

COMPUTERIZED BUSINESS SIMULATIONS: A SYSTEMS DYNAMICS PROCESS

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ABSTRACT

Computerized Business Simulations involve a feedback process that parallels that of Industrial Dynamics and Servomechanisms. This paper suggests that the servomechanism's dynamics in real and imaginary space are paralleled by the business simulation's cognition, affection and workload dynamics. The paper explores these dynamics in terms of their patterns, problems and interactions. The paper then discusses how to overcome these problems and improve learning through the natural and managed responses of the business simulation system.

INTRODUCTION

Gold (2003) explored system dynamics at the simulation model level and in his conclusions stated “*The design of computerized business simulations has focussed on the development of its subsystems*” and suggested “*However, it is clear that from the system-dynamics literature that a more holistic approach is needed*”. But this focuses on the internal

model system and around this is the system that includes the learners and how the relationship between the two progress dynamically as the simulation runs. (The progression was briefly explored by Hall (2004).)

SYSTEMS DYNAMICS PROCESS MODELS

A computerized business simulation involves a feedback process (Figure 1) where the learners make decisions that are processed by the simulation model producing results. Results that are fed back to the learners to compare with their desired results. Based on the difference between the actual and desired results and the changing situation, learners make more decisions that are entered into the simulation model and this process is repeated.

This feedback process is equivalent to the Forrester's Industrial Dynamics model (1961) (Figure 2a). (Forrester's model was developed from the servomechanism feedback process. (Figure 2b).)

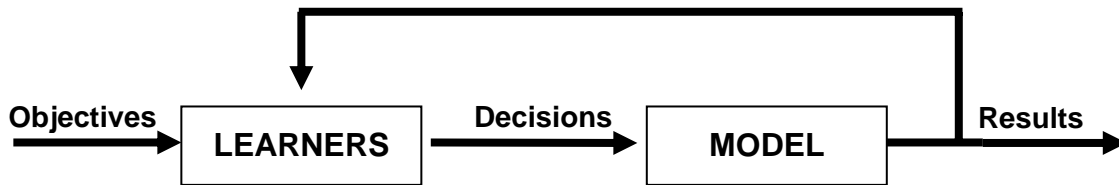


Figure 1: Simulation – basic feedback process

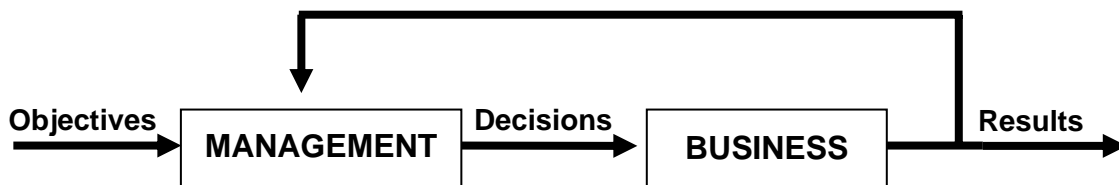


Figure 2a Forrester's Industrial Dynamics model

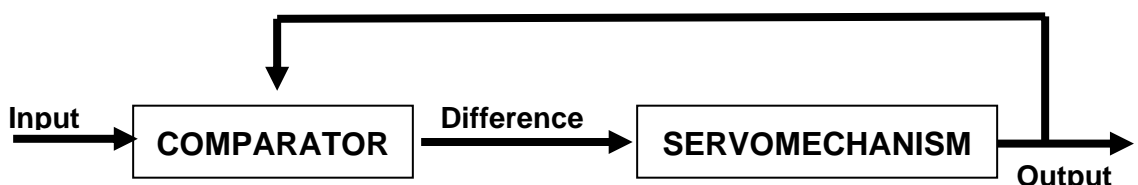


Figure 2b: The basic Servomechanism process

The servomechanism's designer has the problem of maximising the accuracy with which the servomechanism matches output with input and the speed of its response to changes in the input position. Also, a servomechanism is a dynamic system where inappropriate or badly timed feedback can cause catastrophic system failure. Inappropriate corrective feedback can be illustrated by a novice bicycle rider's response to a bump that causes the bike to wobble. The novice attempts to corrects the wobble, but because the response is delayed the wobble increases until the rider falls off. In a similar way, not considering the system dynamics of the learning process can cause a catastrophe.

