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Systems Thinking Curriculum as “Strategy”

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Abstract

The number of Industrial Engineering Departments has recently grown to more than 30 in Turkey, and competition for good students is tough. Most departments follow conventional industrial engineering curricula based on the North American model where systems concepts and systems thinking are not as much in focus as quantitative analysis and mathematical modelling. The IE Department of Middle East Technical University has a tradition of emphasising the systems approach and has recently decided to develop an educational strategy by expanding and building upon this tradition. It is thought that emphasising critical systems thinking is a prerequisite for making effective use of mathematical models and for effective IE practice. This paper reports on the methodology and the process of curriculum planning as strategy.

Key words: *Systems Thinking, Curriculum, Strategy*

1. INTRODUCTION

Universities are undergoing change everywhere and are having to compete for all sorts of funds and bright students. This is taking place in an increasingly turbulent and unpredictable environment, and has certainly gained new momentum over the last two decades or so. Especially bewildering, at least for traditional schools, are arguments calling for varying doses of “market awareness” and commercialisation in higher education. It is not very clear what, if any, the new notion of university-as-institution ought to be, or whether an underlying conception is indeed necessary. This leaves universities face to face with any number of options, choosing among which is often a more painful experience than initially thought.

The Industrial Engineering Department of Middle East Technical University (METU) is the first and largest such department in Turkey. METU is the primary university in Turkey, in terms both of the number and the quality of its graduates, who lead successful carriers all over the world. The IE Depatment started life under the Mechanical Engineering Department and became independent in 1969. The Operational Research (OR) faculty of the Department of OR and Statistics joined the IE Department following a reshuffle of Turkish higher education in 1983. The Department currently accepts around 100 students every year to a 4-year BSc programme. There are about 100 postgraduate students at any time, working towards MSc or PhD degrees in IE or OR. Teaching faculty is 22 strong, several with North American and British PhD’s. The Department keeps in close touch with the alumni who in general have successful careers in industry and maintain an interest in the Department’s activities.

University places are granted in Turkey on the basis of performance in a central examination administered once every year. The engineering profession is highly esteemed and attracts top students; with electrical engineering, computer engineering and industrial engineering leading the list favoured by the brightest pupils. Since the late eighties the METU-IE Department has been able to attract top students; in some years, from among the highest scoring 700 or so, of more than a million and a half university applicants. This provides the Department, alongside a handful of others, with a homogeneously and exceptionally competent body of students. The quality of incoming students is obviously a crucial factor reflecting on the quality of educational and research output of a department. The graduates of the IE Department are actively sought after by the best US, and more recently, European schools where they easily excel in postgraduate work.

This favourable state of affairs still holds, but there are signs of a possible downturn; last year the Department was able to recruit from among the highest scoring 1200 students only. The possibility that this signals the beginning of a steady erosion cannot be dismissed. One contributing factor might be the proliferation of private universities and IE departments in Turkey where industrial engineering is perceived by these schools as a relatively “inexpensive” discipline that can be counted on to attract lots of students. The total number of IE departments is now well over 30 and still going up and similar pressures are currently experienced by other popular departments.

METU-IE Department recognised this, alongside other internal factors that had accumulated over the years, as a case for reorganising the Department and its degree programmes. Work was initiated mid-1998 by holding a retreat and proceeded by writing up mission statements, lists of objectives and devising strategies to achieve goals. After several months of this however, progress lost momentum and efforts put into the project did not come to much; although in the course of this, the ABET organisation (Accreditation Board for Engineering and Technology) granted substantially equivalent accreditation to the undergraduate IE programme *(The ABET organisation does not formally accredit programmes outside the USA)*. The reasons for the slowdown may be numerous and diverse, but what it all came to in the end, was for faculty to realise that success in planned change in an academic environment is very elusive and the best of intentions can easily be thwarted by none other than the same faculty.

Another tangible result of this initiative so far, has been a revision of the undergraduate curriculum as part of a would-be strategy. This is an account of the experience and the methodology used, confined to those aspects directly related with curriculum revision.

