

Towards Making Modeling & Simulation into a Discipline¹

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Abstract

Modeling and simulation stakeholders (government, industry, and educational institutions) firmly believe in the role and importance of educating and training (professional) simulationists. However, there does not exist a consensus on the *what*, *how to*, and *why* type questions pertaining to “disciplined” education and training. In this paper, we suggest a strategic approach for establishing modeling & simulation as an undergraduate degree program within the higher education system (universities). We discuss three fundamental elements (i.e., Body of Knowledge, Curriculum, and Accreditation) believed to be essential for transitioning the existing unstructured education into a recognized *discipline* by an appropriate accreditation board such as ABET.

INTRODUCTION

In recent years, some members of the international modeling and simulation community have voiced their desire for introducing some structure into the Modeling & Simulation (M&S) arena. One such broad-based effort was conducted in a workshop organized by Ralph Rogers [2] with more than forty participants representing industry, government, and academia from several countries. Industry and government, in part, represented customers of M&S professionals while academicians principally represented educators for such professionals. In August 1998, Ruth Silverman [3] organized another workshop focusing on how to teach simulation to undergraduate computer science majors. The workshop participants ranged from newly Ph.D. graduates to authors, educators, and researchers in the M&S arena. The workshop invitee also included simulation software developers and vendors. Both of these workshops focused on M&S education and to some extent on alternative educational programs within a variety of existing

disciplines such as computer science, electrical engineering, industrial engineering, management information systems, and systems engineering.

To further these prior efforts, in July 2000, a new track on M&S Education and Training (MSETT) spanning three regular and two panel sessions was introduced as part of the Summer Computer Simulation Conference (SCSC). The participants of the Education & Training Track included the organizers and participants of the previous two workshops as well as new constituents across a variety of sectors. A particular purpose for the M&S Education & Training Track was to depict a representative picture of the current status of the education and training in M&S from academic, government, and industry perspectives.

Aside from these workshops, a number of individuals have written on specific topics such as how to train modeling and simulationist professionals, academic curriculum development, and principles for creating M&S educational programs [4, 5]. While such focused efforts can (and should) significantly impact the realization of M&S as a discipline, they are insufficient to establish M&S as a discipline worthy of its own recognition by academia, government, and industry. In contrast to this approach, we advocate a top-down approach while taking into account the contributions made from existing individual programs some of which have opted not to label their programs explicitly. Indeed, it is most important to bring about a realistic vision for the establishment of the M&S discipline supported by all stakeholders who have contributed to its long history and its present and future.

MAKING M&S INTO A DISCIPLINE

Unfortunately, given the existing status of M&S, it is no simple matter to bring consensus on various topics [2]. For example, is there a need for the so-called M&S professionals, what would be the criteria for M&S curricula

¹ This paper is an extension of a contribution for a panel (Curriculum for Simulation Education) at WSC-2000 [1].

development, and what the role for academia, professional societies, and industry should be? Perhaps, the chief obstacles in instituting a common vision for M&S is its extensive widespread use in virtually all-existing scientific fields. Unlike more recent areas such as software engineering and robotics, everyone claims and does modeling and simulation of some form to some extent.

During the last several years, individualistic M&S program have been established at several universities (e.g., California State University at Chico – McLeod Institute Simulation Sciences, Old Dominion University, Naval Post Graduate School, and the University of Hamburg). While some of these programs are based on the findings of workshops and serious discussions within the M&S community, others appear to have forged ahead in creating specialized areas

within programs such as Computer Science. A number of such programs serve positively the establishment of M&S discipline. Unfortunately others may have negative impact on a unified, concerted effort that is required to overcome numerous challenges that lie ahead in making M&S into a discipline. A critical view of existing programs raises a number of issues such as the followings. What should an accredited M&S undergraduate program be like? What are the implications of establishing programs independently of organizations such as ACM, IEEE, and SCS (Society for Compute Simulation International)? What are the implications of an M&S discipline given the existence of other disciplines such as various engineering and science programs? Does M&S the province of engineering, science, both, or perhaps something principally different? In the followings, we provide some initial suggestions.

