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# SIMULATION EDUCATION IS NO SUBSTITUTE FOR INTELLIGENT THINKING

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## ABSTRACT

This paper presents a critique of the current teaching practices of Simulation. We challenge the current view of simulation, to the extent that most textbooks' contents will be found to be secondary to the missing necessary primary material. We advocate that (simulation) education has four general objectives, which are to teach students how to *learn*, how to think *creatively*, how to *problem solve*, and how to be *professionals*. These four objectives of education may not be possible to teach. In the words of Oscar Wilde, "Education is an admirable thing, but it is well to remember from time to time that nothing that is worth knowing can be taught." So an education in simulation requires that students be put into learning situations that enable them to learn the requisite knowledge concerning the four objectives. Who can provide such an education? Universities?

## 1 CURRENT SIMULATION EDUCATION

Simulation is sometimes described as a method of last resort, or as an art. Indeed one of the earliest and best books ever published was the pioneering Keith Tocher's "The Art of Simulation" (Tocher, 1963). And yet if you look at most textbooks on simulation, one could ask the question "why do we teach simulation as science?" We propose four general objectives of simulation education. The first objective is to teach students *how to learn*, so that the published body of knowledge can be accessed (but not necessarily believed! For example, how does one give a student an insight into the irrelevance of most of the statistical techniques described in simulation textbooks?). The second is to *think creatively* in order to determine choices, (what-if approaches require thought as to what the "whats" are) estimate problem scale and benefits (is the activity worth pursuing at all) and the general desirability of proceeding (model size should be determined by parsimonious necessity, not potential contract increases). The third is *to problem solve*, which at some stage will require the abandonment of the model (customers do this anyway, analysts are recommended to keep up with them). The fourth is *to be professional*, which leads to the need to understand something of ethics and morality. The latter have potential pitfalls in that customers offering large sums of money to attempt the impossible are rarely turned away by consultants, academia et al.

More detailed descriptions will be given later about our suggested objectives. However, before we set out our vision of simulation education we will provide a critique of the existing text books and how they fall short of achieving the educational objectives, here in the rest of this section.

We shall select one textbook as an exemplar, Averill M. Law and W. David Kelton's widely used book "Simulation Modeling and Analysis", which may well be the best selling textbook of the day and even of all time. The book is now in its Third Edition, with new editions appearing regularly every 9 years (Law and Kelton, 2000). The book has solid chapter titles invoking images of rigor, science and solutions:

- Modeling Complex Systems
- Building Valid, Credible, and Appropriately Detailed Simulation Models
- Random-Number Generators
- Variance-Reduction Techniques, etc.

No doubts here about the ability to problem solve. And Law and Kelton are not atypical in their approach, in fact so good are they I recommend the book to my own students.

Why do they write their material in the form of such chapters? The answer is in section 1.7 of their book, in a section called "Steps in a Sound Simulation Study" (pages 83-86) from which Figure 1 is reproduced below.

Law and Kelton (2000) provide a description of this process, summarized here: step 1 is defined as *problem formulation* which is mainly about setting the objectives of the study and the specific issues to be considered.

Resources available for such a study should also be considered. The second step in Table 1 is *data collection*. Data is collected if it exists based on the objectives of the study (Law and Kelton 2000). Validation of such data is step 3. Law and Kelton (2000) suggest that data collection should correspond with developing the conceptual model. After data is validated then step 4 is entitled *constructing a computer model*, which meant to is based on the conceptual model. After that comes a *pilot run* in step 5. Step 6 is the conducting of *verification* and *validation*.

Steps 7 through 10 are design of experiments for defining the different alternatives for experimentation, production runs for providing performance data on systems designs of interest, output analysis which consists of statistical techniques for analyzing output from production runs, and implementation of a model's findings.

## 2 MY EXPERIENCES WITH SIMULATION

As a young academic, approaches such as that outlined in Figure 1 were rational, tidy and convincing to teach. The students, with marginally less experience than me, also appreciated the elegance of the steps that take you to 'results'. There is a warning in the last two sentences of page 83: "Note that a simulation study is not a simple sequential process. As one proceeds with the study, it may be necessary to go back to a previous step."

And then as I started practicing simulation consultancy, those two sentences became a darkening shadow over this tidy approach, so much so that I started to research into simulation. With practical experience, I have found that the tidy description was completely irrelevant, if not a fantasy. Table 1 shows my revised 10 steps based on figure 1, with modifications made based on experiences gained from my consultancy work.

Vignette **A**: *data*

I collected 5 digit data on sulfuric acid consumption at each pit in a mining company. Five digits, obviously great accuracy. I went to a pit. I looked for a meter on the acid tank. There was none. A pit worker got on top of the tank and with a large poll measured the height of the acid in the tank. This gave an approximate measure of the tank contents, which when adjusted against the last measurement, gave a difference in 5 digits that looked spuriously accurate.

