Learning about Modelling for Learning

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Abstract

It is widely recognised that modelling organisational systems can be used to provide insights into the problems of an organisation, and to induce learning about the context. The objectives are to increase the effectiveness of thinking about the situation, to enable a wide participation in the construction of the models, and to allow an analysis that minimises the need for opaque technical reasoning. It is important, therefore, in the training of future modellers on undergraduate and postgraduate courses, to appreciate the need to identify a system's structure and behaviour, without necessarily placing a strong emphasis on the underlying mathematics.

This paper describes how system dynamics was used to re-design a course on systems modelling, with an emphasis on system dynamics. In the approach adopted, cognitive mapping in conjunction with drawing influence diagrams helped to conceptualise and to think about the situation, and a workshop environment was adopted to design and analyse the models of the course.

In addition, the paper will discuss the nature of the modelling process, and the problems of the distinction between qualitative and quantitative forms of representation. Finally, conclusions will be given on the potential of system dynamics modelling in the education of Systems Analysts, modellers or Operational Researchers.

Learning about Modelling for Learning

Introduction

The need for change has been recognised by many disciplines and in many ways. This paper will address the effect on modelling given the backcloth of change. The paper, in particular, will discuss the nature of the modelling process, and the problems of the distinction between qualitative and quantitative forms of reference. It then looks at how System Dynamics was used to re-design a course on System Dynamics. In the approach adopted, cognitive mapping in conjunction with drawing influence diagrams helped to conceptualise and to think about the situation, and a workshop environment was adopted to design and analyse the models of the course. Finally, conclusions will be given on the potential of System Dynamics modelling in the education of System Analysts, modellers or Operational Researchers.

Modelling: the need for change

Commentators insist on proclaiming that immense changes have taken place in organisational and economic life over the last decade or so. Many managers and academics have acknowledged this view by reminding us that society today is not what it use to be. As a result it is becoming increasingly apparent that the traditional approaches to solving organisational or management problems, and the use of the conventional management sciences, as taught at the universities and repeatedly espoused in text books, have become obsolete. What response is there to this image of change? Is it a simple case of modifying or replacing the traditional tools? It would appear that this vision has a limited wisdom. Many writers on management and organisations, such as Peters (1982) and Senge (1990) have indicated that the terrain of organisational life has changed beyond recognition, and to cope with the new horizons we need not only new methods and organisations, but also a new vision.

It seems there are few adequate tools available to delve the concepts of change. The surface effects are the only things available to us to explore. From these effects a plethora of interpretations may abound, which may leave us feeling as though we are drowning; not an easy feeling to dispel. Even the higher education sector has not escaped this situation, which seems to be running in tandem with changes in organisational life. It appears that the university education system is re-adjusting itself. Within it, new patterns of courses are emerging, and the structure of the curriculum is being re-drafted. The course content of degrees are justified either by what the outside world wants or a perception of a change in the order of knowledge. It would appear that no university course is immune from the contagious spread of a need for change.

At the University of Greenwich, the department of Mathematics, Statistics and Computing has undergone a lot of soul searching over the past few years to establish what identity it has in the provision of mathematics education. In essence the department has realised that its identity lies in that region that makes it different: an emphasis on modelling. This is the heart of its identity, with courses and options feeding into it or using it. Modelling at Greenwich is not only the core of the curriculum, but is also the core of its research and consultancy. For example, it is the home of the Journal of Applied Mathematical Modelling. The main focus of the modelling research has been towards industrial processes (see Cross 1993).

The main text book used for teaching modelling at Greenwich is a book written by two of its lecturers (Edwards and Hamson 1989). The reason for modelling that the authors put forward is that:

"... learning to apply mathematics is a very different activity from learning mathematics. The skills needed to be successful in applying mathematics are quite different from those needed to understand concepts, to prove theorems or to solve equations"

Of a model they said that it ` can be defined as a simplified representation of certain aspects of a real system. A mathematical model is a model created using mathematical concepts such as functions and equations. When we create mathematical models, we move from the real world into the abstract world of mathematical concepts, which is where the model is built. We then manipulate the model using mathematical techniques or computer-aided numerical computation. Finally we re-enter the real world, taking with us the solution to the mathematical problem, which is then translated into a useful solution to the real problem'.

