

# WHAT MAKES A MODELING AND SIMULATION PROFESSIONAL?: THE CONSENSUS VIEW FROM ONE WORKSHOP

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## ABSTRACT

This paper is part of a focused paper panel discussion addressing the results of an invited workshop conducted in Orlando, Florida in February, 1997. The workshop addressed the question: What makes a modeling and simulation professional? The workshop's results included a consensus ideal modeling and simulation professional characterized by eight categories and subsequent elements. Each of the eight categories and elements are presented as well as contextual narrative. The author provides an interpretation of the workshop results and implications for modeling and simulation professionals. Panel members were asked to respond to the goals and results of the workshop, as well as, the author's interpretations and comments of this paper. The paper and panel discussion are an attempt to spark debate on the modeling and simulation profession.

## 1 INTRODUCTION

On February 11, 12, and 13, 1997, the University of Central Florida (UCF) hosted an invited workshop on the modeling and simulation profession. The organizing theme and topic of the workshop was, "What makes a modeling and simulation professional?" The workshop's goal was the identification of the characteristics of an ideal modeling and simulation professional. The workshop included 25 national and international participants from academia, industry, government, and military. The North Star Institute and the National Training Systems Association provided financial support for the Workshop. UCF organized and ran the workshop.

A facilitator led workshop participants through a series of triggering questions, discussions, and activities focusing on the simulation professional, simulation education, simulation customers, and suppliers of simulation products and services. By the conclusion of

the workshop, the participants reached a consensus on a set of characteristic elements of an ideal modeling and simulation professional and further partitioned those elements into eight categories. This paper identifies the categories and their elements and provides the author's interpretation and discussion of the consensus characteristics for modeling and simulation professionals.

## 2 BACKGROUND

In early 1996, a series of informal dialogs took place among organizations in government, military, academia and industry. The series topic focused on current demands for modeling and simulation personnel. From these dialogs, a belief emerged among many in the organizations that a shortage of modeling and simulation professionals existed in meeting current world needs.

What was not clear, however, was exactly what was meant by a modeling and simulation professional. Confounding this issue was the extreme diversity of the simulation community and the general lack of a common taxonomy of simulation. Many organizations indicated a shortage of modeling and simulation personnel, but few had job classifications for modeling and simulation professionals. (Consequently, for purposes of this paper, a modeling and simulation professional will arbitrarily be referred to as a simulationist).

Thus, even if the belief in a shortage of personnel was correct, establishing valid evidence would be difficult because there are few common titles or terms (i.e. frames of reference) to define or discuss the information sought. Characterization or description of a representative or ideal simulationist was needed. To this end, the North Star Institute and the National Training Systems Association provided funds to UCF to conduct the workshop.

### 3 CONSENSUS IDEAL SIMULATIONIST

For classification, the elements of the ideal simulationists were placed into the following categories:

- Attributes
- People Skills
- Basic Skills
- Modeling
- Systems Approach
- Human Factors
- Domain Knowledge
- Simulation methods

Each of these categories and the elements assigned to them are presented in the following sections. Narratives accompany these presentations. The narratives are singularly those of the paper's author and do not signify a consensus opinion of the workshop participants or imply the endorsement of any workshop participant.

#### 3.1 Attributes

- *Creative Problem Solving*
- *Practical Experience*
- *Have leadership skills: the ability to facilitate a collaborative interdisciplinary group effort.*
- *Ability to recognize/adapt to technology changes*
- *Interdisciplinary Skills*

The attribute elements of the simulationist reflect two distinct characterizations. One characterization emphasizes experience and demonstrable achievements. The other emphasizes personality/character. The latter set includes creative problem solving, leadership, and, to some degree, interdisciplinary skills. The element *Ability to recognize and adapt to changes in technology* also fall under this characterization, although it might be more appropriately represented by the terms visionary (or insightful) and adaptable. The *interdisciplinary skills* elements implies two levels of consideration. On one level it is about personality or, perhaps even, intellectual capability associated with open-mindedness and tolerance for ambiguity necessary for an individual to hold simultaneous competing paradigms and explanatory worldviews while observing phenomena.