The servomechanism designer analyses the feedback system in terms real and imaginary dimensions and the frequency response of the system. The *real* dimension is concerned with the way the servomechanism matches output to input and thus parallels the way the simulation marches cognitive learning with learning objectives. The way the servomechanism behaves in the *imaginary* dimension provides insights into its stability and, for simulations it is paralleled with a *affective* dimension that provides insights into the learners *emotional* behaviour. Finally, the frequency response and loop gain of the simulation impacts the speed and stability of response and this is paralleled by the workload facing the learners.

Thus, for simulations the servomechanism's real and imaginary dimensions map to cognition and affection and the servomechanism's frequency response and loop gain maps to workload. This equivalence provides insights and has implications in terms of the speed of learning, participant

behaviour and cognitive load. Specifically there are three interacting dynamics - cognition, affection and workload.

THE COGNITIVE DYNAMIC

Just as the purpose of the servomechanism designer is to maximise the speed and accuracy of the response to changes in the input, the purpose of a business simulation is to meet learning objectives in the shortest possible time. So both are concerned with effectiveness and efficiency.

Unlike the conventional learning where expertise is assumed to increase in an S-curve (Dewey, 2007) and this is similar to the servomechanism's response to a step change in input (Coyle, 1977). For a simulation this is paralleled by a step change in required expertise (learning objectives) that is progressively reduced as the simulation progresses. However, for simulations learning the S-curve is distorted as, initially, there is slight confusion (Figure 3). However, then learning follows the conventional S-curve except, to make most efficient use of the learners' time, the simulation ends before the rate of learning slows significantly.

So, the cognitive dynamic is concerned with effective learning (reaching the desired learning goals) and efficient learning (reaching these goals in the shortest possible times).

THE AFFECTIVE DYNAMIC

In addition to the cognitive (learning) dynamic, there is an affective (feelings) dynamic (Figure 4) that has to be managed.

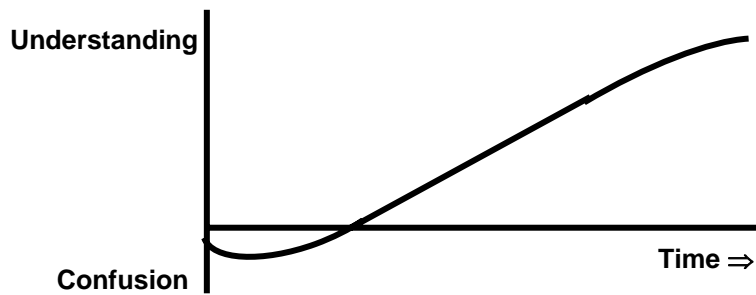


Figure 3: The cognitive (learning) dynamic

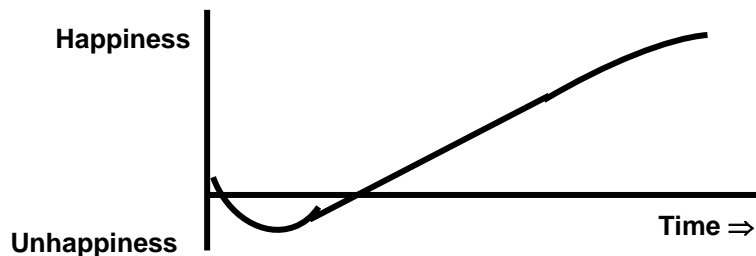


Figure 4: The affective (feelings) dynamic

THE DYNAMICS – PROBLEMS

Typically, participants in a simulation start enthused feeling that their business acumen will mean that they will find it easy to make good decisions. However, when, they find the simulation is harder than expected, their enthusiasm wanes and they may become discouraged. However, as they learn (and see business success) their enthusiasm increases. Affection is influenced by the maturity of learners (their ability to handle stress, success and failure), workload (to high or too low), the relevance of the learning and the structure of their team (mix of knowledge and skills and individual personalities).

So, this design aspect takes into account the *people* aspect of the learning group and how the design addresses this over time. It addresses the extent to which the simulation is engaging.

THE WORKLOAD DYNAMIC

This, the final dynamic, explores how the cognitive workload changes during the simulation (as shown in Figure 5).

Workload starts high as the learners learn about the business that they are to manage and if appropriate, their fellow team members and competing teams. As time passes, if no other challenges are introduced, workload falls. Ideally, the workload pattern should not cause too much or too little work.

