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SIMULATION EDUCATION: PAST REFLECTIONS AND FUTURE DIRECTIONS

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ABSTRACT

The results of two surveys of persons concerned with simulation education in the 1974-76 timeframe are compared with the results of a 1997 workshop entitled, "What Makes a Modeling and Simulation Professional?" Analysis of these two samplings, separated in time by over 20 years and admittedly with differing objectives and under dissimilar conditions, is used to identify persistent issues, beliefs or convictions regarding the needs for professionals. The intent is to establish a departure point for further discussion of simulation education.

1 INTRODUCTION

The objective of this paper is to characterize issues in simulation education some 25 years in the past and compare and contrast them with current issues so as to provide a backdrop for subsequent discussion. This approach serves to identify persistent issues in contrast with the concerns that have emerged in the recent years. Hopefully, the consequent identification of future directions can be better focused.

1.1 The Early Picture

In 1974-75, two surveys were conducted that addressed simulation education issues. The first, in the fall of 1974, was spearheaded by Richard Beckwith of Tulane University "for the purpose of assessing the attitude of users relative to a number of topics bearing on the education and preparation of … simulation practitioners" (Beckwith 1976a). The survey population consisted of members of the TIMS College on Simulation and Gaming (now the INFORMS College on Simulation). Beckwith identifies G.S. Fishman, P.J. Kiviat and R.E. Nance as contributing to the form and content of the survey instrument. The responses were based on numerical rankings of zero to ten (ten being the highest) in nine question categories. Analysis included a mean response, an 80 percent confidence interval, and a clustering procedure following a technique described as "Modified Bernoulli" by Beckwith. A comments section allowed open-ended qualitative responses.

The second survey by Nance and Overstreet (1976) was initially stimulated by an unexpected level of response in the Beckwith survey that showed Simula as the most prevalent special purpose (simulation) language taught. Using this opportunity to seek confirmation of some results given in the earlier survey, the questions were targeted at university departments with the intent of determining the extent to which selected subjects were covered in simulation courses. The survey sought to identify differences among subject areas based on the teaching department – business, computer science or engineering. The percentage of course time devoted to each of ten subject areas characterized the coverage and importance of the topic.

1.2 The Current Picture

The current view is taken primarily from the results of a 1997 workshop organized and led by Ralph Rogers, then at the University of Central Florida. The workshop, with major financial support from an industrial sponsor, bore the intriguing title, "What Makes a Modeling and Simulation Professional?" Its goal was "the identification of the characteristics of an ideal modeling and simulation professional" (Rogers undated, p.2).

The 25 or so invited attendees at this workshop represented a broad sample from academia, industry and government. Moreover, a balanced representation of modeling technique, between discrete event (DES) and continuous (CS), was evident.

The workshop results are supplemented by brief analysis of the programs of the last five Winter Simulation Conferences (WSCs) to give a current picture of topical importance. Admittedly, this contribution effects a bias toward DES, but the differences in the goals of the 1974-75 surveys and the 1997 workshop should already be clear: the latter addresses what is needed to be a productive professional (total educational exposure plus experience), while the former examines the more narrow issue of what is, or should be, taught in the simulation courses. Despite such differences, the sources provide interesting perspectives, promoting comparative examination of the degree to which certain issues within simulation topical areas are persistent.

2 SIMULATION ISSUES IN 1975

The Beckwith survey results appear in three components: a preliminary description given at the ORSA/TIMS Joint National Meeting in San Juan (Beckwith 1974), the full report, which was presented at the 1976 Bicentennial WSC (Beckwith 1976a) and the letter of transmittal for the full report (Beckwith 1976b). The reason for treating the letter as a component lies in its acknowledgment of the non-random sampling technique used in the survey. The letter also references the rather unusual technique employed to produce estimates of the mean response level (on a "0" to "10" scale, with 10 the highest level) and an approximate 80% confidence interval (CI) on the mean. The letter notes the unexpected dominance of Simula as predominant in the educational use of simulation programming languages.

