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Education on Conceptual Modeling for Simulation- Beyond the Craft: A Summary of a Recent Expert Panel Discussion

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Education on Conceptual Modeling for Simulation – Beyond the Craft: A Summary of a Recent Expert Panel Discussion

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1 INTRODUCTION

Until a few years ago, conceptual modeling (CM) for simulation received little attention within the Modeling and Simulation (M&S) community. In recent years, however, the subject has become part of a mainstream academic debate. This is indicated, for example, by a special issue of the Journal of Simulation in 2007; by the first book to provide a comprehensive view of the current state-of-the–art in CM written by an interest group (Robinson et al. 2010); and in dedicated sessions at conferences (for example, the Winter Simulation Conference 2006-2008, 2010, and the OR Society Simulation Workshop 2006-2010).

This progress in research on CM has implications for CM education. One of the first books written about discrete simulation was The Art of Simulation (Tocher 1963), and its title indicates the prevalent view of the day. If this view that simulation modeling is an art is still widely held, it implies that simulation educators need to be experienced craftsmen and women who can pass on their skills to neophytes. These required skills are wide ranging. Thus, authors of simulation texts (e.g. Law 1991), require the analyst to bring together domain specific knowledge and insights, starting from multiple disciplines, especially operations research, statistics, engineering, and computer science. Furthermore, modeling activities are framed within the specifics of a business, military or organizational context (budgetary constraints, resource availability, time frame etc.) and (possibly conflicting) stakeholder interests. Clearly, this places high demands on the analyst's skills. Unsurprisingly, current CM teaching practice seems to rely largely on a teacher's own experience rather than the general availability of adequate means (course/project formats, text books, case examples etc.). Many textbooks at best give a basic entry on CM, but offer little detail and no exercises. Also articles on education for CM are few.

These observations on CM education underpinned a panel session at the 2010 Winter Simulation Conference (Van der Zee et al. 2010). Here, we summarize the panel discussion, as a contribution to the *development of a research agenda on conceptual modeling, with a special emphasis and education of M&S core skills.*

As in the WSC panel, this paper asks whether it is possible to adopt a more systematized approach to teaching and learning in conceptual modeling for simulation. It recognizes that an education in conceptual modeling requires hands-

on experience as well as attendance in classes. Thus, any systematization should aim to enhance the learning that occurs, by providing appropriate methods and by enabling students to appreciate where best to focus their efforts in conceptualization. It also must be rooted in the M&S Body of Knowledge and, where necessary, extend it accordingly. This suggests a neat blending of art and science across potentially many contributing discipline, which would be no surprise to any experimental scientists in other domains. It recognizes, too, that there are different requirements for large, very expensive models that may be run frequently over an extended period (e.g. in defense), compared to quickly developed models designed to address a particular issue (e.g. in business organizations).

As an introduction to the subject addressed by the panel we define conceptual modeling, and address its relevance for simulation study success. Next, we report on the panel according to its topics, i.e.,

(i) requirements for good education on CM,
(ii) an assessment of the current practice,
(iii) suggestions for improving education on CM, and
(iv) tasks for the M&S community in improving education on CM.

The paper is not meant to replace the position statements of the experts published in Van der Zee et al. (2010) but summarizes the highlights of the panel presentations and the subsequent discussions with the audience that extended the viewpoints and also raised some concerns on where we are and where we need to go. As such, we are not intending to give solutions, but we are contributing to a research agenda on the general challenges of conceptual modeling, and, specifically, on the type of education needed to enable high quality conceptual modeling. Interested readers are very welcome to engage in this discussion.

2 CONCEPTUAL MODELING – A BRIEF INTRODUCTION

In defining conceptual modeling for simulation, its outcome, i.e., the conceptual model, and essential qualities of a conceptual model, we rely on a recent work by Robinson (2008). Remark, how the M&S community does not unite on these definitions. However, literature reviews underlying Robinson's choice of definitions suggest significant adherence within the M&S community. For further details see Robinson's references.

