THE ROLE OF MATHEMATICS IN THE FORMATION OF DESIGN COMPETENCE OF FUTURE ARCHITECTS AND BUILDING ENGINEERS

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Abstract. *The foundational principles of design have been built on mathematics since the beginning of time. Based on Euclid's classical geometry, mathematics was one of the branches of architecture in ancient Greece. At this time, graduates of the university's construction and architecture disciplines cannot possibly be expected to have advanced mathematical proficiency. We work on professional-focused assignments and projects with students to help future architects and civil engineers strengthen their mathematical proficiency. Mathematical foundations are required for all design solutions in architecture and construction. Therefore, any architect or civil engineer should be familiar with the theoretical underpinnings of mathematics, have the ability to create mathematical models, and be able to use mathematical-statistical approaches to process experimental data in order to address real-world problems.*
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1. Introduction

In ancient times, mathematics was used in the construction of complex objects of architecture. Such a connection between mathematics and architecture and urban planning lasted from antiquity to the eighteenth century. With the establishment of the first school of engineering in Paris in 1747, the science of engineering moved away from architecture, and mathematics and architecture began to develop in parallel. With the development of computer technology, mathematics and its methods have become more firmly entrenched in architecture and urban planning. The use of modern mathematical apparatus in solving several problems in the design and analysis of structures, buildings, and other structures is widespread. These practical mathematical issues include, for example, the determination of the strength of structures, structural optimization, stability, and modes of managing their performance.

2. Relevance of the topic

The study of mathematics in construction majors at the Technical University is very important because mathematics is the basis for the study of professional disciplines. We became familiar with the writings of O. Boyev and O. Imas [1] and R. M. Zainiev [2], who are of the opinion that the University should provide top-notch instruction in fundamental mathematics. In our opinion, teaching mathematics to students majoring in construction at universities should focus on helping them learn the fundamentals of mathematics, develop the mathematical skills necessary to become a future architect or civil engineer, and learn how to use math to solve real-world problems. Since it is impossible to teach students how to solve every type of practical problem they might encounter in their future professional endeavors in the time allotted to mathematics, it is also crucial to foster a culture of unconventional logical thinking and a creative approach to work-related problems. Developing the capacity to do effective searches in text, reference, and online sources is another crucial factor. Consequently, we concentrate on three topics when instructing mathematics in building specialties at a technical university: 1) enhancing the application of mathematical tasks, 2) fostering logical and unconventional thinking, and 3) encouraging innovation in project execution.

Graduates of the Technical University in the field of construction must be able to formulate a mathematical issue, choose the best mathematical approach and algorithm to solve it, and, if necessary, solve the problem using digital techniques utilizing a computer. draw applications-based findings from research using mathematical techniques.

3. Theoretical part.

A competent architect and civil engineer should know how to calculate the A capable architect and civil engineer should be able to calculate the loads that will impact a building's operation, ensure structural stability, choose the best building materials, and design engineering systems, infrastructure, road crossings, etc. You must understand progression in order to determine the ratio of rhythmic rows and to make the projected object expressive and well-fitted. The knowledge of linear algebra, analytical geometry, mathematical analysis, probability theory, mathematical statistics, mathematical modeling, numerical methods, and other topics is also necessary for future architects and construction engineers.

Higher education mathematics students shouldn't feel cut off from the actual world or their potential careers. As a result, when teaching students about any area of mathematics, we strive to demonstrate them not just the fundamentals but also the practical application of the subject. Solving real-world issues is essentially how this is accomplished.

Here are a few real-world examples of "spinning bodies"-related issues.

1) A cone-shaped pile of wet sand is set up at the construction site. The stack has the following measurements: the slope length is 10 m, and the foundation's circumference is 45 m. Use a 15% discount on moisture to determine the amount of undesirable sand.

2) The gypsum sculpture is shaped like a truncated cone, with a maker that is 20 cm tall and a base that is 35 cm in diameter. How much paint would you need to paint 10 of these gypsum figures on both sides if you need 200 g of paint for every square meter? (The gypsum wall thickness is not taken into consideration.).

