A Review of System Dynamics Models of Educational Policy Issues

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Abstract

A number of papers have been published describing various System Dynamics (SD) models of various Education institutions and issues, on topics including the role of SD in Corporate Governance, Planning, Resourcing & Budgeting, Teaching Quality, Teaching Practice, Microworlds and Enrolment Demand. This paper builds on previous papers by this author that provided a partial catalogue and classification of this work in order to highlight potential areas of research in this field of study and to identify system archetypes at different hierarchical levels and discover new ones. This paper therefore presents a Review of System Dynamics Models in Education. This paper builds on the earlier taxonomy by widening the scope of the survey of completed SD investigations in educational management. The findings from these investigations are briefly described. The Review classifies the completed investigations into seven specific areas of concern and five hierarchical levels.

1. Introduction

The System Dynamics Society's (SDS) Education Special Interest Group (SIG) has twin interests in publicising and enhancing both the contribution of SD to Education Management and the evolution of the contribution of SD to the curriculum - in both cases the interest spans the whole span of education from K-12 (schools) to Higher Education. The Author is the Co-Chair of the SIG and has developed this review of publications of relevant SD Models of Educational Policy Issues to aid future research and to help to spread good practice within the SIG's area of interest. The SIG also wishes to encourage graduate students to consider examining enhanced techniques for improving the contribution of SD to Educational Policy in their dissertations and to improve interaction and collaboration with other groups conducting K-12 based activities.

This paper builds on the author's earlier publications in this area (Kennedy 2000a, 2002). Kennedy (2008) separated the Policy Aspects of Education, examined though the application of SD, reviewed in this paper from the Pedagogic Techniques (described in a sister paper). The objective of this paper is to facilitate and structure debate on the use appropriate techniques for the utilisation of system dynamics (SD) (Forrester 1961) in Educational Policy and in particular by extending the Planning, Resourcing & Budgeting section of the taxonomy. Universities, Colleges and Schools are continually evolving to meet government, employer and student needs, hence the emergence of new management problems (Kennedy and Clare, 1999). Education has been facing a series of changes with legislation and changes in government policy as one the most important driver. Due to the difficulty in managing

complex environments the whole picture in terms of developing interventions is difficult to interpret. The impact of various external interventions and strategies adopted by institutions to manage and control factors is difficult to evaluate and to observe the impact on the system as a whole has been problematic.

To guide management decision making statistical linear models and spreadsheets are widely utilised. We have contended (Kennedy and Clare, 1999) that these essentially static modelling approaches are inadequate for this application domain because educational institutions are dynamic, complex, non-linear systems. However, system dynamics methodologies have sought to redress this problem and find ways of encapsulating problem domains to assess the impact of various interventions on the system and its outputs.

Such a system can be characterised by interactions of closed chains (or feedback loops) that, when combined, define the structure of the system and hence how it behaves over time. I therefore believe SD to be an appropriate modelling technique for education management (Kennedy 2000a, 2002). A number of SD practitioners have addressed some of the problems of education management and the findings from their investigations are outlined in section 3 below. The interest in this field is indicated by the holding on an international seminar on 'Using System Dynamics as a Tool for Decision Making in Higher Education Management' in June 1999 at the Royal Society, London and London South Bank University, under the auspices of the Society for Research into Higher Education (Kennedy, 2000b) and the subsequent founding of a special Interest Group of the SD Society. A follow up event is currently being planned.

2.   A Review of System Dynamics Models in Education

The updated review is based on a survey of completed SD investigations in education management and other (non SD) papers that examine HE policy issues. The findings from these investigations are catalogued and classified below and briefly described in section 3. Plain items refer to models and items in italics refer to underpinning theory. Bold items have been added to the taxonomy in this paper. A more extensive summary of the work that was included in earlier taxonomies may be found in Kennedy (2000a and 2002). Some comments are reproduced from the earlier paper in order to give a better coverage of the area.

The initial Taxonomy was based on a limited survey of completed SD investigations in higher education management. In subsequent versions the number of sources has been greatly increased and both pedagogical issues and provision for School/ K- 12 have been added

To the six original areas of concern (Corporate Governance, Planning, Resourcing & Budgeting, Teaching Quality, Teaching Practice, Microworlds, Enrolment Demand), two more (External forces/ legislation and Human Resource Management Dilemmas) have been added. Teaching Practice is not felt to be relevant to Educational Policy Issues and so has been excluded. Are more needed?

The five hierarchical levels (National, Regional/ State, University/ Institute, Faculty or Department and School/ K- 12) have been modified to group Faculty and Department together and add provision for School/ K- 12. Are more needed?

Some work spans more than one category. A more extensive summary of the work that was included in earlier taxonomies may be found in Kennedy (2000a and 2002). Descriptions and comments are reproduced from the earlier paper in order to give a better coverage of the area.