2.1 The Beckwith Reports

A handout without methodological explanation was provided to attendees of the session at the ORSA/TIMS Meeting (Beckwith 1974). Responses to each of nine categories were given as estimates of "mean response (endpoints of 80% CI)" following the question posed in the survey. The subsequent full report does not include a copy of the survey questions but does present a graphical depiction of clusters of responses that, despite the differences among mean value estimates, "are not intrinsically rank-distinguishable" (Beckwith 1976, p.2). The full report also explains that an initial self-classification of respondents as "Consultant," "Consumer," "Employer," and "Practitioner" had to be abandoned since almost no respondents used other than the first and last designations. A similar result occurred with attempts to self-classify by "philosophies."

Responses garnering the highest rankings as *Major Elements of the Simulation Art* were Problem diagnosis prior to model construction (8.6), Model construction (8.0) and Implementation of simulation results (7.3). Each of the first two constituted singleton clusters. The third belonged to a cluster that included Applications, experience and skill in (6.8), Data analysis definition (6.7), Statistical and mathematical techniques (6.6) and "Selling simulation to the layman (5.7). Programming techniques, General purpose language (GPL) use and Special purpose language packages ranked further down the list.

Within *Application Characteristics of the Model*. Complexity reduction (9.3) and Portability (8.3) ranked well above the rest. Generality (applicability to a class of situations with tailoring by the user) (7.4) and Cost per experimental unit (7.2) formed a third cluster.

Among *General Purpose Languages*, the trend of the times seems to be at work with PL/I (8.2) dominating and FORTRAN (5.1) a distant second. The unexpected leader Simula (7.4), MILITRAN (7.2), GASP (5.4), GPSS (5.0) and CSL (4.6) were the ranked responses in the *Special Purpose Language Packages* category. Surprisingly, SIMSCRIPT accrued a total score of only 0,8, last in the ranking.

Rankings in *Statistical and Mathematical Techniques* placed System dynamics, stability (discrimination of steady-state and transient behavior) (8.2) and Generation of random variates from specified populations (7.7) in a single cluster. Search procedures (7.0), Response surface exploration (6.4), and Goodness-of-fit tests (6.4) formed a second cluster. Generation of random numbers (6.2), Parameter estimation (6.2), Stopping rules (6.1), Process generators (5.9) and Sensitivity analysis (5.7) defined a third.

Within *Methodology in Model Selection, Specification or Construction* the areas of Documentation of coded model (external to the program) (8.1), Defining the problem in modeling terms (7.7) and Coding in a GPL (7.3) placed the highest. However, the last represented an intersection with a cluster formed by the first two and one that included Data collection to assist in model building or in parameter estimation (6.8). A fourth cluster included Basic approach (event scheduling, activity scan, process interaction) (5.9), Employing SPL packages (5.9), Complex models (integrating components) (5.6) and Identifying simulation variables, parameters (5.2).

The area entitled *Programming Considerations* produced the tightest rankings with Control program design (7.7), Initialization (7.7), Debugging provisions, and Interface of simulation program with the operating system (7.2) forming a single cluster. Documentation (of the program) (6.8) and Error message provisions (6.8) joined the latter two above to form a second cluster. A disjoint third cluster included Flexibility for program change (6.5), Summary displays and reports (6.0), Output housekeeping (5.8) and Data handling and manipulation (5.5).

Additional insights were furnished by the narrative responses to two questions in the Beckwith survey: (1) What prerequisite skills, accomplishments or background are needed to be a specialist in simulation? and (2) What additional attributes, characteristics and skills are needed by experts in some aspect of simulation? Supplementary remarks were also solicited, especially as they addressed speculations on trends and future uses of simulation.

