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MODEL REUSE VERSUS MODEL DEVELOPMENT: EFFECTS ON CREDIBILITY AND LEARNING

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ABSTRACT

The construction of generic models and their validity when reused has received much attention in the DES literature. This is with good reason as rapid deployment of a generic model can reduce time, effort and cost of a study. On the other hand the utility of model reuse as an aid to decision making has had little exploration. This is an area that should be considered as the literature on learning from just simulation model use provides contradictory evidence on its effectiveness. This paper proposes that development of models with some client involvement has alternative benefits to reusing a model: improved learning and understanding for clients. To explore this proposition an experimental design to compare how model reuse and model development affect learning in DES studies is presented. Some preliminary thoughts, based on pilot experiments, on the client process of credibility assessment and understanding of resource utilisation are discussed.

1 INTRODUCTION

The use of simulation and particularly discrete-event simulation (DES) models as decision aids for management clients is well documented (Law 2007, Robinson 2004, Pidd 2004). In addition to model use many authors also suggest that involvement in the development of a simulation model provides important client learning for the decision making process (Robinson 2004, Thomke 1998, Paich and Sterman 1993, Banks et al. 1996). However, model development can be a time consuming process (Robinson et al. 2004) and consequently may either increase costs or reduce the scope of a simulation study. Thus a classic problem that DES has posed is how can models be developed quicker? One possible approach is the reuse of a previously developed simulation model. This, theoretically, benefits clients in two ways:

1. Study feasibility can be increased: it is possible to complete the study to time and cost constraints.
2. The time saved can be used to increase the scope of simulation study: more scenarios can be simulated.

Due to these benefits model reuse has received a large amount of attention in the DES literature. For example, Visual Interactive Simulation (Hurrion 1976), component based simulation (Pidd and Carvalho 2006), component storage, discovery and retrieval (Arons and Boer 2001, Bell et al. 2006), grabbing and gluing simulations (Paul and Taylor 2002), reuse at the conceptual level (Balci and Ormsby 2007, Balci and Nance. N 2008), reuse of full, possibly 'generic', models (e.g. Kaylani et al. 2008, Fletcher et al. 2007, Günal and Pidd 2006, Sinreich and Marmor 2004, Brown and Powers 2000, Pidd 1992, Pierce and Drevna 1992) and the validity of reuse (e.g. Spiegel et al. 2005, Malak and Paredis 2004, Tolk 1999).

On the other hand the client perspective of reuse has received little attention in the DES literature. The exceptions are the suggestion to review generic model assumptions with the client by Ozdemirel (1991) and the discussion of client based issues surrounding reuse by Fletcher et al. (2007). However, the advice given by Ozdemirel (1991) seems to have little difference from the steps of a sound simulation study (e.g. Law 2007) and many of the issues higlighted by Fletcher et al. (2007) could plausibly present themselves in any modelling study (e.g. data quality and low client motivation). That said, underlying each of these studies is the recognition that the client must reuse the model as an aid to decision making. This has been recognised in other simulation modelling approaches where there has been some research in learning from model development and use. For example, in a conceptual discussion Alessi (2000) suggests conditions when building and using

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simulation models would be most beneficial. There is also some empirical data on learning from simulations which can be optimistic about learning (e.g. Thomke 1998) and suggest problems in learning (e.g. Bakken et al. 1994). To date no DES study has considered how model reuse may influence what clients learn from simulation models in order to aid their decision making.

The aim of this paper is to present an experiment that explores the impacts on learning outcomes of low and high client involvement in model development. For example, low involvement would take the form of a previously developed model being reused for decision making while high involvement might include some level of participation during model development. The paper is organised into two parts. Part one presents a spectrum of model reuse, client involvement and learning and presents some evidence to support this model. Part two presents an experimental methodology to test the proposition that high client involvement in model development leads to high 'double-loop' learning for clients. Concluding remarks give some preliminary thoughts, based on pilot experiments, on the client process of credibility assessment and understanding of resource utilisation.