In Robinson's view conceptual modeling for simulation, boils down to a process of abstraction in which essentials of a real or proposed system are captured. Outcomes of his literature review further typify conceptual modeling as:

- being about moving from a problem situation, through model requirements to a definition of what is going to be modeled and how.
- being iterative and repetitive, with the model being continually revised throughout a modeling study.
- concerning both perspectives of the client and the modeler.

The outcome of conceptual modeling is the conceptual model, i.e., *"a non-software specific description of the computer simulation model (that will be, is or has been developed), describing the objectives, inputs, outputs, content, assumptions and simplifications of the model"* Robinson (2008). In turn, conceptual modeling boils down to detailing aforementioned elements of the conceptual model. In all observed examples, conceptual modeling is understood as an iterative process of selecting importing elements, attributes, and behaviors combined with abstraction and simplification thereof, resulting in a structure that can be shared and communicated within a simulation team.

Typically, the conceptual model may be presented as a project document, marking an initial decision on project contents. For denoting model contents (structure, scope and level of detail) the analyst may rely on several (non) formal (diagramming) techniques, see for examples Robinson et al. (2010). The modeling exercise itself may be supported by modeling principles (advocating evolutionary model design), model simplification, and modeling frameworks, see for examples Robinson et al. (2010). Here a modeling framework provides a series of steps that guide a modeler in developing

a conceptual model. Others emphasize the future need for formal conceptualizations that allow for support by agents or other software means (Balci & Ormsby 2007, Tolk & Turnitsa 2007)

One of the results of the panel discussion was that the M&S community is still looking for a broadly accepted definition. While Robinson (2008) without doubt reignited the discussion about conceptual modeling challenges and education, we are still faced with several definitions that are not too well aligned. In the discussion, the paper of Pace (2000) that gives a good overview of different views of what a conceptual model is, was mentioned. The more restricted view on conceptual modeling expressed in some discussion contributions pointed out that the primary function of the conceptual model should be to serve as the *mechanism by which user requirements are transformed into detailed simulation specifications that fully satisfy the requirements.* In particular members of the Validation and Verification community were in favor of such a restrictive viewpoint.

The resulting definitions of a conceptual model still cover a significant spectrum of possible specifications, ranging from informal collections of solution proposals and constraints platform independent via formal specifications of conceptualizations to simulation specifications. Without doubt, however, conceptual models are on the threshold between the conceptualization efforts of the modeling phase and the implementation efforts of the simulation phase, and the borderline between these phases is not well defined. As shown by Tolk and Turnitsa (2007), several layered models do exist that try to capture how to bridge the gap between conceptualization and implementation efforts.

Clearly, next to the specifics of the organizational context, success of the simulation study builds on the qualities of the conceptual model. Essential qualities of a conceptual model concern validity, credibility, utility and feasibility (Robinson 2008). The first two qualities refer to the accuracy of the model given the purpose at hand, being considered from the perspectives of the modeler and the client. Utility refers to the model's support, given the decision to be made. Finally, feasibility considers whether to build the coded model, starting from the conceptual model, with the time, resources and data available.

3 REQUIREMENTS FOR EDUCATION ON CONCEPTUAL MODELING

The ongoing efforts on identifying the Body of Knowledge (BoK) of M&S, which is understood as a comprehensive and concise representation of concepts, terms, and activities is needed that make up a professional modeling and simulation domain, show the need for multifaceted and multidisciplinary approaches for education in M&S, including the education on conceptual modeling. Several disciplines and domains contribute to the foundation of M&S, such as:

- Software Engineering
- Differential Equations
- Systems Dynamics
- Probability and Statistics
- Quality Assurance
- Validation and Verification
- Operations Research
- Systems Analysis and System Science
- Project and Risk Management
- Artificial Intelligence and Heuristic Optimization
- Parallel and Distributed Computing
- Computer Graphics and Visualization
- Gaming

As mentioned in the last section, several of these disciplines and domains already have a definition of what a conceptual model in their view should be, and these definitions are not unambiguous. To understand the requirements for education on conceptual modeling, the underlying question that needs to be answered first is how the resulting conceptual model will be used for. The different researchers have disparate definitions, which necessarily creates confusion about how and what to teach.