In my experiences, simulation is resorted to because the problem is not well understood. So I assume my knowledge of the problem is wrong and I use the 10 steps as a debating device with the problem owners. Constantly backtracking, especially to step 1, the aim is to get ever closer to an understanding or appreciation of what the problem really is. Eventually, the problem owners get to a point where they *think* they understand the problem. And then, ignoring simulation, and me, they go off and make decisions and get on with their lives (see B for example). This by definition ends the simulation process.

Vignette **B**: When the problem is understood

One of my students collected data on a paintshop that had massive work in progress (Hlupic and Paul, 1994). The paintshop included an overhead gantry carrying the parts that had to go through cleaning, drying, spraying and annealing. The industrial engineers saw that she had measured the speed of the gantry inaccurately. The student held her ground; she had used the stopwatch accurately enough. Sophisticated gantry speed measurement equipment proved she was right, the gantry was running at 90% of its proper operating speed. With the gantry speeded up, the work in progress immediately started to diminish, as did interest in the student and the simulation

Table 1: My Version of Law and Kelton's 10 Steps

| **Step** | **Law and Kelton (2000)** | **Paul, Eldabi and Kuljis (PEK) for short** |
|---|---|---|
| 1 | Formulate problem and Plan the study | Problems have owners or stakeholders. Problem owners do not understand what the problem is If they did, they would make decisions Hence problem formulation is *wrong* |
| 2 | Collect data and define A model | What data? And how relevant and accurate is it (see A) The model is *wrong* |
| 3 | Conceptual model valid? Goto 4, else return to 2 | The conceptual model cannot be valid (this can rarely be even attempted at) |
| 4 | Construct a computer Program and verify | Computer programs cannot be verified. The computer program is *wrong* |
| 5 | Make pilot runs | The pilot runs give *wrong* outputs |
| 6 | Programmed model valid? Goto 7, else return to 2 | The programmed model cannot be valid The programmed model is *wrong* |
| 7 | Design experiments | The experiments are *wrong* |
| 8 | Make production runs | The production runs produce *wrong* outputs |
| 9 | Analyze output data | The analysis is *wrong* |
| 10 | Document, present, and Use results | The results are *wrong* |

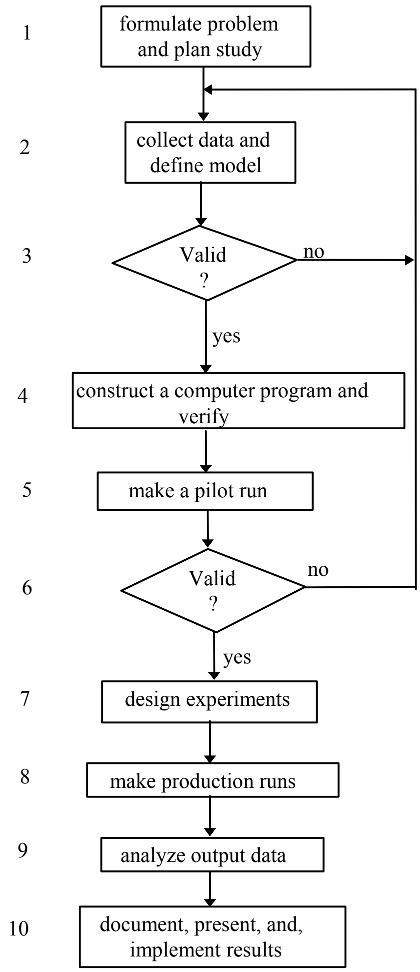


Figure 1: Steps in a Simulation Study (Copied from Page 84 of Law and Kelton, 2000)

If this is the process, what education does the analyst need to carry out this style of decision aiding? The next four sections describe the four general objectives, which are mentioned earlier.

## 3 LEARNING TO LEARN

Although it is suggested in the previous section that the existing text book material does not provide the practical aspects which are much needed by the students, it is still important to access such materials. This objective is not about how to learn the practice of simulation, rather it is about learning about the types of techniques available, and when and how they are relevant to the particular problem at hand. Educating students about simulation is to equip them with the ability to criticize the material and reflect on it with regard to their own practical experiences. This makes it important to have appropriate access to such materials. Accessibility requires the material to be written in a way that reflects real life practice; hence, training the students not to take things as given and prepare them for the fact that real life is not as tidy as suggested in many existing text books.

Ideally the student should be able to read the text book and gain knowledge. Currently this gained knowledge is targeted to be a set of techniques that sound rigorous and scientific and can only guarantee the success of a simulation study if followed tightly. Alternatively a simulation text book could be written in a loose format – reflecting real life – leaving the student to gain knowledge about how to absorb reported experiences and learn from them for future simulation processes. Simulation being more of an art than science – and judging by real life experiences – it is not possible to replicate studies, because if it is then the results will be known and there will be no real reason for using simulation. However, if the problems is different every time then sequential techniques cannot be in the same order all the time. In this case most relevant issue for the students to learn what to learn and how to select the relevant tools as they learn the art of practicing simulation for the sake of solving the problems.

