

A HIGHLY INNOVATIVE MODEL FOR EDUCATION IN ENGINEERING AND APPLIED SCIENCES

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Abstract — Sabancı University is a private university funded by one of the largest industrial holdings in Turkey. It is ranked within the first top five universities of Turkey. The university structure and mission was meticulously planned since 1994 and the university started its undergraduate and graduate education in 1999. In this paper some of the innovative features of Faculty of Engineering and Natural Sciences are described in the context of our overall educational system, university infrastructure and the preliminary results observed within the first three years of our undergraduate and graduate education and research experience. Among the novel features is a flat faculty administrative organisation (no departments) that offers undergraduate and graduate programs mostly in information technology related areas as well as molecular biology and materials sciences. Absence of departmental separation greatly enhances the interactivity required for cross-disciplinary communications in teaching and research. Other features include liberally oriented program curriculums allowing the students a much greater space for choice and facilities that enable students to get involved in independent and hands-on project work throughout their education.

Index Terms — Innovative university, engineering education, higher education in Turkey, liberal curricula in science and engineering

INTRODUCTION

This paper describes a new and innovative private university with a meticulously architected and well-equipped campus placed at the outskirts of Istanbul, Turkey. In order to appreciate the innovative aspects of Sabancı University it is important to understand the prevailing higher education system in Turkey the outline of which we present in the next section. Following that we describe the initial conception and the underlying structure of the Sabancı University. In the section on operational aspects we first describe some positive observations mostly involving the Faculty of Engineering and Natural Sciences and then discuss some problematic areas that await solutions. A few thoughts on future prospects are given in the conclusion .

THE CONTEXT : HIGHER EDUCATION IN TURKEY

According to *The World Almanac 2000* percentage of population at or below age 19 in Turkey – with a total population of 67 million - is 38.5. The world average is 38.9 whereas the figures for the developed and less developed world are 24.8 and 42.2 respectively. The social and political context of having a relatively higher percentage of younger population becomes clear when it is contrasted to the average figure for Europe which is 24.1. Hence if education at all levels and contexts – i.e. primary, secondary, higher, vocational, other professional such as IT etc. – are taken seriously this demographic property can be turned into an advantage : if the context is taken as formal or de facto integration of Turkey into Europe then a relatively educated younger population means a driving human resource much needed by Europe. This is why education in general and higher education in particular has an immediate strategic significance for Turkey.

Turkey has 74 universities out of which 53 are public and 21 are privately governed. All universities, be they public or private, are tightly coordinated by a highly centralized bureaucracy, *Higher Education Authority (HEA)* according to the dictates of an one-size-fits-all higher education law. One arm of the HEA is the *Student Selection and Placement Board (SSPB)* which is responsible for organizing a centrally managed student placement examination given every year simultaneously at selected number of locations both inside and outside Turkey. New as well as old high school graduates - students attempting another go for a desired place in a university - take the exam. The number entering is approximately 1.5 million and over 10-15 %, including open education positions, are admitted to a program in a department in one of the 74 national universities. The logic of placement is that of supply and demand. In simplified terms each student specifies a priority list among available programs offered by the universities ; each university department announces its quota of student intake and the rest is an automated calculation based on these data and the points scored by the students computed according to a rather complex formula taking into account student's exam performance and individual high school standing with adjustments that take into account historical performance record of the school in past entrance exams.

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Possibly owing to a high degree of automation it is a fact that the central entrance examination managed by the **SSBP** enjoys the prestige of being free of corruption where no form of clientalism has ever succeeded in distorting the placement order of this automated process. On the other hand it has still been subject to criticisms on two accounts: the lack of social justice in the selection process; and the validity of the test evaluation system judged by the correlation between the student placement scores and their later academic performance. The social justice aspect is a problem to be solved on a different platform and thus we shall not dwell on it here. Much research has been performed on the scientific evaluation merits of the system and there seems to be some correlation with academic success especially on top echelons of performance. Yet the criticism can be radicalized in a way that calls into question the centralized process of selection judged by its negative influence on the entire secondary education. We elaborate on this below since it bears relevance to some of the innovative features of Sabancı University.

Higher education has become of great concern globally since it implies access to well-paid jobs, a commodity that is becoming more and more scarce in an age of radical automation. In addition to the economic benefits, university education is also an important status symbol in Turkey and a good university education will secure a highly respected social position as well as a good job. Consequently the competition to acquire a decent place in a high rated university has generated a sizable commercial industry of enterprises coaching the students to perform well in the test-style entrance examination. The skills involved for a successful performance are based on categorizing possible test questions in mathematics and sciences into a number of types and subjecting the students to drills on solving problems through exhausting all types. Social sciences are no exception to this approach since Turkish secondary education in social sciences has a high dose of nationalistic indoctrination which makes the contents suitable for rote memorization based on text books approved by the ministry of education. These observations have some serious consequences discussed below.

