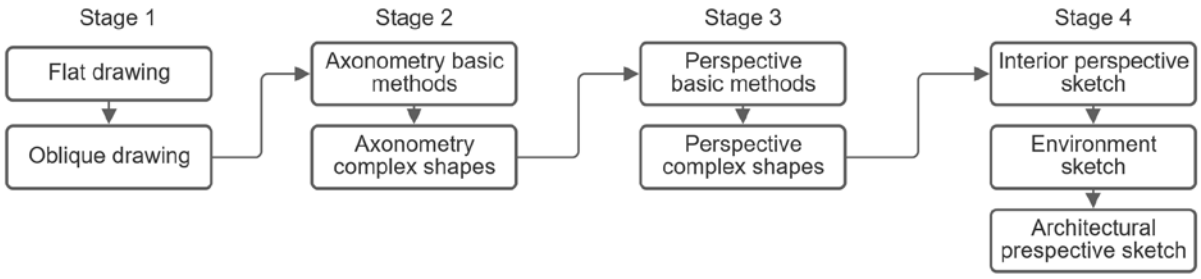
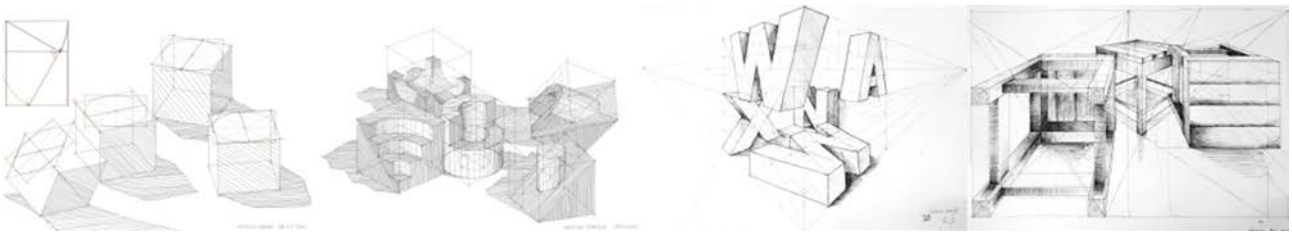


Figure 2: Architectural Drawing course - block structure scheme (Author: M. Gerigk).

Stage 1 includes exercises describing two-dimensional space. This is an introduction to the entire course. The purpose is to select the best drawing tool, where the permanent technique is required. Using a permanent tool, while drawing requires from the drawer focussed attention and taking into account the value of each element added. These requirements are

applied at all stages, where drawing shapes the personal character and style, without the possibility of erasing a potential mistake. Stage 2 includes exercises describing three-dimensional (3D) axonometric space. It consists of theoretical knowledge about the construction of axonometric space and then applying it to different shapes starting from the beginning with simple objects and ending with very complex ones. Sample exercises are presented in Figure 3, where one can observe the skills development in two aspects. The first is the difficulty of the object's construction and the second is the proper shading. Figure 3a shows simple cubes with basic shading. In contrast, in Figure 3b multiple cuttings are integrated creating complex objects, where the shading requires intensification. The next part of teaching architectural drawing, stage 3, is the acquisition of the perspective drawing skill. As in the case of axonometry, this stage begins with the basic elements and ends with multi-element compositions. At first, the exercises of this stage introduce the construction of basic space with simple abstract elements as shown in Figure 3c. In this stage of development, elements inspired by real objects are introduced; for example, a wooden stool as shown in Figure 3d.



a) b) c) d)

Figure 3: Architectural drawing, stage 2 and stage 3. Exercise topics by B. Domsta: a) and b) instruction samples by M. Gerigk; c) and d) drawings by FA-GUT students, J. Kreft and N. Buć.

The above-presented exercises develop and train construction techniques. Drawing skills are now applied in study drawings from nature. Samples from stage 4 study drawings are presented in Figure 4: detailed interior perspective drawings in Figures 4a and 4b; nature study implementing the techniques important in creating natural surroundings in Figure 4c; and the final subject - building perspective study drawings with surroundings in Figure 4d. This is the final exercise, where the level of graphic representation of reality should ensure a clear perception of the presented topic.

a) b) c) d)

Figure 4: Architectural drawing, stage 4. Drawings by FA-GUT students: a) nature study by K. Kropisz; b) GUT Main Building - interior sketch by A. Jeziorska; c) nature study by M. Kolasiewicz; and d) GUT Nanotechnology B Building study by T. Wojewski.

