AN INTRODUCTION TO SYSTEM DYNAMICS IN A NON-TRADITIONAL GRADUATE PROGRAM

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ABSTRACT

System dynamics has been taught for over two years in two doctoral programs offered by Nova University, Fort Lauderdale, Florida. These programs are designed for working professionals in public and business administration and feature the inverse of the usual arrangement in which instruction is given on the university campus. For this reason, a traditional teaching approach cannot be used.

This paper describes the Nova teaching environment, the format and teaching materials used for system dynamics, student characteristics and performance, and the present trends which affect instruction in system dynamics at Nova University.

The introduction of the course in system dynamics has generated a positive response among the students and a limited amount of turbulence in the organization and administration of the programs.

The Nova University Environment

The organization and presentation of courses in system dynamics at Nova University reflect the mission and orientation of the University. Nova University has a mission to serve the needs of a diverse educational constituency. In affirmation of the concept that learning is a life-long phenomenon, Nova offers educational experiences to people of all ages. A commitment to teaching students to employ their education in solving problems and achieving goals in their daily lives underlies the Doctor of Public Administration and Doctor of Business Administration Programs in which system dynamics has been taught. These programs, together with masters degree programs in administration, are part of the Center for the Study of Administration.

Nova has pioneered in the development of new, off-campus programs. A decade of experience has demonstrated that these off-campus programs are an effective way of bringing professional education in administration within the reach of mid-career managers in the public and business sectors. These programs are directed toward the solution of problems of immediate concern.

During this decade, the identification of the characteristics of the target DPA student population has been refined. Specialists who have now become managers make up most of this population. In the United States, governments at all

levels have chosen most of the managers from specialist ranks. There is no evidence that this practice will change in the foreseeable future. For the most part, DPA candidates are men and women who already have advanced degrees. They entered government as specialists, and have been promoted to positions of managerial and administrative responsibility. They seek a broader knowledge of public administration than they have derived from their specialist education and experience, and they are searching for skills and methods to fulfill their integrating leadership roles.

In the off-campus DPA Program, these students are organized geographically into clusters, e.g. a Great Lakes Cluster, Northern Virginia Cluster. The organization of the DBA Program is similar in concept. Although most of the students in a cluster live in or near a major city where the classes are conducted, some cluster members travel long distances to participate in the programs. The South Florida Cluster has had students from Jamaica, Argentina and the Virgin Islands.

Student participants in the program meet together in the clusters of about 10 to 20 with two instructors (a preceptor who teaches the subject material and a cluster director who conducts ancillary meetings and handles cluster administration) for two-day course conferences at intervals of four or five weeks. The subject matter of the program is organized into sequences of related subjects.

A curriculum statement is provided for each sequence to introduce the area of study, review the developments in the field, point up issues, comment on the literature, and set the assignments for all of the unit subdivisions of the sequence. Most of the required reading for the sequences, between 50 and 60 books and more than 25 additional documents, are supplied well in advance of the course conference in which they are to be used.

Participants are required to prepare a paper (or preliminary exercises in the case of the system dynamics unit) for each unit of the sequence according to the instructions of the curriculum statement and to send it to the preceptor in advance of the course conference. This gives the preceptor an indication of the class reactions to the subject material, alerts the preceptor to the concerns and conceptions (or misconceptions), and is useful in planning for the course conference.

The course conferences are held on Friday and Saturday for the DPA students, and on Saturday and Sunday for the DBA students, in a conference center or motel having adequate classroom facilities. The time of meeting makes it possible for the participants to avoid being away from work for more than one day every four or five weeks. The close association of the students and faculty for two full days permits both formal and informal learning opportunities.

The course conferences are traditional in the sense that

student participants meet together with instructors in a face-to-face classroom environment. Participants learn from their efforts in preparing the pre-class submissions, from the sustained contacts with the faculty, and from each other. The sharing of experiences , attitudes, and ideas among mid-career employees of local, state and federal governments engaged in many different functions in the DPA Program, and in equally diverse activities in the DBA Program, is important, and this sharing increases as the program progresses.