Edited response fragments to the two questions concerning prerequisite needs and additional skills and characteristics included:

Ability to see a problem, grasp its essentials, and willingness to grub to acquire necessary data

A background in physical science (mathematics, statistics, physics, engineering)…with experience with computers
The will and ability to solve problems or puzzles
Firsthand knowledge of the activity to be modeled
A pragmatic problem-solving attitude
A genuine interest in the field of the activity being modeled
Should enjoy research and work in unstructured environment
Ability to communicate both orally and in writing
Ability to think in a scientific mode
Intelligence and a searching attitude are far more important than [a] background of technical skills.

The supplementary remarks were identified by respondent type (Consultant or Practitioner), and some examples follow:

Consultant: *It distresses me that exposure to a particular language is viewed by some as constituting an "education" in simulation. Such individuals cannot be proficient in the "art" of identifying the key elements in a process to be modeled. Abundance of detail ... is no substitute for a simplified model designed around the key elements and addressed to their effects on system performance characteristics.*

Practitioner: *As long as simulation is split into two camps, theoretical analyses and practical studies (unpublished for the most part), the art and science of simulation in particular, and management science in general, is in trouble.*

Practitioner: *I believe there is presently too much emphasis on modeling for its own sake. In the military operational research environment there are many models around that have little or no real usefulness, but which someone, somewhere, thought it a good idea at the time.*

Consultant: *A key pitfall in simulation is that [it] becomes an end in itself. The practitioner pursues a more sophisticated/elegant/complex model, often to the detriment of its value and usefulness*

Consultant: *I believe that the designers of simulation languages fall into the trap of trying to "outdo" all other programming languages as [they] make new and "advanced" compilers ... believing that their languages can be all things to all people ... In (perhaps) pleasing a minority they make their languages awkward for the majority.*

Several Practitioners: *Behavioral characteristics are perhaps more important than technical expertise in implementing simulations. The reason is that the model builder must constantly be able to sell the validity of the simulation to the user. We all suffer… from the lack of a theory but we do not suffer from any dearth of individuals ready to apply [simulation] with abandon!*

Several Consultants: *The trend will be to use simulation more and more extensively, but with the quality decreasing, as more and more amateurs "do their own [thing]" without proper assistance. .... Computer aspects will get easier and [will be] more relegated to programmers. More focus will be placed on modeling, on statistics (especially experimental design) and on obtaining an intuitive feel for the operation of systems and subsystems.*

2.2 The Nance-Overstreet Survey

Results from the Nance-Oversteet survey were presented at the Bicentennial WSC (1976). The questionnaire was sent to academic departments offering simulation courses. From the 37 responses to 68 courses surveyed, a total of 28 admitted to a comparative analysis. Among offering academic sources the distribution was 11 in Engineering (seven in Industrial and two in Systems), 10 in Business (four in Quantitative Analysis, two in Management Science, and one in Management) and seven in Computer Science. Two of the Engineering courses were cross-listed (Computer Science and other Engineering); as were one course in Business (Computer Science) and one course in Computer Science (Industrial Engineering and Operations Research).

Responses indicated that a large majority of the simulation courses were offered at the graduate level, and the enrollment of majors varied from 58% for Business to 67% for Engineering and 78% for Computer Science. In all cases a number of students from other majors also populated the course.

The unexpected number of responses showing Simula as the language used in the Beckwith survey was clearly refuted by the evidence here. Only in one course in a Business department was Simula shown as the language of emphasis. GPSS ranked first in all three sources. In terms of languages introduced, SIMSCRIPT ranked far higher than shown in the Beckwith survey; GASP appeared in all three sources; and FORTRAN outranked PL/I in every source.

A major motivation in conducting the survey was to examine and compare the allocation of time to subject areas. The result is shown in Table 1 for the ten choices given: (1) modeling, (2) simulation principles, (3) random number generation (RNG), (4) internal organization (lists, queues, etc.), (5) time management, (6) statistical analysis of input data, (7) statistical analysis for RNG, (8) statistical analysis of output, (9) report generation, and (10) interactive (human-in-the-loop, gaming, etc.). The most glaring variation in responses occurred for statistical output analysis in Engineering, with one course devoting 45% of the time to this area while the average was 14% and the minimum was only 5%. An informal comparison of means among the three sources reveals no glaring differences. The most obvious difference is in the variability among Engineering courses, which is much higher than the others.