		Hierarchical Level				
		National Gov't University Issues	**Regional Gov't University Issues**	**University Wide Management Issues**	**University Faculty or Department**	**School, K-12**
	External forces & legislation			*Green (1994), Mackintosh et al (1994), Gornitzka & Maasen (2000), Robertson (1999)*		
	Corporate Governance			Saeed (1996), Saeed (1998), Kennedy and Clare (1999), *Watson (2000),*		
	Planning, Resourcing & Budgeting	Galbraith (1982) Galbraith and Carss (1989) Bell et al (2000)	Frances (1995, 2000)	Galbraith (1989, 1998a, 1998b, 1998c) Barlas and Diker (1996a, 1996b, 2000) Kennedy and Clare (1999) Bell et al (2000) Vahdatzad & Mojtahedzadeh (2000) *Mackintosh et al (1994) Davies (1997)* Kennedy and Clare (2003) Virtual University (2005a) Bell et al (2005) **Oyo et al (2008) Sandrock with Weinhardt (2005)**	Kennedy and Clare (1999), *Mackintosh et al (1994)* Vahdatzad & Mojtahedzadeh (2000) Virtual University (2005a)	**Lopez et al (2005)**
	Human Resource Management Dilemmas			*Shattock (1999, 1997), Lewis & Altbach (1996)*		
Specific Area of Concern	**Teaching Quality**				Kennedy (1998a) Kennedy (1998b) Eftekhar & Strong (2005) *McKeachie (1990) Schneider Fuhrmann & Grasha (1994a) Schneider Fuhrmann & Grasha (1994b) Fincher (1994*	
	Microworlds			Barlas and Diker (1996a, 1996b) Barlas and Diker (2000)	Sterman (1992) Virtual	Sterman (1992)

				Sterman (1992) Virtual University (2005a) Virtual University (2005b) *Blumenstyk (2000)* *Conte (2003)* *Dekkers & Donatti (1981)* *Sawyer (2002)*	University (2005a) Virtual University (2005b)	
	Enrolment Demand		Sweeney & Schroeder (1975) Jordan (1992) Frances et al (1994) Frances (2000)	Sweeney & Schroeder (1975) Frances et al (1994) Frances (2000)		

Table 1: Classification of SD work in Education Management. Plain items refer to models and items in italics refer to underpinning theory.

3. System Dynamists' Work in Education Management
A number of system dynamicists and others have examined some of the problems with the education management domain. I shall briefly describe a selection of completed investigations and key findings.

3.1 External forces/ legislation

Green (1994)
Diane Green (1994) stresses that since the mid-1980s, public interest in and concern about quality and standards has been intensified by the increasing attention given by successive British Governments to reforming higher education. The reasons for this concern are:
- Rapid expansion of student numbers against a backlog in public expenditure.
- The general quest for better public services
- Increasing competition within the educational 'market' for resources and students
- The tension between efficiency and quality

Managing institutions of Higher Education is a complex task in maintaining their effectiveness. Institutional managers have a crucial role to play in relation to quality in the following ways:
- Finding ways of using the institutions resources to better effect and generate more resources
- Being accountable to the wider society, through use of effective means of assuring academic standards
- Developing improved systems of strategic planning and institutional management."

Mackintosh et al (1994)
Mackintosh et al (1994) discuss the issues that are impacted on Higher education as a result of the public sector reforms. They analyse management and decision making dilemmas in the new concept of 'hybrid' organisations- that is, organisations providing tax supported services that are reliant on income from commercial markets. It is their assertion that theses can be

modelled "as operating on a dual logic, driven by quasimarket pressures on the tax-supported side, and by private market pressures elsewhere."

This has implications for the "nature and quality of outputs of teaching and research, and for the costs, working conditions and management strategies of universities."
The reforms themselves are moving away from budget allocations to public service providers contracting for specified tax supported services. Mackintosh et al (1994) label theses as quasi-market (i.e. the public service contracting and competition as most purchasers are government bodies or professional intermediaries rather than the final users).

The reforms were based on a belief that producers in the public and private sector realms will try to provide as little as they can get away with for the maximum return they can secure (Saunders and Harris, 1990)

This is more complex in the public realm as the motivation of providers includes both social and ethical objectives. The cost cutting nature and profit seeking of reforms therefore potentially have the impact of providing poorer quantity services. Organisations in the public sector are also experiencing pressure to generate increasing proportions of income from non-tax derived sources.

Makintosh, et al (1994) outline the diversity of responses from the reforms- that is: income sources vary, e.g. proportion of income sources vary, e.g. proportion of income from grant and home rate fees from 65.7% (Bradford) to below 45 % (LSE). Other universities had substantial proportions from the sale of services (Salford and Lancaster) to those relying more heavily on research grants, such as Oxford, Cambridge and Imperial) and those that relied on overseas student recruitment for total intuitional income, e.g. LSE and Essex.

Higher Education managers have a major discretion in the implementation of strategies in response to current complex incentives. Mackintosh et al (1994, pp 343) outline the hybridisation as typically generated by a unit cost and investment squeeze on the tax funded services. Thus the total quality and staff morale is threatened by the falling unit of resource: "declining tax funding per student, and deteriorating buildings and equipment. Income generation is then opted, for example:

- Charge a top-up price to make tax-financed service viable, e.g. top-up fees for students;
- Sell' the same service in two markets, for example, differing charges to home and overseas students […], using higher education campuses for commercial purposes in vacations; or research work priced nearer to consultancy rates by higher education research institutions;
- Create a higher quality or a wholly new product for higher price commercial sale, e.g., new short courses for overseas students, or for higher paying local students such as professionals; self-financing postgraduate teaching; a switch from research to consultancy."