2. THE OLD CURRICULUM

The undergraduate curriculum at METU was originally modelled on mainstream American curricula that grew out of mechanical engineering programmes. It has preserved its essential quality with little change through the years. The total 142 credit-hours (each roughly equivalent to a one-hour lecture per week per term) are distributed over eight terms as follows:

- mathematics and basic sciences: 30 credits
- engineering sciences: 22 credits
- social sciences, humanities and computer literacy: 35 credits
- department courses: 55 credits.

In its first half, the curriculum relies heavily on out-of-department courses. Several of these are taken from the engineering science group, comprising such courses as thermodynamics, control theory and material science taught by various engineering departments. A distinguishing attribute of the programme that is not evident from course lists is the underlying focus in departmental courses, on the systems approach routinely emphasised by teaching faculty during delivery even though there are no dedicated courses as such. This follows from an established tradition of operational research and underscoring of methodological aspects by faculty to an extent that is not common in IE departments; although this does not necessarily mean that such aspects are well instated in teaching.

Concern about the curriculum has been voiced over several years both by the students and the faculty. Students thought that the curriculum was disjointed and lacked identity. They found it particularly difficult to connect the engineering science content with the IE content. Indeed the second half of the curriculum seemed not to depend on the first half, except for the mathematics courses. This left the students unable to see the logic of having to take so many science and engineering courses for which they had no motivation. Furthermore, they felt that the curriculum left hardly enough time for gaining mastery of the mathematical models of OR and statistics that should provide the backbone of an IE's professional expertise. They also thought that the systems approach as such, was never explained properly and to most, seemed to remain a mistery.

The whole situation was not helped by the fact that faculty's areas of interest had practically no overlap with engineering sciences.

3. THE STUDENT SURVEY

To find out in detail what they thought about the curriculum the students were surveyed using a detailed questionnaire. Some of the common views were as follows:

- More weight should be given to methodological topics such as the systems approach, research methods, and the analysis of complex socio-technical systems. (92% agreement)
- The share of engineering sciences should be reduced in favour of departmental courses. (90% agreement)
- Greater emphasis should be given to general purpose quantitative subjects such as OR, probability, statistics and stochastic processes. (75% agreement)
- Micro and macroconomics, finance and investment planning should be given a greater share of the curriculum. (70 % agreement)
- If programme content can be partitioned into "problem solving" and "sense making and issue structuring" components; the present curriculum provides 70% problem solving and 30% sense making content according to students; whereas desired shares are 35% and 65% respectively.

4. THE ALUMNI SURVEY

A similar survey of alumni was conducted with 160 full returns. Importance scores (out of 100) attached to subject areas were as follows (Table 1):

Table 1. Importance scores attached to subject areas

SUBJECT AREA		SCORE
1.	Critical systems thinking	95.68
2.	New applications in supply chain management, flexible manufacturing, ERP, etc.	91.98
3.	OR and statistics	90.43
4.	Economics	85.19
5.	Traditional IE topics such as work study, production planning, scheduling and inventories	85.03
6.	Mathematics	84.57
7.	Management topics such as finance, marketing, human resources and contract law	73.77
8.	Social sciences, humanities and politics	59.26
9.	Basic sciences	51.54
10.	Engineering sciences	50.31

Alumni's response to the same question concerning "problem solving" versus "sense making" content, coincided almost exactly with that of students:

> If programme content can be partitioned into "problem solving" and "sense making and issue structuring" components; the present curriculum provides 70% problem solving and 30% sense making content; whereas desired shares are 35% and 65% respectively according to alumi.

5. ENVIRONMENTAL AUDITS

These findings were incorporated into a wider audit of both the external and the internal environments. Adopting a text-book procedure for strategic planning, these audits were conducted with the participation of groups including the faculty, the students, the alumni, the industry in general and employers.