The experience aspects of the *interdisciplinary skills elements* emphasizes direct experience in a interdisciplinary environment or situations. One interpretation would indicate the ideal simulationist has experienced the realities of confronting the challenges and ambiguity of attaining some goal in a risk filled dynamic environment.

The real factor of the experience area of the Attribute Category is simply life experience. The requirement is for a certain maturing or development in the individual to temper his discipline canon knowledge (i.e knowledge not from direct experience) with direct experiential knowledge. The expectation is for the simulationist to have experience with situations where

the ideal form or generalized problem of science or technology is matched against the uniqueness of the details of a specific problem/system. The underlying belief (if not the fact) for the requirement of practical experience is that real life is often a rather untidy affair that overwhelms the general forms of science and engineering with specifics which continually confound the desires and plans of managers, designers, scientists, engineers, analyst, educators, and even parents. The implicit assumption in the desire for experience is that encounters of direct experience are the most reliable markers to indicate an individual possesses skills in how to recognize and cope with life's rude challenges to human expectations and plans.

Thus, the ideal simulationist should have two kinds of experience:

- Practical pragmatic experience of trying to achieve a project goal, though not necessarily simulation experience.
- Interdisciplinary experience drawing on more than one discipline's canons.

Further, the ideal simulationist should have the following personality/character attributes:

- Creative
- Problem Solver
- Leader
- Adaptable
- Visionary
- Open-minded
- Tolerant

#### 3.2 People Skills

- *Excellent written and verbal communications skills.*
- *Group interaction skills. An ability to accept and tolerate the ideas and perspectives of others.*
- *A commitment to life-long learning.*

The People Skills Category emphasizes interpersonal skills. The participants emphasized the simulationist's need to be an effective writer and speaker. Beyond this, however, the simulationist should possess effective group and team interaction skills. Group or team interpersonal skills were considered more than the ability to present one's position or ideas. They emphasize working and dealing with other people in team efforts. Again, the desired skill places an emphasis on the simulationist attributes of tolerance and open-mindedness.

Whether *a commitment to life-long learning* is a People Skill is a reasonable question. An argument can be made that life-long learning element should be an Attribute. However, regardless of the partitioning, it is fair to say that the desire for life-long learning is a quality sought in the ideal simulationists. Perhaps, the placing of this element in the People Skill category

merely emphasizes the participant's belief in the importance of interpersonal skills to the learning.

### 3.3 Basic Skills

- *Good analytic skills in probability and statistics, experimental design, and stochastic methods.*
- *Computing competence/skill.*
- *Mathematics and Operations Research.*
- *Project management skills.*
- *Cost Modeling*
- *A foundation in the physical sciences.*
- *An understanding and appreciation for the scientific method.*

The element *an understanding and appreciation of the scientific method* underscores all elements of the Basic Skills category. The scientific method is the unifying principle and foundation of modern science and scientific philosophy. Consequently, the scientific method is the starting point for exploration and thought as man tries to understand the universe he occupies, as well as, the starting point for discussing Basic Skills for the simulationist.

First and foremost, science is a system to find things out about the universe we inhabit and the scientific method represents the elements of that system [Checkland, 1981]. Science is generally characterized by the application of rational thinking (i.e. the application of the principle of causality) to experience. Specifically, the *practice* of science is the establishment of chains of causality to explain observations from deliberately designed experiments. Science's goal is the concise expression of the laws which govern the regularities of the universe. Ideally, these laws are expressed mathematically. Such laws or models derive their validity from the rigor imposed by the scientific method.

The scientific method has three main characteristics:

- Reductionism: the reduction of complexity under experimental conditions,
- Repeatability: the validation of experimental results by repetition;
- Refutation: knowledge building by the refutation of hypotheses through hypothesis testing.

The development process for the scientific method clearly depends on experimentation and the application of the theory of reductionism. From this perspective, science is both empirical and reductionist.