The recommendation given by the panel was to start with a pragmatic approach and embed conceptual modeling into the life cycle, as recently proposed by Balci and Ormsby (2007). Figure 1 shows the approach. This viewpoint places the conceptual model in the final stage of

the conceptualization or modeling phase that needs to take place before the simulation model design starts.

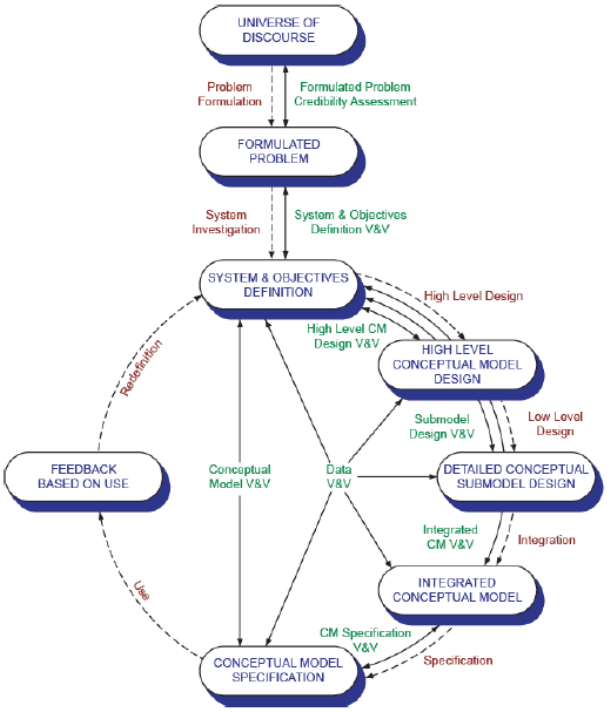

Figure 1: Conceptual Modeling in the Life Cycle (Balci & Ormsby 2007)

In the discussion, alternative views were articulated, like the use of conceptual models to capture the high-level model design as well as using the artifacts of the Unified Modeling Language (UML) or alternatively the System Modeling Language (SysML) to represent the conceptual model. As before, the wide spectrum of valid viewpoints could be observed.

However, we could reach sort of consensus that it makes no sense to define conceptual models and the education thereof exclusively for M&S. Other communities of interest and communities of practice successfully apply similar and comparable ideas to communicate formal specifications of conceptualization that not only assist in the final design, they also enable reuse of systems and components and their integration into a bigger context.

The focus on education may therefore better be understood by the objectives enabled and supported by good artifacts that make up the conceptual model. The following objectives were proposed by the panel and extended within the discussion:

- Assist in designing a solution to contribute to a solution in the problem domain.
- Enable reusability and composability of the solution.
- Enable effective communication with the project team as well as with future project teams (reuse).
- Assist in overcoming – or at least assist in managing – the complexity of solutions.
- Provide a formal basis for integration support (including agent based integration).
- Assist in verification and validation of solutions and their integration.

This viewpoint on focusing on the objectives of conceptual modeling was also supported by practitioners' statements on the panel as well as in the auditorium during the discussion. They observed that novices never know how to build a good conceptual model in the beginning, as their focus quite often is on replicating their perception of the real world. Instead, M&S projects should focus on providing a solution to the customers' problems, and the models and resulting simulations are mere means to support this goal. Consequently, the focus should be the problem structuring with the objective to understand and improve the underlying processes.

If problem structuring is supported by rapid model building, the results can aid an iterative process improvement better than "overdesigning" the solution before executable solutions are produced. In this view, conceptual modeling should support these iterative improvements, but is sometimes perceived to be in the way and blocking the process (Figure 2).

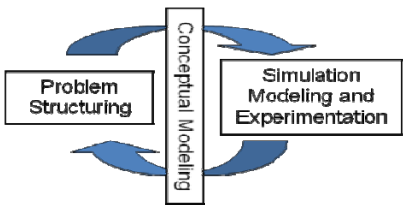

Figure 2: Conceptual Modeling and Iterative Process Improvement

This viewpoint focuses on the need to support the processes of simplifying and abstracting the perceived reality based on a better understanding of what is needed to support the customers' decision. As such, the role of the conceptual model is not limited to the project team, but it is used to inform the client.

