How to Deal with Novel Theories in Architectural Education

A framework for introducing evolutionary computation to students

Ethem Gürer, Sema Alaçam, Gülen Çağdaş

1,2 Istanbul Technical University, Graduate School of Science Engineering and Technology, Department of Informatics, Turkey, 3 Istanbul Technical University, Faculty of Architecture, Turkey

1,2,3 http://www.mimarliktabilisim.itu.edu.tr
1 ethemgurer@gmail.com, 2 semosphere@gmail.com, 3 glcagdas@gmail.com

Abstract. Evolution of/in artificial systems has been discussed in many fields such as computer science, architecture, natural and social sciences over the last fifty years. Evolutionary computation which takes its roots in computation and biology has a potential to enrich ways of thinking in architecture. This paper focuses mainly on the methodology of how evolutionary computation theories might be embedded in architectural education within the theoretical course in graduate level.

Keywords. Evolutionary design; evolutionary algorithms; computational theory; architectural design curriculum.

INTRODUCTION

Over the last fifty years, evolutionary concepts and methods have been examined related to various fields. Especially in design domain, as Rosenman (2006) pointed out, there has lately been a considerable increase in the use of evolutionary methods (Holland, 1975; Heylighen, 1989; Koza, 1992; Poon and Maher, 1996; Fasoulaki, 2003; Rosenman, 2006 etc.). In order to resize the pool of design solutions, various studies were based on adapting notions and systems from biological models to computational design area. However, evolution paradigm has not been embedded enough to the architectural education. In other words, works including evolutionary concepts remarkably focus on one hand on the structure analysis of specific computational systems, on the other hand on the large population of design solutions or on the externalized design object itself rather than on what/how is going on the designers’ part in terms of design thinking and learning. Some other studies exploring the integration of digital design models and techniques with design pedagogy deal with the problem in a general range (Oxman, 2008).

At this juncture, the scope of this paper is limited with introducing only evolutionary design paradigm to the students in a determined course. Related to evolution paradigm, it is supposed that the vocabulary/terminology of different disciplines requires thorough descriptions, excavations and discussions in order to develop architectural students’ understanding through these practices.
DESCRIPTION OF THE COURSE

In this study, we particularly focus on the methodological analysis of the course in Architectural Design Computing Graduate Program at the Faculty of Architecture in Istanbul Technical University, titled “Evolutionary Approaches in Architectural Design” (EAAD). The EAAD is a PhD course of 3 hours per week and is conducted since 2009. General purpose of this theoretical course is to take advantage of evolutionary approaches and processes encountered in nature as a source of inspiration, while solving problems in the field of architecture during one academic semester.

In Fall semester of 2011-2012, the contents and the timeline of the course were divided into five main activity groups including lectures, literature reviews, discussions, presentations and term projects (Figure 1). As an essential part of the course, the lectures were driven both by instructors and guests having expertise on the related topic of the week during first 9 weeks. Literature reviews part, as a direct support for theoretical explanations detailed during lectures, concerned books, papers and articles meticulously chosen by the instructors not only to be aware of the state of the art approaches but also to enrich vocabulary domain used in various studies. The content of the lectures and literature reviews can be listed as:

- Evolutionary processes encountered in nature as an inspiration, while dealing with problems in the field of architecture.
- How genetic algorithms and evolutionary approaches are used in architectural design.
- Biomimesis, lindenmayer systems, cellular automata and emergent systems in general and particularly in architectural design.
- Evolutionary computation and using computer as a partner in pre-design phases.

