System Dynamics Underwood

Kjell Henden
Sogn og Fjordane Distriktshøgskule
P.O. Box 39
N-5801 Sogndal, Norway
E-mail: kjell-henden@sfdh.sognhs.no

Abstract

This paper deals with System Dynamics as an alternative to methods of problem-solving that are tradionally taught in colleges. It is based on my experiences of teaching the use of the methodology for analyzing small systems of finance, hydrography, demography etc.

Testing out any hypothesis where System Dynamics is compared to another methodology is complicated, and I do not present any conclusions. I argue further that this has to be done by a qualitative approach.

In the field of finance quite a lot can be gained by using System Dynamics. The given example of calculating the net present value of a cash flow illuminates my point. In traditional textbooks this value is given by a formula based on the assumptions that interest remains constant over a long period of time, and that there is no or constant depletion of money value due to inflation. In view of economic reality this description is very naive. On the other hand, it is rather cumbersome to develop and use a formula that takes into account variation of annual earnings, varying interest and varying inflation. Similar observations have been my incentive for applying System Dynamics to various sciences. Quite a lot of traditional calculations can be greatly simplified by resorting to the methodology of System Dynamics; especially when it comes to integrating complex, realistic assumptions into the models.

My preliminary conclusion is that System Dynamics enhances the understanding and enables the students to go well beyond the oversimplifications of traditional textbooks, and that the use of the methodology in various disciplines should be advocated. It is further my belief that teaching the subject in undergraduate classes creates an underwood of users; a basis from which future system analysts can be recruited.

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Background

Even for a teacher the mechanism by which the subjects we teach are selected is rather obscure. Looking at mathematics it is hard to comprehend why that much emphasis is put on solving equations rather than devoting more time to number theories. The rate of change is also extremely low; once a subject has become part of a curriculum it often remains so for a very long time. What we teach is apparently bound by tradition because the foundations of most disciplines have been laid centuries ago; in the case of mathematics even more than a thousand years back in history. This stability, specially of the analytical sciences, might be an obstacle to making changes when there is paramount reason to do so. This might affect our aptitude to change pedagogy or methodology of teaching as well as the subjects we teach.

What we teach is in accordance with conventions that have been formed over a long period of time. Typical constraints of curriculums are what is taught at similar colleges. Another obstacle to change is the fact that diverting from the traditional approach, could put you out of pace with what advanced courses are based upon. Given circumstances where less consideration had to be taken to the surrounding world, most likely more teachers would divert from traditional curriculums. However, skepticism against changes of curricula might be well motivated. An example is the dramatic switch to modern mathematics that took place in schools three to four decades ago. This reform, brought about by enthusiasts, was in my country a failure that led to a healthy skepticism.

What should be expected from a theory? 'Do not judge a model by its assumptions, but by its ability to predict (Friedman 1953)' is one answer. Still, I think there is a strong momentum for change when theories bear little resemblance to the real world and describe ideal situations that never occur.

Looking for a methodology that makes analysis and simulations of complex, realistic problems sier has led me to trying out the System Dynamics approach. The focus of my interest has been the process of modelling. I am not introducing System Dynamics as a subject of its own, but as an alternative way of analyzing, rather than solving, the traditional problems we deal with.

Choice of methodology

Reasons for changing curriculums should be strong. And the crucial question is: What research design should be used in order to find out if there is any significant difference between groups of students related to problem-solving methodologies? One way of addressing this query is inspecting the methods used in reports concerning the effects of computer assisted learning. Computers are useful tools for acquiring new skills and insight. And numerous reports support the hypothesis that student with computer assisted training outperform those without. I want to draw attention to a couple of characteristics of these reports. It seems that the increased performance is characterized by duplicating the actions rewarded by the program. The mimic aspects of the programs must necessarily lead to the result that trained students do better in test than those without these mimic abilities. Likewise students with knowledge of System Dynamics can do better than those without when solving a wide range of problems. A methodological weakness of some reports has to do with forming control groups (Schmitt 1989).