This section describes and discusses the problems in terms of cognition (confusion) or affection (disaffection). Problems that are regularly observed and described in the experiential learning/simulation literature (Cryer 1988a, Cryer 1988b, Hall 1977, Jones 1989, Lundy 1984).

With the **cognitive dynamic**, if the simulation is not linked to participant capabilities (in terms of prior learning and experience) or too much or too little time is allowed then cognitive development will be inappropriately complex for the time available and participants will become progressively more confused (Figure 6 – too complex or too little time line). The opposite problem is where the simulation is too simple or too much time is allowed for it and this results in the learners rapidly reaching competence and then making inefficient use of their time (Figure 6 – too simple or too much time line).

In practice, the more likely problem occurs because the simulation is too complex or too little time is allowed for the activity. Providing too little time is the outcome of the pressure to have short courses. Unfortunately there is a very strong correlation between simulation complexity and required duration (Hall & Cox, 1994). If duration is shortened too much, learning does not occur as participants never climb the learning curve.

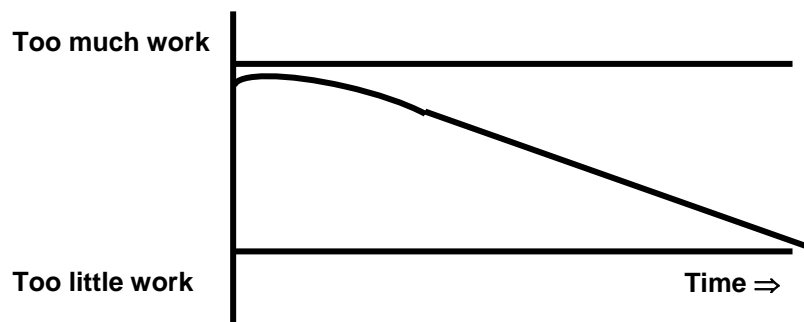


Figure 5: The (cognitive) workload dynamic

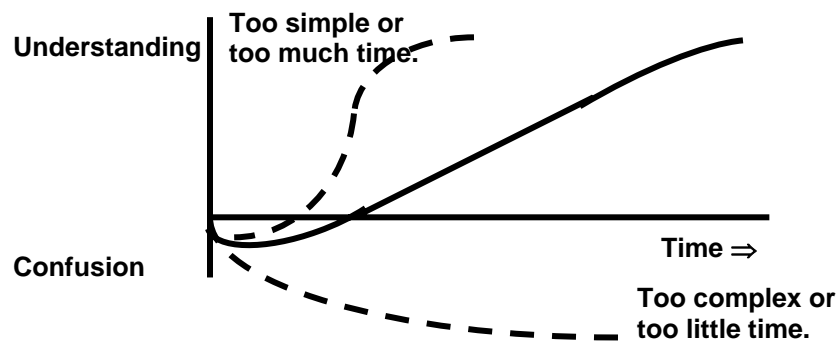


Figure 6: Cognitive Dynamic problems

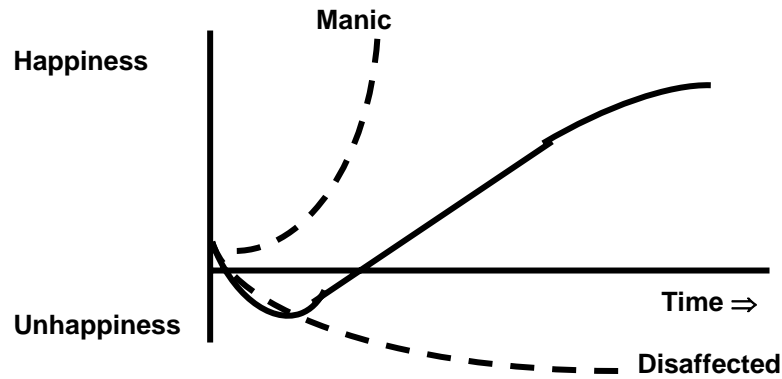


Figure 7: Affective Dynamic problems

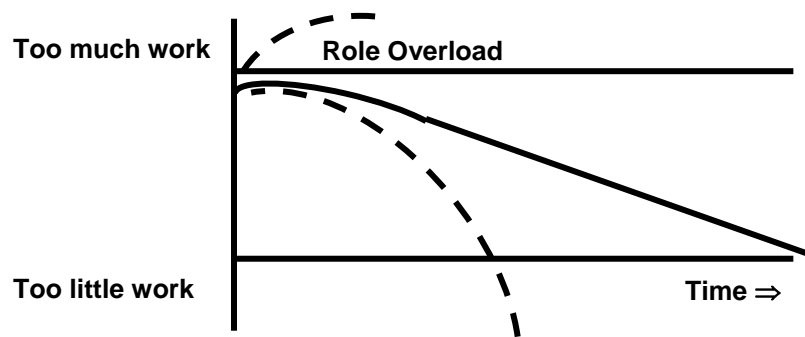


Figure 8: Workload problems

Just as design for the cognitive dynamic has to take into account prior learning, the design for the **affective dynamic** must take into account maturity, the ability of the learners to handle ambiguity, uncertainty and stress and how the dynamic changes over time. This leads undesirable behaviours – manic where learners over react to success and disaffection where learners overreact to failure (Figure 7)

The final dynamic is **workload** (Figure 8). Even if the simulation is suitable in terms of cognitive and emotional challenge, an unsuitable workload causes problems. If the cognitive workload is too high then learners will not be able to make think through decisions and this *role overload* (French and Caplan, 1972) will cause disaffection. Equally, if the cognitive workload is too low, participants will not be challenged and become disaffected as they perceive that they are wasting their time.

THE INTERACTING DYNAMICS

Although shown separately, these dynamics interact with one another and influence the effectiveness and efficiency of learning. For instance, if the time set for making the initial decision is too short, this will mean that there is cognitive overload (role overload) and this will both add to the confusion (cognitive dynamic) and cause disaffection (affective dynamic).