The most significant pointers underlined in environmental analysis were:

- Advances in knowledge technologies call for the basic system optimisation and integration functions of IE be henceforth exercised not on the platform of machines and work places, but on a knowledge platform.
- Evolving IT technologies call for new modes and methods of instruction.
- New areas such as strategic management, organisational restructuring, scenario analysis, performance evaluation and knowledge management are gaining importance. There is renewed emphasis also on project management, logistics and financial engineering.
- Employers expect graduates to have capabilities and skills of critical and strategic thinking, teamwork and team building, communication skills and conflict resolution.
- More and more IE's are having to address complex problems with societal implications. Even routine problems are becoming more complex.
- Courses and teaching should be embedded in real world settings.
- Good students will be at a premium in the future due to increased competition.

Some pointers coming out of the internal analysis were:

- 45% of all graduates are employed as IT managers, project managers or "change managers"; 22% are employed in production, finance or quality management.
- Undergraduate students call for an integrated curriculum that emphasises skills for issue structuring and modelling and therefore devotes more time to systems thinking. At the same time, quantitative skills such as OR and statistics are thought to need strengthening.
- Alongside a call for more systems content, students also call for reduced engineering science content.
- Alumni tend to view current curriculum to be out of touch with contemporary issues in business and IE practice.

6. STRATEGIC CHOICES FOR METU-IE

The current mission and vision statement of the Department that faculty last agreed on reads as follows:

MISSION

The IE Department studies organised human activity and educates engineers capable of creating value in socio-technical systems. Our work is founded on critical reason and systems thinking and on strong quantitative analysis. Our approach emphasises identifying and structuring issues and formulating problems, as much as it seeks to develop and implement courses of action. We promote interdisciplinary research and participation in joint research programmes. We encourage the involvement of the industry, the students and the alumni in departmental activities.

VISION

To be a research department that communicates knowledge of organised human activity. To connect research with instruction and educate professionals who are exceptionally competent to deal with complex issues in socio-technical systems.

These statements appear to be distinctive of the Department vis-à-vis both the competition, or mainstream IE conceptions; the emphasis is on socio-technical systems and effective use of quantitative techniques. There is a tendency to regard any problem of significance as a more or less complex problem which calls for the full force of critical systems thinking. Interdisciplinarity and industry involvement are also stressed but traditional areas of IE application are not mentioned.

It is not easy to say that these statements were endorsed wholeheartedly by all faculty. Some members were more than a little uneasy about the emphasis of social or soft aspects which they thought could steer the Department away from its engineering hard core, or from theoretical research areas in which theory mostly means mathematics. Most saw the emphasis on systems thinking as relevant only for educational objectives and did not really see how it could be connected with their own research. Nevertheless, the importance attached to the systems approach was so remarkably embedded in Department culture that the mission statement came out as it did after endless hours of debate.

It was remarkable also that the importance attached – albeit somewhat reluctantly by some faculty – to systems thinking and OR, was fully shared by students and the alumni. The alumni's forceful endorsement of systems thinking as the foremost single success factor in IE practice was especially supportive of strategies chosen by the Department.

The audits pointed to several directions for the Department in general, and for the undergraduate curriculum in particular. The chosen direction and strategy had to be in line with the Department's mission, but it was not at all clear whether the stated mission was indeed compatible with current practice and capabilities. The requirements of the accepted mission and vision statements can be summarised as follows:

- enable value creation in socio-technical systems
- emphasise critical systems thinking and strong quantitative analysis
- emphasise structuring issues and formulating problems
- promote interdisciplinary work
- involve the industry and the alumni
- connect instruction with research
- create capability to deal with complex issues in socio-technical systems

The list clearly reflected aspirations yet to be fulfilled. In the event, faculty decided that any wortwhile and workable strategy should involve trade-offs. The location of the Department in Ankara is not within immediate proximity of business centres and industries and there isn't much tradition of industry cooperation of significance. Competing departments located in Istanbul have much better chances of developing close relations and collaboration with the industry. The Department therefore chose to give priority to strengthening undergraduate education by a stronger academic curriculum, which should be feasible given the capabilities and interests of the faculty. Within this project, steps could also be taken towards securing industry's cooperation through sponsored – capstone – student projects.

Attempts were made to formalise these ideas methodically since faculty felt that the new curriculum should not just be a concoction that addresses assorted demands but that it should possess a unifying logic and direction to the satisfaction of the faculty.