Using a quantitative approach implies forming representative groups and teach them different problem solving methodologies. This strategy is equivalent to a "pill and placebo experiment". I see overwhelming problems attached to this type of design when it comes to comparing System Dynamics to an alternative methodology. Firstly constructing a control group is generally difficult. In this case even more so because what the methodologies in question encompass is in itself diffuse; different methodologies have overlapping areas, and making a clear distinction between what has been taught or not may be infeasible. In this case it is not a question of "pill or no pill". The next step would be to compare the results of the two groups with respect to cognitive skills rather than ability to solve problems. I found it very hard to develop quantitative measures of attributes without ending up with irrelevant variables like number of problems solved, time used to solve a specific problem etc. I regard these variables as irrelevant in light of an ambition to compare cognitive skills between groups of students. In light of the possibility that inadequacy of control groups would infirm the validation of any hypothesis - about variables which might be irrelevant - use of a quantitative approach seem futile. I also regard course evaluation as irrelevant. The results are significant only when it comes to measuring students' satisfaction with a course. Even combinations of the elements of a questionnaire are of little use when it comes to estimating the merits of a problem-solving methodology.

The insight I want is a holistic one, encompassing the totality of a problem solving situation rather than fragmentation. The holistic method considers a complete activity like training as an interrelated system with a deep structure (Weiss 1966). From my point of view this is the closest I can come to forming an idea of the cognitive skills of students. This calls for a qualitative approach. The characteristic of which is participant observation. Since inspecting the work of students is a normal activity of any teacher, this activity do not significantly affect the situation under examination.

Operationalization

In the outset it is not explicit what should be observed. Characteristic of a qualitative method is that categories emerge from what is actually happening rather than from artificial, preconceived notions (Light 1983, 60). The cognitive skills of students incorporate more than the level of problem solving ability.

The category *novel patterns,* which I consider very important, is one I have adopted from the theory of observational learning. This theory acknowledged modelling the most powerful means of transmitting values, attitudes, and patterns of thought and behaviour (Bandura 1986, 48). The mechanism works like this: By observing we can learn approximately what to do trough modelling before we perform any behaviour. That means the model contains conceptions and rules for generating our structures of behaviour. Modelling must necessarily be a process, and the value of this paradigm, as I see it, depends on how well this process can be understood. A model is not a sort of response mimicry or imitation. Learning means making a model by processing the information about the structures of events that we observe. The information is transformed into symbolic representations that serve as guides for action. The way we analyze phenomena no doubt affects the ways we understand them and the level of cognition we attain. The mechanism of observational learning is, according to my view, such that the analytical approach of system dynamics has a structure that induce the modelling process characteristic of observational learning. Observational learning is shown most clearly when models exhibit *novel patterns* (Bandura 1986, 49). In the process of analyzing and solving problems it is possible to observe solutions that students had very little probability to come up with prior to learning System Dynamics even if they possess the prerequisite knowledge. This corresponds with the definition of *novel pattern.* And such novel patterns are frequently observed.

An important part of group work is the exchange of ideas between students. When solving problems of mathematics, discussions often are a one-way communication from one student to another, and the content of what is being communicated is technical help. System Dynamics apparently has inherent properties as far as communications are concerned, and discussions over flow charts are ample. Unlike mathematical formalism System Dynamics rarely inhibits students from communicating their views.

Preliminary conclusions

So far my main effort has been focused on developing the course I am giving. As far as comparing methods of problem solving is concerned, I want to proceed in accordance with the design outlined above before forming any conclusions. In the following I shall present my preliminary experiences with System Dynamics.

The foremost advantages over traditional ways of solving problems is the possibilities of introducing dynamics in otherwise static models. Another advantage, which is by far underestimated in my view, is that the modelling to a large extent make formulas expendable. A simple example that illustrate both these assets is shown in figure 1. The flowchart shows the calculation of net present value of an investment. This flowchart can easily be transformed to a worksheet model or a Dynamo program without resorting to formulas. Textbooks of finance usually operate with constant interest or weighted average cost of capital. Here variation of interest is taken care of by introducing a table containing the cost of capital. If the cost of capital is replaced by a constant, the internal rate of return is easily found by doing a few simulations to find what value of this constant makes the NPV equal to zero. These calculations are rather cumbersome to do mathematically.