The pressure is then focused on the private markets, e.g. falling unit costs by increasing student/staff ratios. Within the private profit seeking elements, organisations have restrictions on how income can be generated. Common strategies include short courses, full cost courses in business and professional training, consultancy, publishing and internal profit centres.

Competing pressures emerge for interaction between the tax- based and private hybrid activity. For example, those with limited tax financed incomes seek to maximise this for commercial income generation. This then increases the need for scrutiny. Mackintosh et al (1994) conclude that increased mutual dependence means "the management problems of an increasingly divided organisation cannot be solved by a simple division into two commercial and non-commercial parts [p344].

Mackintosh et al (1994) identify 4 dilemmas:
- If the main tax funded services are the core activity of the organisation- how far will they allow the quality to fall?
- If the commercial elements of the HE are allowed to dominate then management time and effort become focused on marginal sums.
- How much cross-subsidy is provided by the commercial to the tax-supported activities? How does the reinvestment get made between the two elements of the hybrid organisation?
- Can the commercial element float away? The commercial elements of the organisation may seek greater autonomy, although they are still dependent to some extent on the host organisation.

Gornitzka and Maasen (2000)
Gornitzka and Maasen (2000) have outlined the pressures on Higher Education to " 'modernise', 'adapt', 'diversify', 'marketize', it is expected to become more 'entrepreneurial', 'competitive', more 'efficient' and more 'effective', more 'service oriented', and more 'societal relevant', while it also has to improve the 'quality of its processes and products', its relationship with the labour market', and the 'governance and management' of its institutions, the universities and colleges […]" (p217).

As the socio-political pressures increase there is also a corresponding reduction in funding that has culminated in the "demand overload". "Many actors pour their (regularly changing!) demands in an almost constant flow on higher education and expect a rapid and fitting reaction. But are universities and colleges capable of reacting adequately? Do they have the structures, cultures, mechanisms, human and other resources that allow them to transform in the way and pace expected?" (p217). Moreover, Gornitzka and Maasen (2000) challenge what the capability of universities is on meeting these future challenges to change and the research necessary on the dynamics of higher education. They quote a study by 30 researchers from 8 different countries- including the UK, of examination of organizational change in response to or interaction with other governmental policies and programs. The study called HEINE sought to explore the relationship between higher education and the economy.

Robertson (1999)
Robertson (1999) outlines the policy consideration of the Dearing report. The report outlined the major repercussions for management of higher education. He considers that policy maybe temporary as "…in the light of the national inquiry's advice, Government could be firing up the process again in two or three years time."

3.2 Corporate Governance
Saeed (1996, 1998)

Khalid Saeed (1996) investigates the dynamics of collegial systems in the context of developing countries. He states that collegial organisations consist of groups of professionals creating intangible products or services. A university is a typical example of a collegial system. While Saeed states that the model is applicable to many of the academic and research organisations established in the developing countries, in my opinion much of the analysis is transferable to other economies.

Saeed (1998) considers the rather wider topic of "Maintaining professional competence in innovation organisations", but this paper is also relevant to HE management.

Kennedy and Clare (1999)
Kennedy and Clare (1999) examine the debate between the "managerialists", favouring strong central direction and the "collegiumists", who see the university as a community of scholars. They also identify the HE Stakeholders and Customers. They argue that the stakeholders of a university fall into the four distinct groups (Clare, 1995) of students, employers, the Government and the wider community. Each institution has obligations (although it may not have realised them) in the areas of access to the facilities, contribution to the wider academic community, providing services to the international community and the welfare of society in general.

Watson (2000)
Watson (2000) discusses the nature of management in the University environment and draws parallels with the management of other public sector institutions. Watson (2000) cites a seminal paper by Rittel and Webber (1973) to explain the slushy nature of policy development: "The search for scientific bases for confronting problems of social policy is bound to fail, because of the nature the nature of those problems. They are 'wicked' problems, whereas science has developed to deal with the 'tame' problems. Policy problems cannot be definitely described. Moreover, in a pluralistic society there is nothing like the indisputable public good; there is no objective definition of equity; policies that respond to social problems cannot be meaningful correct or false; and it makes no sense to talk about 'optimal solutions to social problems' unless severe qualifications are imposed first. Even worse, there are no 'solutions' in the sense of definitive and objective answers Rittel and Webber (1973).

Watson (2000) also highlights: "In many sectors- especially the public service in general, and education and higher education in particular- it is associated with perceived loss of personal professional control and the 'new managerialism'…"

3.3 Planning, Resourcing and Budgeting

Galbraith (1982, 1989, 1998a, 1998b & 1998c) (Galbraith and Carss, 1989)
Peter Galbraith in an extended series of papers (Galbraith (1982, 1989, 1998a, 1998a, 1998a) (Galbraith and Carss, 1989) has investigated the impact of managerial policy on HE institutional performance, with particular emphasis on time delays between policy change and the results being evident.