## 4 THINKING CREATIVELY

It was suggested in section 2 that simulation should be used as a debating vehicle to elicit knowledge and share it amongst the problem owners and the modelers. To do so the student should be able to learn how to develop models that can facilitate such debates. It is well known that communication and knowledge sharing is highly dependent on the senders and the receiving audience, which changes from one problem to another. One can instantly see that a fixed structure to develop simulation models will not be able to cope with all the situations all the time. This is the essence behind this objective and that is to educate students to enable them to think creatively. This is in order to think outside the box and creatively develop models that will facilitate debate and problem understanding by problem owners. It is important to plant and nurture this skill by highlighting the importance of creative thinking.

One of the most important and well known benefits of simulation is to experiment with a set of scenarios and see which are preferable to the problem owners. This means it is important to enable the students to think creatively and collaborate with the problem owners to imagine what types of scenarios to experiment with in order to understand the problem and explore realistic alternatives. One other aspect that requires creative thinking is knowing when to stop which is probably related to the first and the last objectives. Simulation is a seductive tool and can lure problem owners and modelers alike to go into details which are not necessary for solving the problem. The ability to brake in the right time is not supported by any textbook and can only depend on the creativity of the modeler to manage the stopping rules.

## 5 PROBLEM SOLVING

Step 1 in Figure 1 is probably the core objective of most simulation projects. The usefulness of a simulation model is directly related to solving the problem. However, there is an important point to remember and that to make informed decisions the decision makers have to possess an understanding of the problem. Such a state is achieved only through iterative process of modeling. The gradual change of levels of understanding is usually reflected on the perception of the model as a representation of the modeled system. Hence, the initial versions of the model might *not* be as useful to the problem owners at latter stages of the modeling process. For this reason it is important to educate the students not to be sentimentally attached to the problem while they should always concentrate on the problem at hand. They should always be able to abandon the model if it does not take the problem owners any closers to the solution. It is often the case when regarding the modeling process as a rigorous development process that modelers get too attached to the model and forgo the interests of the problem owners, only to create a rift between them and the problem owners.

Another point that needs to be considered is that a model which is developed for the purpose of experimentation should seldom be dependent on the accuracy of data. This is for two reasons; data is never accurate. And if it is, the model will then be a mere mirror of past experiences that has no relation to the future nor does it give a chance to alternative scenarios which negates the most important benefit of simulation. One can argue that accurate data is needed to generate accurate results. As a counterargument one can say that accurate model results are not necessarily useful for solving the problem. And if the result is generated out of a hypothetical experimental scenario. " How can one guarantees that this result is accurate. Simulation models by their very nature are not based on robust representation of the system, in fact – sometimes – models are purposefully distorted to get better insights about the system. Models are simplifications of what the problem owners think the system is, which is always changing, so accuracy is not just unnecessary it is irrelevant.

Students should learn that simulation models are not about being correct or incorrect, they are about enabling the problem owners to solve their problems and take informed decisions.

## 6 BEING PROFESSIONAL

If I were offered $1 million to do a study would I say yes, no, or is it feasible? I might easily succumb to *The North American Unwritten Research Agreement*: Research funders largely improve their career track by being responsible for larger, rather than smaller budgets. The researchers largely improve their career tracks by attracting large grants and more often. Research funders and researchers are therefore able to offer each other complete satisfaction as long as the issue of feasibility is not discussed seriously.

As Paul's Law of the IT Concept Fallacy states, "There exists a belief that any concept can be realized if only enough time and money is spent on the realization attempt. Such a belief is guaranteed to lead to the spending of much time and money."

The North American Unwritten Research Agreement is the antithesis of what is required in PEK's view of simulation; a contract that stops when the problem owners take decisions, not continuing to spend money.

Students need to learn that objective modeling helps problem elicitation, but that being completely objective is impossible, so how close can one get? Recognizing bias, prejudice etc of oneself and others, and making it an open issue that needs to be addressed, not hidden with the pretence of non-existence, would be a minimal requirement.

## 7 HOW TO EDUCATE?

Textbooks are only a small part of the educational process. There are of course other components to it; such as the instruction process, modes of delivery, assessment, and media. To be able to achieve the four objectives set in the previous sections, it is evident that textbook based exams are not the way forward. These objectives are based on learning by practice, which can only be achieved by living the experience itself rather than receiving digested knowledge.

We propose project based teaching. This may be supported by textbooks and lecturers as references and guidance but the students should be given freedom to conduct their projects. One possibility is to use senior students as project leaders and junior students as developers and analysts. There could also be some role-playing, by having problem owners and modelers, whilst changing roles helps the student to see the process from different perspectives. These are all details which can be drawn according to the educational institute. However, the underlying principle is to give the student a taste of reality by putting them in environments similar to what they will face after graduation. Either academic environments, in which they have to develop questioning and curious minds, or industrial environments in which they have to obey different rules from those of the textbooks.

Thus it is possible to enmesh the four objectives more efficiently. The students will be able to learn from their own experiences enhanced by the experiences portrayed in the textbooks. They will be able to think creatively as each project is a new experience compelling them to try alternative ways for solving the problem. It will help them to learn more about what it means to deal with problem owners and how to deal with them professionally. The simulation exercise should not become a means for collecting credits, rather it should be considered as learning experience through which the students learn that in real life work is judged differently from that of the classroom.

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