Equally, if participants feel that they are not learning (cognitive dynamic) as adult learners they will become disaffected (affective dynamic) and see the activity as a waste of time (workload dynamic). Also, if the workload falls too far then participants will feel that their time is being wasted and become disaffected (affection dynamic). Further, this means that learning efficiency is lessened (cognitive dynamic).

When designing and using a business simulation it is necessary to take these dynamics and their interactions into account and the next section discusses how the simulation can progression period-to-period or stage-to-stage and how the problems can be overcome.

DESIGN PRACTICALITIES

NATURAL RESPONSE

The dynamic design of a simulation involves designing to take into account the dynamics. In effect this is designing the *natural pre-planned response* of the simulation. Here we are concerned with the simplification and stylisation of the simulation to enhance learning (Hall 2008). Specifically, we are concerned with the behaviour of the model and how the simulation progresses from period-to-period or stage-to-stage (Hall 2008) in terms of:

Table 1: Results (Viewpoint) Progression (Hall, 2008)

Product Launch – Results Progression	
Period	Report
1	Single, basic report showing outcomes for the period
2	Basic report plus comments to stimulate thought
3	As for period 2 plus a report showing decision and result trends
4	As for period 3
5	As for period 4 plus report showing trends in marketing issues
6	As for period 5 plus profitability report and sales graph
7	As for period 6 plus sales forecasting report and income & profit graph

Table 2 – Decision Progression

Decisions	Period
Percent Mark Up	1
Inventory Purchases	1
Marketing (Sales Support)	1
Staff Numbers	2
Training Days	3
Number of Products	4
Receivable Days	4
Electronic Linkage	5
Demo Equipment	5
Demo Room	5
Small Project Initiative	5

- **Model Responses**
- **The Economic Progression**
- **Result Progression**
- **Decision Progression**

The **Model Responses** (the dynamics of the model, the impact of decisions and delays in their effect) have considerable impact on learning. This is illustrated in extremis by the MIT Beer Game where delays and interactions cause team results become unstable with increasing *amplitude oscillations* (Sterman, 1992). Sterman discusses the reason for this in terms of *multiple feedback loops, time delays and nonlinearities in the system*. Although this instability is a planned characteristic of the Beer Game, it is a situation that can occur with all business simulations. Hall (2008) described that the first version of his Product Launch simulation *realistically* delayed the impact of price reductions. But because of the ambiguity of this “*it was impossible for participants to visualize the impact of their price decision*”. Instability as illustrated by the Beer Game is a characteristic problem with servomechanisms as illustrated by the novice bike rider earlier.