Although participation of the students were always encouraged, these two parts (such as lectures and literature reviews), show instructor-centered learning motivation of EAAD course. On the other hand, it is supposed that term projects part totally reflect a student-centered learning motivation aiming to develop an evolutionary design model in general terms with a final report in an article format. In project development phase, students were expected to concentrate on combining the evolutionary theories with a particular design problem they did choose or to develop ideas through experimental embodiment of the abstract concepts via physical and digital models. Although the term projects went on in a regular timeline (for the last 5 weeks) similarly to lectures and literature reviews, they were situated
on opposite sides in terms of subject/object relation (the subject was instructors in lectures and literature reviews while it became students in term projects part). In order to bridge the gap between these two opposite learning motivations, two different collaborative activities were engaged within partial frequentations in timeline: discussions and presentations parts help to include students more in the course (Figure 1).

During discussions, students were encouraged to have a critical distance to examples and theories as much as possible (hence, these parts had been divided in three sub-parts for different weeks) in order to enable development of their own insight and ability of interpretation. Discussions also provided face-to-face feedback from each student to others and to instructors. Finally, another activity bridging the gap between two opposite learning motivations was presentations. They were separated into three sub-parts with different weights per week like discussions (Figure 2). The tasks consequently were to present a review of an evolutionary design model from literature, to introduce their very initial ideas about term projects of students and to gather final critics.

In the long run, such a part-based distributed division in the course had been concluded related to experiences and feedbacks gained since 2009. During and at the end of the semester, we observed that these partitions enriched the general vocabulary of designing via transitions from theory (lectures and literature reviews) to practice (term projects) through discussions and presentations parts.

**Evolution of what? Epistemological excavation in different disciplines**

One of the main difficulties while the theoretical topics are being discussed is that there are pre-determined vocabularies belonging to different disciplines. For example, not only the evolution concept itself but also the related vocabularies refer to a variety of different meanings, connotations and relations in Darwinian terminology of biology, in economics or in computational theory.

We use the ‘epistemological excavation’ in terms of a series of research, discussion and re-thinking process about the epistemological origins of the existing terminology. In archeology the ‘excavation’ term literally refers to a dynamic digging process

![Figure 2](image)

*Figure 2*

_Distribution of the course parts._
involving the actions of exploration, recording, recovery of different relations and interpretation. The excavation usually begins at a defined area, while in the beginning what you look for is not so clear. Subsequently, other series of connected areas or other layers from different time zones should be evaluated in an interrelated manner. The methodology, the techniques, the type of tools might differ according to the specific requirements. Regarding the theories and in particular the evolutionary theory, each discipline has been accumulated different semantics of their own terminology. At this point conducted with deconstructive thinking, epistemological excavation is required in order to explore new findings with new relations.

Other problem is grounded on the nature of theories which creates reduction and a gap between the reality and the idealized theory. Liddament (1999) defines this gap as on one hand methodologies, techniques and vocabularies and on the other hand “the subset of the wider spectrum of human cognitive activity”. Especially in theoretical courses we had observed in the previous years that, students had the tendency to deal with the theories given as they were. Similar to the Polanyi's (1966) bicycle example, theoretical courses concern bicycles instead of the experience. Within 3 hours per week of a theoretical course it is not possible to teach the experience of riding a bike. However it is possible to trigger the curiosity of the students and discuss at least different ways of riding a bike.

During the EAAD course in the beginning of the 2011-2012 fall semester we asked how we could stimulate/trigger students keeping a critical distance to the varying concepts of the evolution instead of accepting them without interpretation. Other issues that we concerned about were the interrelated theories of evolutionary computation, embedding the evolutionary approaches in architectural design process, questioning the limitations of methods/vocabulary such as optimization, selection, search in solution space, dependency to the initial assumptions, genetic algorithms, natural systems, shape evolution, and evolutionary model examples of creative design. Besides these, we were interested in how “evolutionary computation by designers” paradigm- which not only occurs in computers but also physical environment and designers’ minds.

