CHEMICAL ENGINEERING EDUCATION IN TURKEY AND THE UNITED STATES

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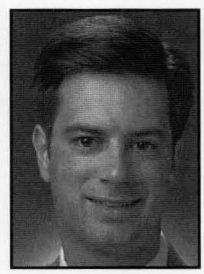
A few years ago, Floyd[1-3] wrote an interesting series of articles comparing the chemical engineering educational systems of the US and Japan. As an undergraduate at Tokyo Institute of Technology and a graduate student at the University of Wisconsin, he was able to identify a number of striking differences between the two systems. In this article, I would like to reconsider a number of Floyd's observations in relation to another country—Turkey. This presentation goes beyond Floyd's presentation in providing more systematic comparisons between the students' performances and backgrounds. The expectation is that seeing a number of educational systems juxtaposed in this way can lend some insight into the strengths of each system and suggest improvements for all.

According to Floyd, the most notable differences between the American and Japanese systems were related to the formidable entrance exams in Japan and the practice of attending intensive preparatory schools (*"junku"* in Japanese) during the period of secondary education. This intensive preparation evidently led to two significant outcomes: 1) greater preparation of the entering students made it possible to place much of the technical content earlier in the curriculum, and 2) a person's performance in college was less important than the college attended, so most of the college experience was considered as a time of rest (a kind of "relaxation" phenomenon). Since the Turkish system has a similar pre-college program (*"dershane"* in Turkish), one point of interest was to determine whether a number of Floyd's observations regarding the Japanese students might also be recognized in Turkish students.

There is a more broadly global justification for considering a country such as Turkey in relation to countries such as the US and Japan. If you made a list of all the countries with chemical engineering departments and sorted them according to gross domestic product per capita, the US and Japan might not be considered as being globally representative.[4] Countries such as India, China, and Argentina share measures like gross domestic product per capita more closely with Turkey than with the US or Japan. Thus, one might hope that the insights gained with respect to Turkey should reflect similar insights that might come from studying any one of many countries around the world.



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This paper compares the curricula and, perhaps of most interest, characterizes the differences between the students by means of quantitative comparisons. Specifically, I have conducted the same course in thermodynamics at Bogazici University in Istanbul, Turkey, that I have taught for eight years at the University of Akron. A detailed description of my personal emphasis in this course was previously presented[5] but, for the most part, this course represents a standard course in the chemical engineering curricula worldwide. Both sets of students used the same primary text and syllabus, had access to the same computational facilities, and faced identical examinations. By comparing performance on identical examinations simultaneously with other indicators of performance and background, a connection can be drawn between the local system and its overseas counterpart.

The essential computational resources were made available through the generosity of the Fulbright Program in that they funded programmable calculators for every student in the Turkish course. Normally, Akron students are expected to purchase their own calculators with sufficient RAM (32 KB) to support programs for compressibility factor and departure function calculations as well as vapor-liquid K-ratios and bubble point pressure by the Peng-Robinson equation of state. The necessary programs are made available if the students purchase either a Sharp EL9300 or HP48G. Questions that are greatly facilitated by these programs are included on the tests and final exam. Through the Fulbright grant, all the Bogazici University students were provided with pre-programmed calculators that they could keep and carry to the exams. In the Turkish system, it is not typical for computational resources to be so integrated into the coursework at the undergraduate level, but, in order to give identical examinations, it was necessary that the computational resources be equalized to this extent.

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BACKGROUND ON THE CURRICULA AND STUDENTS

The curricula of the schools are compared in Figure 1. The Bogazici University (BU) curriculum resembles the University of Akron (UA) to a higher degree than the Tokyo Institute of Technology (TI) curriculum. The TI curriculum reflects a considerably greater emphasis on general subjects and foreign languages. The major difference between BU and UA is that the BU curriculum places more emphasis on the specialization/research option than the UA curriculum, with a corresponding decrease in the general science emphasis. Both the TI and BU curricula place significant emphasis on the specialization/research option, whereas UA's research emphasis is relatively light. The most striking feature of the UA curriculum is the high proportion of emphasis on general science courses. The emphasis on general science at UA limits the time available for specialization/research.