The **Economic Progression** of a simulation defines the way the simulation’s business and economic environment changes and evolves over time. Thus it incorporates the economic progression/evolution, the business progression/evolution and the issue progressions. A common method is to start the simulation in a liquid situation and over time erode this liquidity as the learners grow the business. Because the initial situation is liquid, learners do not have to be concerned with cash flow and this reduces the cognitive load. However, as the simulation

progresses and as the cognitive load decreases, learners are able to handle the additional cognitive load caused by having to handle liquidity (or solvency) problems. An example of the practical application of Economic Progression is pre-defined sales pattern of the TEAMSKILL simulation (Honeywell Information Systems, 1971). TEAMSKILL was a complex operations management simulation where participants ran a factory on a month-by-month basis for a year. Participants had to ensure that the factory was able to meet sales where these had a significant seasonal pattern. When the participants started running the factory, they had reasonable levels of finished inventory. To help them as they learnt to schedule the factory, sales were moving into the seasonal dip in the middle of the first half-year. This meant that for the first few months participants could make multiple scheduling mistakes yet still have enough finished inventory to meet sales demand. In the second half of the year, the sales peaked and in doing so stressed the participants’ ability to schedule. This meant that cognitive pressure started low and then increased at the point when the participants had learn enough to be able to handle it.

Results Progression allows the progressive introduction of different viewpoints and issues and hence stimulate thought and discussion about different business issues. The data behind the reports must be built into the simulation. But as, in general, this is required as part of the design, it is unlikely to lengthen design time and increase design cost. An example of results progression was described by Hall (2008) where he describe how for his Product Launch simulation new results were introduced (Table 1)

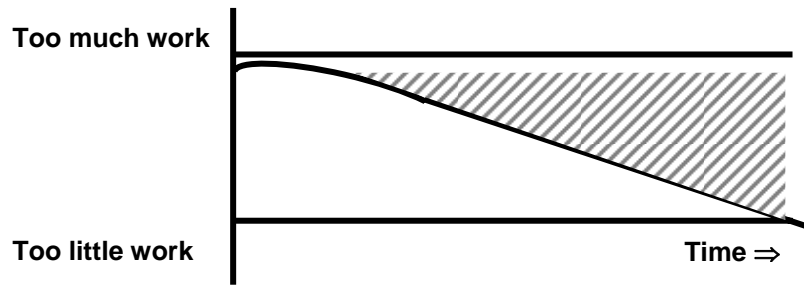


Figure 9a Impact of managed response on workload

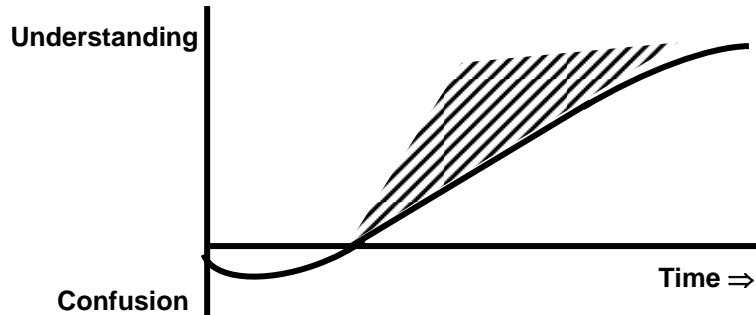


Figure 9b: Impact of managed response on cognition

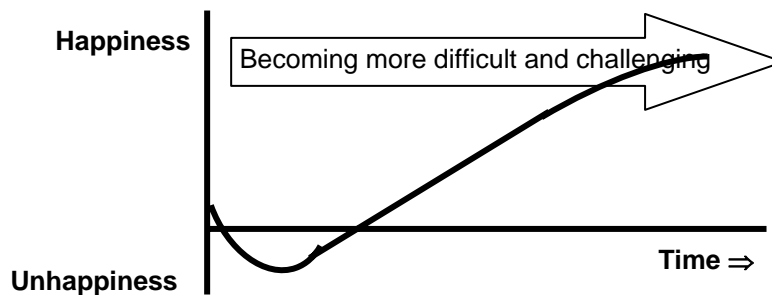


Figure 10: Impact of managed response on affection

Decision Progression allows the progressive introduction of different issues and tasks. As the decisions are introduced, it is necessary to introduce reports indicating their outcomes. The DISTRRAIN simulation introduced new decisions during the simulation (Table 2). Introducing new decisions also impacts affection as is illustrated by this statement from trainers running the DISTRRAIN simulation “*the continuous introduction of new ideas kept everyone interested*”.