The program is non-traditional in that the curriculum, the books, and the faculty are brought to the students. In a real sense the university goes to the student, rather than the student to the university. The program also reverses the traditional relationship in that the student provides much of the real life experience. The instructor does not have to provide the laboratory or clinic to simulate the real world since the students are practitioners of public or business administration.

The format of instruction changes after the sixth sequence. For the last three sequences, participants go to Nova University in Fort Lauderdale, Florida, for week-long workshops. Participants from all clusters participate. The DPA candidates spend four and a half days of the first of these sequences in a system dynamics workshop. A system dynamics workshop is not scheduled in the DBA Program. The absence of the workshop for the DBA students is unfortunate in that it deprives these

students of the opportunity to experience the art aspects encountered in the development of system dynamics models.

Instruction in System Dynamics

The course materials distributed to the students in advance of the weekend class include a copy of the System Dynamics Primer, selected readings describing the history, characteristics, and selected applications of system dynamics, and the requirements for study and the development of the preliminary exercises.

The primer describes the mechanics of system dynamics in very simple terms. Most of the DPA students, and many of the DBA students, have little interest or education in mathematics. One student had resorted to therapy recently to overcome her paralyzing fear of mathematics. (It didn't appear to have been totally successful.) Each chapter of the primer contains references to related material in three basic publications; Professor Forrester's Principles of Systems, the companion reference written by Michael Goodman, Study Notes in System Dynamics, and Professor Pugh's manual for the compiler, DYNAMO Users Manual. The students are expected to study the chapters on causal and flow diagramming, levels, rates, and constants, and equation writing. They should then be able to complete the simple preliminary exercises.

The exercises progress from a model with a single level and

no feedback to a single level model with feedback, and conclude with a two-level model involving feedback. The students complete a causal diagram, a flow diagram, the equations, and tabular/graphical data illustrating system behavior in each of the three exercises. These exercises are reviewed, corrected, and returned to the students with comments and a set of solutions to the exercises.

The format for the weekend class is quite stable. It begins with a short quiz covering the background of system dynamics, the meaning of various symbols, and the development of a model based on a very simple problem statement. A discussion of all the questions follows the test. This quick test is very useful in determining the state of preparedness of the students.

The next three hours are devoted to differentiating system dynamics from other analysis methods, motivating the need for system dynamics, reviewing the WorldI and WorldII models and other major milestones. This stimulates many questions and comments from the students because the knowledge and understanding of analysis methods and applications of most of the managers and administrators in the program is second hand, at best.

At this point the students have a reasonable understanding of what system dynamics is about. A full review of the mechanics is then conducted by going through the entire primer. A

continuing set of examples is presented to illustrate all of the DYNAMO capabilities. The basic operations are given the greatest emphasis. The trigonometric functions, for example, are merely mentioned. Table functions and delays are treated at some length; test functions are described and illustrated, but the student is expected only to keep their existence in mind. This review, which completes the first day, is quite demanding on both the students and the instructor. Because of their importance and complexity, the second day begins with a second review of the table functions and delays.

A model dealing with work, and the workers required to complete the work, has been used for several years to tie together many of the notions and elements of system dynamics covered previously. Modifications of this generic model have been used in several interesting applications so it is easy to relate it to real-world problems. Furthermore, the basic problems the model addresses lie within the experience of almost all the students. From a teaching perspective, the model is particularly valuable because it is very transparent, yet the behavior is definitely not intuitive. It illustrates very well the great power of negative loops in stabilizing behavior.

The pace of the two-day session varies, but between two and three hours are reserved at the end for dealing with student problems. This is the first real opportunity for stressing the art. The point is frequently repeated that although the

mechanics may seem difficult, they quickly become quite easy to handle, while the causal diagram--the problem boundaries, the structure and the relationships-- are really the difficult part.