7. POSITIONING THE CURRICULUM: PERSPECTIVES AND TRADE-OFFS

Before considering any of its details, we can think about the coordinates, or the essential quality of the curriculum. This would depend on the external perspective taken and also on working out internal trade-offs. Adopting perspectives determines how a curriculum views the world. Deciding trade-offs will fix internal dimensions concerning curriculum content.

Consider perspectives first; they can help us construct a world-view. The choice could be defined to be between a Newtonian and a systems paradigm. In a Newtonian world reality exists and encirles us, before we can do anything about it. In such a world problems we face can be reduced to manageable parts, and solutions for each part can be sought, since the whole can be broken down into pieces that can be studied separately and our knowledge of each part can be brought together afterwards to make up our knowledge of the original whole. Emphasis in engineering education will be primarily on attaining functional, and to a lesser degree, cognitive competence. Reflective competence on the other hand, needs hardly to be addressed at all. All students undergo the same experience qualitatively and quantitatively. The system is concentrated on instruction; outcomes and assessment are prespecified and assumed to be objective and context-free. In such a system, faculty relies on prescribed texts to deliver subject matter. Students are taught data and information, rather than meaning and understanding. Learning is a response to instruction. The supposition is that there is truth, and that the faculty knows what it is. A consequent attribute of this type of education is that it communicates strong messages about hierarchy and conformity in line with existing power structures.

According to the systems paradigm on the other hand, the world is complex and connected; it is unpredictable and chaotic. Even if reality exists objectively, there is no objective way of knowing it. Meaning is imposed on an objective world subjectively; that is the only way we can know it and this can only be possible by considering the whole, rather than its parts one at a time. If we focus on one aspect of a situation, we tend to abstract that aspect out from the whole, and risk losing sight of associated possibilities. Furthermore, the demarcation line between science and nonscience is not at all clear; at the very least, inquiry can no longer depend simply on the generalisations of science. In human activity systems, each process is arguably unique. Abstractions, more often than not, fail to provide adequate instruction for our specific needs, such as how to fix this particular tyre or how to fly that particular kite. Failure to recognise vagaries and singularities, the variousness of purpose and aspirations of people will result in dismissal as irrelevant, of much of what we strive to achieve through cognitive competence.

In a systemic world, social reality is the ever-changing outcome of social practice in which we all act on imperfect knowledge and nobody is in possession of the actual truth. Education therefore, should be founded on learning in a social context; working with others in open dialogue. Sense making, meaning construction and understanding are important; attaining reflective competence must be emphasised. Such a system must rely on contextual, as opposed to contextualised learning, situated in real-life settings that are meaningful for the learner. To truely learn, the learner would ideally apply what he learns and learn from the application.

Fixing a perspective is establishing a vantage point between two opposing views such as the Newtonian and the systems views. Several such opposites that might be relevant for planning an IE curriculum were put to the faculty over a scale, asking them to mark the cell they thought the present curriculum occupied; and also to mark the cell they thought it should occupy in the future. For instance the first pair of opposites was:

1A) *the world exhibits much regularity and order;* *it is analysable, knowable and predictable*

vs

1B) *the world is messy and irregular; it is hard to analyse and hard to predict;* *it is systemic in nature but this nature cannot be determined easily*

Markings for the present curriculum were:

1A	3	13	3	1		1B

and for the future curriculum, they were:

1A		1	8	10	3	1B

where the number in each cell shows the number of faculty who marked that cell.

Four such questions were posed, returning the following results (Table 2):

Table 2. Results I

	present	*future*
1A) *the world exhibits much regularity and order, it is analysable, knowable and predictable*	*70.25*	*34.66*
1B) *the world is messy and irregular; it is hard to analyse and hard to predict; it is systemic in nature but this nature cannot be determined easily*	*29.75*	*65.34*
2A) *reality exists out there, in itself, independently of us*	*68.95*	*37.14*
2B) *reality is a historical construct subject to human conditions and human choice*	*31.05*	*62.86*
3A) *truth is one harmonious body of knowledge that can solve all theoretical and practical problems for all men, everywhere*	*71.32*	*35.0*
3B) *truth is subject to social validation and relative; we have to live with the unbounded variousness of human aspiration*	*28.68*	*65.0*
4A) *there exists absolutely necessary conditions for there to be a betterment of the human condition*	*72.5*	*47.86*
4B) *the necessary conditions for the betterment of the human condition either cannot be known or do not exist*	*27.5*	*52.14*