The commercialized university entrance examination market has damaged Turkish secondary education in radical ways. Students, during their last two – if not three – years in high school focus entirely on university entrance activities by choosing and attending one of the private preparatory coaching courses. The high schools, even the most reputable ones, accept this as a fact of life and simply support the students in their extra-curricular preparation activities instead of supplying them with a rigorous secondary education.

The necessary skills for solving test questions have little to do with the requirements of contemporary higher education. Nor are they related to a good secondary education. Among the qualities that lack in most high school graduates are *literacy*, *purpose guided socialization* and *hands-on experimentation* as explained in the following paragraphs.

- In general students do not possess the oral and written comprehension and self-expression skills even in their native language of Turkish, leaving aside extending those skills for a universally valid language like English.
- Students have little or no exposure to working in simple team projects whereby a group of participators organize themselves to shape a loosely defined project topic into an operational program. In such an exercise the students learn something about leadership, initiation and communication.
- Finally students lack a sense of hands-on experimentation, an important preparatory step in *learning by doing*. For example carefully designed laboratory experiments orient the youngsters to professions in science or engineering or exposure to computers orient them to professions in information technologies.

On the positive side let us, nevertheless, admit one useful attribute that all Turkish students possess before they enter a university: a strong sense of self-guidance and a fighting spirit for survival in a competitive environment.

Before we move onto the next section it is important to mention two distinct peculiarities, one linguistic the other professional, of the Turkish higher education.

In the 50'ies Turkey had a few universities which were structured in the German style where professors occupied chairs and younger faculty members did not have the authority to teach or supervise research work independently. After the founding of a new state university in 1956, the Middle East Technical University (**METU**), the entire Turkish university system gradually transformed into an US-like system. **METU** was the first example of a purely national – as opposed to foreign missionary based schools carrying over from the 19th century - education institute whose official language of teaching and research was English. Adoption of English as the official operational language of **METU** had an immediate practical consequence: students after completing a one year preparatory language course attended university courses in which internationally accepted text books were used which eliminated the necessity and dangers of being bound to a Professor's possibly outmoded notes or books in Turkish. The access to a large number of resources in English gave the students a self-confidence which culminated in a different culture and attitude of graduates coming from

METU. All of this survived among heavy criticism on grounds of cultural degeneracy. Adopting a foreign language was taken an insult to the national pride. Yet there was no viable example of any educational institute that could successfully teach professional courses in the national language and teach enough English on the side as, for example, practiced in the Scandinavian countries. The national pride criticism continue to date though with much less influence since after the example of METU the new understanding kept on proliferating. The **top** ranked five universities of Turkey perform all academic activities, including teaching, in English. This is a remarkable and unique example of cultural pragmatism with a bottom-up support in a country without a colonial past under British Empire or any other English-speaking power.

Three areas that are extremely popular in Turkey are electrical engineering, computer science and industrial engineering. According to the 2002 entrance examination statistics, students who were accepted to the departments of the top five universities offering programs in these areas come from the top 1% of those accepted to universities. Even for low rated universities in less developed regions where quality of education is questionable, students accepted to these high demand departments are in the top 10-15%. This shows an overwhelming concentration of demand for a small number of areas mostly in engineering. Other relatively high demand areas are management and economics, molecular biology and medicine. Demand for mathematics, pure sciences and social sciences are lower except for a very limited number of positions in some elite private universities that offer scholarships.

Two important conclusions can be drawn from the observations above. The first is that the demand for higher education in Turkey fits international job markets of the developed world. That is, a work force that consists of fluent English speakers trained in information technologies and other technological areas for which there is definite shortage in regions like Europe and US. This probably is no coincidence since a great number of university graduates from Turkey in these areas fill up graduate schools or silicon valley jobs in the US. The second conclusion is that this collective demand pattern overrides individual tastes or concerns of the students in choosing professions. A gifted student choosing a low demand area, such as say psychology, is viewed as an anomaly and a waste of the gift. Advisers in coaching enterprises have been successful in generating an environment in which students are already conditioned to choose areas and universities compatible with their performance.

