Art and Literature as a Teaching/Learning Interface of Mathematics for Students of Architecture

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Abstract: This paper discusses an educational approach emphasizing the changing role of mathematics and potentials of mathematical thinking in architectural education on the course of changing design paradigm: from designing the product to designing the process. In this context, randomly selected samples of student works, realized within the context of an elective undergraduate course, Arch 333 “Mathematics in Architecture” at Middle East Technical University, Ankara, Türkiye are presented. It is shown that mathematical thinking provide not only to science people a solid ground for further explorations, but also new inspirations to people involving art and design and help them to overcome prejudices and fears related with mathematics in their minds. It is believed that this approach encourages them to discuss complex problems with meta language of mathematics and develop ability to consider the design process as a whole.

Keywords: Mathematical thinking; mathematics in architectural education; multi-dimensionality of data; mathematics as meta language.

Evolution of design process in architecture and the role of mathematics

In the last decades, architectural design has been continuously evolving not only with advent of rapidly developing technologies, innovations but also with emerging environmental problems and as a result: the demand for sustainability and/or performance. While introduction of computational technologies and tools providing new potentials to architects in dealing with these “new complexities”, it demands new learning and thinking skills.

In brief, architectural design process has become more complex than ever before and architects should be acquainted with these continuously changing technologies and related new terminologies, communicate with other knowledge domains through their design process, and to be able to think parametrically to integrate huge amount of resulting data.

Consequently architects should not only model “building” as an end product, but he/she should “well define” the multi dimensional ill defined design problems and provide design models incorporating all possible complexities and different actors of various disciplines in the design process. This rapid and incessant change in design paradigm also necessitates the revision of architectural education and practice. As Kuhn points out:

“… communities who share a paradigm also share the belief that the kinds of problems they are prepared to address have solutions for which their skills are
needed. They reinforce this belief by accepting only those problems into their community that they can solve. Problems that lie outside of their field of knowledge are considered to belong to another discipline or need to be rejected because they are too difficult. The result can be that the community is isolated from those important problems that are not reducible to their puzzle form and hence cannot be stated in conceptual terms they understand.”

He also suggests that paradigm shifts occur whenever there is critical situation or a crisis which we are witnessing in recent architectural practice (Eberhard, 2009). The tension between nature and technology, together with new skills to use and to master these technologies and design media that architects should have, can be considered as such a crisis or a critical situation.

Thus, it is inevitable for today’s architects to shift their minds to new mind sets and to find ways to cope with new and continuously evolving design paradigm. In this context, several researchers, academicians and practitioners have been questioning architectural education, related curricula, revise their programs, discuss teaching/learning methods and propose new courses/programs accordingly.

In the framework of current discussions on changing design paradigm, the role and potentials of mathematics in the education of architecture should be re-investigated as a teaching/learning interface.

**Phobia of mathematics**

Mathematics meaning “learning” in Greek has always been an integral part of the architectural design process like in many other disciplines. It is also seen that as mathematics broadens its subject of interest in the course of time, its role has been pronounced more. Moreover, mathematical reasoning which can be defined as recognizing the parameters of a problem and proposing a logical process to arrive a solution becomes an essential skill for those who work on/with computational media. In short, today, mathematics through abstractions, constructs, logics and models provide not only to science people a solid ground for further explorations, but also new inspirations to people involving art and design.

Although mathematics has been recognized and implemented at every aspect of life in solving simple problems to constructing intricate models to understand the ‘complex phenomena’, it is still one of the ‘fearful subjects’ in education. It is possible to propose several explanations for this anxiety even “phobia”. It has been observed in the experience in teaching mathematics to the students of architecture that, one of the major reasons is the difficulty of understanding symbolic language of mathematics. Most of the students can not associate mathematical expressions and the related phenomena. A very simple but striking example of this is to ask a student what Newton’s second law is. All the students answer this question without any difficulty. On the other hand, when differential equation representing the second law as \( F = \frac{d(mv)}{dt} \) has been asked to interpret, almost all of them confuse. Second reason which has origins in the very first years of education is to regard mathematics as an abstract discipline and as a consequence not to teach/learn mathematical reasoning which is a must to solve complex problems and computation in general. Consequently, education of mathematics should be perceived as a three-fold task: overcoming the anxiety/phobia of mathematics, teaching mathematical reasoning and finally teaching subjects of mathematics. It is necessary to point out that in developing education strategies for mathematics, age, background, subject matter of the disciplines should be considered in order to set a meta-language between mathematics and the discipline itself.