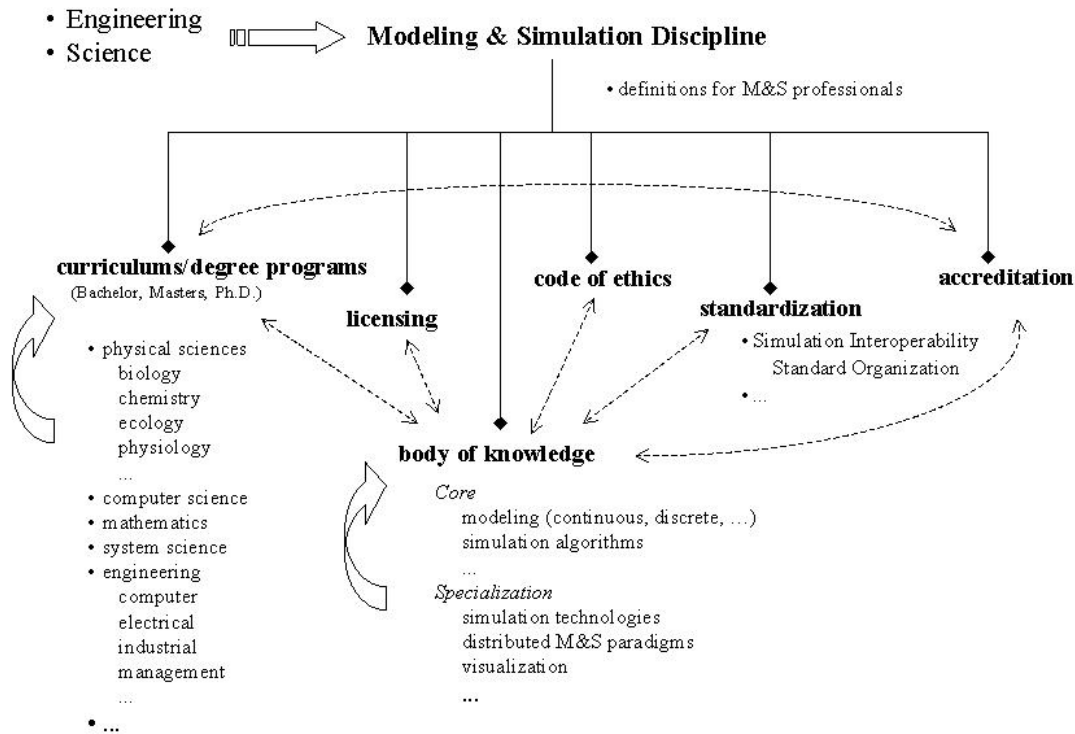


Figure 1: Necessary elements for making of the Modeling & Simulation discipline

A STRATEGIC APPROACH

The impetus for making the fragmented M&S field into a “discipline” need come from practitioners and users (e.g., government and industry,) tool developers (e.g., commercial entities and academia,) and theorists and methodologists (e.g., academia and research institutions). Since, we believe

there is a growing body of constituents to structure M&S education and training, in this short writing we suggest a preliminary comprehensive foundation appropriate for transforming M&S into a discipline. This approach is inspired by underpinnings developed in the making of Software Engineering into a discipline [6].

A fully recognized professional status is achieved by prescribing to a developmental path identified by G. Ford and N.E. Gibbs [7]. The ideal professional (e.g., Electrical Engineer or an architect) is educated by obtaining initial professional education (generally Bachelorette Degree), receiving on-the-job training and experience (skill development), obtaining license or certificate, exercising code of ethics, and continual professional development. Within some professions (e.g., M&S,) government and commercial entities (Defense Modeling and Simulation Organization, Aegis Technologies, Cisco, Sun Microsystems, and Rational to name a few) offer short courses and alike to educate student/professionals about their standards, tools, and methodologies. Henceforth, academic institutions, employers (e.g., industry), professional societies (e.g., ACM and IEEE), and commercial entities collectively realize the necessary infrastructure in the creation of M&S professionals.

Figure 1 shows the key elements for the establishment of M&S discipline. At this time, we cannot expound on all details and various relationships shown in Figure 1. Relationships exist both vertically and horizontally. For example, there exist direct interdependencies between, curriculums/degree programs and body of knowledge (see next section). To transform current ad hoc M&S education efforts into a cohesive, disciplined one, not only we need to arrive at a balanced view of our field but also work closely in collaboration with other related disciplines to achieve short and long terms goals of the M&S discipline.