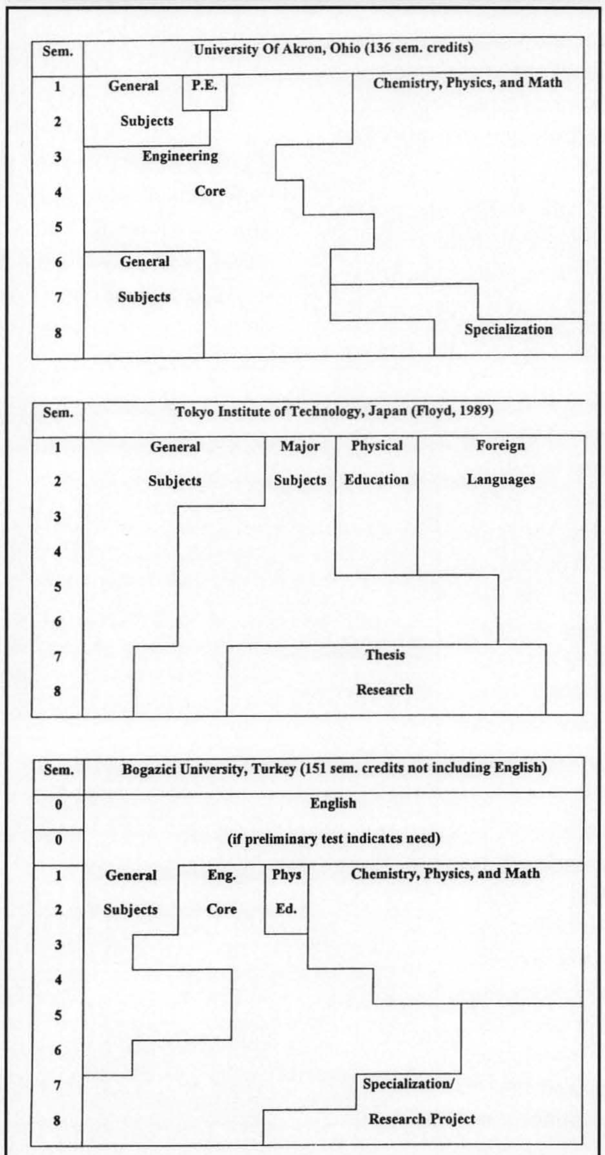

Figure 1. *Outlines of undergraduate currucula.*

A detailed comparison of the courses shows that the BU students are required to repeat the freshman calculus, chemistry, and physics at the same level as their UA counter parts. This suggests that not every country takes advantage of the higher degree of preparedness of students admitted by a competitive national exam. One might suspect that calculus and physics are not covered on the BU national exam, but they are.

Another significant difference between the three curricula is the requirement of more total credit hours to graduate from an overseas university—151 at BU vs. 136 at UA. These extra credit hours are largely dedicated to industrial chemistry courses. The emphasis on industrial chemistry is similar to that in the TI curriculum, although it is not quite as intensive in Turkey.

Concerning the BU and UA curricula, a couple of slight curricular deviations are relevant to the thermodynamics course. The BU students take chemical engineering thermodynamics in the fall of the junior year vs. the spring of the sophomore year at UA. Furthermore, the BU students have had a full year of physical chemistry prior to the thermodynamics course. This deviation makes for a slight difference in the degree of preparedness of the students, beyond their pre-college backgrounds. A small allowance was made for this difference by adjusting the grade scales, which will be discussed later.

It should be noted that BU has historical ties with the US educational system, especially in that all courses included in the four-year degree program are conducted in English. This is also true of Middle East Technical University, another engineering school in Turkey with a substantial number of chemical engineering graduates. With this in mind, it is not too surprising that the BU and UA curricula are so similar.