As the models linking the decisions and results must be built before a decision is introduced, the simulation may have to *intelligently* make the decision for the participants. For DISTRRAIN, where ultimately learners decide staff numbers, before the staff number decision is introduced the simulation model calculated the *best* number of staff to employ.

IMPACTS ON THE DYNAMICS

Combined Economic, Report and Decision Progressions ensure that workload is maintained (shaded area Figure 9a) and this allows additional learning or shortens the simulation (shaded area Figure 9b). For example by phasing decisions (Table 2) this allowed DISTRRAIN’s duration to be reduced to a day as well as introducing additional business issues.

Besides managing the cognitive and workload dynamic, there is a need to manage the **affective dynamic** in terms of the *style* of the feedback and simulation difficulty (Figure 10)

As the simulation progresses, the initial feedback should be positive (concentrating on business strengths) but later, it can become negative (extending to business weaknesses). So, for initially the simulation might make comments about good levels of profitability, sales growth, etc but not mention losses and weaknesses. Later the simulation would identify areas of

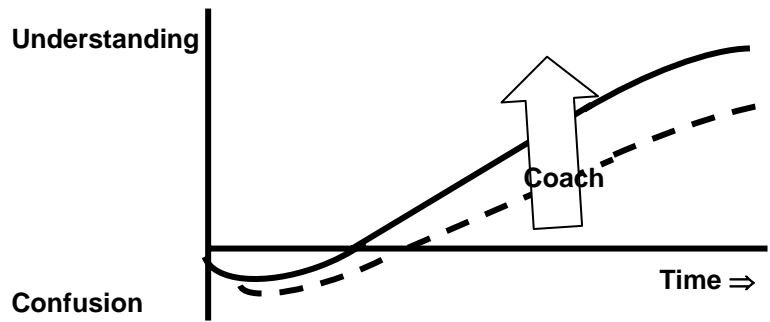


Figure 11a: Trainer Managing Cognition

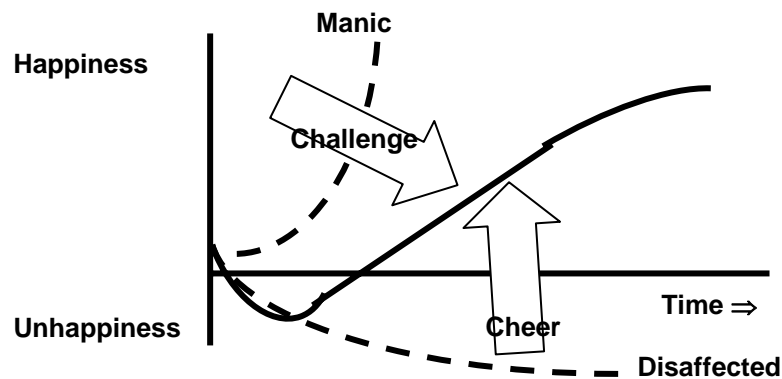


Figure 11b Trainer Managing Affect

weakness (such as a poor mix of business, losses on individual product sales, etc.) and, perhaps, raise profitability expectations. Further, the *ramping* of economic difficulty and the number of results and decisions, prevents work (role) overload in the early stages of the simulation. An example of how this was a vital aspect of the design was the DISTRAIN simulation. Here the client's desire was to replicate closely an electrical equipment distributor. Characteristically, such businesses have very low margins and it is difficult to make adequate or any profits. The alpha test version of the simulation replicated this. Unfortunately, this was totally disaffecting causing major problems. As a consequence, the margins were increased, sales growth was built into the markets and it was possible during the simulation to improve operational and marketing efficiency significantly. The result was a simulation where learners could *turn a failing business around*. A stylisation that overcame the problem and ensured *happy learners!*

MANAGED RESPONSE

Where a business simulation is run by a trainer, he or she can coach and challenge learners and answer their questions on a proactive basis. Providing trainer-managed feedback allows the **cognitive and affective dynamic** responses to be *managed* based on the actual knowledge, experience and maturity of the learners. Appropriate *content* feedback can reduce cognitive learning problems and increase learning (Figure 11a) and how

the appropriate *style* of feedback can deal with problems with the affective dynamic (Figure 11b).