Uncontroversially, most mathematics schools would agree that the objective of teaching modelling is not just to provide the student with a set of techniques to use, but to allow them to apply common sense. Although it is appropriate to use mathematical principles that are based on sound reasoning, when it comes to modelling some given problem the student is free to construct the model using whatever mathematical relationships seem appropriate.

All this fits a traditional Applied Mathematics course with traditional students. The trend, however, is to attract different students by offering courses that reflect not only Industrial, Management or Business applications, but also Environmental and Social Scientific ones as well. The question this raises is, would the traditional view of modelling be justified on these courses? Given that modelling is to remain at the heart of these courses, a new rationale for the modelling process needs to be explored. In this paper we will discuss one of these courses, called Business Systems Modelling.

The Business Systems Modelling degree was designed to have systems thinking and Operational Research (OR) as the central modelling methodology. The members of the course design team were well aware of the soul-searching OR and other management sciences have been going through, and thought it might be pertinent to bring some of the outcomes of the reflection to the design of the course.

The course would have to be designed to maintain the idea of a practically based philosophy as opposed to a theoretical one. A different rationale was needed so that it would be possible to move away from courses based on modelling methods that were relevant only to prescribed problems, as in hard systems. This would not mean rejecting hard modelling, but showing it is part of a more general soft modelling framework, ie. those that deal with `messes' or complex systems. We accepted this premise recognising that the general level of theorising on the relationship between hard modelling and soft modelling was relatively young, and realising that it was not even clear to a mathematics school that such a relationship should be explored. However, even amongst the hard modelling staff they recognised that the nature of modelling had changed (as can be seen from the fact that much of the research work of the department now is in the area of simulation in all its forms) and that novel methodologies should be adopted.

Alternative views on modelling

What were the changes in perceptions about modelling? The view taken by de Geus (1992), seemed to us to capture the feeling about a new attitude to modelling. It was that:

" we are no longer talking about the model as the understanding of this world as it has been acquired by a modeller or a planner. We are no longer talking about a modelled understanding of this world as it has been acquired by an academic or some outside institution like a plan bureau to be use to make predictions. We are talking about the understanding of [a clients'] world as it has been acquired by them....[M]odelling the world we give them a toy.. with which they can play, with which they can experiment without having to fear the consequences".

Or alternatively the view from Morecroft (1992)

" Models should capture the knowledge and mental data of the [client]; models should blend qualitative mapping with friendly algebra and simulations; models can be small; their purpose is to support team reasoning and learning; they encourage systems thinking. Simulations provide stories about the future not predictions".

The above quotes are taken from practitioners and thinkers in the System Dynamics field. They have been remarking on the timely re-emergence of System Dynamics as an important modelling methodology for management problems. Others like Wolstenholme (1982, 1990) have provided a detailed description on how to use System Dynamics as a soft modelling methodology. In particular, he outlines the modelling process in terms of a descriptive phase and an exploration phase, saying that `the qualitative analysis facilitated by this is often sufficient in itself to generate problem understanding'. Such a view of modelling would ask a modeller to describe and explore complex systems by drawing a systems diagram as a model to formalise and communicate `images' of problems which would lead to an understanding of a given situation in a way that language can not. These models could then be used to facilitate quantitative modelling, to further explore the system under investigation, using, for example, simulation.

The quotes seem to make clear the importance of modelling the qualitative aspects of the situation as well as the quantitative, and explore the relationship between the two regions. Following on from this the system representation is sufficiently rigorous to be turned into accessible mathematical equations (for example difference equations) capable of being handled by a computer.