2 LEARNING LINKED TO MODEL REUSE AND CLIENT INVOLVEMENT

Whilst the time and cost implications of model development can be discouraging for organisations thinking of employing simulation several authors suggest that the time spent developing a simulation model in addition to use is an important factor in client learning. This learning includes:

1. Informed choice of one or more implementation options in the current study. (Robinson 2004, Banks et al. 1996).
2. Improved understanding of the system: ability to describe, explain or predict system behaviour. (Shields 2002, Shields 2001, Alessi 2000, Forrester 1994, Senge 1990).
3. A more generalized change in attitudes, beliefs and intuition about dynamic systems that can be transferred to future decision making situations and domains. (Robinson 2004, Alessi 2000, Thomke 1998, Bakken et al. 1994).

It is suggested that these learning outcomes can be related to model reuse through the level of involvement that a client has in a simulation study. This section discusses Figure 1 a theoretical arrangement of the three learning outcomes on a spectrum of reuse and briefly reviews supporting and contradictory literature.

2.1 A Spectrum of Reuse, Client Involvement and Learning

Figure 1 illistrates a theoretical spectrum of model reuse linked to client learning. This section discusses three distinct learning outcomes highlighted in the spectrum: informed choice, system understanding and structural insights.

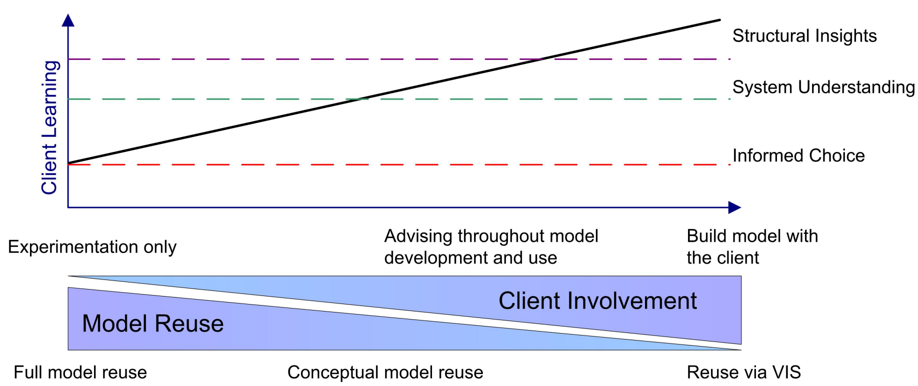

Figure 1: Learning outcomes linked to a spectrum of reuse and involvement

Informed Choice

The far left hand side of Figure 1 represents 'maximum reuse', for example the reuse of full or generic simulation models as aids to decision making. The consequence is that clients are minimally involved in the simulation study, that is, only in use of the model for experimentation. This, of course, may be very useful as an aid to learning for decision making. For example, reused models, for a particular objective, will be able to assist clients in choosing the best implementation option and possibly providing time to look at a greater number than if the model had been developed.

System Understanding

Closer to the centre of Figure 1 clients are involved more in the simulation process, but the level of reuse has decreased. This, for example, may be in the form of reuse at the conceptual level (Balci and Ormsby 2007, Balci and Nance. N 2008). Clients may discuss the conceptual model, even if they do not change it, before the model is implemented. Debates around the model such as "why is or isn't this included" may be beneficial for the clients understanding of the system under study beyond experimentation. Similar learning outcomes may occur when clients do not have direct contact with a simulation model, but they are still advised about and participate in the process of conceptualisation as well as comment on the results of experimentation.

Structural Insights

The far right hand side of Figure 1 represents the maximum level of involvement for a client. In industry this refers to a modeller reusing Visual Interactive Simulation software. Modellers interact with clients to conceptualise the system and use the model to provide feedback on progress and use. This may be the most beneficial learning area for clients as they receive direct feedback on their understanding of the system. This may point out errors in their reasoning or simply show that their understanding was missing crucial interactions or processes in the system under study (Alessi 2000). One result could be structural insights about the type of system under study. In the case of DES it is assumed that this would reflect insights into the dynamics of queues.