Workload can be managed by shortening the time between decision periods, providing additional reports that cause the learners to discuss new aspects of and issues of the business that they are managing or playing the role of *head office* and asking the learners to provide information.

MANAGED RESPONSE CONTROL PROCESS

Initially, the Management Response control process involves *analysing* learning progress through observation, decision and result analysis (Figure 12). Based on this analysis, the trainer must decide whether there is a learning problem and if there is, whether this is Cognitive (C), Affective (A) or Both (B).

TRAINER FEEDBACK INFORMATION

Although the simulation cannot help with the observation of the team, it can be a vital aid to analysis of decisions and results, identification of whether there is a learning problem, and the style and content of the response.

At the **analysis** stage, the simulation can warn of decisions that are illegal, unusual or sophistic – decisions that may indicate misunderstandings or lack of business knowledge (cognitive dynamic problem) or are arbitrary (affective dynamic problem).

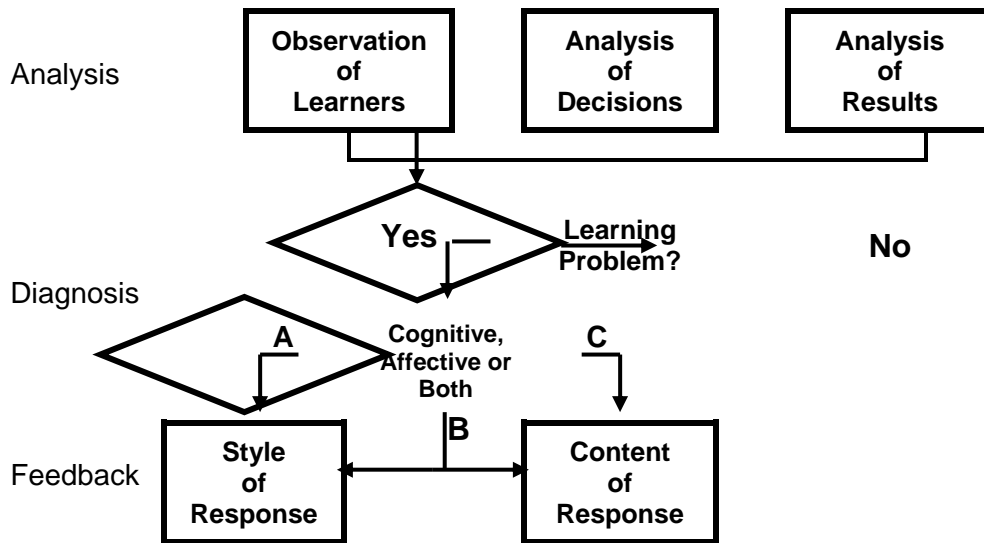


Figure 12: Managed Response Control Process

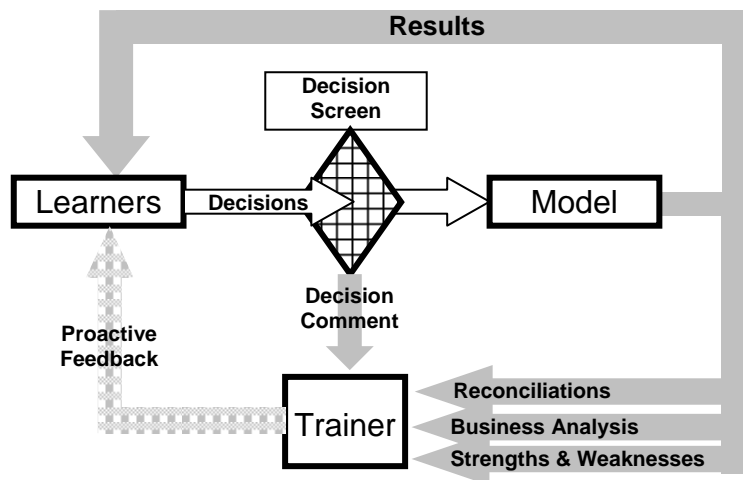


Figure 13: Trainer Feedback Information Flows

After processing the decisions, the simulation can analyse results to identify *strengths* and *weaknesses*.