Outside the system sphere, qualitative representation or modelling has been well established. The most prominent example is the Cognitive Mapping technique developed by Eden (1983) for modelling complex organisational problems. What is interesting about the emergence in the qualitative modelling methodologies are that they have emerged in a wide field. For each of the techniques it is claimed that they would be able to incorporate subjective elements in models. There is no space here to discuss the implication of the above, but a paper by Taket and White (1994) has provided a discussion of this in a wider context.

Modelling as Learning

Interestingly, another aspect of modelling that certain System Dynamics authors are espousing is the idea of modelling as learning. They ask, how can models influence thinking and action in teams? (Morecroft 1992) The answer suggested is, by stressing the use of conceptual models, that they can be used to aid the learning processes of individuals and groups. Members of a group will `use models when it is clear to [them] that their ideas and knowledge are represented in the model... learning takes place when people discover for themselves the contradictions between observed behaviour and their perceptions of how the world should operate' (de Geus 1992), or even when the contradictions between different individual viewpoints are represented.

Returning to the development of the course, some members of staff were familiar with System Dynamics, and were interested in soft modelling methods. System Dynamics was thought to be an important component for modelling on the degree, because it helped to stress that models should help decision makers understand the world and the way that they construct that world; it provided a toy to support decision making in teams, and it induced learning, among the decision makers, about the complex systems they are part of.

In the event, System Dynamics was seen as the lynch-pin modelling methodology on the Business Systems Modelling degree. It was used to emphasise the need to assimilate novel ideas on modelling and to stress an alternative orientation for would-be modellers. Unfortunately, our view of the grand order of things was not shared by the students. Even after the first year of the course they still had a very narrow reductionist view to modelling, and found it difficult to look at issues holistically, and they could not see the point of the unit. Whilst acknowledging their right to this view, we felt that it was a view based on limitation rather than choice. The course was failing to get its points across. Whilst feedback about units is often produced at the end of the course using questionnaires, the course team decided to use issue-structuring approaches to explore how staff and students saw the unit. There were four reasons behind this choice.

First, the review team wanted to tap into the staff and students experience of the unit -it was a chance to learn from them and thus about modelling in general on the course.

Second, there was the need to get active involvement in the structuring of the issues, and in thinking through how to tackle them.

Third, it was an opportunity for staff and students to learn from one another and to break down barriers of profession and authority.

To tackle this issue it was thought appropriate that System Dynamics should be used to learn about the unit on modelling for learning. Last, it was an opportunity to practice what we preach.

Evaluation of the process

How should we explore and learn about the impact of the modelling unit? We might try interviewing some students and staff to generate data of the situation `as they see it'. However, would this data be amenable to analysis, induce learning, and facilitate change? One of the authors has used cognitive mapping as a tool to explore problems with community groups (Rosenhead and White 1994). Can this tool be used in conjunction with System Dynamics?

It is now accepted that cognitive mapping is a reasonable modelling tool. It can be used to produce a picture of the situation as the individual 'sees it', by sketching the relationship between ideas, values and attitudes. The picture produced is a construction using arrows that imply causality between concepts. In its abstract form, the map can be seen as a directed graph. An influence diagram can also be seen in its abstract form as a directed graph. Can a cognitive map be related to an influence diagram?

Eden shows, in his book (Eden 1983) how a cognitive map can be the basis of an influence diagram for a System Dynamics model, recognising that they are from different provinces. The link between the two provinces is established through the process of `problem-helping'. The process for `problem-helping' does not preclude the use of quantitative modelling. If required, a System Dynamics model could potentially be incorporated in the process of `problem-helping' because, in Eden's own words, `it can take into account the dynamic consequences of perceived feedback loops... and because they are relatively easy to construct using influence diagrams which are similar **in form** to cognitive maps (my emphasis)'. Eden (1983) points out that a cognitive map `is so called in order to lay emphasis on the idiosyncratic [and subjective] aspects of the model constructed - it is not supposed to be a scientific model of an objective reality in the same way some influence diagrams are (for example, those used by System Dynamics modellers)... - it can never be shown to be right or wrong in an `objective' sense.' (Here Eden is referring to 1st generation system dynamics). Eden sees System Dynamics as modelling some `objective' reality and cognitive mapping as representing the `reality' as defined by an individual in their own `language and theories'.