Galbraith (1998a, 1998b) has identified many positive and negative loops in Queensland University. An example of a positive loop is the process by which an increase in enrolments

provides additional resources, which supports an increase in academic staff, which provides for the enrolment of more students, which produce additional resources and so on. An example of a negative loop is the process by which an increase in staff increases the salary bill, which reduces resources available to employ staff, which reduces the rate at which new staff can be appointed, which leads to a reduction in staff etc. In both of these two loops, delays of the order of years are involved before the loops are closed. The structure of complex systems ensures that they are inherently difficult to manage. As Forrester (1994) confirms:

> *"A problem is perceived, an action proposed, a result is expected but the result does not often occur. Symptom, action, and solution are not isolated in a linear cause-to-effect relationship, but exist in a nest of interlocking structures."*

Galbraith argues that recent pressure on the administration of Australian universities is due to government interventions, which has created tensions between the achievement of academic and fiscal goals. He has constructed a SD model to simulate competition between different schools that belong to a faculty that has limited funds. A wide range of employed and postulated policies are investigated. He demonstrates cyclic behaviour is endemic within the current climate despite the intention of managers to achieve stability. Finally, the results of the policy analysis are embedded within a wider discussion of the climate of institutional management, in which the concepts of "corporation" and "ecology" are employed as contrasting metaphors.

Key Findings
• Behavioural outcomes for a university, as for any complex system, are determined primarily by the combination of multiple interacting feedback loops that are a consequence of structural arrangements. The delays and non-linearities in the loops mean that behaviour cannot be predicted easily.
• Strategic plans serve a variety of purposes. For example, within teaching and learning contexts plans to improve teaching methods and to make assessment procedures more accountable are demonstrably worthwhile. Their impacts on university practices are direct, and the image of the institution indirect as public perceptions of changes in quality accrue over time.

• The production of separate plans for faculties, departments and schools means that pursuit of individual targets can in fact undermine the attainment of general institutional goals. If every unit succeeds with an ideal of achieving student growth in a situation where total funding is limited then some units must loose. Galbraith sees this as a version of the 'tragedy of the commons' because there exists a 'commons' or a limited resource shared amongst a group of competing units and the units dictate their own actions in order to maximise their own gains from the common resource. The common resource becomes less productive per individual demand as units work harder for less and less.

• It is argued that the culture of institutional administration, to the extent that it limits its vision to a corporate identify, lags a metaphor behind the world at large. While the world at large, including corporate interests, is moving its thinking beyond self-interested practices, to consider issues such as global warming, the replenishment of forests, and the protection of endangered species, institutional management remains locked in a competitive corporate prison. As Senge (1990) reminds us *"Few large corporations live even half as long as a person"*.

As we point out in Bell *et al* (2000), although Galbraith demonstrates the usefulness of the SD technique for HE planning through highlighting its explanatory strengths, he did not work with any key decision-makers at Queensland University. This is a significant limitation of his research, because the findings, though interesting, so far have had little impact on the planning of the university. We contend it is important to work with stakeholders in order to identify the relevant problems. Moreover, model ownership must be achieved through passing verification and validation tests to the satisfaction of the stakeholders.

Barlas and Diker (1996a, 1996b)
The main objective of their research was to construct an interactive dynamic simulation model. The model examines a range of problems such as student growth, faculty ratios, poor teaching quality and low research productivity.

Key Findings
• Simulation experiments with graduate versus under-graduate study orientation has considerable positive effect on research output.
• If, when faced with increased enrolments, we try to keep small class sizes, this implies having multiple sections (or many elective courses) in order to satisfy the class-hour needs of the students. This in turn would mean increased teaching loads for faculty, which would make it difficult to maintain the faculty body (increased quit rates) and the potential faculty application pool ("supply") would shrink.

Kennedy and Clare (1999)
Kennedy and Clare (1999) discuss the factors that should be incorporated in a system dynamics (SD) model designed to assist in policy analysis regarding resource management issues. In a brief survey of current higher education approaches to planning they examine the problems with current methods. They argue that the problem with most input /output models are that they adopt a static, linear view. Such models thus ignore both dynamic interactions between the input /output factors and the nature of the 'transformation' taking place and are thus of little use when considering process improvement. They also examine problems in the utilisation of spreadsheets and the influence of quality/performance measures and indicators on funding.

Holon Methodology: Bell et al (2000, 2005), Kennedy and Clare (2003)
Bell et al (2000) categorises their updated Holon Methodology, as a 'soft teleological approach'. They state that the underlying principle of the Holon Planning and Costing Framework is: "*To identify an agreed future and to design ways of bringing it about within cost constraints*"

The Holon Planning and Costing Framework combines a soft methodology (Holon) and a hard technique (SD). The Holon Methodology addresses 'the who', 'the what', 'the where' and 'the when' type questions at the current state S_0, and generates a vision of a desired state S_1. Additionally, this produces a relevant metrics programme, and the collected metrics can be used as dynamic behaviour patterns. The explanatory capability of SD tackles 'the how' and 'the why' type questions.

They report that the Holon Planning and Costing Framework is being applied within SCISM at London South Bank University in an exploratory case study. They have conducted a

review of QAA and the RAE literature to assist in the identification and labelling of the relevant holons, i.e. 'the where'. We have identified relevant academic and administrative staff, i.e. 'the who', participants in the planning process. Individual and group meetings have been held to identify the problems, i.e. 'the whats', associated with the current state S_0 of SCISM. This has led to the formulation of an agreed desired state S_1, i.e. the vision and an appropriate metrics programme.

Bell et al (2005) and Kennedy and Clare (2003) describe extensions and enhancement to the Holon Methodology

Frances et al (Frances (1995), Frances (2000))
See under 3.6 'Enrolment Demand'.