2.2 Empirical Studies of Learning from Simulation

An extensive study of how attitudes of management clients change during a group model building (GMB) process is given by Rouwette (2003). Using theories of persuasion and behaviour Rouwette measures and provides evidence that GMB can build consensus and change attitudes towards implementation options. However, evidence strongly suggested management were unaware of insights or changes in attitude from the GMB process. This may be a particularly problematic outcome for the second and third learning outcomes detailed above. Specifically participants may reconcile modelling outcomes with their existing mental models of the system without realising the inconsistencies between the two (Rouwette 2003).

The second and third learning points are evidenced empirically by Thomke (1998) in a study of the development of simulation models in the automotive industry. Illustrated using a time series of insights into different variables during the model development process the study showed that the building and improvement of crash simulation models led to increased knowledge of crash dynamics. Model development also made a lot of the firms 'tacit' knowledge explicit meaning that 'insights could be transferred within and beyond firm boundaries' (Thomke 1998).

There is a large literature on learning from the usage of simulation models, specifically for gaming opposed to management interventions. Studies such as Shields (2001) and Shields (2002) provide evidence that model use improves users understanding of system complexity. However, the extent of the effectiveness of just this approach can be questioned. Bakken et al. (1994) measure the transfer of modelling insights from one simulation model to another. They found that management participants performed poorly compared to students. Student participants were very exploratory with the first simulation model and subsequently tested a large number of their assumptions. Management participants appeared to have an underlying assumption of 'I know about this market so I just do in the game what I do in real life'. This assumption was counter-productive to learning as it appears that feedback from the model was ignored and consequently exploration was low.

Problems are not limited to management users: students can also have learning difficulties. Paich and Sterman (1993) provide evidence that students typically do not learn good strategies for managing an organisation in a competitive market when using a simulation model. Students fail to out perform a naive benchmark especially when feedback in the model is increased. In their summing up Paich and Sterman conclude that to learn when dynamic complexity is high participants need to become modellers not merely players in a simulation game. Approaches to rectify this may be to increase the transparency

- defined as clarifying or increasing the visual display of the model diagram or equations - of the model (Rouwette et al. 2004).

2.3 Learning Theory and Simulation Models

These results and contradictions are consistent with the theory of double and single-loop learning. The theory assumes that underlying all individual behaviour and decision making is a theory-of-action (Argyris 1992, Argyris and Schön 1996). As an example of a theory-of-action consider the theory that a manager of several regional call centres uses to manage the service level of call answering. The manager might reason that small groups of call takers can be specialised to increase the speed of call answering and, at the same time, maximise their utilisation. Thus, the manager uses separate regional call centres for handling customers. A simulation study may highlight that combining all or some of the call centres increases service level and improves the call taker utilisation factor. The call centre manager should find this result suprising and learn from it. A positive outcome of the study is that the policy is implemented and long term service level improves. This is defined as single-loop learning: a correction of errors in the management of the specific business problem. If the manager reflects upon the difference between his theory and the performance of the simulation model then a second level of error correction may take place. This is double-loop learning: a correction of the theory that governs long term decision making and behaviour (Argyris 1992).

