Proceedings of the 2001 Winter Simulation Conference
B. A. Peters, J. S. Smith, D. J. Medeiros, and M. W. Rohrer, eds.

THOUGHTS AND MUSINGS ON SIMULATION EDUCATION

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ABSTRACT

Proper education of a modeling and simulation professional meeting the extensive criteria imposed by the community poses significant challenges. In this paper, we explore the formation of a university-based education in modeling and simulation to meet the challenges. We examine the factors affecting the composition of a modeling and simulation course. Based on the anticipated consequences, we propose potential solutions.

1 INTRODUCTION

Simulation education is quite deservedly a major discussion topic at this juncture. Perhaps triggered by the workshop with the thought-provoking title, "What Makes a Modeling and Simulation Professional" (Rogers 1997b), the increase in interest is manifested by sessions devoted to simulation education at every WSC since 1997. For the past two years education has warranted mini-track status.

The objective of this paper is to explore the question: *What form should university-based education in simulation take?* We begin by examining the factors affecting the composition of a simulation course. The consequences of the number and nature of the factors are briefly considered along with their influence on degree programs. Casting the answer to the question above as a decision problem, we identify the potential solutions, noting general advantages and disadvantages. Hopefully, these "solution alternatives" raise further discussion on both a general and institutional level in the future.

2 FACTORS AFFECTING SIMULATION COURSES

The topical composition of simulation courses and the allocation of time to each subject is addressed in (Nance 2000). The results of two surveys (Beckwith 1974, 1976a, 1976b) and (Nance and Overstreet 1976) are compared with a consensus generated by attendees at the workshop cited above (Rogers 1997b). The earlier survey results conveyed wide disparity in time allocation to subjects in only two cases comparing courses based on discipline (business, engineering, or computer science). However, the number of subjects from the early surveys (ten) is far less than the number from the 1997 workshop. In fairness, the questions related to subject matter in the latter case are broader and less directed to specific course content; they focus on the knowledge required to be a successful professional. Moreover, the population represented by the workshop attendees is much larger and more diverse than that of the earlier surveys. Yet, the conclusion is clearly warranted that the expectations of breadth in educational subjects are considerably higher in the consensus of the workshop attendees.

2.1 Type of Simulation

One might argue that the effect of technology has served to expand the subject matter covered in the education of a modeling and simulation professional. We list below the types of simulation identified in current use today:

1. Combined simulation
2. Continuous simulation
3. Discrete-event simulation
4. Distributed simulation
5. Gaming
6. Hardware-in-the-loop simulation
7. Human-in-the-loop simulation
8. Monte Carlo simulation
9. Parallel simulation
10. Software-in-the-loop simulation
11. Synthetic environments bringing together simulations and real-world systems
12. System dynamics simulation
13. System theoretical simulation

From this list, items 4, 6, 9, 10 and 11 would not have appeared in 1976.

Clearly, the time allocation in a single semester course (45 hours of contact time minus that used for testing, review and examination) would permit no in-depth treatment of all the types. Although each type might be noted and briefly defined, choices would have to be made in the coverage. If complete coverage at a suitable level is demanded, how many courses would be required? We leave the answer to that question as an exercise for the reader.

2.2 Objectives of the Simulation Study

A second factor affecting the subject content of a modeling and simulation course is the study objectives. The historical development of simulation for many of us is based on the implicit assumption that our objective is *to analyze* the behavior of a model of a system in order to reach decisions regarding changes to the system. While simulation has a long history as a systems analysis technique, the use of simulation within gaming and exercise scenarios intended for *training* or *education* is almost as lengthy.

We distinguish education from training based on whether the learning is to support the understanding of concepts (education) or the development of skills to perform specific tasks (training). Admittedly, the distinction between the two can become blurred in a specific application.

System acquisition has the objective of using simulation to decide to acquire a system or a subsystem that must be integrated within a larger legacy system. The consequences of such a decision force more precise requirements on the modeling study than are imposed by an analysis objective.

The *research* objective is likely to involve the simulation model within a game scenario. Differences among human players of the game can be correlated with derived personality traits, behavioral characteristics or some other measurable attribute.

The most recent discrimination according to objective is *entertainment*. Clearly, the rapid and rather phenomenal developments in computer graphics have proved the enabling technology for simulation.

2.3 Discipline Offering the Course

Although the early surveys referenced above showed few notable differences among courses according to discipline in the mid-1970s, our speculation is that today the differences are more pronounced. The emphasis on topics related to statistical analysis is greater in courses offered by departments of engineering or operations research. Simulation courses from statistics departments give more attention to Monte Carlo models in addition to statistical techniques in discrete event simulation. Computer science courses in simulation focus more on topics related to data structures such as model development, time flow mechanisms, and object-oriented techniques in model design.