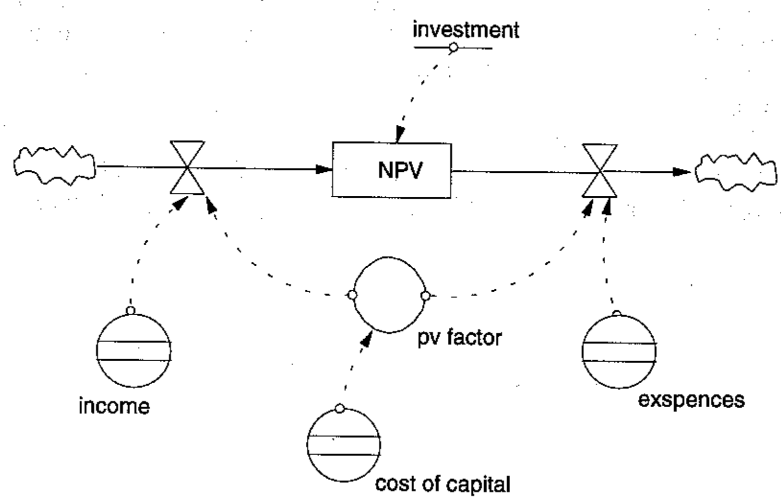

Figure 1. Flowchart of net present value.

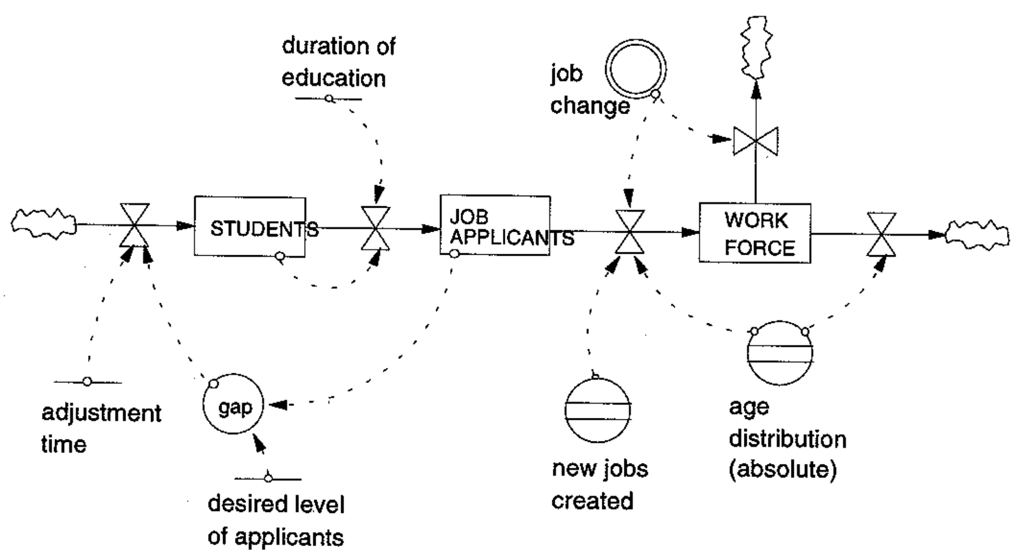

Figure 2. Flowchart of work force model.

The next example I give has a strong bearing on the future life of the students. The flowchart in figure 2 is a starting point for a more complete model. And as such it is a pedagogical success; everybody can understand it and participate in discussions.

A problem I have met has to do with transforming causal diagrams into flowcharts. Quite a lot of students find this remarkably hard. Hence the basis for development of the models have been flowcharts. A more fundamental problem has to do with identifying causal relations and to understand the concept of *causality*. This word has three principal meanings (Bunge 1963, 3-21). In science we often observe constant and unique connections. An example is the velocity acquired by a freely falling body after the elapse of time t, which is $v(t)= gt + v_0$. The velocity is determined by the time. But the word *determination* does not convey the activity and productivity inherent in causation. So this is not a causal law. Another problem is associated with distinguishing between correlation and causation. A statement like: 'the words *cause*, *affect*, and *influence* are used here to mean approximately the same thing (Roberts 1982, 12)' is superficial. Even for an elementary course a more analytical approach has to be developed.

This is the third year I have given a course for undergraduate students. The credits correspond to one month's work. Main textbook written by Gottschalk and Wenstøp (Gottschalk 1985). So far 60 students have chosen this course. The variances of their background and academic level are such that they are representative for our undergraduate students. My supposition is that quite a lot of problems can be analyzed and solved more efficiently than by methods most commonly used to day, and the students achieve, as far as I see, a reasonable standard of modelling proficiency and ability to perform the simulations. We have been fairly successful in solving problems from the following domains: education, finance, epidemiology and demography. And I intend to develop this course further.

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