There are three senses in which science is 'reductionist' and important to the simulationist. In first sense, reductionism is ingrained in the way science has been practiced since Descartes published his *Discourses* [Eaton, 1927.] Science deeply absorbed Descartes's advice to break down problems into smaller and smaller

components and analyze them piecemeal, component by component. This breaking into separate parts is the central principle of scientific practice. All of this, however, rests on the assumption that dividing up the problems being examined into separate parts will not distort the phenomenon being studied. So, science is reductionist in method.

The second sense in which science is reductionist lies with the principle known as Ockham's Razor and its importance in framing scientific explanations. Ockham's Razor states: "when faced with competing explanations, accept the most simple." [Checkland, 1981]. Science, under Ockham's Razor, provides the minimum explanation necessary to explain the observations under consideration. Its importance stems from the fact that only one explanation or description can be minimum. Thus, application of Ockham's Razor results in the simplest model necessary to explain the observed phenomenon. In this sense, science is reductionist in explanation.

The third sense in which science is reductionist concerns observations and experimental data. Collecting data in the real world is challenging. The real world is messy, noisy, chaotic, and complex. To make coherent investigations, scientists simplify their tasks by selecting some items to observe and investigate out of all those items which could be observed. The designed experiment is a special type of observation inexorably linked to the scientific method. In designed experiments, the investigator seeks through reduction in the extent of his experiment, the complete control over the investigation. He does this so that the changes which occur are the results of his actions, rather than the results of complex interactions of which he is unaware. Simply, to define an experiment is to reduce the universe of observations. Therefore, science is reductionist in observation.

The other category elements are disciplinary partitions of modern science and engineering. They are the paradigms and the tool sets necessary to describe, explain, and explore observable phenomena. They are also more; they embody the worldviews, explanatory paradigms, validated models, and accepted doctrine of the different disciplines. Consequently, the Basic Skills Category provides the disciplinary reference, analytical methods, and explanatory power which are the basic building blocks for the simulationist to work with in the prevailing disciplinary paradigms.

The Basic Skills Category identified the following specific disciplinary threads of a simulationist:

- |                            |                       |
|----------------------------|-----------------------|
| • Probability & Statistics | • Operations Research |
| • Experiment Design        | • Project Management  |
| • Stochastic Methods       | • Cost Modeling       |
| • Mathematics              | • Cost Engineering    |

- Physical Science

The participants generally believed that these skills should be encountered through formal classes or disciplinary integrated programs (i.e. subjects encountered in more than one class). This category reflects a belief that an ideal simulationist requires a strong education in a science or engineering curriculum. The uniqueness in this set is the emphasis on the mix of traditional (i.e. hard) science areas (e.g. math and physics) and operations/human activities (e.g. organization, planning, scheduling, managing and costing).

Traditional science provides the skills to observe phenomena, describe it, represent it, model it, categorize it, gather it, analyze its data, and developed associated inductive and deductive knowledge. More importantly, traditional sciences represent disciplines that arose from and were firmly anchored in the application of the scientific method to provide explanation of the physical phenomena.

The operations/human activities area reflects the workshop's participant belief that the ideal simulationist requires skills to address problems of managing time and resources within constraints. Moreover, 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. Thus, the emphasis placed by the workshop's participants on the Basic Skill threads of project management, economics, and cost engineering.

High levels of computer competency and all it implies is mandatory for the simulationist because of modern simulation's dependency on computer technology. For current simulationists, computer software is the principal target media for representing a model and computer systems are the cosmic engines of the model's universe. To these reasons, the workshop participants believed a simulationist must know, to a "sufficient" level of competency, how to use computer operating systems, high level programming languages, simulation languages, spreadsheets, wordprocessing, presentation packages and data bases. Additionally, the simulationist must be more than a cursory users of software packages. An ideal simulationist has studied and understands basic principles of data structures, algorithms, and software engineering. Specific current areas of topical importance to simulationist include object-oriented programming and distributed/parallel processing.