The reasons for these differences are quite justifiable: they fit within and mutually support other subjects in the discipline. Students majoring in a discipline can be unable to deal adequately with some subject matter. A consequence is that fewer simulation courses are cross-listed between departments. This lack of disciplinary diversity among students can deny potential educational benefits.

2.4 Course Instructor

Instructors often interpret and teach simulation with a bias toward their area of specialization. A statistician might view simulation as producing the results of a statistical experiment and teach simulation with a heavy emphasis on output analysis. A computer scientist might view simulation as predominantly an application of computer programming and teach simulation emphasizing that aspect. Course subject content and the educational perspective are quite dependent on the background and interests of the instructor. That assertion is not a criticism but an undeniable fact.

2.5 Degree Level

The final factor is the degree level: undergraduate or graduate. The expectations for independent learning and expanding beyond disciplinary boundaries are higher for graduate students. We would expect that a graduate course would require more readings in the journal literature. We might speculate that a graduate course would entail more writing, but that might be simply a personal bias.

3 CONSEQUENCES

Considering the factors affecting the composition of a simulation course, the conclusion is inescapable that a single course covers only a small sub-domain of simulation knowledge. Even if the types of simulation are restricted to discrete event and Monte Carlo, the allocation of time for adequate coverage of the necessary subject matter is insufficient. How many courses are needed?

The course work required at a doctoral level is not sufficient to provide the in-depth exposure required to cover all simulation types. Each simulation type requires particular background knowledge gained in several non-simulation courses. We speculate that at least eight courses are needed to cover all 13 types of simulation. However, the required number of prerequisite courses would increase the requirements beyond the level imposed on a Ph.D. student. What subset of the eight would be considered adequate breadth for a M.S. student?

The coverage issue is somewhat of a red herring *unless we are describing curricula in modeling and simulation.* Only in a very few institutions is this the case. The objective in typical university offerings is to carve out a very reduced sub-domain and, depending on the discipline, tailor the course (and subject) requirements to satisfy the needs of that discipline. The departmental solution suffices because of the historical fact that *simulation has no disciplinary home*. However, if we as "simulation professionals" (educators, practitioners, employers, etc.) no longer find a "disciplinary homeless" solution to be acceptable, we have a problem.

4 POTENTIAL SOLUTIONS

The most obvious alternative is to establish an option for a modeling and simulation curriculum within an existing department. The immediate question is: Which department? The typical university answer is: The first to have the idea. Leaving aside the issue of whether that department is the best step-parent for simulation, how do the other step-siblings react to this elevation? The political carnage could be disastrous.

A second alternative is to create a department in modeling and simulation. Now the question is: Which college? The same issues arise but at a slightly higher level in the university.

The third alternative, somewhat cynically labeled "the Dean's choice," is an interdisciplinary program within a college. Deans prefer this for two obvious reasons: the compromise avoids inter-departmental fights and the program has a weak claim on resources (they come from the participating departments). Of course, the affected faculty might cross college boundaries, leading to no obvious home at that level.

Creating an interdisciplinary program at the university level is likely to be a "hard sell" at this time, but the alternative could have a bright future. This solution violates the neat hierarchical packaging preferred by most university administrators and requires a strong program director to be successful in acquiring the necessary resources and navigating through potentially choppy political waters. Attractiveness in the future could come from the need to create other interdisciplinary programs at the university level, e.g., bio-informatics or composite materials.

The last academic alternative to be offered here (but this list is not seen as exhaustive) is a multi-university program in modeling and simulation. Forming a consortium of universities with complementary strengths could forge an exciting high quality program. All the attributes of a successful program director within the single university setting would need to be present and at even higher levels.

A final solution might be to step outside the traditional academic setting and establish a simulation program using web-based and distance education courses. While avoiding a host of problems, such a strategy faces a major hurdle in achieving credibility, even with subject coverage and course delivery by individuals with stellar reputations.

5 SUMMARY

The growth of knowledge and pervasive use of simulation has created a situation where the creation of a modeling and simulation professional meeting the extensive criteria imposed by the community is not possible. Continuing to limit the recognition of differing educational objectives in developing simulation courses and curricula is irresponsible in our opinion. The lack of a disciplinary home, or the expansion beyond the "apartment status" in other "disciplinary buildings," exacerbates the resolution of this problem. Several alternatives are offered for the development of curricula that facilitate the production of professionals meeting the published needs (Rogers 1997a). To the extent that these suggestions and the attendant issues cause others to consider their personal or institutional reactions, we have succeeded in meeting our stated objectives.

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