The result of the study presented by Thomke (1998) can be interpreted as double-loop learning. The theories users and clients had about the dynamics of car crashes were corrected and understood to an extent where they could be transferred to different domains. Unfortunately double-loop learning is not an easy task to accomplish (Argyris 1992) and this distinguishes the theory from earlier learning loop work. For example, under the well known framework of Kolb (1984) - an experiential learning loop consisting of conceptualisation, testing, concrete experience and reflection - it is assumed that an individual will learn from a simulation given enough time and resources. The theory of double and single-loop learning adds to this understanding by providing empirical evidence that *it is the theory-of-action that clients use to learn from simulation that is key*. The Bakken et al. (1994) and Rouwette (2003) results illustrate this problem. The participants in Bakken et al. used a theory that inhibited their learning from simulation use and were unable to recognise that they were doing so. As a result they failed to learn new strategies for managing the system under study. The clients in Rouwette's study used a theory that inhibited their learning from the difference in model results and their own assumptions. As a result they failed to recognise a difference between their insights and their own management theory. However, unlike Bakken et al. the clients in Rouwette's study, even if they did not recognise it, gained an improved ability explain and predict system behaviour.

The theoretical spectrum of Figure 1 suggests that the key difference here was the level of involvement in the simulation study. The participants of Bakken et al's and Paich and Sterman's studies had no involvement in development. Hence they could not alter the theory they used to learn from the simulation model. The involvement in model development in Rouwette (2003) and Thomke (1998) appears to change that theory, albeit with Thomke demonstrating the more successful results. At present no study considers how different levels of client involvement affects learning from DES models. The next section of this paper presents an experimental design to explore this area.

3 EXPERIMENTS ON LEARNING FROM MODEL DEVELOPMENT AND MODEL REUSE

This section details an experiment, conducted as part of PhD research, to explore the differences between model development and reuse in terms of client learning. The methodology presented here was piloted in a small study and some discussion of this is included in section 4. Although the format of the experiments remains the same, there are some small differences between the two. Specifically the pilot was used to improve the wording of questionairres and decide which reasoning scenarios should be included. It is structured as follows. Firstly, a formal proposition is stated and a short review of the theoretical framework of double and single-loop learning is presented. Secondly, the experimental design, procedure, case study overview, dependent variables and limitations are presented.

3.1 Proposition

Put formally this research makes the following proposition:

High client involvement in model development leads to high client double-loop learning

As illustrated by Figure 1 high client involvement is assumed to reflect some level of client participation in model development. Low client involvement in development is equivalent to a study that incorporates reuse of a full model; for example, a study reusing a generic model.

3.2 Experimental Design

A between-groups design is to be used with the independent variable - the simulation study process - taking three levels: client interaction with a reused model, client interaction with time bound model development and client interaction with 'non' time bound model development. These are summarised in Table 1.

The difference between levels one and two tests the benefit of increased time for model experimentation. Participants in condition one use the time to perform a large amount of experimentation and participants in condition two use the time to build the model and perform a small amount of experimentation. Thus the two levels of independent variable have a controlled time span.

The difference between levels two and three tests the benefit of increased cost (in this case defined as time) of simulation study. Participants run the same number of base scenarios as condition one and are involved in model development in the same way as condition two.

Table 1: Independent Variable: Three Levels of a Simulation Study Process

Level	**Participants must...**
1. Client interaction with a reused model.	a.) review model assumptions, simplifications and dynamic behaviour. b.) form an attitude toward the credibility of the model. c.) simulate all improvement options. d.) think of additional improvement options to simulate.
2. Client interaction with model development for a limited scope study	a.) interact with simulation modeller to conceptualise the model. b.) review model assumptions, simplifications and dynamic behaviour. c.) form an attitude toward the credibility of the current model. d.) iteratively improve the model by increasing the level of detail e.) simulate a limited number of improvement options.
3. Client interaction with model development	a.) interact with simulation modeller to conceptualise the model. b.) review model assumptions, simplifications and dynamic behaviour. c.) form an attitude toward the credibility of the current model. d.) iteratively improve the model by increasing the level of detail. e.) simulate all improvement options. f.) think of additional improvement options to simulate.

3.3 Participants

Sixty second year business undergraduate volunteers, with no simulation experience, will be used to test the proposition; 20 for each condition. To encourage response participants will be paid a small fee for their time. To improve participant motivation an additional cash prize is available for performance.