The viewpoints represented during the panel are hardly alignable, as the objectives seem to be often antipodal: Shall we capture high-level concepts or focus on simulation model designs? Shall we focus on reuse of solutions or the specific support of a very particular research questions or customer request? Do we require formal consistency or support conceptual modeling as a free art form? Depending on where the reader stands regarding these different viewpoints, he will have very different answers to the question of requirements. Although the panel was not bale to unify the viewpoints, at least the focus on objectives and how they can be used guide different ways of conceptual modeling, was shared.

4 ASSESSMENT OF THE CURRENT PRACTICE

To be able to assess the current practice on conceptual modeling education we do not only need a definition of the term and the underlying processes, activities, and interim results, we also need a set of metrics. Such a set of metrics is currently not available and likely not to be agreed on for the foreseeable future. However, some general observations were discussed during the panel discussion that have the potential to contribute to what hopefully will become the foundation for future evaluation. The first obvious observation is that we do not have a clear picture on conceptual modeling and the education thereof in the M&S literature, and the panel members and discussion partners in the auditorium were in particular not aware of any good textbooks on this topic. Even the recently published book by Robinson et al. (2010) is more a compendia than a textbook.

The reason behind this is that we observe another inversion of theory and application: we have several methods that support conceptual modeling as a tool application, but we did not yet establish a common theory on conceptual modeling. It may be of interest to evaluate the different approaches supporting conceptual modeling and identify common underlying concepts, relations, and processes by research towards theory building, but such an effort is still to be conducted.

One reason may be that the focus of current M&S curricula lies more on learning how to implement the simulation, and not so much on all the steps that have to be conducted in the process of modeling the conceptualization to be implemented. In discussions on this emphasis on simulation it becomes often clear that modeling is sometimes perceived to be more of an art form while simulation is understood as applying engineering methods to make the thing work. This should not diminish the importance of all required implementation knowledge, reaching from good programming skills to parallel program understanding and the awareness of network and infrastructure challenges, but the modeling part is as important for an M&S engineer as the simulation part is. However, in the current education mastering the simulation software and its modeling support seems often to be perceived sufficient.

While in the domain of engineering the phase of conceptual engineering is valued as a necessary step in systems engineering, conceptual modeling is not necessarily perceived to produce something that is useful. This mindset needs to change.

Finally, in order to access the current practice, the philosophical foundations need to be firm. As pointed out in Tolk (2010), the ontological (what do we know), epistemological (how do we gain knowledge), and teleological (how do we act on the knowledge) foundations are missing and not part of the curricula, but such philosophical underpinnings are mandatory for establishing M&S as a discipline of its own. The education on conceptual modeling must be rooted in and contribute to this foundation, as it clearly has the potential to become pivotal regarding ontological and epistemological foundations of M&S.

In the discussion on where we are it was observed that although we say M&S we often still only mean simulation. Modeling remains a lip service, and as conceptual modeling builds the final step of capturing the results of the modeling process as a formal specification of the resulting conceptualization, it is often excluded as well. Some even perceive modeling as a not teachable art form that hopefully comes with experience. If taught, the focus is often on the application of various modeling paradigms and the appropriate use of tools. This cannot be sufficient.

Where we want to be, is that modeling is recognized as one of the major characteristics that distinguishes M&S engineering from computer engineering for simulation. To reach this goal, modeling must become an integrated process resulting in valued and useful artifacts; it needs to be based on a philosophy of M&S engineering, comprising ontology, epistemology, and teleology of M&S; and it needs to be specified by implementation independent methods derived from a common theory. All these are currently open requests on the research agenda, but the discussion showed that these challenges are perceived as gaps that need to be closed by the M&S community.

5 SUGGESTIONS FOR IMPROVED (USE OF) EDUCATIONAL MEANS

The next topic of the discussion panel focused on to identifying areas of improvement in education on CM. From the discussion so far it became clear that the panel and audience would not reach conclusive ideas about the basic concepts of CM, such as “what is conceptual modeling?” and “what level of CM is needed?” Nevertheless, it was suggested that in terms of education two main aspects require the attention of the simulation community: the content that should be taught as part of CM (what) and the teaching methods (how). These two areas of improvement will be the focus of this section but with most of the insights and discussion focused on the ‘how’.