The aim of freehand drawing in engineering fields should be a technical presentation, focussing attention on the object, rather than the drawing expression. The variety of teaching techniques may result in a more artistic than technical drawing character. Despite the wide variety of approaches to teaching and cultivating the art of drawing, the trend of integrating freehand drawing with digital presentation techniques is particularly visible. Hence, the basis for course modifications to increase its adaptability to contemporary trends should be professional practice.

SYSTEMIC APPROACH TO TEACHING ARCHITECTURAL DRAWING BASED ON A STEAM PROGRAMME

Architectural drawing is an educational structure primarily related to the development of design thinking (DT), and then to other disciplines and methods [25]. The extended teaching methodology provides the complementary basic structure of elements based on the modern approach of a CDIO-based STEAM programme - an implementation-oriented programme dedicated to the improvement of interdisciplinary professional skills [26]. Here, science, technology, engineering, art and mathematics represent the multidimensional, implementation-oriented educational structure. In effect, the interdisciplinary approach improves the drawing skill as the language of communication, where analysis is driven in parallel with simulation. Solving a design problem through freehand drawing is crucial in contrary to just applying drawing theory through copying and following the instruction, and therefore, the systemic approach together with the implementation of a dynamic teaching structure focussed on professional practice methodological issues is

a step forward and a key improvement of teaching methodology. The scheme of the proposed teaching model with the dynamic teaching structure is presented in Figure 5.

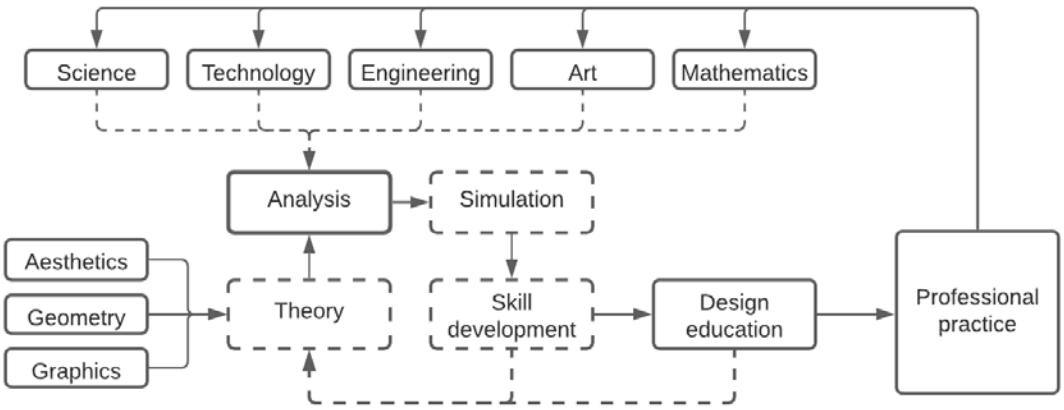
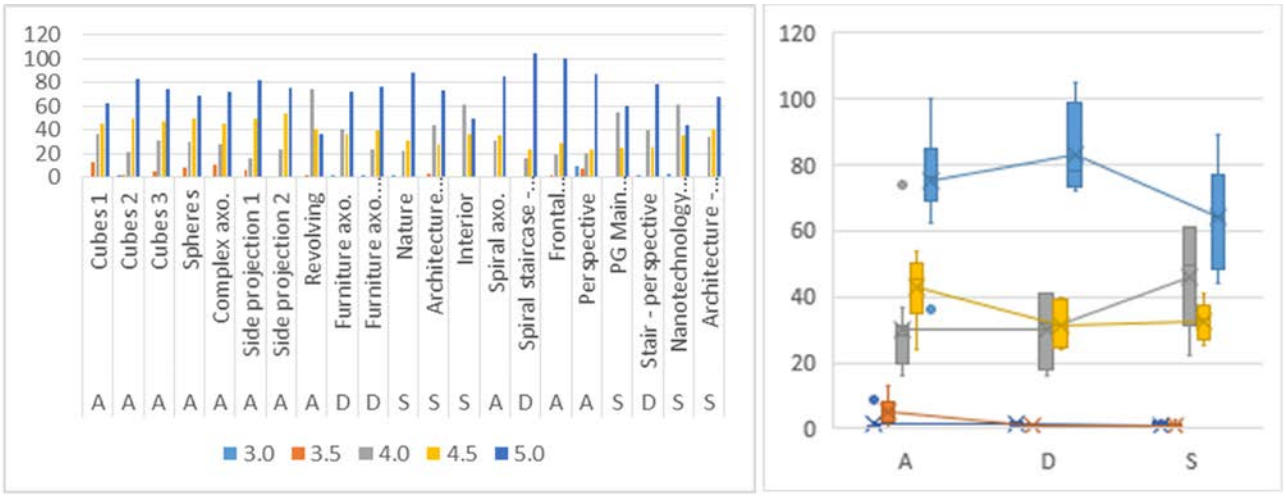