As for the student backgrounds, entrance into BU is extremely competitive. Students indicate the schools and departments into which they would like to matriculate on their test papers. Students are matched with departments according to their performance on the exam and the availability of positions in each department. In a recent instance, of roughly 1,200,000 applicants taking the national entrance exams, the lowest score admitted to the BU chemical engineering program belonged to the 1400th student from the top (approximately the top 0.1% on average).

On the other hand, once admitted, all courses are practically free of charge, and it is somewhat difficult to fail a student from the curriculum. Furthermore, meals are subsidized, making housing the only significant expense after admission. To reduce housing costs, many students commute long distances, living with family members. It was suggested to me that the underlying student educational capacities should be roughly equivalent. The reasoning was that the UA students should be motivated by their more substantial tuition costs and fear of failure. BU students, on the other hand, should be predisposed to be successful based on the selection process for admission, but the advantage is somewhat nullified by the "relaxation" effect. It should be noted that most UA students pay the bulk of their tuition themselves, either through cooperative education or through part-time work.

Entrance to UA, like many US institutions, is not based on a competitive exam. America is known as the land of opportunity, and UA subscribes heartily to this proud tradition. Our admissions procedure is to admit virtually anyone who applies into the general program. Students may take courses in any curriculum until the junior level, by which time they are expected to achieve sufficient success to be admitted into a degree program or to continue sophomore courses until they can be admitted. A natural consequence of this admission policy is a relatively high attrition rate. To illustrate, our football coach was once challenged because only 60% of his athletes were graduating. After about a week of his fumbling around, someone informed him that 60% was nearly double the University average!

While the admissions policy and attrition rate at UA are subjects of some concern, it is not entirely obvious how to devise an alternative policy that serves our mission of widely available public education. As for typical results in the chemical engineering department at UA, of 90 UA students initially registered for the sophomore course in material and energy balances in 1992, 40 eventually graduated. Approximately 120 students expressed an interest in chemical engineering at the freshman level and 60 students began the thermodynamics course (about 50% of those expressing interest at the freshman level). During a comparable period at BU, 50 students graduated while 55 students were admitted at the freshman level.

There are a number of other potential differences between the students and their backgrounds. To address these, the questionnaire in Table 1 was developed. The questions address issues such as commute times, part-time work hours, and course loads. The results from Table 1 suggest that UA students live away from their families and have shorter commute times and lighter course loads. They work part-time to about the same extent. According to Floyd, TI students tended

TABLE 1
Student Background Information Questionnaire

	BU		UA
1. The average time I spend commuting ***from*** home ***to*** school is ___ hours per day. Please do not count the return trip. I will do that.	0.7 51%	avg (hrs) % > 0.75	0.3 12%
2. At the beginning of the semester, I was working part-time ___ hours per week in addition to my engineering studies. (*e.g.*, private lessons/tutoring for pay, tour guide, McDonald's, . . .)	11 54%	avg hrs among those working % working	9 50%
3. I am taking ___ total course credits this semester.	19	avg	15
4. My cumulative grade point average including all courses *completed* to date is: ___/4.0	3.4 2.4 1.3	max mean min	4 3.2 2
5. I found the instructor's use of English to be a significant impediment to my learning this material relative to professors in my other classes. For example, he either spoke too fast or used vocabulary I could not understand, or in some other way spoke differently from my other professors such that my performance was impeded. ***Agree • Somewhat Agree • Somewhat Disagree • Disagree***	20%	% agree or somewhat agree	13%
6. Mostly, I have been living with family members while attending school this semester. ***True • False***	51%	% true	25%
7. Chemical engineering was not my first choice as a field of study, but it was the best I could do if I wanted to come to this school. ***Agree • Somewhat Agree • Somewhat Disagree • Disagree***	56%	% agree or somewhat agree	13%
8. My career goal is to work my way out of engineering in the next five years and into some business or management position. ***Agree • Somewhat Agree • Somewhat Disagree • Disagree***	70%	% agree or somewhat agree	31%