AN APPROACH TO UNIVERSITY CURRICULUM DEVELOPMENT

Both academic (university-based) and non-academic (professional organization) can educate and train traditional and professional students. In an academic setting, learning is broad-based and combined with concentrated knowledge per student's chosen discipline. In contrast, education by professional organization is generally tailored for professionals and focused on single subject matters. Therefore, distinction between university and professional education is important in order to satisfy requirements posed by each one individually without engaging into a risky proposition whereby the needs of both are to be met simultaneously under one single umbrella.

For a university-based approach to M&S education, we consider the elements of M&S discipline as shown in Figure 2. The inner ring suggests that Body of Knowledge, Curriculums, and Accreditation to be the primary components². The numbering of these components suggests

² M&S "continuing" educational programs for professionals (non-university students) provided by professional organizations or extensions of universities generally do not

the dependency among them. Of course, these are to be determined together since they affect one another significantly and directly. For example, curriculum must be based on predetermined body of knowledge and accreditation is applicable to existing/proposed curriculum. The outer ring suggests Code of Ethics, Standardization, and Licensing to be the secondary components. The ordering of these components as shown in Figure 2 is suggestive since their dependency is primarily with the components of the inner ring. The categorization of the rings is based on priority and is not intended to suggest importance of one category over another.

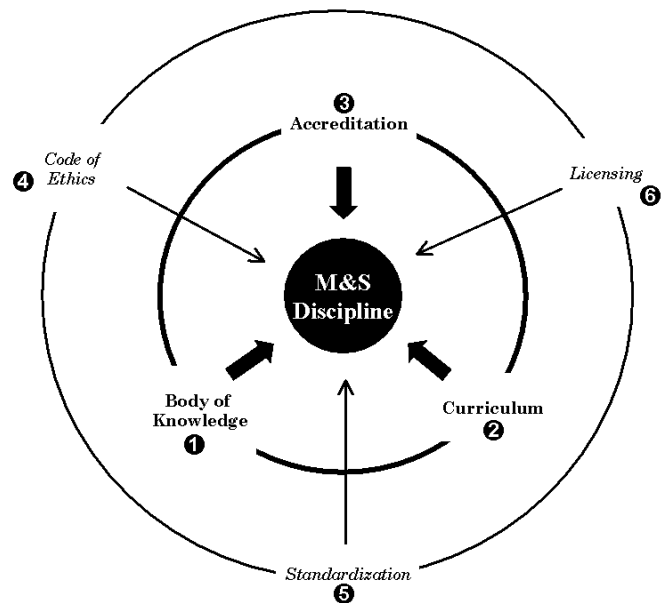


Figure 2: Realization of M&S discipline

University curriculums are generally developed by selecting from a set of courses offered by departments and special programs. A necessary condition for M&S to become a discipline or multidisciplinary program is to have a curriculum – that is a general *blueprint* to be used and tailored by each institutions offering its own *customized* degree program. Since a curriculum is a set of courses constituting general and specialization knowledge, we need to consider a couple of questions. First, should M&S become a discipline or a multi-disciplinary program?

subscribe to the tight interdependency among body of knowledge, curriculum, and accreditation. Furthermore, curriculum and accreditation are not considered – that is curriculum can be developed internal to the offering organization and may not necessarily be subjected to stringent external accreditation criteria due to factors such as time and cost.

Second, what are the candidate courses appropriate for an M&S curriculum? We consider each of these questions next.

Disciplinary vs. Multi-disciplinary M&S Program

Curriculums can be developed for a discipline (e.g., Computer Engineering) or a multi-disciplinary program (e.g., Computational Sciences). A multi-disciplinary program generally spans multiple colleges (e.g., science, engineering, and medicine) and/or multiple departments within a college (computer, electrical, industrial, mechanical, system, etc). However, multi-disciplinary programs are inherently less constrained compared to that of a disciplinary one. (1) Students can choose from a larger pool of courses towards meeting course requirements. (2) Selection of courses is less vigorously monitored by various entities within a university. (3) Multi-disciplinary programs are not accredited by any independent organization (e.g., ABET). Nevertheless, both discipline and multi-disciplinary programs must usually be recognized at the university level and therefore at the college and department levels. In comparison, specialized programs are generally recognized by departments and therefore are regulated and supervised internally without any higher level oversight. Therefore, while M&S can be either a discipline, multidisciplinary, or a specialization program, we believe it should become a “discipline.” Our rationale is that specialization is inadequate since it cannot provide a uniform basis for education across all participating educational institutions worldwide. While making M&S into a multi-disciplinary program has merits and potentially easier to achieve, it cannot per se be accredited and thus inappropriate for providing the intended uniform basis (e.g., accreditation) for educating students in universities.