With respect to the content of education on CM (what), it was argued that a transparent teaching syllabus should be agreed. Some of the topics suggested as suitable for inclusion are:

- The stages of CM.
- The process and tools that can be used in each stage of the process to reach the conceptual model.
- One or more formats to represent the conceptual model.
- How to involve and communicate the conceptual model to the client(s), and
- How to ensure conceptual model validity.

Undoubtedly any teaching curricula would benefit from inclusion of the above topics, assuming that the research supporting these topics is fully developed. As there are still many views on these topics our arguments will focus on how to communicate these topics to students. What seems to have transpired so far is that these topics could be communicated through text books (e.g. Robinson 2004) but other suggestions were put forward during the panel discussions such as the PartiSim Conceptual modeling toolkit.

The PartiSim CM framework (Tako et. al, 2010) was highlighted as a new product available to M&S community that could be also useful for teaching CM. It provides a structured and participative approach to undertaking conceptual modeling by engaging with the clients in facilitated workshops. This recently developed product consists of a paper based toolkit, including a user guide and manuals to assist the CM process. It borrows tools (as they are or adapted) from Soft Systems Methodology (SSM) (Checkland 1999), building on the existing body of work that promotes the use of problem structuring methods as a means of abstracting and identifying the problem modeled (Pidd 2007; Kotiadis and Robinson, 2008). Although text books are an established approach to disseminating knowledge, students may also respond to other forms such as a document (or collection of documents) that an academic might describe as a practical guide to CM i.e. written in a non-academic mode. Although the example of PartiSim was put forward in this panel discussion, other such developments in the M&S community were encouraged.

Moving on to improving the methods used to teach CM, the focus turned on to finding ways of making it more appealing to students. In this

respect, the personality and teaching experience plays an important role to inspiring the students and engaging them in an active learning experience. However, the use of innovative methods, such as use of case studies and videos, virtual learning environments and of practice exercises could also provide a motivating learning environment for students. The use of practical examples, would serve as evidence of the relevance and the added value of undertaking CM. As already mentioned, varied opinions were expressed by panelists and participants in the auditorium about how useful could the teaching of CM be for novice modelers (students), who have not had experience of completing a real simulation study. It was mentioned in this discussions panel that perhaps the best way to learn CM is that of "trial and error". However, making CM a more systematic process, by introducing transparent rules and tools, could help the process of undertaking CM, especially for novice modelers. The 21st century marks an era of a wider accessibility of computers and simulation software (Robinson 2005), where modeling is not always undertaken by expert simulation modelers. It is hence timely that common and transparent rules are set prescribing the art of modeling, for novice modelers to follow, ensuring that the right problem is modeled.

During the discussions it became evident that the M&S community does not hold a common perception of CM and consequently teaching of CM remains more or less isolated, depending on educators' views or experiences of undertaking CM. This discussion panel initiated an interesting debate on CM alone, which shows that perhaps education on conceptual modeling could benefit from further research and shared effort which could in turn shape education on CM in the future. Indeed improving the dissemination practice in the M&S community could help towards this direction. Some areas for improvement that the M&S community could consider include the following:

- Developing a teaching depository to share teaching materials, including case studies, examples of undertaking CM in practice, CM exercises, etc).
- Developing an open forum to share experiences of teaching CM.
- Organizing a special issue on CM and education.

These efforts would be helpful not only to set out a common perspective of education on CM, but it would also be especially beneficial for educators at the beginning of their teaching career.

6 WHAT SHOULD THE MODELING AND SIMULATION COMMUNITY DO?

Within the panel presentation and the following discussion, the group distinguished between fundamentals and required actions and tasks.