to share similar backgrounds with the Turkish students. The higher grade point averages among the UA students probably reflect a difference between the two educational systems. For example US students with lower averages would have sought another major by this stage in the curriculum. Even so, when considered in conjunction with the test results presented below, the difference in grade point averages suggests a significant degree of either grade inflation at UA or "deflation" at BU. Until recently, the math and science courses at BU have been the exclusive domain of engineering students. It seems possible that the teaching of these courses may have been designed to obtain a normal distribution in the grade scales that would be very different if the courses were offered to more diverse groups of students, as they are at UA.

TABLE 2
Grade Scales Applied at the Respective Universities

Bogazici University		*University of Akron*	
82	AA	A	80
76	BA	A-	75
70	BB	B+	70
64	CB	B	65
58	CC	B-	60
52	DC	C+	55
46	DD	C	50
		C-	45
		D	40

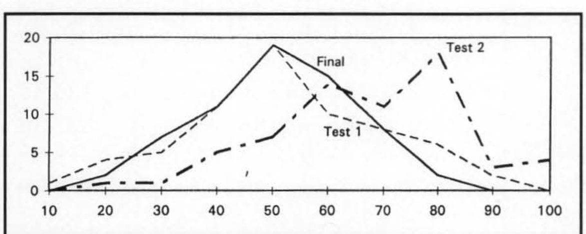

Figure 2. *Frequency distribution plot based on test scores at the University of Akron.*

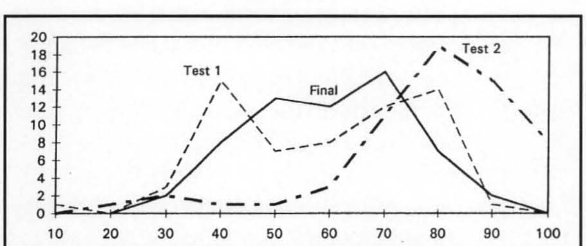

Figure 3. *Frequency distribution plot based on test scores at Bogazici University.*

TABLE 3
Summary Statistics for Tests at UA and BU

	University of Akron					Bogazici University				
	Min	Med	Max	Mean	Std Dev	Min	Med	Max	Mean	Std Dev
Test 1	4	45	85	47	18	0	53	89	54	18
Test 2	12	64	96	63	17	50	78	97	77	11
Final	13	48	81	47	16	20	55	85	55	15

It was surprising to learn that one of the BU students was working 42 hours per week (not counting the commute) and taking 21 course credits. The most similar UA student was working 30 hours per week while taking 13 course credits. BU faculty were generally surprised at the extent to which the students were working part-time. Another surprise was the number of BU students for whom chemical engineering was not a first choice—56% at BU vs. 13% at UA. The observation that 70% of BU students hope to work their way out of engineering in the next five years (31% for UA students) is perhaps related. Altogether, these results lend some insight into the manner by which a homogeneous selection of students still leads to a broad distribution in performance. The systematic placement of students into curricula that do not represent their first choice would seem to indicate a broad distribution in levels of motivation, especially considering that prospective employers rarely ask about the cumulative grade point averages of BU graduates.