The DBA class format differs slightly from the DPA class format. More emphasis is given to system dynamics applications and less to the mechanics. Because the DBA students do not have a system dynamics workshop, the question arises from time to time about the value of spending time on the procedures for writing equations or considering the pulse, step, and similar functions. Without these details, however, little appreciation is developed for the great power of system dynamics; it is important to demonstrate that, for the most part, whatever the student can conceive can be modeled. Without this, the unit becomes just another show-and-tell experience about quantitative methods for management.

Student Data

The numbers in the following tables need some explanation. Because of the off-campus program format, a student may complete the weekend class and the workshop in the same year, or may complete the workshop in a following year. Also, not all students who complete the weekend class come to the workshop. Some drop out of the program, some fail.

	Years 1980	1981	1982	Total
Number of Sessions, Total and Average Attendance				
DPA				
Classes	1	5	5	11
Attendance	14	42	56	112
Average	14	8	11	10
Workshops	1	2	2	5
Attendance	14	28	50	92
Average	14	14	25	18
DBA				
Classes		2	5	7
Attendance		51	53	104
Average		26	11	15
Total Class Attend.	14	93	109	216
Class Average	14	13	11	12
Course Composition				
DPA				
Male	12	34	47	93
Female	2	8	9	19
Foreign	1	6	6	13
DBA				
Male		48	45	93
Female		3	8	11
Foreign		11	6	17
Totals				
Male	12	82	92	186
Female	2	11	17	30
Foreign	1	17	12	30

Table 1. Class and Workshop Sessions, Attendance and Composition

The number of clusters, or class meetings, the average attendance, and the number of workshops is shown in Table 1. Note the considerable variation in both class and workshop attendance and the smaller number of women in the DBA program.

The distribution of the students, also shown in Table 1, is about 83 percent male in the DPA program and about 89 percent male in the DBA program. Of the total, about 14 percent are foreign. Some of the foreign students have excellent English language capabilities, but communication and discussion of technical or abstract ideas has ranged from average to poor for most.

Year	Grade A	B+	B	C	F
80 (Class)	36	21	36	7	
(Wshop)	36	21	36	7	
81 (Class)	21	26	36	14	2
(Wshop)	14	43	36	7	
82 (Class)	22	31	35	11	2
(Wshop)	24	28	36	10	2

Table 2. Percent Grade Distribution in the DPA Program

The grades for the 1980 cluster and workshop are identical because the entire cluster participated in the workshop about six months after the cluster meeting and a single grade was awarded based on the overall performance. This would be a preferable way of grading, but some students delay taking the workshop for more than a year and need a grade for the cluster to obtain reimbursement from sponsoring organizations. Some students who do well on the preliminary exercises and at the cluster meeting do less well in working with a team and performing the workshop tasks. Others, who may have found the preliminary work far removed from their experience, and therefore performed poorly,

gain insight from the weekend session and then proceed to do very well in the workshop. For all, however, the workshop is very valuable complement to the cluster in establishing a reasonable perspective of system dynamics. To provide adequate assistance for the students in the workshop, the authors teach the workshop together.

Year	A	B+	B	C	F
81	16	29	41	12	2
82	20	20	30	24	6

Table 3. Percent Grade Distribution in the DBA Program

The grades for the DBA students may be affected negatively by the greater average math capability among these students. The DPA students generally have little familiarity with math beyond arithmetic and simple algebra, and regard the preliminary exercises and the class meeting as dealing with a new topic. In contrast, some of the DBA students seem to regard system dynamics as just a slight variation on a familiar theme, so they fail to take the preliminary study requirements seriously. Unfortunately, they have no workshop opportunity in which to compensate for their poor performance in 'winging it.'

	DPA		DBA	
	Pcent	Av Grade	Pcent	Av Grade
Women	17	3.4	11	3.3
Men	83	3.2	89	3.0

Table 4. Distribution of Average Grades by Sex and Program
All Students--A=4.0

Taken together, the women in the programs perform better than the men, although the exceptional students seem to be about evenly distributed. The lower average for the men is eliminated when one portion of the foreign students (all male) are removed from the data. This group had poor language skills and also had problems in conceptualization. Part of the conceptualization problem might be attributed to the communications deficiency, but other foreign students with equivalent language skills performed at the highest level with ease.