Making of a Curriculum for M&S Discipline

Assuming M&S is to become a discipline, under the existing educational systems (e.g., University of Arizona), the M&S program is to be housed within a college (e.g., Engineering). This potentially brings up a highly

controversial, contested concern/question – namely whether to place M&S program in engineering, science, or some other college. We believe engineering is the right choice from the point of view of M&S most widespread use (study, develop, and operate natural/engineered systems). Clearly, if M&S is to become a discipline, like its siblings such as computer and software engineering, its curriculum must include courses from a variety of other colleges (e.g., earth sciences, management, science, social and behavioral sciences, and medicine). Additionally, courses and training provided by special programs (both internal and external to an educational institution) may also become part of a curriculum. A curriculum blueprint can be developed based on M&S Body of Knowledge topics and related prerequisite topics.

The development of a curriculum, however, requires a major *joint concerted effort* among various stakeholders. As shown in Figure 3, with M&S discipline accreditation at the undergraduate level, Masters and Ph.D. follows the guidelines of other major graduate study programs. Having an accredited undergraduate program enables pursuit of advanced degrees in modeling and simulation in a systematic fashion (e.g., transfer of courses from one university to another). Furthermore, other aspects of M&S education (i.e., Licensing, and Standardization) can be associated to degree programs given their roles and mandates.

Table 1 shows knowledge areas for M&S curriculum. The purpose of this simple classification is two folds. First, it shows that M&S is an engineering program and thus similar to its siblings and it will include subjects from other areas substantially (e.g., computer science, medicine). Second, the curriculum will need to provide sufficient generality to for developing subdisciplines based on specialized areas. Therefore, the list of courses for an individual program will be devised and selected from the M&S body of knowledge topics as well as prerequisite topics.