2.3 Summary Picture

Since the questions are framed so differently in the two surveys, drawing a consensus is difficult. Note that complexity reduction, which would seem to be included in modeling, draws the highest score in the Beckwith survey (9.3) yet at least one Engineering course devotes no time to it. On examination of Figure 1, similarities in course composition appear more obvious than contrasts. The course in simulation draws comparable attention, irrespective of the offering source, to nine of the subject areas, with only the interactive area receiving minor treatment. Considering the lack of widespread interactive computing on campuses at this time, this outcome is not surprising.

Rearranging the subject areas with an ordering by source in Figure 2 assists in recognition of a key difference: variations in percent coverage allocated to each area is much higher in Engineering than for the other two. In fact the value of E{Range} for Engineering (12.5) is over twice that for Computer Science (6.0). The value for Business (8.0) compares more closely with that of Computer Science. Note that two Engineering departments offered nine of the eleven courses so the disparity is not attributable to a larger number of offering departments.

Based perhaps more on the narrative responses, but with consideration of the quantitative values, the following observations seem warranted:

- Considering the attention given on the average to subject areas, no major differences are apparent based on the offering source.
- Within the sources for a simulation course, the variations are notable for Business and Computer Science and even much greater for Engineering.
- .Pragmatic problem-solving ability in loosely structured or unstructured domains is required.
- Physical sciences and engineering receive more emphasis than management science or computer science (could be affected by the sampled group).
- The programming language of emphasis is viewed as important but concerns are expressed that the programming knowledge not be over-emphasized.
- Reservations are expressed regarding the over-use of simulation, particularly in the military, and the preoccupation with overly detailed model content.

3 SIMULATION ISSUES IN 2000

The classification of elements of the ideal simulationist from the workshop included (Rogers 1997, p.1376):