6.1 Fundamentals

It is important to recognise two fundamentals in this discussion. The first is that the issue of conceptualisation in modelling is not unique to the simulation community. Anyone wishing to develop a model to support understanding, planning and decision making must decide on the form of the model and the elements that it will include. This is rarely best done by diving straight into what seems, initially at least, appropriate computer software. The British academic, Ray Paul, has long been fond of saying, at conferences, 'Simulation is no substitute for intelligent thinking'. We can generalise this aphorism by insisting that keyboard and mouse skills are no substitute for critical thinking and analysis. Recognising this issue, Pidd (2009) defines a model as 'an external and explicit representation of part of reality as seen by the people who wish to use that model to understand, to change, to manage and to control that part of reality.' Chapter 4 of the same book is wholly devoted to a set of principles for developing appropriate and valid models, based on sound conceptualisation. These principles are not restricted to computer simulation.

The second fundamental is that it is hard to distinguish where conceptual modelling ends and detailed model implementation begins. It is tempting to distinguish these two as if they were wholly distinct, but experience suggests (see Willemain, 1995) that the two are intermingled, with

considerable iteration taking place between the two. Thus, rather than treating conceptualisation as a wholly separate activity, it may be better to keep in mind that it is one element in a system of activities that we often label as 'modelling'.

These two considerations suggest that, when designing courses to enable students to develop their conceptual modelling skills, it should be done in the context of other elements important for the successful development of a suitable model. This in turn raises the question of what we might mean by successful. It seems reasonable to assume, based on Pidd's definition of a model, that intended and actual model use are important considerations to which students should be exposed in their education and training. Given what has been learned about problems structuring in operational research, this in turn suggests that any conceptual modelling education must included explicit consideration both hard and soft approaches. Currently this might mean the exposure of students to approaches such as soft systems methodology (Checkland, 1981) and cognitive mapping (Eden and Ackermann, 2001).

6.2 Towards an Agenda – Identifying Tasks

So far, the M&S community at large put little effort in founding CM in science. Efforts in research, education and practice – as far as they are made explicit – seem to be more directed towards "making the coded model work", rather than stressing a structured (multidisplinary, domain oriented) approach towards (conceptual) modeling. Although efforts are put in conceptual modeling they seem to be largely unnoticed – also for the project customers. Starting from CM's relevance for project success, those people present at the panel session strongly disagree with this situation.

So, how to increase and direct our efforts – in an attempt to improve education on CM? A first issue to consider is the acceptance of CM as being an intrinsic and explicit part of the simulation project. This is not only true from the perspective of the modeler, but also from a stakeholder perspective. Increasing awareness is a first task here. This does not only refer to establishing CM as a research topic, it also refers to students and novice consultants being informed on CM. It even concerns stakeholders, given their relevant role in solution finding/creation and validation. Stressing the latter point may also help to avoid less productive modes in doing CM, according to which the analyst is the only one doing CM (and benefitting from it?).

A second task concerns the increase, direction, and combination of efforts on education in CM of those involved in the M&S community. So far efforts are scattered among disciplines (compare Sections 1, 3), domains (especially military, business), and practice (industry, consultants) and academia. This points at a great need for concerting efforts. Societies and interest groups may be instrumental in realizing this.

Finally, there is a need for creating a joint aim in building and certifying theory and standards for CM. This will require a coming together of researchers, teachers and industry, in rigorous theory development, being validated in empirical research.

7 CONCLUDING REMARKS

The expert panel discussion did not result in a common and final view on what conceptual modeling is and how education on conceptual modeling shall be taught. Nonetheless, it helped to shape the necessary ongoing discussions and clarified some of the different positions. It was recognized that we – as the M&S community – are still far away from a common view on what conceptual modeling should be and how different viewpoints can be aligned to contribute to a common theory of conceptual modeling. However, the discussions showed that there is a way forward by focusing on the applicable benefits of different approaches and identify where they can be mutual supportive and where we have real alternatives that are exclusive. This diversity does not have to be bad, as this allows evaluating really different facets of problems, but we need to gain a better understanding in order to overcome the current confusion. As such, the expert panel discussion was not an educational event presenting solutions and definitions but a common start towards a multifaceted under-

standing of conceptual modeling and how to teach solution oriented methods that support the academic growth of the discipline as well as the workforce in the emerging new discipline of M&S.

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