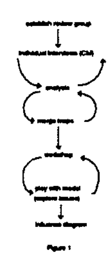
Morecroft (1988) has recently written about how System Dynamics has been used for group model building with management, and has discussed that this development might be used to influence thinking and actions in management teams. He states that `increasingly modellers have turned their attention to the mental models of managers and the learning processes of the individuals and groups'. He sees the System Dynamics model, like other methods for generating mind maps, ie. as a tool to `support cognitive processes and group problem structuring'. It seems reasonable to conclude that although cognitive mapping has a different origin to influence diagrams, it has a place in generating group coherence, which can be subsequently developed into influence diagrams or modelled using the System Dynamics concepts.

Once the cognitive map is drawn up, through negotiation it can be developed into an influence diagram. Eden suggested that in the process of the transformation the problem-helper concentrates on the nature and significance of feedback loops, usually meaning that concepts are translated into monotonic concepts (which may mean some of the rich meaning is lost in the translation). During this transformation some of the relationships common to cognitive mapping and influence diagrams can be discussed with the team. This provides the motivation for the members of the group to sketch out the influence diagrams, to implement the rules for putting in the System Dynamics `plumbing' and to use the model for further analysis. The model produced can be then seen as a `toy' which, following Morecroft (1988) can be used as a `microworld environment', where playing and learning, (with facilitation) can take place. This tentative sketch of a process was used as a basis for exploring the modelling unit.

Procedure

As a first step the research team brought together some members of staff and students as the review group. Of course they had experience in the learning and delivery of the unit. Their remit was to explore the issue of running the unit, and set out what were the impacts, the opportunities and weaknesses.

The research team used the approach shown in Figure 1. After the review team has been selected each member of that team would be interviewed using cognitive mapping. The maps would then be analysed and fedback to the individuals. Following this, the revised maps would then be merged and the composite map analysed. The composite map could then be used by the review team in a workshop environment where they could explore the issues and feedback loops. The aim of the workshop would be to produce an influence diagram (available for further analysis) and a structured debate of the issues.



Individual interviews

The individual interviews were intended to give each member of the review team the opportunity to raise any issue they saw affecting the running and understanding of the unit. This was conducted in an open, and unthreatening environment, where the individuals were free to say what ever they wished. Each member of the review team was allowed to elaborate freely on their views of the course, and were asked to raise any issue they saw as being significant. The interviews were unstructured. The research group then had the task to translate the interview results into a map, which was consequently fedback for clarification and modification. From the feedback an explanation of the mapping structure was given, to help guide the interviewee in their thinking about the issues raised and the connections between them.

Workshop

The interviews were followed up by a workshop with the review group as a whole. A concept map was presented (the reduced composite map), and the research team facilitator gave an overview of the issues, arguments, concerns and options which had been raised during the interview stage. It was explained to the review group that the map had been reduced to a concept map (see Eden ()) in which clusters of ideas were identified and the relationships between the clusters were drawn up (see Figure 2) in order to structure and stimulate discussion. The review group then prioritised which concepts (issues) they wanted to tackle.

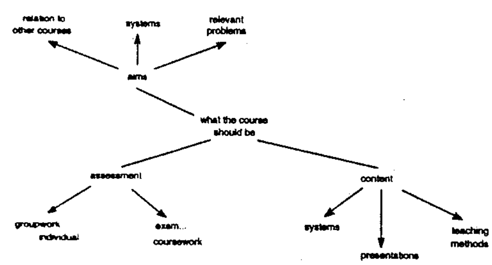


Figure 2. Concept Map

For each concept, those that varied monotonically were identified, as the discussion developed, in the form of feedback loops. The relationship of the loops with each of the other loops were built up into an influence diagram. During this process differing viewpoints, opinions and assumptions were aired and discussed. This helped to clarify a lot of implicit misunderstandings, especially between staff and students. Many criticisms of the unit were made and yet it all took place in a very positive and constructive atmosphere. The result was a shared understanding of the methods and aims of the unit which led to an easy acceptance of the resulting influence diagram. This diagram was then used as a focus to discuss the dynamics between various concepts and to identify the polarity of feedback loops.