As an example, the first score is calculated as follows:

Present Situation

1A	3	13	3	1		1B

Score: (3*95 + 13*72.5 + 3*50 + 1*27.5)/(3+13+3+1) = 70.25

The interpretation for this would be as follows: 70.25 % of the present curriculum content assumes that the world exhibits much regularity and order, it is analysable, knowable and predictable.

The remaining 29.75 % of the present content assumes, or takes into account the fact that the world is messy and irregular; that it is hard to analyse and hard to predict; that it is systemic in nature but that this nature cannot be determined easily.

Next a number of internal dichotomies or trade-offs were formulated and put to faculty. This was for probing how faculty perceived the present curriculum in terms of aspects it emphasises as against aspects it should emphasise. For instance the first trade-off was:

1X) *seeking optimal solutions for narrowly defined problems*

vs

1Y) *making sensible decisions in the face of complex realities*

Present curriculum stands:

1X	7	7	6			1Y

Future curriculum should stand:

1X		1	8	9	4	1Y

Six such questions (Table 3) were posed which led to the following returns (the first column of numbers at the end are results for the present curriculum and the second column, results for the desired curriculum):

Table 3. Results II

1X) *seeking optimal solutions for narrowly defined problems*	*73.63*	*35.91*
1Y) *making sensible decisions in the face of complex realities*	*26.37*	*64.09*
2X) *focus on solving problems; "how do we do it?"*	*70.25*	*40.8*
2Y) *focus on structuring issues; "what do we do?"*	*29.75*	*59.2*
3X) *focus on theoretical content; quantitative modelling; research literature*	*75.88*	*50.0*
3Y) *focus on implementation and execution; business literature*	*24.12*	*50.0*
4X) *preparing students for staff careers; a "micro" focus*	*63.03*	*42.84*
4Y) *preparing students for managerial careers; broad strategic focus*	*36.97*	*57.16*
5X) *instruction specific to an application area or relevant to a context*	*61.25*	*44.64*
5Y) *no specific area of application; context-independent instruction*	*38.75*	*55.36*
6X) *teaching a body of knowledge; statistics, LP, queues etc.*	*73.63*	*44.64*
6Y) *developing skills; self-learning, team-work, communication skills etc.*	*26.37*	*55.36*

Finally these dichotomies were collected together along axes that were labelled "**optimality**" and "**systemicity**" so as to form a curriculum "plane" as follows (Fig. 1):

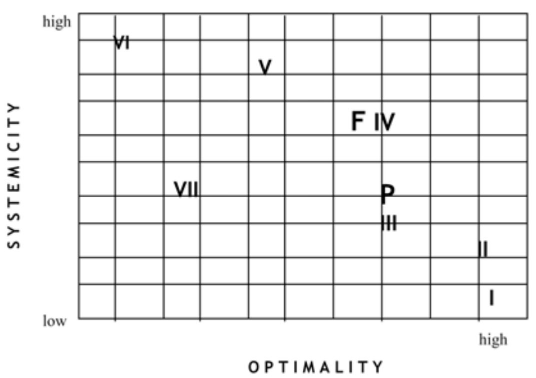

Figure 1. Curriculum "plane"

The regions marked by Roman numbers on the plane can be interpreted as corresponding to the following prototype curricula:

- ***(I)*** ***technology development***; hard-core engineering applications such as product design, process control, CAD/CAM etc.
- ***(II)*** ***traditional IE***; “hard-IE”, focusing subjects like work study, plant design, inventories etc.
- ***(III)*** ***generalised IE***; “soft-IE”, focusing operations management and OR models
- ***(IV)*** ***hard OR***; mathematical modelling emphasised, broad application, no area focus
- ***(V)*** ***soft OR;*** mathematical modelling not emphasised, broader application, no area focus
- ***(VI)*** ***systems;*** no mathematical modelling; action research emphasised; very broad application
- ***(VII)*** ***management***

The letter **P** in the diagram represents the weighted centre where faculty thought the current METU/IE curriculum is located, and the letter **F** where they thought it ought to be located in the future.