### 3.4 Modeling

- *Model builder.*

- *Conceptualization---high level tools provide a framework and vocabulary*

- *Empiricist.*
- *Appreciate the capabilities and limitations of experimental methods.*
- *Ability to use abstraction, look at system from different perspectives*
  - *Using different perspectives to map to simulation "world views"*
  - *Adjusting level of abstraction to achieve proper degree of fidelity*
  - *Tradeoff in cost/level of detail/effectiveness*
  - *Retain clarity of causality where warranted*
- *Ability to use various paradigms in building models*
  - *representational form can be critical in the expression and communication of concepts.*
- *Model human, physical and hypothetical systems*
- *Feasibility assessments*
  - *Cost-benefit considerations and risk analysis.*
- *Knowledge engineering*
  - *Understand data gathering and validation techniques and structural relationships.*
  - *Linking analysis techniques to presentation methods and media.*

The Modeling Category may be the most important and pivotal category for the establishing the ideal simulationist. At the same time, the Modeling Category is the most "problematic" category with regards to the workshop participant's responses. The elements of this category refer to concepts, ideas, and methodologies that are contextually sensitive. Their meaning, importance, and application can vary with how and why the model was created, as well as, with the degree of objectivity and subjectivity associated with a particular model. As such, the category's elements refer to factors and issues that are pertinent within a continuum of model types and modeling issues. Recognizing and understanding the elements within this reference of multiple model types is primary in establishing the importance of modeling to the simulationist, as well as, identifying the model knowledge and modeling skills required of the ideal simulationist.

Part of the problem associated with discussing the Modeling Category is the semantics of models and modeling. While no attempt was made during the workshop to build a consensus definition for model, a starting point that most of the workshop participants would probably agree is "a model is something used in place of something else". Beyond this, agreement may breakdown. However, for the needs of this discussion it is necessary to narrow the definition further. Based on the previous review of the scientific method, for these

discussions, a model is: "a representation of a system or phenomenon that is associated with any hypotheses required to describe the system or explain the phenomenon." (While generally neutral, this definition is still certainly potentially contentious.)

Models of the scientific method are minimal explanations of the observations of a designed experiment composed of the simplest possible components of nature under the complete control of an investigator trying to disprove a specific hypothesis. Models, consequently, are the essence of reductionism and are endemic to science and the scientific method. In this context, models should be characterized and considered in some minimalist criteria with respect to its referent phenomenon. Therefore, models should be made up of: the minimal elements which make up the whole (constituents), the minimal structure of the constituents in the whole (composition), and the minimal processes introducing the dimension time (interactions). The only additional point to be made here is that minimal has meaning only with respect to some objective or purpose (e.g. the hypothesis under consideration). The two criteria of 1) minimum in constituents, composition, and interaction and 2) created for some purpose or objective, establish the fundamental standard for all models and model types.

After the fundamental criteria, the most important question of modeling and models is: When is a constituent, composition or an interaction so significantly involved in the phenomenon of interest that it warrants inclusion in the model? The Principle of Ockham's Razor coupled with designed experimentation provides, at least in theory, the principle and mechanism to answer this question. (If the model does not explain the phenomenon, a constituent, composition, or interaction is added until the model explanation is consistent with the designed experiment's observations). It is important to remember that the tradition and roots of the scientific method are grounded in the discovery of fundamental laws of the physical universe. Specifically, the scientific method's designed experiments, are to be carried out in the real world on real elements. The success of this approach is predicated on the investigator, through reduction, maintaining complete control over the variables and environment of his experiment.