- Attributes
- People Skills
- Systems Approach
- Human Factors

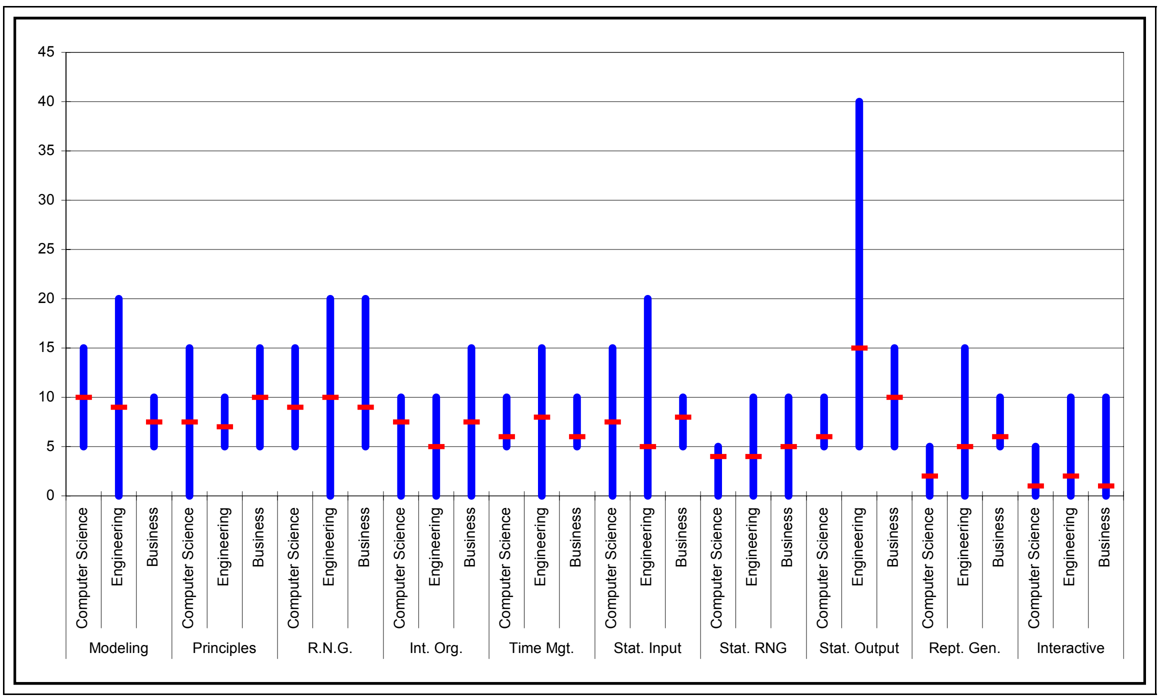

Figure 1: Allocated Percentage of Course Time (Ordered by Subject Area)

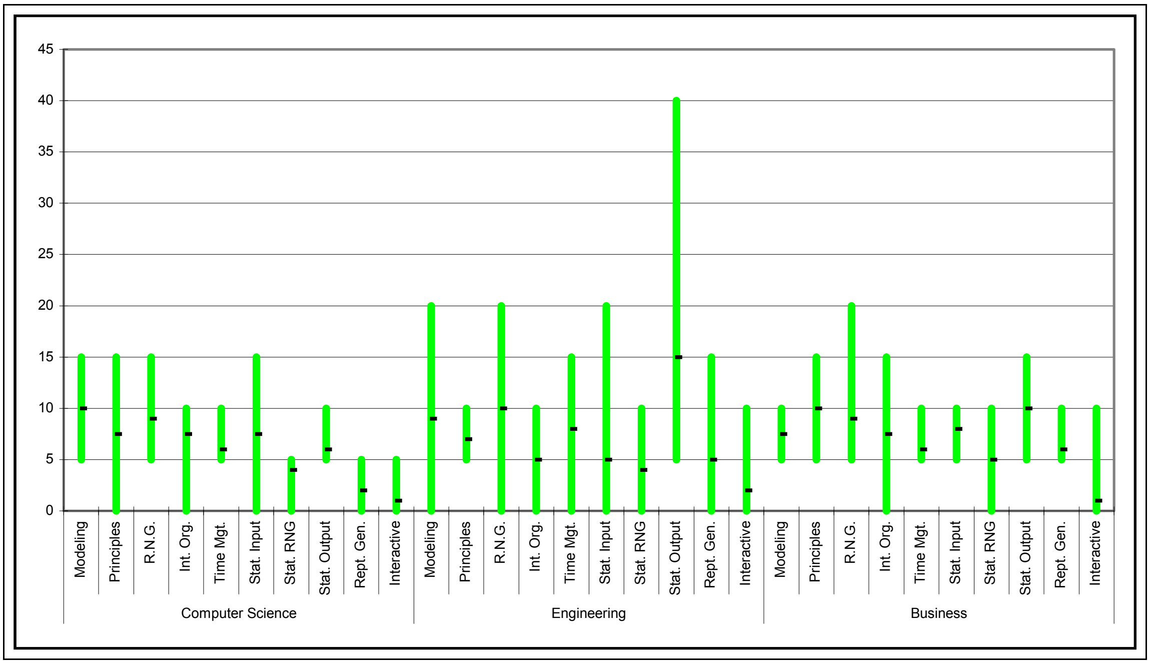

Figure 2: Allocated Percentage of Course Time (Ordered by Source)

- Basic Skills
- Modeling
- Domain Knowledge
- Simulation Methods

Attributes divide into two characteristic sets: (1) experience and achievement and (2) personality and character. Terms describing the required attributes, such as leadership skills and the ability facilitate a group in a collaborative, interdisciplinary effort, exemplify the latter. Creative problem solving and practical experience are descriptors of the former.

People skills encompass interpersonal traits such as strong written and verbal communications capabilities, tolerance for the ideas of others, and a commitment to life-long learning. That major simulation projects are a team effort is clearly implied here.