Figure 5: Architectural drawing teaching model based on a STEAM programme (Author: M. Gerigk).

The model defines architectural drawing as a resultant of a circulation path defined by theory, analysis and simulation to achieve the desirable skills, where the *theory* is an integration of the complementary knowledge, adapted *skill development* and *design education* demands. The *analysis* is the main structure point where the *professional practice*-based problems are defined. Its purpose is to solve the interdisciplinary tasks including *science*, *technology*, *engineering*, *art* and *mathematics*. To achieve the expected outcomes of today's professional practice, it is necessary to provide all the key subjects in the design education. Finally, the defined skills affect the *design education* system, which impacts the *professional practice*. The *skill development* through the architectural drawing course is centrally located. With this focus, it is possible to determine the best way of teaching architectural drawing for the purpose of professional practice in dynamic terms.

ANALYSIS OF DRAWING SKILL DEVELOPMENT IN THE PROPOSED TEACHING MODEL

The analysis of the drawing skill development is presented throughout the examination of the results of students' exercises. It is based on the statistical data and on-line monitoring of the Architectural Drawing course outcomes at the FA-GUT. The complete training cycle carried out through remote teaching was analysed. Data were collected from a group of 158 students for the 1st semester and 154 students for the 2nd semester who were involved in the entire set of exercises. The monitoring of the course was provided by a survey carried out by a two-level analysis. The aim of the first level was to collect the results of individual tasks performed by students, which is shown in a bar graph in Figure 6a. The second level involved further processing of the collected data using a candlestick chart as presented in Figure 6b.



a) b)

Figure 6: Monitoring of the Architectural Drawing course by a survey with a two-level analysis: a) bar graph for the categorised grade results; b) candlestick chart for grades in categories: A - abstract subject, D - design subject and S - study subject.

The bar graph presents the quantities of positive exercise results in a grade scale from the worse to the best, respectively from grade 3.0 to 5.0. Each exercise was marked with a letter indicating the subject category: A - abstract subject (11 exercises), D - design subject (four exercises) and S - study subject (six exercises). These qualities were crucial when defining the trend of the course development.

The analysis of the candlestick chart indicated a quantitative range of grade occurrences in the subject categories. This technique is commonly used to predict tendencies, for example in financial patterns [27]. The value on the vertical axis is the indicator of the number of exercises. The assessment of the teaching process and development of individual notes can be observed as the variation of lines between the indicator centres.

The best obtained result is a grade of 5.0 (marked in light blue) for design category D. The increase of 5.0 grades from A to D and the decrease from D to S indicates a weakness in the implementation of category S. The 4.5 grade indicator shows that the number of this value is decreasing to D and maintains a constant level up to S, and its size is getting smaller. The 4.0 grade indicator is augmenting reaching the top point for the S subject category, which, together with a significant drop of 5.0 grades requires consideration. The tendency number of 3.5 grade variation is descending, which is a positive sign. The last grade indicator, 3.0 increases slightly; however, the impact of such a change is marginal. The above analysis enables to determine, if the design teaching approach is being implemented with the best effect.

IMPROVEMENT OF THE TEACHING MODEL

After evaluating and analysing the trends of the skill development results, it is possible to commence the refining of the course. The presented approach assumes a dependency path that will enable the definition of new exercises according to the established system, treating the stages of development as a permanent template supported by the complementary knowledge. The flow chart of the improved architectural drawing teaching model is presented in Figure 7.