Results indicate that faculty approves the present level of emphasis on quantitative analysis and mathematical modelling and does not envisage an appreciable shift from this position. At the same time, a greater demand is made for more systems content. This conclusion is only in partial agreement with student and alumni demands calling for a shift of the curriculum from its position on the systemicity-optimality plane to a north-easterly point as much as possible. Faculty was clearly unsure about how such a position could be attained, not least because extreme north-easterly regions are normally not inhabited.

In the end, a checklist was drawn up indicating that the new curriculum should in general:

1. place greater emphasis on systems thinking; OR&Statistics; recent IE topics (JIT, CIM, ERP, SCM, data mining etc.)
2. reduce “problem solving” content; expand on problem structuring and “meaning management”
3. emphasise practical relevance; establish real-world connections; enhance application content
4. avoid rote learning; encourage active learning and learning by application
5. provide coherence and focus in curriculum
6. address contemporary issues and complex socio-technical problems
7. support skills for synthesis, for system design and construction, and for generating implementable solutions
8. strengthen functional competence without compromising cognitive competence
9. address new challenges associated with: integration problems, effective communication, multidisciplinary team-work, strategic thinking and business planning, knowledge management, financial engineering, project management

and in particular:

10. distribute IE courses more evenly over four years
11. reduce engineering science content
12. place greter emphasis on economics, finance, management, social sciences and law

The overall conclusion points to a divergence on the part of the Department from a conventional IE programme in the North American tradition, towards an OR and management science orientation, influenced by systems thinking. When implemented, it was thought such a strategy could provide the Department with a unique position among the competition.

8. CURRICULUM VOTING

Having arrived at an understanding it appeared; a committee could do the detailed work and draw up a new curriculum without much dificulty. The appointed committee, after much deliberation, decided that to implement all proposals would not be feasible in the short term and duly come up with a more modest, first draft. The committee proposed to:

- strengthen systems content
- strengthen OR and Statistics content
- address more fully, the contemporary methods and issues in manufacturing.

To this end, it proposed a new curriculum which:

- increased the number of capstone design courses from one to two so that finishing projects could be spread over two semesters
- introduced a new course dedicated to systems thinking
- increased the number of introductory OR courses from two to three
- increased the number of statistics courses from one to two
- dropped the engineering science course Statics and Strength of Materials from the curriculum
- increased the number of Production Planning courses from one to two
- relegated the required course on Human Factors Engineering to elective status.

The draft proposal seemed to do what the Department had already decided, but from thereon things did not proceed as expected. When it came to the final decision, it soon became clear that part of the faculty, despite all previous progress and the common ground gained, would tend to resist any type of change in the status quo. This pointed to a stronger reaction than expected and the Department felt that if there was going to be any change, it sould be decided as nearly on a consensual basis as was practically possible. Hence it was decided that in the final vote, the new curriculum would have to be passed with not less than two thirds majority. Next, all the change items proposed in the draft curriculum were opened to debate one by one and each item was voted on.

Accordingly, the committee produced a new proposal which differed from the previous one only in the number of required OR courses, all other items having passed the vote. Members of the committee felt that the chances of a two thirds majority were good.