There are always risks related to how to introduce these theories. Keeping this in mind, we tried and encouraged an open-ended epistemological excavation in different disciplines regarding evolution paradigm. Instead of thinking only within the limitation of these ready-given concepts, we motivated students:
• to explore semantics of the vocabulary
• to gain a better understanding of relations/interactions among the concepts of evolutionary computation
• to represent and to externalize their own understandings from the abstract concepts via digital and physical models

**From analyze to interpretation**
Students were expected first to analyze examples focusing on evolution paradigm accompanied with readings and then to explore some of the algorithms shared in the literature review part. In order to reveal an interpretational skill in design process, students were encouraged to visualize concepts via physical and digital models.

In the analyze process, students were expected to be not only a translator but also an interpreter between their minds and the computer. We observed the advantage of visualization process of the abstract concepts. On the other hand this process has been occurred two sided. Physical environment - natural and/or artificial - was also used as a source of inspiration and was converted to the abstract schemas.

Different from conventional theoretical courses supporting only students’ reading and writing skills, in EAAD we let the student to explore their own way of understanding of the abstract concepts and to deconstruct the ready-given concepts within their semantics and connotation.
METHODOLOGY
In this paper, we defined the listed criteria in order to evaluate the process of the term projects’ belonging to the 8 students with different backgrounds:
- Level of predictability: The end product can be predicted by the initial assumptions of the student or there are emergent outcomes during the project development process.
- Level of internalization: This includes level of adapting both concepts and techniques to their own projects. If the student used one of the existing evolutionary methods as it is, this is defined as ‘repetitive’. If the students met new vocabularies/rules while dealing with the present ones, this is defined as ‘explorative’. Finally if he/she developed his/her own methods, we define it as ‘interpretative’.
- Type(s) of the media: Which type(s) of representational model(s) was/were preferred (Physical/digital/both).

Evaluation of the student projects
In this part, the process of 8 term projects is evaluated depending on the pre-defined criteria. As it is shown in the Figure 3, there is a variety of analysed methods and each student focused on different topic for the term project. 5 Master and 3 PhD students have attended to the course with different backgrounds and different computational experiences. Although, the scope and the scale of the term projects were so different from each other, all students used 3 dimensional modelling programmes and scripting environments. 2 out of 8 students experimented with physical models, besides digital modeling (Figure 4).

It is seen that (Figure 3, Figure 4) since there are two students who experimented with physical models had also explored emergent outcomes. One of these students (Figure 5) started with poems as a generative algorithm input. At the same time she made a large number of physical models. Symbolic representation of Haiku poem, verbal representation of algorithms and visual representation of study models were developed simultaneously. Other students (Figure 6) started with observation of natural and artificial environment including analyses of pomegranate patterns, frosted glass patterns. She set up a series of experiments with bubble plastic and iron. The second student also tried to understand the logic of existing algorithms such as voronoi diagrams and delaunay triangulation. She additionally developed her own algorithm and explored new relations and forms via parameter change (Figure 6). Depending on these two examples it is possible to assert that interaction with the physical material might provide a better understanding of the abstract concepts. However, in this assumption other coefficients such as the effect of symbolic and mathematical thinking are excluded.

Another student who explored emergent outcomes worked in digital environment (Figure 7). Although he was examining existing algorithms of voronoi, he focused on mathematical equations and developed his own assumptions. In this sense, we evaluate his study as interpretative and explorative. After these experimental studies he integrated his findings into structural optimization of surfaces.

CONCLUDING REMARKS
A dynamic approach in terms of divergent and convergent thinking is evaluated via a theoretical graduate course and student projects. One of our initial finding is that, using physical models in the analysis process might both improve student’s understanding of the abstract concepts and support emergent explorations besides defined solution domains of the design process.

The part-based distributed division curriculum of EAAD was built up depending on experiences and feedbacks gained since 2009. This structure is considered to be reconfigured each year. According to the balance of theory (lectures and literature reviews) to practice (term projects), we planned to re-evaluate the ‘lectures’ part via spreading out the lectures over the whole semester.