At the **feedback** stage, the simulation can help provide supporting information. The information that the simulation can provide to help the trainer to manage the process is summarised in Figure 13.

Here the trainer is in a second feedback loop that provides the information warning of problems and the information necessary to answer questions, challenge and coach. First as decisions are entered, the simulation screens these, and highlight issues. Then after a period is simulated, the model provides *reconciliations* (showing detail calculations) and *business analysis* to help identify *strengths and weaknesses*. Based on this information, the trainer can *proactively* provide feedback to the learners.

CONCLUSIONS

Allowing for the dynamics of the learning process takes simulation design beyond the creation of a simulation model and its decisions and results. It accounts for cognition, affection and workload and how these change as the simulation progresses. In effect it moves design from a static representation of reality to one that takes into account the wider system – the learners, the trainer and the dynamics of use.

This systems dynamics view of how a simulation progresses allows one to design the *natural response* of the simulation and in doing so improve cognition, overcome affective problems and ensure the more efficient use of learners' time. However, as learners are not homogeneous there is also a need for *managed response*. Here separate *feedback loops* are provided to allow the trainer to manage learning.

REFERENCES

- Coyle, R.G. (1977) *Management System Dynamics* John Wiley & Sons
- Cryer, P (1988a) Managing and behavior in educational games, simulations and workshops: a motivational perspective, *Simulation/Games for Learning*, 18 (2).
- Cryer, P (1988b) Insights into participant's behaviour in educational games, simulations and workshops: catastrophe theory application to motivation, *Simulation/Games for Learning*, 18 (3).
- Dewey, Russell A (2007) *Psychology: An Introduction* <http://www.intropsyc.com/index.html>
- Forrester, J.W. (1961) *Industrial Dynamics*, MIT Press
- French, Jr. J. R. P and R. D. Caplan (1972) Organisational Stress and Individual Strain in *The of Success* ed Alfred J. Marrow AMACOM American Association Inc New York
- Gold, Steven (2003) The Design of a Business Simulation using a System-Dynamics-Based Approach *Developments in Business Simulations and Experiential Exercises* Volume 30 Reprinted in the *Bernie Keys Library*, 8th Edition [Available from <http://absel.org>]
- Hall, J.J.S.B. (1977) *Decision Administrator's Guide*, Hall Marketing, London
- Hall, Jeremy J. S. B and B. M. Cox (1994) Complexity is it Really that Simple *Developments in Business Simulations and Experiential Exercises* Volume 21 Reprinted in the *Bernie Keys Library*, 8th Edition [Available from <http://absel.org>]
- Hall, Jeremy J. S. B. (1994a) Computerised Tutor Support Systems: the tutor's role, needs and tasks, *The Simulation & Gaming Yearbook Volume 2* eds. Roger Armstrong, Fred Percival and Danny Saunders Kogan Page London.
- Hall, Jeremy J. S. B (1994b) Computerised Tutor Support Systems *Developments in Business Simulations and Experiential Exercises* Volume 21 Reprinted in the *Bernie Keys Library*, 8th Edition [Available from <http://absel.org>]
- Hall, Jeremy J. S. B. (1994c) Computer Paced Project Management Simulation *Developments in Business Simulations and Experiential Exercises* Volume 21 Reprinted in the *Bernie Keys Library*, 8th Edition [Available from <http://absel.org>]
- Hall, Jeremy J.S.B. (1996) *SIMULATION: Virtual Business Experience*, Hall Marketing, London
- Hall, Jeremy J. S. B. (2004) Computer Simulation: A Design Architectonic *Developments in Business Simulations and Experiential Exercises* Volume 31 Reprinted in the *Bernie Keys Library*, 8th Edition [Available from <http://absel.org>]
- Hall, Jeremy J. S. B. (2008) Corporate Cartooning: The Art of Computerised Business Simulation Design *Developments in Business Simulations and Experiential Exercises* Volume 35 Reprinted in the *Bernie Keys Library*, 8th Edition [Available from <http://absel.org>]
- Jones, K. (1984) Running, or stumbling through, simulations, *Simulation/Games for Learning*, 1984.
- Lundy, J. (1984) The effects of competition in business games, *Games and Simulation*, 10.
- Sterman, J. D. (1992) Teaching Takes Off: Flight Simulators for Management Education, *OR/MS Today*, October 1992