Basic skills can be considered general or prerequisite knowledge: computing, physical science, probability and statistics, experiment design, stochastic methods, project management, mathematics, operations research, cost modeling and cost accounting. Rogers (1997, p. 1378) notes that the participants held the belief that "a strong education in a science or engineering curriculum" was needed. Underscoring the importance of this class is the statement that "the workshop's participants believe that managing time and resources within limits while successfully accomplishing the specified goal is the major (some argue the only) effective measure of performance for a successful simulationist" (Rogers 1997, p. 1378).

The modeling category is labeled as pivotal and maybe the most important for the ideal simulationist while also raising significant problems. The elements include: model building (conceptual and tool knowledge); full understanding of abstraction principles, modeling paradigms and experimental methods; familiarity with knowledge engineering and the modeling of human, physical and hypothetical systems. The extent to which this category influences the ideal requirement can be fully appreciated only after reading this section in the more complete source (Rogers undated, pp. 10-14).

The systems approach is the methodological basis for achieving a known and defined result. This "basis" can be comprised of several methodologies; systems analysis, systems engineering and operations research are given as examples. These methodologies are instructive in problem definition, objective resolution, representation (level of abstraction), analysis, verification and validation, and model testing.

Human factors includes the understanding of human/computer interaction, cognitive and behavioral representation, sensory methods for data reduction and interpretation, and ergonomics.

Domain knowledge must be possessed by the ideal simulationist unless a team effort is employed. In that case a domain expert furnishes this form of expert guidance.

Simulation methods extend across several modeling paradigms, and the participants chose not to comment in an evaluative fashion. The awareness of varying paradigms and the ability to integrate new technologies with simulation were considered to be requirements. Similarly, the ideal simulationist should be able to translate current knowledge to new and challenging applications.

4 COMPARISON AND DERIVED QUESTIONS

First, we look at the comparison and contrast in issues as derived from the earlier surveys and the workshop. That is followed by a discussion of issues taken from recent WSC proceedings and personal experience.

4.1 Survey and Workshop Issues

An immediate temptation is to view the 1997 workshop consensus as unrealistic and a manifestation of ignoring the fact that major simulation projects are team efforts. However, the point should be stressed that an ideal simulationist is being defined. Clearly, the coverage of certain knowledge categories might be accomplished by other than the "simulation expert" in the team.

Both the surveys and the workshop stress project management skills and team leadership. Both express the belief that modeling skills (complexity reduction, problem definition, model construction) are more important than programming skills. From both sources, the pivotal role of modeling surfaces quite clearly from not only the answers but the questions themselves. Methodology and theory are important, but a pragmatic approach, problem-solving skills in an unstructured environment, and resourcefulness are cited in both sources as equally important.

That an academic background in science or engineering is essential emerges as a conviction in both the surveys and the workshop. Application domain knowledge is seen as vital to a successful study in both.

Concerns with model management (documentation, model portability, applicability to a class of situations) seems to be of greater concern in the early surveys. The workshop does not express the concern for "modeling for its own sake" reflected in the earlier survey results.

4.2 Issues from Other Sources and Personal Experience

Current educational issues that are most glaring in their absence in the 1974-75 surveys for the most part are technology driven. Here the educational questions are focused on how and where the intersection of the technology and simulation should be treated. For example, should distributed simulation be addressed in a simulation course or a distributed systems course? Similarly, should parallel discrete event simulation be a subject in parallel computation? Would the same answer be the response for parallel continuous simulation? Can virtual environments and virtual reality be fitted in a simulation course, and if not, does the order of exposure matter?

Still more questions surround application domain issues. Should training, analysis and acquisition uses be treated in a single course? Should important applications such as computer performance evaluation, supply chain organization, and communications networks be addressed in a simulation course or in courses addressing the technical domain?

Perhaps the summative question, and certainly one that arouses considerable controversy: Has simulation evolved to that point where it must be viewed as a discipline in its own right?

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