Moreover, we think that in order to gain intellectual understanding, beyond limitation of only one discipline the concepts should be epistemologically
<table>
<thead>
<tr>
<th>Student</th>
<th>Method(s)</th>
<th>Subject</th>
<th>Types of Media</th>
<th>Definition of unique rules/Adaptation of an Existing Method</th>
<th>Level of internization (Interpretative/explicative/repetitive)</th>
<th>Level of Predictability</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1, MSc</td>
<td>Lindenmayer systems</td>
<td>Form finding experiments</td>
<td>computer modelling (scripting via Grasshopper)</td>
<td>Defined and used specific assumptions in lindenmayer systems scope.</td>
<td>Explorative and interpretive</td>
<td>Explored emergence forms</td>
</tr>
<tr>
<td>S2, PhD</td>
<td>Cellular automata + genetic algorithms</td>
<td>Fair stand design</td>
<td>computer modelling (scripting via Grasshopper)</td>
<td>Explorations in the domain of the given method.</td>
<td>Repetitive</td>
<td></td>
</tr>
<tr>
<td>S3, MSc</td>
<td>Rule based-designer</td>
<td>Designing a sin plan according to the topological relations of neighborhood</td>
<td>computer modelling (scripting via Grasshopper)</td>
<td>Defined and updated own rules and assumptions.</td>
<td>Explorative and repetitive</td>
<td></td>
</tr>
<tr>
<td>S4, MSc</td>
<td>Genetic algorithms</td>
<td>Facade design optimisation</td>
<td>computer modelling (scripting via Grasshopper)</td>
<td>Defined rules in respect to genetic algorithm.</td>
<td>Repetitive</td>
<td></td>
</tr>
<tr>
<td>S5, PhD</td>
<td>Voronoi diagrams and Delaunay triangulations</td>
<td>Recoding one Delaunay triangulation script.</td>
<td>Physical modelling + computer modelling (scripting via Grasshopper)</td>
<td>Defined and updated own rules and assumptions.</td>
<td>Explorative</td>
<td>Explored emergence forms</td>
</tr>
<tr>
<td>S6, MSc</td>
<td>Rule based-designer</td>
<td>Interpretation of Haiku and poem</td>
<td>Physical modelling + computer modelling (scripting via Grasshopper)</td>
<td>Defined and updated own rules and assumptions.</td>
<td>Explorative and interpretive</td>
<td>Explored emergence forms</td>
</tr>
<tr>
<td>S7, PhD</td>
<td>Biomimetics in structural design</td>
<td>Form finding experiments</td>
<td>computer modelling (scripting via Grasshopper)</td>
<td>Explorations in the domain of the given method.</td>
<td>Repetitive</td>
<td></td>
</tr>
<tr>
<td>S8, MSc</td>
<td>Rule based-designer</td>
<td>Experimental structural optimisation</td>
<td>computer modelling (scripting via Grasshopper)</td>
<td>Defined and updated own rules and assumptions.</td>
<td>Explorative and interpretive</td>
<td>Explored emergence forms</td>
</tr>
</tbody>
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**Figure 3**
Correlation between pre-defined criteria and project development.

**Figure 4**
Level of internalization and level of predictability correlation.
digged. Besides grammatical items, it is also important to discuss semantics of existing vocabulary of different disciplines. At this point, we think that the syllabus types developed for new language learning might provide pedagogic advantages/clues in terms of teaching approach and methodology. Particularly the pedagogic potentials of notional-functional syllabus type is considered to be examined for the following semester of EAAD.

In addition it is observed that collaborative learning environment including face-to-face feedback (especially tried in discussion and presentation parts) provides positive reflections in understanding abilities; however we did not make qualitative research about it within the scope of this paper. Correspondingly, the influence of the literature review and the example search (presentations) parts on students' way of thinking might be examined within scope of another study.

Figure 5
Sample of an explorative and interpretative student work by Tugce Darcan.

Figure 6
Sample of an explorative and interpretative student work by Benay Gursoy.
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