Facilities

The classroom facilities for the weekend sessions have been quite adequate. The use of a portable terminal to demonstrate how the system dynamics programs are entered and output obtained has been considered from time to time. This has not been done, however, because of the limited time available for covering the basic notions of system dynamics.

The facilities for the workshops have been improving. At first the computer terminals were scattered on different floors

of the building used for the workshops which made it difficult to respond quickly to student problems. After the first two workshops the computer terminals were clustered at just two areas, and in the future it is expected that a single classroom may be available with sufficient terminals. In the workshops, one terminal is needed for each team of three. So, with the maximum of thirty participating in a workshop, ten terminals and several printers are essential.

Response to System Dynamics

System dynamics has been well received by the students. The applicability of system dynamics to the jobs performed by these working professional students is apparent. In many cases, models developed by earlier students in workshops, or described in the readings, are related directly to the students' professional interests. Although the workshop students are urged to refrain from modeling a problem of immediate importance to their work because it creates an imbalance among the team members and distracts the students from the broad learning objective of the workshop, a third to half of the workshop models end up being work related. Although the models are quite simple and elementary, they frequently create much interest and enthusiasm. The high point of the workshops is the presentation of the models by the several teams on the last day of the workshop. It strengthens the students' grasp of system dynamics and contributes significantly to their confidence.

The reception of system dynamics by the administration has been warm and encouraging. However, the same arrangement which benefits the students by bringing the faculty to them requires considerable travel and thus reduces the contact among the on-campus and adjunct faculty. There has been scant opportunity to acquaint more than a few of faculty and administration with system dynamics and the pros and cons for its inclusion in the various programs. So, system dynamics is not well understood in comparison with more established subjects. In addition, the general environment is somewhat disturbed because the notion of a professional degree, in contrast to a research degree, at the doctoral level generates some confusion and ambivalence. This is, no doubt, a continuing problem in which the balance will swing as changes in faculty and administration bring new perceptions to these Nova University programs.

Recent Developments and Trends

Several promising developments are underway. Although the students in the DBA and DPA Programs are far from being skilled system dynamicists, a surprising number are using causal diagrams in the development of their proposals for various projects and their dissertations. Ray Thompson, a Nova DBA candidate, is presenting at this conference a description of the work he has undertaken, in the manner of Senge, to critique some of the practices followed by accountants. A DPA student is well along in the development of a personnel model reflecting the operations of the Inspector General of the Department of Agriculture. Given

the very short period that system dynamics has been taught at Nova University in this format, it appears to be achieving more than expected.

Beginning in January, 1983, system dynamics was deleted from the DBA program in order to accommodate more pressing professional material, but it is being considered for inclusion in some of the Master of Business Administration Programs. To allow more flexibility for the students in the DPA Program, the workshop will be an optional in the future. There are some advantages and disadvantages in this, but on the whole it should increase the motivation and student performance of the workshop participants.

Dr. Abraham Fischler, the President of Nova University, is anxious to introduce a further innovation in the doctoral programs which would have a very positive effect on the instruction in system dynamics. In the near future, students will be required to possess a personal computer compatible with the systems employed in the Nova University-New York Institute of Technology computer network. The implications of this initiative for teaching system dynamics are far-reaching. For example, a basic level of computer familiarity and the availability of a rudimentary electronic mail facility would permit additional emphasis on exercises and model development which would improve the level of student competence in system dynamics.

Conclusions

An introduction to system dynamics can be taught satisfactorily in the Nova University format which limits classroom contact between the instructor and students to a two-day session. The inclusion of a workshop for the system dynamics students significantly extends their appreciation of system dynamics and improves their ability to identify problems where system dynamics could be helpful. The introduction of a course in system dynamics in a graduate program, like any other new course of instruction, requires a number of teaching and administrative adjustments and should be expected to produce some turbulence in the program.