Of course, the real phenomenon of interest may not be available, or may be too expensive, or may be too complex, or may be too dangerous to use in a designed experiment with the extent of control required to rigorously and iteratively apply the Principle of Ockham's Razor. Such situations require relaxing the rigor of the scientific method's designed experiment. Rigor relaxation affects the degree of control of the designed experiment and the concept of minimal

observation. In this sense, the designed experiments move from the highly controlled idealized environment of the laboratory to less controlled environments of somewhere else. In these situations, science stills tries to discover the laws associated with the observed phenomenon and the scientific method is still the basis for discovery of the underlying laws. What is different from the designed experiments of the strict scientific method is the uncertainty introduced in the observations. The challenge is how to use these observations to create a model which meets the two criteria of the fundamental standard for models. In such situations, data parsimony (i.e. reduction to level of usefulness but not beyond) to meet the fundamental standard may be realized through technique or human interpretation [Flood and Carson, 1988]. Such techniques and interpretations are often referred to as data filtering.

Data filtering is the root concern of many of the elements identified by the workshop participants in the Modeling Category. It is important to note, however, the workshop participants were much less concerned with the *techniques* of data filtering (e.g. mathematical tools, statistical, pattern recognition, clustering analysis). (This could be because many of the data filtering techniques were identified in the elemental threads of the Basic Skills Category). Most data filtering concerned human interpretation. This can be attributable to the belief that while many techniques are available and used in data filtering to support data parsimony, the investigator, both consciously and unconsciously, intuitively performs data filtering---sometimes a little, sometimes a lot.

Intuitive judgments are inevitable even in the strictest sense of the scientific method. Consider the formulation of a conceptual model (i.e. conceptualization). The conceptual model provides an account (often in narrative) of what the components must do in order to explain the observations. During conceptualization, both constituents (i.e. complexity) and composition (i.e. structure) are largely determined [Flood and Carson, 1988]. A number of assumptions (i.e. judgments) must be addressed during conceptualization including aggregation (the extent to which different components are lumped into a single entity), abstraction (the degree to which certain aspects are considered in a model), and idealization (the approximation of structure and behavior when observed structure and behavior is difficult to describe). The investigator must make personal judgments about the constituents, composition, and interactions of a model.

An important point must be remembered: The choice of significance, while often made by human judgment, is not arbitrary. The choice still must satisfy the standard criteria for models and explain, in a chain of causality, the observations. Repeatability still must be satisfied.

Objectively proving satisfaction of the standard criteria, however, becomes more difficult as the uncertainty in the observations increases and the data filtering depends more on human judgment.

So far, discussions have centered on models to explain natural laws of the physical universe as derived from the scientific method. Other elements and elements aspects identified at the workshop pertain to models associated technology's purposeful creation of things. Specifically, models associated with engineering, operations research, training, and entertainment. While the standard reference for such models are based in the scientific method, these contexts reflect different aims and purposes of models.

The strategy of engineering is to obtain (or develop) a model of the process, system, or object concerned. The model in which the overall performance is expressed in some explicit measures of performance. The engineer improves or optimizes the model in terms of the chosen performance criterion. This evaluation of improvement is done through experimentation on the model. The engineer applies the same standards for designed experiments of the scientific method to experiments conducted on his engineering models. Finally, the engineer attempts to transfer the solution derived from the model to the real-world situation. This is an heroic attempt to be scientific in the real-world (as opposed to the laboratory) and the difficulties are great. The strategy obviously requires the model to be shown to be valid.

Not surprisingly, the defining characteristic of engineering and other applied science disciplines are the validated models each claims as their own. Most of these models arose from physical laws validated through the scientific method. But not all models of the applied science disciplines meet this requirement. Many are heuristics and simply standard practices that are accepted as part of a discipline's model set and do not meet the rigorous standards of the scientific method. In the applied sciences, data filtering most often consists of matching observations or conceptual situations to the models of the discipline of the specific engineer or applied scientist.

Human interpretation in applied science modeling building efforts is different from the modeling building of the scientific method. In the scientific method of modeling building, human judgment is used to provide hypotheses for the components and structure necessary to explain the observed phenomenon. Science is concerned with why. In applied science modeling building, human judgment is used to provide hypotheses of which validated or accepted models match the observed phenomenon and then use the knowledge from science to achieve some desired manipulation of the physical universe (e.g. cure polio). Applied science is concerned with how.