Vahdatzad and Mojtahedzadeh (2000)
Vahdatzad and Mojtahedzadeh (2000) uses system dynamics to explanation of the process of allocation of funding from a department that is seeking to expand with only limited resources available to it. They used system dynamics to explore appropriate policies for the sustainable development of the university.

The approached impinged on the tensions between finding ways of development of the research function without losing the quality and integrity of the school. Vahdatzad and Mojtahedzadeh (2000) identify the growth of the University of Yazd in terms of student numbers and faculty members. University resources however have not increased in the same way as the growth of the university. The research function was identified as the means by which the revenues could be increased for further expansion. There is an increased gap between the allocated budget and the projected need. The researchers point to the development of visions for the university according to stakeholders' position, which leads to an in cohesive response to development.

Their research highlighted the limitations of the current progress of the university in terms of research and decision-making. They identified specific ways in which the university needs can be addressed. That is, by focusing more of their allocated resources on the research element to generate more revenues.

Mackintosh et al (1994)
New management accounting information systems are being created with increasing importance on short-term objectives that get translated into financial targets. Mackintosh et al (1994) outlines how the objectives and qualitative objectives often conflict and result in dysfunctional behaviour. The also state that 'product costing' in HE is difficult as costs are common to more than one educational 'product'. This results in the attribution of overhead costs to products being arbitrary and imprecise.

These costing problems may lead to poor allocation of resources to faculties and schools.

Davies (1997)
Davies (1997) states that: "Uncertainty and the turbulent environment calls for highly responsive and flexible policies and procedures, especially in terms of academic programmes, admissions and personnel…The interpretation of environmental signals

becomes and institutional role of key significance, and the design of diagnostic and early warning devices of stresses to come is critical" [p131]

Davies (1997) produces that following table of categories of financial reduction in universities

Category	Most common causes	Characteristic institutional response
1. Slowed institutional growth; possibility of contraction	Externally imposed fiscal constraints, e.g. recession, government spending limits Stable enrolments or decline in enrolment growth rate Inflation above rate of budget increase	Efficiency measure Deferral of planned programmes and buildings Institutional self-study Increased student market efforts Increased fund raising activities
2. Moderate, "temporary contraction	Externally imposed budget cuts High rates of inflation Decline in enrolment	Increased efficiency and productivity measures Some staff development/ redeployment Deferral of certain types of expenditure (principally one-time cuts) Programme reviews as basis for selective cuts Intensified student marketing and fund raising activities Early retirement policies
3. Substantial contraction over relatively short time	Fiscal crises, e.g. severe recession or depression or fiscal solvency Sharp decline in enrolments Reorganisation/ merger of institution	Crisis personnel policies; redundancies redeployment Suspension of capital expenditures Intensive mission/ programme studies Closure of units and courses Explicit personnel and resourcing policies
4. Long term contraction	Permanent state of uncertainty surrounding institutional viability Organisational, political or economical entropy	Programme closures Heavy focus on personnel policies Planned disposal of assets Institutional mergers
5. Relative contraction in finances, and expansion in demands	Government driving down unit of resource Separation of teaching and research funding Mass HE and lifelong learning Value for money demands of universities Quality	Intensive academic and financial evaluation: indicators Efficiency drives Personnel contract revisions Programme closures Reform in teaching and learning methods Multiple income sources Intensive marketing for new students, new business: home and overseas Entrepreneurial ethic dominant: competition Restructuring Mission diversification

Virtual University

The "Virtual University" initiative (Virtual University, 2005a) is described under 3.6 Microworlds

Oyo et al (2008)

Oyo et al (2008) present a model to examine the impact of managerial policy on HE institutional performance (see also Galbraith & Barlas and Diker above) but in the context of the developing world in general and Uganda in particular. They state that in the developing countries, the dependencies are far from straightforward due to ad-hoc reactions to reduced funding.

Lopez et al (2005)

Lopez et al (2005) present a model to examine the impact of managerial policy on aspects of institutional performance in Schools. This work is significant in that previous work in this area have been in the HE domain (see Galbraith, Barlas and Diker & Oyo et al above). The work was conducted in the context of Nicaragua.

Sandrock with Weinhardt (2005)

In a new category of work Sandrock with Weinhardt (2005) examine E-Learning business models. They state that the simulation for different pricing and licensing scenarios for E-Learning products reveals the complex feedback structures in the pricing setting process and their impacts on the performance of an E-Learning content provider.

3.4 Human Resource Management Dilemmas

Shattock (1999)

Shattock (1999) "The accompaniment to the rapid rise in student numbers was a very sharp fall in actual and planned unit costs. In UK terms, this is manifested itself of course in a considerable worsening in the student/staff ratio with all its attendant problems and need for adjustments in teaching arrangements, and an inability to invest in the academic infrastructure- libraries, equipment and buildings, including teaching rooms- to match the increased numbers." [p11]

Shattock (1997)

Shattock (1997) "The impact of 'massification' has become much more evident: first, in the rising costs of higher education […]; second, the increasing tension over the preservation of research excellence within mass higher education systems; and third, the structural questions of how institutions and the state should seek to cope with a growth in expectations which may produce an age participation rate of at least 50 per cent by 2010 in nearly all the advanced industrial nations. It has certainly become clear that a modern state which is both seeking to hold down public expenditure and make provision for the growth in the size of its economically non-productive population (i.e. the elderly), for the costs of health provision and for social welfare generally, cannot afford to fund the mass higher education system that it encouraged into existence." [p27-28]

Lewis and Altbach (1996)

Further impacts on university personnel have been researched by Lewis and Altbach (1996). They comment on the Carnigie International Survey of the Academic Profession, as there is a rising tension between academic faculty staff and administrators. This has wide repercussions on the future of higher education in the context of governmental legislative constraints and pressures that HE is under for change.