3.4 Procedure

All participants read a case study based around reducing the length of stay in an A&E department and told that they must take the role of management. They read that the A&E department is performing poorly against a government target and that a recent consultation with staff has suggested a number of operational improvements. The task is to use simulation to evaluate the options and how A&E performance against the target can be improved.

Participants in condition one are informed that the model was developed for a different hospital with a similar process and objective. They must review the model results, logic, simplifications and assumptions, and decide on the validity of using the model for decision making.

Participants in conditions two and three are informed that a researcher will develop a simulation model of the A&E department; they must review model results, logic, simplifications and assumptions, and advice on the workings of the A&E system and the validity of the model.

All participants are introduced to Simul8 (the software used for the study) and DES through a simple one queue model. This is firstly deterministic and then stochastic to illustrate the need for multiple replications (although a long run was more efficient, it was decided that the concept of multiple replications is quicker to explain and understand). Condition one is then presented with the full model. Conditions two and three then go through an additional five iterations of model development and validation.

Model development participants see the researcher increase the level of detail in the one queue model in front of them and are presented with the simplifications, assumptions and results for review. At this point the model is oversimplified and produces inaccurate output. Participants suggest what they feel should be included in the model to improve its validity. Unknown to the participant a set of pre-built sub-models are available to the researcher to accommodate any suggestion made for increasing the level of detail in the model. The researcher can then access the relevant model and give them instant feedback on choices. All participants converge on a final model by iteration six. This is the same model that is used in condition one.

At each stage of development and for each scenario participants can choose to view the model running in addition to getting batch results. Results of 10 replications are automatically exported to Microsoft Excel for review and scenario comparison. Objective validation criteria are provided by a confidence interval for the performance target and subjective validation is operationalised by conceptual model review (Law 2007) and histogram comparison of simulation output (Sargent 1996).

3.5 Case Study

The case study is a fictional Accident and Emergency (A&E) department - St. Specific's - a simplified version of the generic models described in Fletcher et al. (2007) and Günal and Pidd (2006). The objective is to reduce the percentage of patients that are in A&E for longer than four hours over a six month time horizon. Embedded in the case are several contrived learning outcomes for participants. For example a participant may discover:

- Reallocation or removal of nurses from apparent slack periods reduces the performance of the system.
- Eliminating the variable arrival of non-A&E patients to radiology increases the performance of the system.
- The pooled cubicle setup increases the utilisation of resources as well as always having better performance than dedicating cubicles to particular emergency streams.
- Junior doctors add more variability to the performance of the system and in particular the performance of minor patients.

Points one and two are included as base scenarios to investigate and hence are always explored by participants. The latter two points and others can be explored on request in conditions one and three, but are also evident given some careful thinking about the case study and output. For example, a participant in the pilot experiments suggested that the problem was like a 'one lane motorway' and the best solution was to split the streams of emergency patients into a 'two lane motorway' - dedicating various resources to different streams of patients. An adapted model is available to explore and test this theory; the researcher can quickly open it for the participant to explore.

3.6 Data Collection

All participants answer a short pre-test questionnaire. They are then involved in the reuse or development of a DES model and finally they fill in a longer post-test questionnaire. A section in the post-test questionnaire tests the participants reasoning skills on queuing problems. No calculations are required, although in reality it would be advisable for some of the questions to be simulated to confirm intuition, instead participants must choose an answer out of two to four options and specify their reasoning. Inclusion of the full questionnaires is beyond the scope of this short paper, but they are available on request from the authors.

All reasoning questions test one out of two fundamental areas: intuition about the trade off between utilisation and service level and intuition about the effect of process variability on system performance. These are tested in three domains: healthcare, service call centres and manufacturing. Table 2 provides an example of how this is tested. Both the healthcare and manufacturing scenarios test intuition about the trade off between utilisation and service level. If the trade off is properly understood then given the service level targets and current performance intuitively the participant should plan for spare capacity.