**Teaching mathematics to the student of architecture**

Questions like “what design is, how inspiration, intuition and cognition take place in the design process, what creativity is” have been inquired for years in various disciplines. In the last decades, these
discussions are extended and the roles of technology in particular the role of computational technologies, integrated/interdisciplinary studies have become controversial subjects in art and architecture. Along with these discussions, integration of mathematics to the architectural design process should be investigated regarding nature of architectural design problematic.

One of the generic definitions of mathematics as “the studies on quantities, forms, changes, forces, relations, logic and space through models constructed resulting of mathematical reasoning process” has many clues in exploring how mathematics can be taught to design students. The “mathematical model” concept in the definition is the key for further exploration on how mathematics and mathematical reasoning in architectural design process can be integrated.

A mathematical model is an abstraction of a real phenomenon which is plausible by different disciplines, constructing a part or whole of reality, depending on the present state of knowledge and required level of precision. Regarding the complexity of real phenomena, identification of endogenous and exogenous variables, parameters/effects/forces to be included/ignored together with necessary assumptions and solution systematic/algorithm have direct impact on the efficiency of models. Design as a process has many similarities with mathematical modeling. Any designer should start with well-defining the design problem, its constraints, goals, parameters, forces shaping the process and end-product(s), actors involving and many other dimensions and has to conceive the big picture “design” itself. Moreover the design model/end-product is a manifestation of space, quantities, and changes as mathematics aims at.

Despite these similarities, phobia/anxiety of mathematics is still an obstacle. There are many researches and theories as well as on-going studies in literature about how mathematical education should be in order to overcome those mind blocks. In all these studies, the consented part is to show students that mathematics is not only some abstracted symbols, formulations and so on but rather a ‘universal language’ that everyone can speak and understand.

The motto of the authors is ‘mathematics is everywhere’ (Gönenç Sorguç, 2005a) in their series of courses related with basic design and computational design in the Department of Architecture, METU. As in many other teaching approaches, the authors also prefer to give some examples from literature and art supporting their motto and to forces students to inquire these medium in the realm of mathematical thinking. Games, literature, paintings, sculptures, patterns and tessellations, movies, music, dance and nature which students are already acquainted with, have been employed to introduce fundamentals of mathematics. Playing with Tangram to introduce shape grammars, using origami as a medium to understand spatial transformations and topology and thus structure, seeing Gulliver’s Travel as a criticism of Euclidean Geometry and finding seeds of fractal dimensions, reading Alice in Wonderland to explore concept like scale and dimension, finding out ways to perceive and represent higher dimensions by reading Edwin Abott’s Flatlanders, dancing to project multi-dimensional information to lower ones without diminishing information, deciphering patterns and motives, discussing the importance of reference systems including spherical, cylindrical, parabolic, hyperbolic and multi-dimensional on Escher’s prints on exploration of topology and space are some of encouraging examples that are employed in the course to associate mathematics into design thinking as well as to overcome mathematics phobia.

Last four years of teaching experience of mathematics through examples of art and literature in the introduction phase shows that such examples motivate students to explore the subject more deeply and encourage them to spend effort to learn mathematical thinking and considering design problem as a whole.
Integration of mathematical thinking to the design and design process

As it is shortly discussed, teaching mathematics is a task requiring some effort not only limited with subjects to be thought but to search for proper ways/tools/medium to establish new mind sets.

In this context, authors intend to share a part of their teaching experience in Mathematics of Architecture course given to second and third year students of Architecture in METU through some fundamental assignments aiming at forming a basis for further studies linking mathematics and design process with all potentialities.

The first assignment endeavors for introducing what mathematical modeling is by stressing the role of mathematical reasoning to further elaborate discussions on design and mathematics. Students are asked to model a plane tree leaf and a cat and to discuss their models and no other explanation or hint is given. Prior to this one week assignment, a lecture focused on mathematical and computational thinking and modeling process, the role of computational technologies with some examples was given. Symbolic notations, postulates, theorems in the lecture were implicitly described on the examples with which students are familiar. Some of these assignments are given below (Figure 1 and Figure 2).