THE FOUNDING PRINCIPLES AND STRUCTURE OF THE SABANCI UNIVERSITY

Sabancı University was officially founded – by law like all the other universities – in 1997 and started its undergraduate and some of its graduate programs in 1999. The principal investment and operational funding comes from a foundation of Sabancı Holding, one of the two largest private industrial holdings - both of which are family owned - of Turkey.

The university is composed of three faculties : Faculty of Engineering and Natural Sciences (**FENS**), Faculty of Arts and Social Sciences (**FASS**) and Graduate School of Management (**GSM**). Together with an undergraduate program in management sciences to be offered next academic year there are 12 undergraduate programs, 7 out of which are offered by **FENS**. These are: *microelectronics, telecommunications, computer science, mechatronics, industrial engineering, genetics (molecular biology) and materials science*. In addition to undergraduate programs there are graduate (MS and PhD) programs offered by the three faculties. **FENS** academic graduate programs are: electronics engineering and computer science (an integration of the first four **FENS** undergraduate programs stated above), materials science, molecular biology, industrial engineering and mathematics. In addition **FENS** offers two professional masters programs, one in IT and the other a industry sponsored double degree program in a field of engineering and management with the collaboration of **GSM**. The size of the university is small: first stage planning targets a total number of 3500 students - including the graduate students which will constitute 15-20% of the total. This target is expected to be reached in 2007. The campus is built on an area of 900 acres with 10 large buildings and a small artificial lake.

The actual planning of the university formally started in 1994 and in 1995 an international search conference was held with participants from 25 countries ranging from academicians, technocrats, businessmen to students and parents. The purpose of the search conference was to brainstorm in order to generate an outline of the founding principals of a university for the 21st century. There were no constraints or preconceptions other than the fact that the university was to be built in the outskirts of the 1500 year old city of Istanbul. Much of the innovative aspects, which we discuss next, of the Sabancı University has its origins in this search conference.

Sabancı University enjoys a *departmentless* system. That is, there are no formal administrative units under the faculties. This puts some additional load on the faculty deans where an informal and flexible delegation is used for coordinating activities like the academic programs. The existing faculty sizes have rendered this arrangement of flat organization administratively manageable. On the other hand the advantages have already began to reap their fruits. Recent internal projects such as using liquid carbon dioxide as a coolant in high-speed machine tooling or synthesizing micro-surfaces for automated biological sample analysis are just a few examples of research collaboration between materials science, mechatronics and biology disciplines. What is, however, more important is the multidisciplinary atmosphere of the **FENS** building within which the students get educated and do research. **FENS** building is the largest building in the campus that occupies 17500 meters squared of space with over 50 research labs, auditoriums and classrooms and faculty and graduate student offices. To take a striking example consider a biology student that is constantly in *contact* with students in computer science mechatronics, electrical engineering, materials science or mathematics. By the word *contact* we mean sharing common elective courses, participating in common informal discussions, participating in undergraduate or graduate projects possibly of interdisciplinary nature etc. This is a remarkable feature that is non-existent in any Turkish university or even in other world universities, at least at undergraduate level.

Sabancı University stands unique in Turkey in allowing students to declare their diploma areas at the end of their second year in an absolutely unconstrained manner – i.e. no program quotas, no performance requirements etc. The purpose of this liberal principle is to maximize student motivation and responsibility. In a patriarchally oriented and hierarchically organized educational system - and in general a society - this comes as a cultural shock to all the students. There is a faculty advising system that informs and helps students in choosing their diploma areas and that supports them in solving their academic and social problems. In addition to faculty tutoring and advising system there is a *Center for Individual and Academic Development (CIAD)* in which professional staff as well as bright junior and senior students perform tutoring activities to freshman and sophomore students.

Sabancı University is also unique in the country in its well-designed IT infrastructure. All undergraduate and graduate students are given a laptop computer for their use as soon as they enter the university. After two years all laptops are renewed through an agreement made with the company that leases the laptops. The university has a high bandwidth internal fiber network and external connectivity is one of the best in the country. There are nearly 9000 network entry points at a large number of classrooms, student dormitories

and faculty housing, all information center (library) study desks, faculty and graduate student offices, all labs etc. Access to information is smooth and uninterrupted. Such an infrastructure helps students become computer literates at an early stage after they enter the university even before taking a single formal course in computer science.