In the event, voting produced an ambiguous, sitting-on-the-fence result, with eight members of the faculty saying no to the proposal. These members complained that no alternatives were made available to choose from, whereas the committee insisted that all alternatives had already been considered previously and the proposal was drafted at the end of a consensual process of inclusion and exclusion of each change item. In the end however, the Department decided that further attempts be made to achieve broader consensus and more alternatives be provided. According to this, everybody would be able to propose an alternative, in the form of a complete curriculum even though this might run against the logic of the methodology followed so far. Eleven such proposal were submitted. The Department decided this time that each member would vote for any three of the alternatives. The three votes would be weighted, carrying four, two and one points respectively. Voting took place and this time none of the alternatives attained the requisite two thirds majority. So keeping the highest scoring three alternatives only, another round of voting took place.This time however, the Department decided that every member would vote zero or one for each of the three alternatives. In the event, one of the alternatives was finally carried with more than the requisite majority. It turned out that the chosen alternative was almost the same as the original, sitting-on-the fence proposal, except in place of an extra course on statistics, this had an extra course on OR. It also turned out that three faculty members had still failed to vote positive for the chosen alternative.

Probably the most notable change in the curriculum, commonly endorsed in all the eleven curriculum alternatives, was the introduction of a dedicated course on systems thinking required of all third year students. This is probably a first in an IE programme anywhere. Part of the document required by the Engineering School for approval of the course is reproduced in the Appendix. It lays out in detail the justification for such a course in an IE programme.

9. CONCLUSION

Lessons to be learnt from the wider experience, of which curriculum-as-strategy is one part, seem to be that:

- Even in the case of an apparently impersonal and detached issue (such as an academic strategy or curriculum plan), the method of strategy making cannot be expected to follow an orderly or even analysable sequence. Peer pressure and group behaviour can force an academic to go along with the dominant view at least in appearance for a while; but it is perfectly possible to have to discard all progress any time and start once more from the beginning.
- Strategy in academia is more about what you want to do than about how you do it. Writing vision and mission statements is very well so long as it inspires questioning and debate; and it may even be possible to arrive at some sort of accomodation or even consensus in the end; but trying to link clauses of such consensus to action plans is not a good idea. Setting targets and evaluating performance too, will be counterproductive, especially if such evaluation involves only simple feedback. This is not only because such planning will restrain change and renewal but because plans will not stand a chance against faculty's deeper concerns. In this light, the many texts that have recently appeared on strategic planning for universities would appear to offer relevant counsel only if a sizeable dose of academic commercialisation is in order.
- Organisations can always be expected to act naturally, (ie. bent on individual interest and survival); but not always rationally (ie. for a common cause). Eventually there is no logic strong enough to convince many academics than the logic of self interest.
- Academic self interest is not restricted to concern for survival or promotion but also to the concern to assert and contend one's position against the opposition on matters of academic or intellectual interest; regardless of whether that position is tenable or not.

Embedding systems thinking within an IE curriculum and reconciling meaning management and issue structuring with quantitative analysis has to be more of an experiential process than a matter of planning.

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APPENDIX

New course proposal: systems thinking

Course objective

Achieving competency and critical understanding of systemic inquiry. Explicating systems thinking and critical reason to complement disciplinary inquiry and quantitative analysis in order to enable effective application of IE knowledge.

Course content

Inquiry and research. Methods of science. Fundamental systems concepts and notions. Systems thinking as a mode of inquiry; an historical and methodological account. Contrasting and clarifying the systems position vis-a-vis science. The relation between systems thinking and OR. Systems approach and social theory. Principal strains of systems thinking and the systems approaches.

Justification for the course

IE addresses sociotechnical issues in human organisations that are foremost matters of priority and choice, often twisted into an intricate complex. IE aims to bring the power of abstraction and analysis to bear on difficult tradeoffs so that managerial action will have the highest chance of achieving improvement. This aim generates two – dual – objectives in IE education: (i) attaining adequate command of quantitative analysis and mathematical modelling, and (ii) building systems skills needed to put this knowledge into practice. The IE Department determines that the present programme needs improving on both accounts; the quantitative as well as the systemic foundations of the IE curriculum are in need of strengthening.