The survey found that internationally academics are satisfied with their careers in spite of dissatisfaction with their academic life. Lewis and Altbach (1996) cite unhappiness with their institutions and poor leadership. Academics feel that budgets should move directly on academic functions. There is an apparent loyalty that is felt towards their academic fields but not the institution as a whole.

Academics are also reportedly unhappy about the bureaucratisation in HE. Governance structures have become more hierarchical. Most feel that they have influence on decision-making within their academic departments but not within the organisation as a whole on an institutional level. There is a general marked distrust of administrators. A high proportion of academics from the international research sample reported an autocratic governance structure with a lack of their involvement in decision-making. However, the researchers cite evidence from the sample that academic staff don't wish to take on more responsibility in administration as these potentially interfere with their teaching and professional commitments.

Lewis and Altbach (1996) attribute this to the financial burden of HE that contributes to faculty unrest. Generally there is deterioration in working conditions:
"Generally, classes are getting larger, there is pressure for academics to teach more, funds available for research are declining, and salaries are not keeping abreast of inflation. There are signs that the morale of the academic profession is beginning to be sapped. Academic administrators, who must say "no" more often, are obvious and easy targets for those feeling exploited and unappreciated." [258].

There is a reported decline in the autonomy of the institution as there are more calls for accountability and the growing need to change in line with legislative reforms, in addition to the pressure to reduce expenditure and centralize decision-making:
"Universities worldwide face a dilemma. There is near universal trend toward more emphasis on teaching, demands that faculty member's account for their activities with assessment as a means of measuring the effectiveness of academic effort, and a growing societal unease with traditional ideas of university autonomy. These trends have gone furthest, perhaps, in England, where our survey makes it more transparent that faculty morale has plummeted, and alienation is widespread." Lewis and Altbach (1996) [p258].

3.5 Teaching Quality

Quality, Pedagogical and socio- economic aspects of SD in Schools

The earliest teaching of SD was almost exclusively to graduate students but relatively early the potential of teaching SD to schoolchildren was appreciated. Foster (1972) [in one of the many MIT "D" notes] considers the impact of "Education in the City" as an extension of the Urban Dynamics programme. As such this included the socio- economic impact of education (or the lack of it) on a community.

Roberts (1976) describes an early "System Dynamics Curriculum Development Project for Elementary and Secondary Education". As well as examining some practical pedagogical aspects of SD in Schools she critically examines Bloom's Taxonomy of thinking skills (see Anderson & Sosniak, 1994). In particular she considers whether the assertion in Bloom's Taxonomy that "higher level" skills should not be taught until the previous (lower level) skills have been mastered in full holds good.

Forrester (1989) considers shortcomings in US school education and suggest that System Dynamics could form a more satisfactory basis for High School Education and proposes a programme of action in order to realise this potential.

Quality, Pedagogical and socio- economic aspects of SD in Universities

The information management and modelling research group (IMMaGe) have developed an initial SD model to examine quality management issues at London South Bank University (Kennedy 1998a, 1998b). Interviews were conducted with academic members of staff to guide the construction of the model. This investigation is considered to be the first part of a long-term project.

Key Findings
• The identification of sectors, *e.g.* Administration, Staff Performance, Department Effectiveness, Funding, Research and Funding, needed to be considered for a future quality management model.
• The identification of metrics (or performance indicators) needed to be collected for further SD investigations.

In an ambitious project somewhat reminiscent of Roberts (1976) earlier work in schools Eftekhar & Strong (2005) examine the process of learning in colleges & universities and outline some aspects of the debate among experts in education as to the most effective approaches to influence or reinforce the learning process. This work is an ambitious undertaking that implements a programme that includes the combination of education metrics and computer simulation. Like Roberts, they include a discussion of Bloom's taxonomy of thinking skills (below)
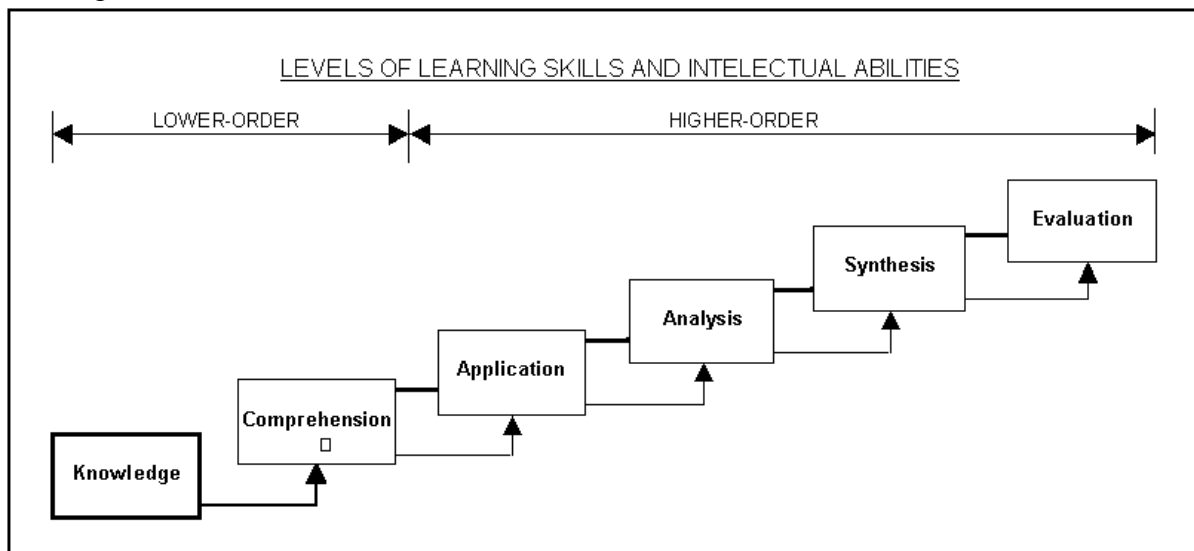