Students were able to define clearly all the steps of the modeling process and became mentally prepared for further discussions on paradigmatic change in design to design process and new mind sets necessary to cope with this shift. They were eager to experience more complicated design models. Moreover, it is surprising that although it is not asked to search any similarity between a cat and a leaf (in the assignment these two are considered as non-biased) some of the students through their models and assumptions attempted to show certain levels of similarity among these subjects. As it is seen in the examples that they use simple geometric constructs which they already learnt to prove/to show similarity/similitude not in form but in behavior as well. The shift from simple geometric similarity to similitude is the most striking outcome of the assignment and encouraged both authors (teachers) and students to broaden the subject of discussions.

The second example introduced here is related with exploration of isometric transformations and relations between different geometric line shapes. Students are asked to provide a wall paper using isometric transformation with any initial ‘kernel’. They are also asked to clearly indicate their definition set or their domain which is actually their ‘vocabulary’ and their rules i.e. the mapping functions in this process without revealing the link of the assignment with design computation and shape grammars in order to set them free to investigate relations with simple mathematics and to see the problematic as a whole i.e. the range set as well. Following the first part, students are expected to provide variations

Figure 1
Modeling of a leaf and a cat by Dilan Kara
i.e. different output/range by interchanging the sequence of the process or even changing some rules. Prior to this exercise, several tessellations, patterns and paintings belonging to different periods were introduced and discussed in regard to the topics covered at that moment.

In the next stage of the exercise, students are asked to exchange their assignments with each other but only their domain and their mapping functions excluding their range i.e. their pattern and they are asked to reconstruct the pattern accordingly. The results were not fully successful as expected by the authors and majority of the students failed in reconstruction. This formed a basis to discuss further the need for designing the process and the final design product by the help of mathematics and its by product ‘algorithmic thinking’ (Gönenç Sorguç, 2005b).

The pattern exercise also served for exploring multi-dimensionality of any data (including n-dimensional space) to be processed and included in a design problem. In these considerations, space, transformations, reference systems, different scales, data systems, data exchange, among different media were discussed and students are forced to visualize different dimensions. In exemplifying these subjects, stories like Gulliver’s Travel (Swift, 1986), Alice in Wonderland (Carroll, 1999), MicroMegas (Abbott, 1956) and Flatlanders: A Romance of Many Dimensions (Voltaire, 2002) and Fantasia by Walt Disney (Disney, DVD, 1942) which students had familiarity were chosen. Then it was requested to realize
transformations from 1-D, to 2-D and 3-D space by creating a stable structure from a piece of paper. In this challenge Japanese paper folding art ‘Origami’ is used as a medium.

The final stage of the assignment was to construct a transformation from n-Dimensional space to 2-Dimensional space providing patterns similar to the ones in previous stages. First it was seen that students in proposing their own examples related with subject experienced difficulties and could not properly realize the process. Then, students were asked to reconsider dance in terms of music and rhythm as ‘scaling’ then choreography as being isometric transformations. Each student analyzed them freely and they attempted to use the information produced by dancing to produce a pattern and process as they exercised before as shown in the examples below. In their examples, they tried to include as many data as possible and demonstrate multidimensionality with different tools like geometries, colors, moulds etc… and they interpreted dance as an algorithm designing the process rather than the final design product.

It is shown that literature and art forms solid grounds for students of architecture to explore the potentialities of mathematics and mathematical thinking and help to overcome prejudices and fears related with mathematics in the minds of students. Moreover this approach encourages them to discuss...
complex problems with meta language of mathematics and develop ability to consider the design process as a whole.

**Results and future remarks**

In this paper, authors aimed to share a part of their teaching experience in Mathematics of Architecture course given to second and third year students of Architecture in METU through some fundamental assignments aiming to form a basis for further studies linking mathematics and design process with all potentialities. Examples presented in the paper are random samples in order to prevent any bias. It is desired to emphasize two main points: first how mathematics as with their tools and as a way of meta language describing and modeling the design process can help designer in his/her design process and in the evaluation of final product, second how mathematics can be coupled to design process by considering art as a teaching/learning interface on which student can overcome their prejudices and fears related with mathematics and can be encouraged to use mathematics as a part of their design process as well. In four years experience in teaching this course, it is seen that this approach i.e. using art as an interface help both students and instructors to improve the education of mathematics and allow students to bring that knowledge in their design education successfully as well as having ability of mathematical/algorithmic thinking and seeing the ‘the whole’.
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