Sabancı University is structured to make up for the gaps in the Turkish secondary education mentioned in the previous section. These are very briefly summarized below:

- **University courses.** These are mostly first year courses to make up for the lack of literacy both in sciences and mathematics and social sciences . All students are required to take these courses. The emphasis is more on concepts and less on background building and technicalities. For example there is a two semester freshman course *Science of Nature* integrating concepts in physics, chemistry and biology where, for example, in physics, rather than exhausting all topics three concepts : mathematical formalization, action at a distance and the universe of small particles are covered in the context of classical mechanics, electromagnetic theory and quantum theory respectively. *Humanity and Society* is an introductory anthropology-history course which presents to the students a well-designed set of topics rich and meaningful in intellectual contents and not overridden with indoctrination concerns. Taken together university courses expose students who aspire to become engineers or scientists to historical and social concepts to enlarge their vision of the world in their post-university lives as professionals and citizens. On the other hand it exposes students who want to study arts or human sciences to the concepts and culture of sciences without overburdening them with technicalities.
- **Faculty courses.** These are mostly second year courses offered by **FENS** and **FASS**. These courses are basic professional or background courses of the diploma areas. Faculty courses give the students a deeper understanding of a diploma area and in that sense can be used as instruments of window shopping in making their choices.
- **Independent team projects.**
 - a) All students, either in their language preparatory year or first year are required to participate in a community activity for a total of 40 hours. For that purpose the university has established close links with NGOs such as Earthquake Relief, Human Rights, Amnesty International, Care for Street Children etc. both in the vicinity of Istanbul and in more remote and deprived parts of Turkey. This sharpens the students' socialization habits with a strong

- component of commitment and responsibility.
- b) All **FENS** students are required to take a team project course at the spring semester of their first or second year. The project topics are suggested mostly by the faculty members and sometimes by the students themselves.
 - c) At the end of their third year all **FENS** students are required to complete an 8-10 weeks of internship in an industry. The internship is also structured on a team project where a technical representative of the industry and a faculty member either jointly advise the project or at least maintain a reasonable amount of coordination. All internship projects are publicly presented in poster sessions within a specified week of the following semester.
 - d) Finally **FENS** students are required to take a two semester design and implementation course in their senior year. Since students have already acquired prior experience in independent project courses or activities as summarized above, our professional expectation from the design and project course is more ambitious. The outputs of these projects are desired to be at most one step away either from a commercializable or a precompetitive product or process of high calibre. The evidence so far neither confirms nor negates our ambition. More time and experience is needed for further structuring this course into a positive and fruitful experiment.

To summarize, independent team projects described above enrich the hands-on learning, communication, presentation and socialization abilities and skills of the students.

Sabancı University can be viewed as a managerially run university in the fashionable parlance of university management theories. At the topmost layer of management is the board of trustees that usually meet four times a year. The administration of the university has a dual structure. Non-academic administrative tasks are run by an administrative staff managed by the general secretary of the university. The administrative functions of the faculty members are reduced to purely academic matters such as tasks in committees for curriculum improvement, juries for graduate theses or undergraduate projects etc. The rector, as the highest administrative and academic officer of the university plays a key role in maintaining a healthy communication between the business or bureaucrat minded

administrative staff and the academic community. There is a separate office directly responsible to the rector that manages all external relations such as funded projects, relations with other research institutions or commercial companies etc. Because of the widely differing cultures of managers and academicians the system requires good communication between the parties involved. It is a common hope that as the system evolves, institutional learning will gradually build a unique collective culture.

So far we have described features of the university related to education and administration. The research vision of the university is aptly summarized in the understanding stating that *the dissemination of the research results for the good of the society at large is a distinct mission of the university*. In the context of **FENS** this translates itself as getting involved in activities like technology transfer to public or private companies, assuming a primary role in founding hi-tech start-up companies, actively participating in technoparks etc.

FENS research strategy is founded on three pillars. The first pillar is basic research, the output of which is scientific publications and practical know-how accumulated within the research labs. The second pillar is possibly commercializable research in knowledge intensive hi-tech areas. So far as the university mission goes this is the pillar of greatest strategic importance. The third pillar is fund generating activities or projects. Such a project may have been originally initiated by a faculty member as an R&D activity and after reaching a saturation phase where things become routine the project can be continued by specially hired staff or university related companies to generate steady funds for the university. The most desirable R&D projects are those for which the three objectives above overlap. However, reality is not always that generous and maintaining a suitable balance between these activities is important.

The undergraduate and graduate programs as well as research interests in **FENS** constitute interwoven, future-looking and knowledge-intensive areas. There is a definite harmony between the choice of areas, research strategies and interdisciplinary concerns. Short term research concerns heavily lean on applications of information and communication technologies in all aspects of life whereas longer term research concern is that of *engineering in the small* in materials, biology, mechatronics, microelectronics and optics.

PRINCIPLES IN ACTION

In this section we summarize some of our observations and comments based on the past four years of experience.