As an applied science, engineering extends the concern with *how* to hypothetical phenomenon or systems. That is, models for referents which do not yet exist anywhere except in the modeler's or engineer's mind. Here human judgment is almost exclusively used to select component models and model structure. Such model's validation are often described by terms like face validity, standard engineering practice and reasonable performance. The engineer's design, while guided by the laws of science, are initially mostly matters of human judgment. The analysis and experimentation of the engineering approach brings the rigors of science into the process and contributes to eliminating design errors and uncertainty.

As the elements of the Modeling Category reflect, the ideal simulationist requires a range of modeling perspectives and skills most of which can only be described as qualitative or judgmental. Currently, achievement of these abilities are primarily attributable to experience. Some techniques and methodological tools do exist to support the simulationist in certain tasks and aspects of modeling. However, as currently practiced, most of abilities identified in this category by the workshop participants are intuitive and are, at best, developed in apprenticeship environments and, at worse, in sink or swim job assignments. There appears to be little conscious effort to develop these abilities in individuals and their emergence at all appear to be rather happenstance. Yet, the workshop participants identified mastery of the issues surrounding modeling as one the key determinants of an ideal simulationist.

### 3.5 Systems Approach

- *Define the problem.*
- *Systems perspective to identify critical items of the systems (what to include in model).*
- *Determine correct level of abstraction.*
- *Develop a functional specification of the model.*
- *Apply a systematic approach to analysis*
- *Possesses assessment heuristics (sanity checks, cause and effect) to insure reasonableness.*

The systems approach refers to a set of closely related methodologies which attempt to select an efficient means of achieving a known and defined goal. A large number of system methodologies have been proposed under the general headings of systems analysis, systems engineering and operations research. Typical is the method consisting of the seven steps of 1) problems definition, 2) selection of objectives and performance measures, 3) generation of alternative solutions, 4) systems analysis, 5) optimization of alternatives, 6)

decision making, and 7) implementation [Flood and Carson, 1988].

Although founded on the tradition and principles of the scientific method, the systems approach is, in one sense, its complement. While the scientific method's focus is on understanding of the universe around us, the systems approach's focus is on creating something in the universe for a purpose or goal. The systems approach starts from an organizational definition of systems as a complex grouping of objects and/or phenomenon for which there is an overall objective. The system approach then selects the system which will achieve the goal. Science establishes a rational explanation for observed phenomenon. Reductionism and empiricism underpin the scientific method. Emergence and hierarchy underpin the systems approach.

Emergence assumes the existence of "emergent" properties which appear only when certain levels of complexity in nature and systems are reached. Emergent properties cannot be reduced in explanation to lower levels of complexity. In the other words, the whole is greater than the sum of its parts. The concern is with wholes and their properties. Hierarchy looks at phenomenon in terms of the fundamental differences between one level of complexity and another.

The ideal simulationist is expected to be able to effectively apply the systems methodologies to the range of problems which he encounters. What is heavily implied for the simulationist is the importance of understanding the life cycle of a model or simulation and that a simulation is a goal oriented system that is typically part of some other system with higher order but different objectives. All systems methodologies reflect some variation of this theme. Another issue in the Systems Approach Category is the consideration of complexity as a confounding factor in understanding the real-world phenomenon. Specifically, the simulationist recognizes the implications of the concept of emergence and hierarchy when trying to model phenomenon.

### 3.6 Human Factors

- *Understanding Human/Computer Interaction Including: Sensory perception and limitations for key senses such as haptic, visual and aural; appreciation for the psycho-physiological factors involved in derivation of perception and creation of meaning.*
- *Understanding of Cognitive Representation: That is, Artificial Intelligence (e.g. knowledge representation, expert systems, logic methods, planning, symbolic reasoning and cognitive science.*

- *Understanding of Behavioral Representation for individuals and groups*
- *Interpret and present results deriving meaning through techniques including data reduction, visualization and other sensory methods.*
- *Understanding of Ergonomics*

The concern with the Human Factors category falls under two considerations. First, the simulationists should understand the issues and difficulties in modeling both individual and group human behavior. This may be thought of understanding the problems more than knowing how to solve it. The second consideration involves the Human /computer interface with the simulation. This includes issues of data representation and man-in-the-loop issues. Generally, this issue recognizes that humans may be a user of simulation, a part of the simulation itself, or both and that human factors and ergonomics are important considerations for these humans. The ideal simulationist is expected to be aware of both considerations, as well as, conscientious about addressing human factor related issues.