Table 2: Example Scenarios for Transfer of Learning

Context:	Healthcare	Food Manufacturing
Scenario:	Utilisation of resources is approx 75%. Demand for service will increase in next month.	Utilisation of resources is approx 70 - 86%. Losing orders to faster rival company
Objective:	Service level must be maintained	Service level to be improved.
Options:	Hire more staff; Leave as is	Replace bottle neck; Increase utilisation.

3.7 Dependent Variables

Single-loop learning is inferred from the change in participants *attitudes towards (management) behaviour* (for an overview of the theory of planned behaviour see Ajzen 1991). These management attitudes refer to, firstly, balancing the trade off between resource utilisation and service level and, secondly, considering the effect of variability in the system over time when predicting performance. Changes in the attitudes can be used to infer that participants have *at least* learnt new strategies for managing A&E i.e. single-loop learning.

Double-loop learning is measured by two dependent variables (DVs). The first is the participant's *ability to predict and explain system behaviour*. This is measured using open ended questions that relate to the case study simulated. The second measure is *close and far transfer of modelling insights*. For example, if a participant clearly understands the trade-off between utilisation and service level in the A&E system they will not run machines in a factory at 100% utilisation given a similar objective. In addition *the confidence in the validity of their reasoning* is measured. It may be that participants are less certain that they are correct when applying new knowledge to solving problems.

Three additional DVs are included to help understand the process of learning. Firstly, credibility of the model and its results is measured in two ways: a *credibility assessment* and *the confidence that a participant places in their credibility assessment*. Secondly, in conditions one and three participants are allowed to suggest *new simulation scenarios*. This in part reflects their commitment to public testing of their beliefs (a requirement for double-loop learning) but may also reflect how creativity is influenced by model development and reuse. Lastly, a record is also kept of the order and type of *conceptual decisions* made by participants when involved in model development.

3.8 Limitations of the Experimental Approach

Due to the time constraints of the PhD research there are, of course, some limitations to the methodology described in this paper. Firstly, the simulation model and choice of case study may affect learning. For example, a simulation model with the same objective designed by a different researcher may yield better results or a model from a different domain (e.g. manufacturing) may make it easier for a participant to gain a deeper understanding. Secondly, the measurement of learning can be problematic. For example, it may be that a different set of questions are easier or more difficult for participants to transfer insights. In addition as learning is assessed by questionnaire a ceiling effect may be present. That is, learning can only be inferred up to a participant answering all questions correctly. Lastly, the experimental setting and design may also influence the answers from participants. For example, exposure to the pre-test may influence answers on the post-test (Field and Hole 2003). Careful interpretation of results is needed in light of these limitations and the simple experimental design presented in this paper assists in this process.

4 RESULTS OF PILOT TESTING

A number of experimental pilots were run to trial the methodology put forward in this paper. While no strong evidence can be drawn from the pilots they did provide some food for thought on the dynamics of learning in simulation studies. Some indications found were:

1. The experimental conditions appear to lead model reuse participants to perform a heuristic judgement of credibility.
2. It is likely that participants fail to understand the trade-off between resource utilisation and service level. In particular participants may strive for maximum utilisation.
3. Although correction of the management of utilisation can be achieved, the transfer of that understanding to more abstract scenarios appears to be difficult.

This section provides a short overview of these indications and how this fits in with the existing literature.