An interesting example of unleashed student energy occurred a year after the introduction of student team projects in Spring 2000. Motivated by this project course and through the efforts of the mechatronics faculty members a number of first and second year students decided to enter a national competition in robotics which was part of a world wide competition organized by Japan. As a result of hard and arduous work these students were able to win the national competition by eliminating groups of fourth year mechanical engineering students coming from two of the best rated and well established state universities. They then went to Tokyo and were able to end up within the first eight contestants out of approximately 25 nations and won a prize for that. This has set an example within the university making mechatronics a popular choice and further accelerating the competition between the seven programs for attracting the best students.

A program that has proved extremely popular is the community projects done in cooperation with the NGOs as described previously. A significant number of junior and senior students still maintain their ties with the NGOs with which they had first worked a number of years ago. Aside from having developed a sense of social responsibility and political maturity this activity has been the *first* occasion in which they improve their computer literacy by becoming fluent power point and excel users and by learning to make ample use of information resources of the library and the internet.

In a liberal environment where students were forced to make their personal choices and program their daily routines under academic pressures two problems became visible. These were time and stress management problems faced by the students. Special courses were organized by **CIAD** on both time and stress management which in time became popular and are still repeated every now and then.

On the research side there have also been spiriting developments. Sabancı University recently became a partner in a technopark company that is now actively launching training and recruiting activities for attracting progressive hi-tech companies. This technopark is placed within a privately funded industrial site about ten kilometers away from the campus. The expectation is that at some stage this technopark to become an outlet for our entrepreneurial students and the creative technological research carried out in the university labs.

As an example for progress in commercializable research activities two short term projects have been completed for a multinational German company, one in computer vision applied to industrial production process and the other a control problem involving removal of a belt instability problem in a serial production system. Sabancı University has again set a unique example in successfully completing

research projects for a reputable European company in a very *professional* manner.

Notwithstanding these positive moves and success stories there are also problems. In order to meet the challenges in education and research faced by **FENS**, high calibre students are needed. This however depends on the scholarship policy, which in turn depends on the business plan according to which the ratio of students with full scholarships will have to drop to less than 30% from the original 50%. This means that systematic and creative publicity and promotion campaigns of the university targeting high schools with highly rated students who can afford to pay tuition fees must be repeated intensively and frequently. Or other creative arrangements must be sought for generating repayable loans for good students who cannot afford to pay.

Students usually respect the views of their peers and seldom trust advice coming from academic or administrative officials. This means that as the new culture starts settling in inter-student communication is the most effective means of proliferating and transforming the new mentality into a liberal academic tradition owned up by the students. This takes time and the university management must exhibit persistence and determination to guard the liberal environment within which students can freely express their views and practice their creative activities.

Another difficulty is to generate a common culture among faculty members whose origins constitute a heterogeneous mix: either fresh PhDs mostly from US universities or engineers or scientists from other academic institutions, research institutions or industry. The correct balance between academic or scholarly activities and technologically creative activities that fit the **FENS** research strategy mentioned above requires an unorthodox academic performance system that must be designed and implemented in support of a common culture and understanding. We are at best halfway in our efforts in this direction.

CONCLUSIONS

As we approach the end of the first four year undergraduate program cycle this year, Sabancı University has already established a reputation for being one of the most innovative universities in the nation.

In the last fifty years two universities in Turkey have made history by setting examples to others. The first one was a milestone for moving the entire system to a US-like structure from the old Germanic model and normalized English as a universal language of communication. The second one was the first private university in Turkey that proved that by moving outside the boundaries of the state system one can build a world class institution measured by

its scholarly activities. Sabancı University aspires to become a third such milestone through its impact on society by gearing its activities to transferring technological innovations into industry through its agents, namely its faculty and its graduates. This is why and how education meets research in the context of **FENS** of Sabancı University.

Sabancı University will perhaps resemble in time to one of the five entrepreneurial European universities thematized in Burton Clark's celebrated book:

Creating Entrepreneurial Universities : Organizational Pathways of Transformation, Elsevier 1998.

Yet there are a few differences in the nature of innovations reported here. The innovations in Clark's examples stem from very creative managerial maneuvers in the context of highly rigid state university systems in four European countries. The managerial dynamism to transform the income base of universities by an order of magnitude by mobilizing the technological and educational capability of the faculty is no trivial matter. The same challenge is valid, important and indeed even a greater one for Sabancı University in view of the less developed technological base of existing industries in Turkey. On the other hand the strong student-centered and faculty-involved internal component of innovations mentioned here is non-existent in Clark's examples.