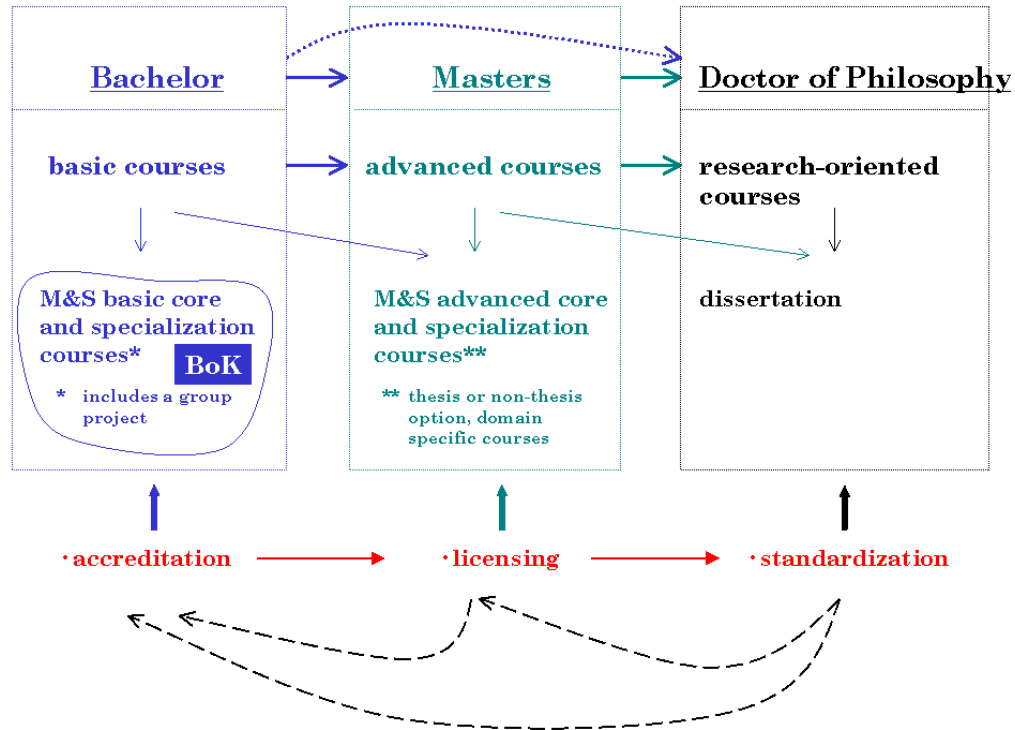


Figure 3: Academic ladder for M&S education

A list of candidate topics for Body of Knowledge is suggested in Table 2. Each of these needs to be defined in terms of specific topics to be included in courses/curricula. For example, Team-oriented, Multidisciplinary Design will concentrate on the lifecycle of a large project spanning two semesters (three quarters) selected from a specific domain (e.g., enterprise resource planning).

Basic Non-Engineering Areas*	Engineering Areas*
Arts	Aerospace
Biology	Chemical
Chemistry	Computer
Communications	Industrial
Computer science	Modeling and simulation
Mathematics	Mechanical
Management/Operations Research	Software
Medicine	Systems
Physics	

* not all areas are listed

Table 1: Knowledge areas for M&S education

BODY OF KNOWLEDGE TOPICS	
Core	1. Analysis
	2. Modeling
	3. Simulation
	4. Verification and Validation
	5. Team-oriented, Multidisciplinary Design
Specialization	6. Hybrid systems
	7. Collaborative/Distributed Modeling and Simulation
	8. Human Computer Interface & Visualization
	9. Management

Table 2: Body of knowledge topics for undergraduate M&S degree program

From Body of Knowledge to Curriculum development and Accreditation

After a team of stakeholders, independent evaluators, and customers (e.g., employers, students, and instructors) following a systematic approach have drafted, evaluated, and approved M&S Body of Knowledge, the curriculum can be determined, evaluated, and approved as well. Upon the

acceptance of the curriculum, individualized programs can be accredited by ABET. Fortunately, we can adopt an exiting approach [6] to define BoK, Curriculum, and Accreditation.

PANEL: VISIONS FOR THE FUTURE M&S EDUCATION AND TRAINING

The development and growth of Modeling and Simulation – as a discipline, a profession, and an industry – is strongly bound up with the growth of education and training. Modeling and Simulation has become a technical field that pervades a wide cross-section of science, business and engineering applications and projections for growth in the future indicate an exponentially increasing curve. Unlike some software related tasks, education and training in M&S is essential to enable people to carry out tasks involving M&S with a competence that is not otherwise possible. At this time, the offerings in education and training are not capable of meeting the current and future demand and there must be significant developments in this regard. The panel members brought up some major objectives to further this process:

- Professional modeling and simulationists must be defined and accreditation mechanisms developed
- University degrees at the undergraduate and graduate levels must be defined and institutionalized
- Professional development – distinct from university degree programs – must be an essential component of the full education and training package

To realize each of these objectives will require a lot of effort.

Universities

- Need to characterize the discipline of M&S and clearly delineate the discipline from the neighboring ones such as systems engineering and computer science/engineering.
- Must work with other sources of professional training to work out areas in which each should concentrate and combinations of offering that work as a coherent whole
- Must work with funding agencies to establish programs of research and education needed to advance the field and adequate funding for their implementation

M&S-based Companies/ Corporations using M&S

- Must work with Universities to characterize the current and future types of M&S professionals they will hire and what their educational background should be
- Must coordinate their education and training programs with those of Universities for a coherent set of offerings
- Should collaborate with Universities to establish research teams that can respond to requests for proposals from government funding sources.

(Each company/corporation will have a different response to these imperatives depending on its own situation.)

CONCLUSIONS

In this article, we have discussed key elements that are required for making M&S education into a discipline. Our discussions focused primarily on university-based education with the possibility to include “professional” course offerings by non-university institutions. We suggested M&S to become a discipline at the undergraduate level. Further, we offered “topics” for the body of knowledge which is key to curriculum development and accreditation. We also discussed how the adoption of the M&S discipline at the undergraduate level leads to enabling undergraduate students to transition systematically into graduate level degree programs.

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