GRADE SCALES AND PERCEPTIONS

One difference in the manner of conducting the two courses was the grade scale. Although the difference could influence the conclusions of this study, some differences were unavoidable and others were judged to be the best compromise between maintaining comparability between the two courses vs. adaptation to local influences. The most unavoidable difference was that the grade scale at BU was composed of fewer gradations. As shown in Table 2, there was only one intermediate grade between each whole grade level, instead of the A, A-, B+, . . . that exist at UA. Comparing the numerical values, it should be apparent that the whole letter grades were roughly matched at the A level (82 vs. 80), but there was a more significant deviation at the lower end of the scale. A 58 was a C at BU vs. a 50 for a C at UA. This difference might be expected to bias the BU grades to higher averages. On the other hand, the BU students had already taken physical chemistry and were juniors instead of sophomores. The minimum standards for such students should naturally be slightly higher. There was one other justification for this slight upward shift that had to do with what I refer to as a local influence. A sample of students revealed that 74% of students from BU graduated with two or more Ds on their transcript, vs. 19% at UA. Evidently, students at BU perceived a D less negatively than UA students. This last observation provides support for the suggestion that BU students become complacent about their grades once they have been admitted.

RESULTS OF EXAMINATIONS

Figures 2 and 3 present the distributions of test scores at BU and UA. Table 3 presents summary statistics. The means at BU were significantly higher than the means at UA at the 95% confidence level on all examinations. This seems to support the expectation that the more highly selected students should perform better. On the other hand, some influences apparently act to broaden the distribution of the highly selected group relative to the narrowness of the initial selection.

There are some differences between the groups of students that go beyond the summary statistics. The most striking difference is that the BU students went from a high-low bimodal distribution on the first test to a high unimodal distribution on the second test. As a result, the BU mean went from being seven points higher than the UA mean to fourteen points higher. Means at both schools were higher on the second test, indicating that it was a relatively easy test.

> ***. . . this [thermodynamics] course represents a standard course in the chemical engineering curricula worldwide. Both sets of students used the same primary text and syllabus, had access to the same computational facilities, and faced identical examinations. By comparing performance on identical examinations simultaneously with other indicators of performance and background, a connection can be drawn between the local system and its overseas counterpart.***

One interpretation of these observations would be that BU students needed to adapt to the new professor. On the other hand, I provided both groups with sample tests from the previous five years on both tests. Informal interviews with BU students who had made the switch indicated that the switching students had not studied the sample tests on the first test, but studied them seriously on the second test. The distribution on the second test and final were closer to what one would expect based on the differences in admissions policies. The UA test distribution was broader, reflecting a broader selection of admitted students.

It is interesting to note that a number of students achieved high scores at both schools, indicating that US schools are capable of producing top students despite the relatively low intensity during secondary education. Another observation about the differences relates to a qualitative observation about the way the students answered the questions. Over the years, I have become accustomed to writing the tests such that the more mathematical questions come at the end, because many of the UA students tend to have difficulty with these questions, but I noticed that the BU students tended to solve the test questions in reverse order (the first page was often left blank). It seems that the difference in the means on the second test is largely attributable to the difference in performance on the last question (worth 20 points on each test). This would concur with the other anecdotal observations about the stronger mathematical backgrounds at foreign schools. Copies of the test questions can be obtained by contacting the author.

CONCLUSIONS AND RECOMMENDATIONS

The transition from making observations to making recommendations regarding such evolved educational systems is very delicate. The observations are never complete, and the recommendations often require personal judgements that may conflict with those of others. Noting these limitations, I have attempted to present the data completely in the preceding sections, such that alternative interpretations are not precluded. On the other hand, engineering estimates occasionally require making the best recommendation based on the limited data at hand—this is the spirit of the recommendations below.

My most significant impression was that a substantial fraction of the BU students were underachieving. This impression derives primarily from talking with students who were having difficulty and learning that their problems related simply to a lack of study. The reasons why this might happen are reflected by the fact that most of them are not really interested in chemical engineering and because administrative practices and employment prospects are less motivating than those experienced by UA students. The BU administrative system makes it very difficult for them to fail and discourages transfer to other majors. Prospective employers show little interest in what grades the students have obtained; their primary interest concerns from which school the students have graduated. Tuition is free, so there is little penalty for taking extra time to graduate. Entirely different attitudes prevail for the UA students on each of these scores.