Fig 1: Bloom's Taxonomy of Thinking Skills

They state that their work is based on using a package of a simple control engineering concept, a model of an educational process, a computer simulation in conjunction with a combination of education metrics and that the main purpose is "to develop a model by which one can gain a better insight into the possible dynamic behavior of a learning process".

Eftekhar & Strong (2005) cite some very useful literature on aspects of learning theory and research including:
- Schneider Fuhrmann & Grasha (1994a)
- Schneider Fuhrmann & Grasha (1994b)
- Fincher (1994)

- McKeachie (1990)

3.6 Microworlds

Barlas and Diker (1996a, 1996b, 2000)
The main objective of Barlas and Diker's (1996, 2000) research was to construct an interactive dynamic simulation model, on which a range of problems concerning the academic aspects of a university management system can be analysed and certain policies for overcoming these problems can be tested in a "Microworld" format. More specifically, the model focuses on long-term, strategic university problems that are dynamic and persistent in nature, such as growing student-faculty ratios, poor teaching quality, and low research productivity. The model generates numerous performance measures about the three fundamental activities of a university, namely, teaching, research and professional projects. The interactive decision variables of UNIGAME are: New Graduate Students, New Under-graduate Students, Graduate Faculty Hiring Decision, Under-graduate Faculty Hiring Decision, Share on Official Projects income per Faculty Member and Weekly Release Time per Graduate Faculty Member.

The purpose of the simulation model is to investigate the difficulties of keeping the delicate balance that must exist between education, research and service and what measures can be taken to alleviate the potential problem. The validity of the model is tested using 1983-1997 Bogaziçi University data. In the "participatory" (gaming) version of the model (which starts in 1993), certain decisions are made by a "player" interactively during the simulation. The different decision making units of the universities can potentially use the model, especially in strategic planning.

Key Findings
- Simulation experiments with graduate (versus under-graduate study) orientation shows that graduate study can have considerable positive effect on research output, provided that it is coordinated with other related decisions such as instruction-hour requirements, research recognition and rewards etc.
- If, in order to obtain improved teaching quality, we keep class sizes too low, under the condition of high student enrolments this may mean multiple sections (or too many electives). This, in turn would mean increased teaching loads, which may cause serious problems in maintaining the faculty body, because of decreasing faculty supply and increasing number of faculty quit rates.
- The simulation model demonstrated the systemic nature of university management in the sense that a single decision in isolation may yield counter-intuitive results, if not coordinated with a number of other related decisions.

Virtual University
The "Virtual University" (VU) initiative (Virtual University, 2005a) is also included under 3.3 Planning, Resourcing and Budgeting. The VU is one of a new generation of "Serious Games" (below) that combine video game presentation norms with serious content and substantial simulation capacity.

The VU claims very large numbers of users with over 90,000 downloads by over 800 institutions in over 90 Countries no doubt partly because it has received sponsorship that enables it to be free to most users. The composition of these users is:

- 5% administrative staff (chair to president)
- 15% professors
- 24% grad students
- 29% undergrads

VU states that it:
> *"is designed to foster better understanding of management practices in American colleges and universities. It provides students, teachers, and parents the unique opportunity to step into the decision-making shoes of a university president. Players are responsible for establishing and monitoring all the major components of an institution, including everything from faculty salaries to campus parking.....*
>
> *VU models the attitudes and behaviors of the academic community in five major areas of higher education management:*
>
> - *Spending and income decisions such as operating budget, new hires, incoming donations, and management of the endowment;*
> - *Faculty, course, and student scheduling issues;*
> - *Admissions standards, university prestige, and student enrolment;*
> - *Student housing, classrooms, and all other facilities; and*
> - *Performance indicators.*
>
> *VU players select an institution type and strive for continuous improvement by setting, monitoring, and modifying a variety of institutional parameters and policies."*