For example, when studying the topic of "Integral Computing", you can consider the following tasks:

1) Determine the location of the center of gravity for the figure whose coordinate axes are in the I quarter and are circumscribed by the arcs $x = 3\cos t$ and $y = 4\sin t$;

2) determine a three-axis ellipsoid's volume;

3) A concrete was lifted hemisphere from the river's existing bed using a crane. What work is done if the hemisphere is between 500 and 250 mm in size? Concrete has a density of 2000 kg/m^3, while water has a density of 1000 kg/m^3.

Any construction-related student should be able to design a mathematical model using the relevant information. After instance, many organizational, planning, and construction management tasks are defined by a wide range of potential outcomes, frequently accompanied by significant uncertainty and dynamic processes. It's important to weigh your options and choose the best criteria when creating a construction plan for any construction site. An indicator that is specified, a standard, or a gauge of conformance is called a criteria.

Modeling in planning and construction management, along with the search for the optimal organizational structures, are utilized for the initial examination of the object.

The process of modeling involves building a model that duplicates the key characteristics of the original, learning from the process, connecting pre-existing data about the model with actual data about the item, and experimentally verifying the results. Building system analysis, optimization, and synthesis all benefit from modeling. According to the paradigm, we comprehend an abstract, idealized, and logical-visual representation of the thing under study (a process), which is simpler to learn than the process itself [6].

Through modeling, a researcher can determine key characteristics of an actual thing, facilitating the performance of experiments. The researcher will most likely examine the outcomes of the computations and tests performed on the model with a computer. In other words, since a model is a study tool, it should precisely represent the characteristics of the actual item.

Three steps are involved in the mathematical modeling process: formalization, problem solving within the model, and interpretation. We focus particularly on the formalization and interpretation stages when instructing students in mathematical modeling since these two stages pose the biggest challenges to learners [6].

Students compare actual items and their mathematical models in math classes. For instance, a comparison to the linear function $y = kx + b$

is made in the section on the study of analytical geometry.

a) velocity and time in a plane accelerating motion $v = v_0 + at$;

b) The relationship between the gas's volume and temperature at constant pressure is $V = V_0(1 + at)$;

c) constant volume pressure and temperature of the gas $P = P_0(1 + bt)$.

Students are urged to continue this comparison at home by providing illustrations from architecture or construction.

Subject problems are a crucial teaching tool for students learning about mathematical modeling. In order to put plot difficulties into mathematical language, we use them in the study of several branches of mathematics [7].

Consider one of the tasks.

In the city, there are two concrete plants. One of them will create 300 tons of concrete daily, and the other 450 tons will be distributed to five construction sites from these factories. Each day, 120 tons of concrete will be delivered to the first section, 200 tons to the second, 150 tons to the third, 160 tons to the fourth, and 120 tons to the fifth. It is known how much it will cost to carry one ton of concrete from each factory to each location. Concrete must be transported from factories to building sites in an organized manner that keeps the overall cost of transportation to a minimum.

Let's explain the issue in mathematical terms. If the price of moving one ton of concrete from plant I to the j-construction site through C_{ij} is established, and through x_{ij} - the quantity of tons of concrete that must be moved from plant I to the construction site (these are the necessary dimensions), the price of all transport is determined using the following function.

$$f = \sum_{i=1}^{2} \sum_{j=1}^{5} C_{ij} x_{ij} \quad (1)$$

$$\sum_{j=1}^{5} x_{1j} = 300, \quad \sum_{j=1}^{5} x_{2j} = 450, \quad \sum_{i=1}^{2} x_{i1} = 120, \quad \sum_{i=1}^{2} x_{i2} = 200, \quad \sum_{i=1}^{2} x_{i3} = 150, \quad \sum_{i=1}^{2} x_{i4} = 160,$$

$$\sum_{i=1}^{2} x_{i5} = 120 \qquad (2)$$

In mathematical language, the problem is structured as follows: If its arguments satisfy the system of equations (2), find the minimum function (1).

Finding the extremum of a given function with few arguments is necessary within the created mathematical model. We employ mathematical programming to resolve the issue.

Probability theory and mathematical statistics are two key areas of mathematics for aspiring architects and civil engineers. Numerous issues with practical significance can be given in accordance with probability theory.