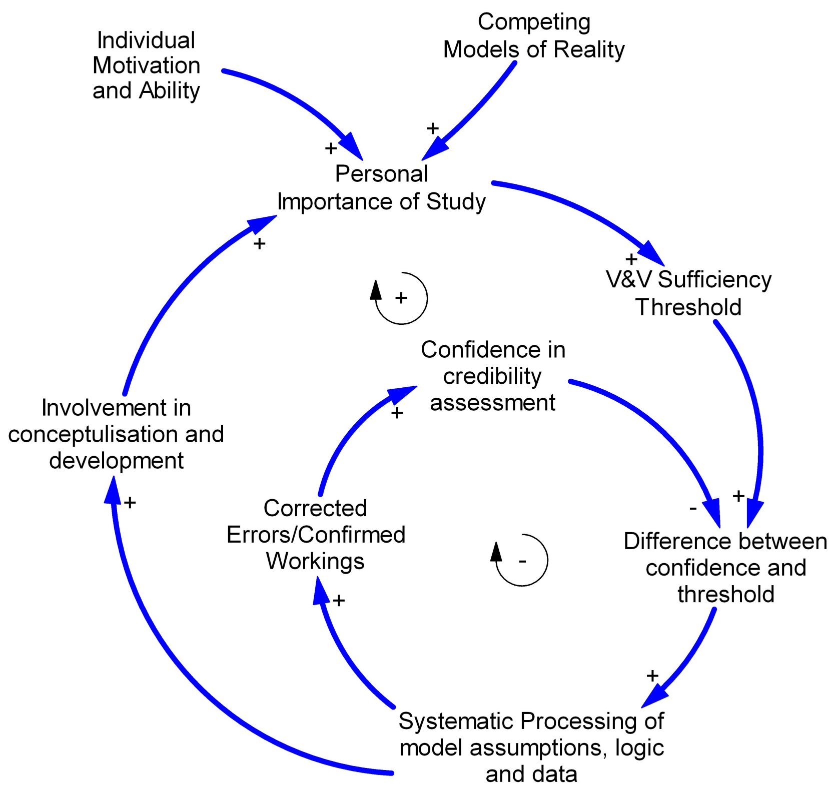

Figure 2: A Dynamic Hypothesis of Credibility Assessment

4.1 Assessment of Credibility

Point one was noticed because the pilot experiments have indicated that model builders and model reusers both rate the model as highly credible. However, they may follow very different approaches to forming their attitude. For example, model reusers quickly accept the model with little questioning where as model builders openly question assumptions, simplifications and data.

If the position is taken that credibility is a client attitude towards the model and its results (Robinson 2002), as opposed to an attribute of the model (Balci 1994), then this appears to be consistent with dual-process persuasion theory (Chaiken et al. 1989, Petty and Cacioppo 1986). To illustrate this a dynamic hypothesis is depicted using a causal loop diagram in Figure 2. The direction of the arrow head in causal loop diagrams indicates the direction of causality while the sign of the arrowhead indicates the effect of the causality (Pidd 2004). The small loops containing positive and negative labels indicate the reinforcing or balancing feedback of the loops respectively.

A key variable in the theory is the *personal importance of the simulation study* to the client. This will be affected by an individual's natural motivation and possibly any competing models of reality that can also explain system performance. High involvement in the conceptualisation and development of the model increases personal importance of the study above what it would have been. This in turn increases the threshold for where verification and validation (V&V) of the model is viewed as sufficient. Importantly a higher V&V sufficiency threshold increases the systematic processing of information (Chaiken et al. 1989): in our case model assumptions, logic and data. This reinforces involvement in the study as re-conceptualisation may be required. Balancing this loop is confidence in the validity of credibility assessments. The higher the systematic processing of information the more errors in the model are exposed and fixed or workings confirmed. The more clients participate in this way the higher their 'thought confidence' becomes (Petty et al. 2002). This continues until the V&V sufficiency threshold is reached. Thus it is predicted that clients with high involvement in development will apply more scrutiny to the model and have high confidence in the validity of their credibility assessments. It is also predicted that participants with low involvement in development will use more heuristics in forming their attitude of credibility (e.g. the model has been built by an expert) as their sufficiency threshold for V&V is lower. In other words, although both model development and model reuse clients may rate the model as credible, model reuse clients may have low confidence in the validity of their assessment of credibility - a sort of heuristic credibility. Model development clients may hold a more systematic high confidence attitude to the credibility of the model and its results as they have scrutinised the model to a greater extent.