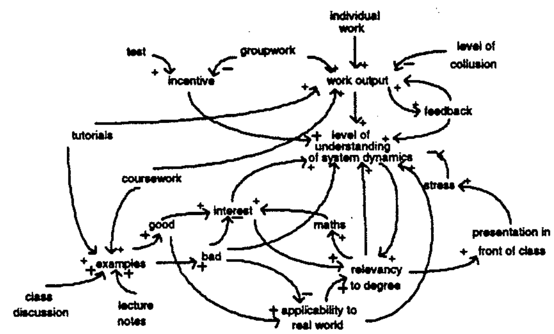


Figure 3. *Influence Diagram*

Figure 3 is the influence diagram agreed by the review group at the end of the workshop. There were numerous influences and concepts modified during the workshop due to initial differences of viewpoints and experiences. The five main ones were:

Relevancy to the degree
Incentive to work and assessment
Level of maths to include
Value of presentations
Importance of examples.

To explore one: the value of presentations. At the beginning of the workshop the staff saw presentations as being relevant to the degree and a good way of increasing student understanding of their presentation topic. On the other hand, students saw little relevance to the course, and the presentations leading to stress which actually reduced their understanding. After discussion the review group drew up the influences shown.

The final step in the analysis of the issues affecting the unit was to build a System Dynamics model of the influence diagram. This inevitably led to modification and simplification of the influence diagram into a combination of quantifiable stocks, rates and constants. Whilst this helped us look at the influence diagram with a different view, and clarified the ideas of what could (should?) be quantified, the resultant model did seem a gross simplification. The quantitative results depended upon judgemental concepts (eg goodness of examples, effects of stress) and led to no conclusive results apart from those that could be deduced from the influence diagram.

Conclusion

Our education system helps to perpetuate an accepted view of models and modelling. It is the traditional view of modelling, where it is held that knowledge is about something `out there' which is either uncovered or discovered. Models are held to be built in order to reflect or mirror reality and it will be more or less accurate a representation of reality depending on the ingenuity of the modeller. Such models can then be tested to declare them to be a `good reflection of reality'. Senge (1990) elaborates on this as a problem for managers, for example he states:

" We are taught to break apart problems, to fragment the world. This apparently makes complex tasks and subjects more manageable, but we pay a hidden and enormous price. We can no longer see the consequences of our actions, we lose our intrinsic sense of connection to a larger `whole'".

He claims that managers should be encouraged to change the way they perceive issues about the changing world. In attempting to model the world it is not a case of finding some simplified objective abstraction of reality, but a need to represent the diverse and rich view of individuals `as they see the world'.

In this way, we believe that students need to be educated about differing viewpoints (many of which are valid), about levels of appropriateness, not about extremes of right or wrong. Furthermore, they should try to view the system being investigated as a whole and not a set of parts. We think System Dynamics helps to achieve this by encouraging groups to look at complex systems as a whole and allowing them to represent their views (and other peoples) explicitly.

Our use of System Dynamics and Cognitive Mapping reinforced the view that they are both useful tools for representing different viewpoints and helpful in leading groups in constructive debate. Their visual similarity and conceptual differences made the transfer from cognitive maps to influence diagrams straightforward and also thought-provoking at the same time. This ensured we re-examined our ideas on a continual basis. The transformation from influence diagram to System Dynamics plumbing was not as successful. Once more the transfer made us re-examine our ideas, but we could not place much faith in the enforced quantification necessary to produce a working model.

This failure at the last hurdle does not discourage us nor invalidate the process. The visualisation and communication needed to build the maps and diagrams had enormous benefits. It does, however, make us aware that System Dynamics is a many faceted jewel, with some facets bringing a clarity to the issues and others distorting them. It should be handled with care.

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