Students are given both plot and table-creation homework to demonstrate the practical focus of the mathematics curriculum.

Creating a table at home on topics like "The Importance of Mathematics in Architecture" (for future architects) or "Mathematics and the Relationship of Construction" (for future civil engineers) has been assigned to students in one of the first math sessions, for instance. Students can compare the definitions of common terminology like symmetry, ratio, point, line, geometric figure, geometric object, space, curve, surface, volume, and others with those of basic mathematical and architectural concepts in this table. The terms used in the table were chosen to show how well their definitions align with those of mathematics and architecture (construction).

Instead, students are given homework to build a table called "Classification of Mathematical Methods Applied in Modern Architecture (Construction)" in one of the university's final math classes. Students realize that mathematical techniques are necessary in architectural design. The principles utilized to build a table are as follows:

1) the choice of methods used in the creation of mathematical models;

2) formation of design tasks for three-dimensional architecture and urban planning;

3) establish connections between tasks and methods.

Students should participate in project activities as they learn mathematics in order to enhance their creative thinking skills and their capacity to look for missing knowledge in a variety of sources. This will help them demonstrate the practical application of mathematics. They work on multidisciplinary integration projects and the bulk of the upper mathematics course. The project's initial focus is on "The Golden Section in Architecture and Life." The mathematical formula known as the "golden section" determines the proportions of architectural structures. The Pearson statistical criterion was employed in the analysis of the experimental work's findings to ascertain the causes of the shift in the pupils' degree of mathematical proficiency. The zero statistical hypotheses predict that there will be no difference in the mathematical proficiency levels of children across all categories.

4. Results of experimental work.

The professional competency of university graduates includes mathematical proficiency. Therefore, in order to improve the pupils' mathematical abilities, we carried out an experimental study. One group of students in the field of "Architecture" and two groups in the field of "Construction" were chosen to participate in the experiment. In "Building and Structure Construction," the final two groups will receive instruction. These groupings, I, II, and III, are defined. The project started with the formulation of criteria and indicators for the students' level of progress in their mathematical proficiency [9]. An initial assessment of the pupils' level of mathematical skill growth was done in the mathematics groups. This indicated that pupils' enthusiasm in mathematics, creativity, and project-based learning was low. Mathematics is not viewed as having any relevance to students' future employment.

Group III received instruction in a typical fundamental mathematics course throughout the experiment. Groups I and II participated in project activities, worked on real-world assignments, and received basic mathematical instruction. A revised diagnosis was given at the conclusion of the university's mathematics course. According to the experimental work's findings, more pupils now have average or high levels of mathematical proficiency, and the majority of them are aware of the value of mathematics in their future professional endeavors. The children were quite excited to talk about their project-related activities.

Table 1. Changes in the levels of development of students' mathematical competence as a result of the experiment

Group	Number of students	Period	Level of knowledge			Pearson criterion
			Low	Medium	High	
I	23	Initial	14	7	2	0.13
		Last	2	15	6	10.52
II	24	Initial	14	9	1	0,17
		Last	2	17	5	7,66
III	22	Initial	13	7	2	-
		Last	9	11	3	-

As a result of the experiment, the condition of using professionally focused activities and projects in the process of teaching mathematics in experimental groups I and II is statistically significant for the growth of students' mathematical competence. As a result, a different theory was chosen. As a result, the successful development of mathematical abilities among the builders and architects in the first and second groups under consideration is not a coincidence; rather, it is a result of the use of mathematical preparation tasks, projects, and assignments that are practical and professionally oriented.

5. Conclusion

Any design solutions used in construction and architecture must be supported by mathematics. This means that every architect or civil engineer must understand the theoretical underpinnings of mathematics and be able to develop mathematical models, solve real-world issues, and interpret experimental data using mathematical-statistical techniques. He must, then, possess a strong foundation in mathematics.

The experiment's findings demonstrated that students of architects and builders have higher levels of professional competency when they apply their mathematical skills to practical tasks and carry out practical assignments and projects.

Students participate in project-based learning activities in math classes, have the ability to translate professional assignments into mathematical terms, learn their specialized subjects more quickly, and are better able to adjust to contemporary economic circumstances. They should have a high level of professional competence by the time they graduate from university.

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