An extension to this hypothesis, that the main research will consider, is the influence that the personal importance of the study and the confidence clients have in their credibility assessments have on learning. Some evidence is already available in the simulation literature: one of Rouwette (2003) conclusions is that 'if the issue [being modelled] is not sufficiently important [to the client], learning effects may be absent and thus implementation of modelling conclusions hampered' (Rouwette 2003).

4.2 Theories for Managing Resource Utilisation

Another interesting indication from the pilot was that participants may hold a strong belief that to speed up a system then all resources should be working at maximum utilisation. While this may be a good value for money argument, simple queuing theory will show that if there is an objective to meet a specific service level then their will be a trade-off with utilisation (Cooper 1972, Suri 1998). Most pilot participants failed to recognise this at the start of the experiment. Thus it was observed that participants appeared confused when their strategies to reallocate staff from less busy shifts to busy ones produced a decrease in performance.

One conclusion could be that this indication comes from the use of undergraduate students who have failed to encounter this problem before. However, this result agrees with surveys done in real manufacturing organisations. Suri (1998) found that 73% of a sample of 450 manufacturing CEOs and managers held this belief. This would suggest that the results of queuing theory and DES do not just provide confirmatory and quantitative estimations of performance to clients, but, sometimes, also provide counter-intuitive insights.

4.3 Correction of Theories to Manage Utilisation

One positive indication from the pilot was that this erroneous theory could be corrected by development or reuse of a simulation model. However, to transfer this insight to another domain may have more variable results. For example, in the post-test questionnaire participants are asked about what they would do about resource utilisation in two domains: healthcare and manufacturing. Participants may answer that in order to maintain a service level in the face of increased demand in a healthcare context then additional staff should be hired. The same participants may then propose that the utilisation of machinery in a manufacturing environment is increased to 100% in order to improve on service level. Qualitative answers that accompanied these responses may be along the lines of 'the machine is not used optimally'. In fact their management of the system increases system time as large work in progress will accumulate.

Evidence suggests that transfer of learning is strongly influenced by the perceived similarity of the transfer problem to the original (Barnett and Ceci 2002). If a participant successfully transfers a strategy they learnt to manage the simulation to a new scenario then it is because they perceived it to be very similar to the case study (e.g. healthcare scenarios). They would fail to transfer insights to a manufacturing scenario if they do not recognise the deeper structural similarity of the scenarios (Barnett and Ceci 2002). Thus, lacking this understanding, participants make the same mistakes and mismanage the new domain.

An explanation of this lack of recognition may be related to difficulties in double-loop learning. Individuals employ an approach to learning that is actually counter-productive to the very thing they are trying to achieve (Argyris and Schön 1996). Similar to Rouwette's finding it may be that insights about utilisation are simply reconciled against existing assumptions and beliefs. The full experimental results should provide more insight into this area.

5 CONCLUSION

The construction and validity of the reuse of generic models has received much attention in the DES literature. On the other hand there are only a small number of papers that explicitly consider the simulation clients perspective of reuse. One factor to consider stems from authors and practitioners often stating that clients learn from both simulation model development and use. Thus, it is important that the effects of reusing models as opposed to some level of participation in developing one are explored. This paper presents an overview of an empirical experiment to explore and test for differences in learning outcomes in simulation model reuse and development studies. Argyris and Schön's theories-of-action framework (Argyris and Schön 1996) is chosen as a theoretical basis to study this phenomenon. The concepts of single and double-loop learning being useful to study short and long term impacts of simulation studies. The results of the pilots presented in this paper should only be viewed as *indications* of the learning outcomes of DES development and (re)use. It should also be acknowledged that this research has time and resource constraints and thus cannot test all aspects of learning in simulation studies - it is hoped that further research will either refute, replace or extend the theory discussed in this paper. This exploration of the learning process contributes to the understanding of model reuse, for example the validity and construction of generic models, by highlighting the issues and benefits for DES reuse as an aid to decision making.

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