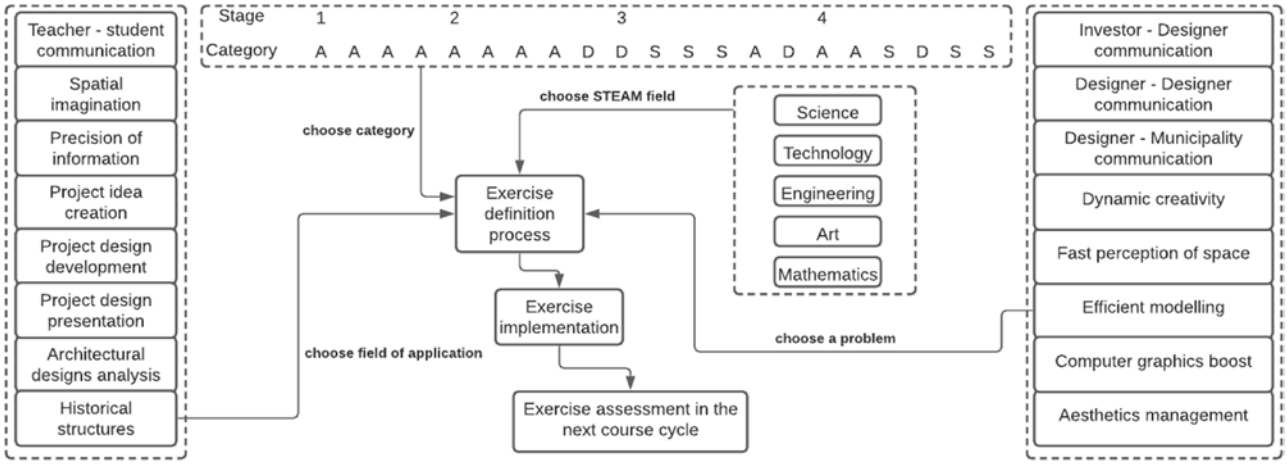


Figure 7: Flow chart of the improved architectural drawing teaching model (Author: M. Gerigk).

The model provides a four-step exercise creation. It is defined by the coexistence of architectural drawing education and professional competencies sections along with dynamic interactions between the constituent elements. The main elements selected in the analytical part are a problem to solve from the professional sector, application of STEAM interaction conditions, application of the teaching field and the exercise category. The relations with all subsystems define the overall improvement of the teaching model as the final objective of the course is the ability to create professional freehand drawings and to develop design thinking.

IMPACT ON DESIGN EDUCATION AND DISCUSSION

The presented model can be adopted in many fields of engineering education. The strength of the model, where through a series of exercises the set goals are pursued, lies in the achievement of better didactic results and increased student involvement. The proposed model, as part of the STEAM application course, introduces a new way of personalising exercises by course participants according to their own needs. The presented findings indicate the importance of this teaching model. Due to the current pandemic restrictions, the Architectural Drawing course has been provided on-line using a workflow created on the basis of the presented model. However, the evaluation of freehand drawing takes place on the monitor without the possibility of assessing the individual stages of the drawing's creation. The presented approach ensures the effective transfer of knowledge and the desired skills attainment by students. Step-by-step time-lapse instructions and on-line descriptions maintain the seamless learning curve without any obstacles in the course continuity.

CONCLUSIONS

The 21st Century is a time of rapidly developing digital technology. Despite this, traditional manual skills can still improve professional competencies. In the field of architectural design and related disciplines, architectural drawing is a necessary tool for developing design projects and to maintain effective communication for implementation. The presented research makes it possible to define the monitoring and improvement of the teaching model, which modifies standards according to the assumed practical purpose. Providing a systemic approach to teaching

architectural drawing brings tangible benefits to engineering education. The sample drawings by students included in this article confirm the validity of the introduced model as the students due to their manual graphic skills have been able to present the reality and ideas in a clear and coherent way.

The presented engineering design educational methodology integrated with skills development and expected competencies constitutes an improvement to the architectural drawing teaching model. The holistic approach is oriented towards anticipating the expected effects of the teaching methods. This approach satisfies the conditions of an innovative and dynamic educational framework and its implementation. The actual teaching model using the established patterns extends the knowledge gained in a creative way. Regardless of the format of the course, face-to-face, on-line or hybrid, the essence is the improvement of teaching effectiveness and students' architectural drawing skills with a comprehensive impact on their personal development.

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