### 3.7 Domain Knowledge

- *Experiential education (e.g. on-the-job, internship, cooperative education, exchanges, etc.)*
- *Sample Domains: (e.g. Medical systems, Legal systems, Social systems, entertainment systems, military systems. business and industrial systems). NOTE: exposure of simulationists to various domain uses and interests as well as exposure of domain experts to nature and use of simulation.*
- *Domain and technique interaction*
- *Bring simulation support to the domain expert.*
- *Important concept: only the domain expert can judge domain-specific assumptions.*

The simulationist should have knowledge of the domain with which he working. However, if the simulationist is part of team, the domain expert must provide the judgment of domain assumptions.

### 3.8 Simulation methods

- *Aware of the broad perspective of simulation methods and can do one or two areas well.*
- *Integrate new technologies with simulation where appropriate.*
- *Translate current knowledge to new and unique applications.*
- *Knowledge of current simulation and modeling tools and their appropriate use.*

The workshop participants recognized the extensive range of simulation technologies and methodologies associated with the equally broad range of domains and applications with which modeling and simulation is used. The participants saw no need to declare one method superior to another. What was deemed important for a simulationist was that he knows of the breadth of methods and, as a practical case, they use well one or two methods within the limits of the methodologies.

#### 4 DISCUSSION

The elements of the ideal simulationist in the categories of Attributes, People Skills, Basic Skills, and Domain Knowledge are typical of those identified for any ideal engineer or applied scientist. Indeed, one can conclude from these results that the an ideal simulationist begins as an engineer or applied scientist. Moreover, if a cursory interpretation of the other four categories were used, then most engineers and scientists could claim to be simulationist for most could claim the necessary breadth from their undergraduate education. Most are heavily exposed to models, have a nodding to extensive exposure in systems approaches, have been admonished to recognize the human component of technology and science, and have experienced the use of some form of simulation. However, clearly from the narratives, a simulationist requires more depth of knowledge and experience than suggested in this interpretation and, actually, much greater breadth.

Specialize knowledge and, particularly, direct experience were emphasized by the participants as essential characteristics of a simulationist. Also emphasized was a breadth of knowledge across disciplines, worldviews, learning systems and organizing paradigms. Acquiring the experience and the breadth of knowledge is left to the individual much like lost explorers each blazing their own trail through the wilderness to a new civilization. The ideal simulationist identified must rely on singularly acquired experiential knowledge and apply it generally to new situations as they arise. The workshop participants reflected this in many comments. There is little science in this aspect of a simulationist and much art and luck. He is, in effect, asked to form his own rules of nature and apply them to new situations. Further, the simulationist is asked to assimilate polar concepts. The simulationist must be a seeker of knowledge and solver of goal directed problems; he must be a reductionist and an integrationist; he must be an experimenter and a theorist; he must design the structure and then build it; he must have formal education and serve an apprenticeship.

Checkland [1981] states: "It is characteristic of the engineering world that principles should be learnt from experience and grasped intuitively long before they are codified and expounded." This would also appear to characterize simulation and the simulationist. The questions of concern, then, at this point are: Is there a sufficient body of knowledge and critical mass of experience to codify and expound which can lessen the dependency on experience and intuition in the creation of a simulationist? If so, what is it and where is this being done? If not, how will we know when it is sufficient, if ever? Perhaps even more importantly, the efforts of the workshop raises the more fundamental question of: Do simulationists really exist and are they even needed?

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