Systems thinking lays the groundwork for IE practice. It is a prerequisite for making sense of human activity, for structuring issues and for defining problems. Most importantly for IE, without a good conception of systems, the link from quantitative analysis to management practice will not be complete; designs will not work out as planned and improvements will fail to materialise. This view is strongly shared by the IE faculty as well as the students and the alumni. Yet, faculty determines an inadequacy in student skills in this respect. At the present, there is no course in the curriculum that addresses systems thinking and systems theory in a formal and systematic treatment. Furthermore, references to systems concepts throughout the curriculum remain weak and often misguided. Students are generally confused and tend to regard the systems approach as a catch-all category that they cannot properly pin down. At the same time, surveys indicate that alumni are not able to make effective use of mathemetical modelling and quantitative techniques in the course of their professional practice. This too, can partly be attributed to a less than satisfactory grounding in systems thinking that leaves students at a loss when they need to reap the benefits of quantitative analysis. The situation is directly at variance with the importance attached to the systems approach.

Systems thinking has emerged as a significant and overarching mode of inquiry that subsumes and complements disciplinary thinking in such areas as biology, physics, management and OR. Within the OR tradition it has developed its conceptions to such a degree that an adequate coverage is not possible in the absence of dedicated courses. Attempts to teach systems thinking by dispersing systems ideas throughout the curriculum would not only not work but would also weaken disciplinary content and run counter to the dual purposes of the curriculum.

The present course seeks to rectify the deficiency in the systems foundation of the IE curriculum

Draft syllabus and conduct

- **Decision making and decision models**
  - Rationality and rational choice
    - ♣ decision maker(s), problem owners, users, consultants, the affected etc.
whose problem?
  - Limits to rationality
    - ♣ bounded rationality:
imperfect information
asymmetric information
information overload
    - ♣ search and satisficing
    - ♣ intuition and reason
- **Science and scientific inquiry**
  - Assumptions of science
  - Objectives of science:
explanation
prediction
understanding
  - Brief history of science:
pure science, applied science
science, mathematics, logic
natural science, social science
empirical sciences, engineering science
Enlightenment, modernity
  - The scientific method - a stylised account:
problems
hypotheses
research design
measurement and data collection
analysis and testing hypotheses
generalisation
  - Positivism:
the two levels research: conceptual and empirical
causation: covariation, time order, nonspuriousness
longitudinal analysis: experimentation and control
validity and reliability of research
  - OR and science: hard OR and positivism
- **Systems concepts**
  - System definitions: emergence, hierarchy, equifinality, boundary and environment etc.
  - Closed systems and feedback
  - Open systems, entropy and energy transport
  - General systems theory
  - Human activity as a rational system: functional systems
  - Human activity as a natural or social system
- **Systems thinking as a mode of inquiry**
  - Science and systems
    - ♣ analysis
    - ♣ reduction and reductionism in science
    - ♣ boundaries and boundary setting
    - ♣ "environmental fallacy"
    - ♣ interdisciplinarity
    - ♣ scientific inquiry versus systemic inquiry
  - OR and systems thinking
    - ♣ cognitive interests in human activity
    - ♣ "lifeworld" and "system" (Habermas)
    - ♣ hard OR and soft OR methods
- **The systems approach**
  - Formulation
  - Modelling
  - Implementation
  - Critique, critical systems thinking
- **Systemic problems in IE and OR**
  - Examples

The old curriculum

First Semester
Calculus I
General Physics I
General Chemistry
Computers and Programming
English I

Second Semester
Calculus II
General Physics II
Engineering Graphics
IE Orientation
English II

Third Semester
Differential Equations
Microeconomics
Production Engineering
Non-technical Elective
Engineering Materials
Computer Elective

Fourth Semester
Linear Algebra
Macroeconomics
Statics and Strength of Materials
Financial and Cost Accounting
Probability Theory
English III

Fifth Semester
Systems and Control
Work Study
Engineering Economy
OR I
Statistics

Sixth Semester
Thermodynamics
Production Planning
Human Factors Engineering
OR II
Simulation

Seventh Semester
Management for Engineers
Production Information Systems
Quality Planning and Control
Technical Elective
Technical Elective
Advanced Communication Skills

Eighth Semester
Seminar in IE Practice
Systems Design
Technical Elective
Technical Elective
Non-technical Elective
Free Elective

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Calculus I
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General Chemistry
Computers and Programming
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OR I
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English III

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OR III
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Management for Engineers
Work Study & Plant Layout

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Engineering Materials
Production Planning II
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