Many of these issues are beyond the control of the faculty, but faculty can influence the curriculum in a way that might help to balance their negative impact by integrating the students' motivations into the overall plan. Regarding the curriculum at BU, it seems that the nature of the students' backgrounds and interests are not taken into account with optimal efficiency. Calculus, physics, and chemistry are required elements of the national entrance exam. Students scoring in the top 0.1% on this exam can be assumed to know something about these subjects, but the curriculum begins with these subjects in direct emulation of its US counterpart. Anecdotal reports indicate that these courses tend not to enhance the students' attitudes towards learning.

Shortcomings at such an early stage in the college curriculum reinforce attitudes deriving from the "relaxation" effect occurring after the intense preparation to pass the entrance exam. My recommendation is that the BU curriculum be revised to reduce the required credit hours in freshman chemistry, physics, and mathematics. Students should begin these subjects at the sophomore level, similar to the Japanese students. Such a step would bring the total number of required courses much closer to the 15 credit/semester level.

At the same time, a strict limit should be applied on the number of credits that a student is allowed to take if his cumulative grade point average drops below 2.25. A computer program should be implemented to enforce this limit since human nature is not always reliably strict. Such a simultaneous give-and-take should have the effect of emphasizing quality over quantity in a way that would be purely beneficial.

As for the organization of the curriculum, the large number of BU students who expect to be out of engineering in five years would seem to indicate a need for some innovation. It is easy to proclaim that engineering instruction is the only proper domain of engineering educators, but my experience has been that motivated students are more effective learners. Furthermore, the interests of the students may reflect a practical perception of the opportunities available in the local job market. Such practical considerations should be of interest to the engineering educator.

Is it possible that the same engineering content could be covered while recognizing the motivations of the students? I believe it is possible, and I would like to outline one example of how it might be achieved. Most of the investment economics, costing, optimization, and safety aspects of the traditional senior design course require little knowledge that is limited to senior status. There is no reason why the bulk of this coursework could not be moved to the sophomore year at the latest. Since the students are primarily motivated by the business aspects of engineering, such a move would bolster their interest levels at a time when they might still be positively influenced. Given such a background at an early stage, incorporation of business-oriented projects into the remaining curriculum would be greatly facilitated. This is one example of how adaptation to the local educational environment can be achieved with little practical penalty, and I expect that many more could be conceived.

As for the UA students, it is encouraging that the best UA students were not significantly disadvantaged relative to the BU students. This means that their pre-college preparation was not entirely disabling. On the other hand, there were a number of students in the UA thermodynamics class who were not competitive at the international level. This observation reaffirms the need for maintaining significant minimal performance standards in the UA curriculum and, perhaps, indicates a need to raise them slightly. Furthermore, the emphasis on pre-college preparation often cited by engineering and science educators, especially with regard to math skills, should be reiterated. The self-determination of the UA system offers the advantage of more motivated engineering students, but the reduction in the level of technical preparation at the pre-college level should not be ignored.

More generally, US faculty should recognize some differences in chemical engineering education as practiced in other parts of the world. One benefit of such a global perspective is in helping to understand the educational developments of many of the students who come to the US for graduate school. About 10% of BU graduates pursue graduate school abroad. By understanding the environments in which students were brought up and how they differ from the US environment, it should be possible to develop favorable interactions more quickly and easily.

At the undergraduate level, the greater emphases on industrial chemistry and undergraduate specialization/research are common to Japan and Turkey at least. We should ask ourselves whether there might be some validity in emphasizing these topics to a greater extent in US curricula. ABET's emphasis on enhancing the "design content" of chemical engineering curricula is somewhat similar to the manner in which schools overseas are already practicing. We should also question the significance and implications of grade inflation in the US.

Finally, US professors must exhort themselves to produce globally competitive graduates in spite of all obstacles. The evidence shows that fairly average but highly motivated undergraduates are capable of nearly catching up with others who are highly selected. Apparently, there are advantages to a fairly broad admissions policy that should not be discounted.

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