The growing popularity of "Serious Games" may be indicated by the holding on April 15-16 2005 of a two-day workshop at M.I.T entitled "Game Simulations for Educational Leadership & Visualization: Virtual U and Beyond" (Virtual University, 2005b). This event is designed to examine
> *"the past, present, and future of games about education and educational life". The organisers state that "to date, there have been over a half-dozen entertainment and non-entertainment efforts dealing with school management and leadership that have been produced or planned".*

They continue
> *"These games explore such topics as the future of community colleges, how universities are managed, how rumours circulate in schools, and how social cliques form within school environments. We want to examine these games and their application to school management as we reflect back on the evolution of the Virtual University Project over the past four years".*

Sawyer (2002) describes "Serious Games" as follows:
> *"The mission is simple - to create a better understanding of how commercial game and simulation developers, practices, and technology can be utilized by a wider field of organizations that build and apply models and simulations in the area of public policy.*
>
> *This includes identifying and detailing specific steps organizations and game developers can take to blend game technology and approaches with proven model and simulation approaches to improve existing and future offerings.*

Any casual observer who has seen someone interact with a computer or video game can easily understand how games can quickly captivate their audience. With their exciting visual and audio power, computer and video games take the competitive and fun nature of games to an entirely new level. Combining simulation, strategy, and the ability to play alone (if partners are not available) electronic gaming builds on basic instincts for competition, interaction, and imagination that are instinctive in so many people. By combining these elements with instructive materials, or wrapping important content in a gaming package, the hope is to utilize the strength of gaming to elevate learning and especially strategic learning among players."

Blumenstyk (2000) examines the issues re such simulations; Conte (2003) examines the impact of such simulations on public awareness and hence public policy while Dekkers & Donatti (1981) consider the research agenda re the use of simulation as an instructional strategy.

3.7 Enrolment Demand

Sweeney & Schroeder
Sweeney & Schroeder (1975) in an early piece of work in this area, consider the impact of fluctuations in College Enrollments consisting of various Career Tracks by constructing and running a SD model. They make some policy recommendations based on the model results.

Frances et al: Jordan (1992), Frances et al (1994), Frances (2000)
Carol Frances and co-workers [Jordan (1992), Frances *et al* (1994), Frances (2000)] have reported on several interventions by constructing system dynamics models to improve planning and budgeting for higher education, both to inform public policy /State Management [Results from Arizona], and to inform university wide policy [Results from Houston, Texas]. She has also reflected on wider issues in other papers (Frances, 1995).

A SD model was constructed for the Arizona Board of Regents. The model was used to examine student enrolment demand over a period of 20 years. Further modelling work was conducted with the University of Houston System investigating strategies for generating new enrolment demands amongst Houston's Hispanics and African American populations.

Key Findings
• If a system is on a slow-growth path, it may be very difficult to alter the course of that path, but SD can help identify the areas where policy or management changes have the potential of being most effective in producing desired results. Additionally, counter-intuitive patterns are frequently discovered. Multiple sub-systems interact over time to generate results that are often beyond the causal observers' ability to project.
• Another insight gained from the sensitivity analysis using the models is that when wrong decisions are made and, for instance, the financial situation of an institution deteriorates, reversing the decisions does not immediately restore the previous financial conditions. These findings accord with those of Galbraith.

3.8 Other Higher Education Contributions

Radzicki, Winch and Boucher have developed SD models in higher education management and (at present) this proprietary work remains unpublished. However, Winch and Boucher hope to publish materials based on their work for Higher Education Funding Council for England (HEFCE) in due course

4.   Future Evolution of this Taxonomy

As indicated above this review is an attempt to produce a focussed taxonomy by continuing the separation of these SD Policy Aspects from the Pedagogic Techniques initially created in Kennedy (2008). Currently it has retained the same structure but the author suspects that this will not prove ideal for the Taxonomy of Pedagogic Techniques. In addition the author is keen to add more publications – particularly in the K-12 area. Your ideas and contributions to any of the above are therefore most welcome!

There are strong reasons to believe that System Dynamics has a valuable role in the evolution of Education Policy. The dynamic and unstable nature of the university environment leads to difficulties in the management of the system. The SD approach allows for the decision-makers or other stakeholders of the model to experiment with various factors and variables included in the model. This allows the assessment of the impact of certain policy decisions prior to their implementation. Without the use of these models it is difficult to predict the outcomes of certain policy decision without actually implementing decisions prior to assessment of their impact. This allows for, amongst other things risk minimisation.

In our previous work (Kennedy and Clare, 1999) we have suggested that the potential combination of SD to IS/IT HE management appears to lie in three areas:

- Replicate existing models developed originally using other modelling styles or techniques
- Produce SD models of some of the issues mentioned in this paper.
- Develop models showing HE management processes before and after a proposed process change. At present assessing the impact of new educational technology is of particular importance (Frances, 2000).

Bolland and Fowler (2000) suggest, "…a fundamental framework based on systems theory should underpin management initiatives such as performance improvement, using the terminology and tools of "systems thinking". This potentially provides clarity of process, structure and method which can help to focus perceptions with respect to issues such as the polarity of causality (distinguishing cause from effect0, the dynamics of policy formulation, appropriate implementation of controls and the promotion of understanding with respect to the overall complexity of the organisational situation generally.

Furthermore, "Public sector management occurs within a complex system involving several nominally independent stakeholders, coupled with informational and resource flows and behaviour that is characterised by inertia and multiple feedback loops. It is therefore apparent that the generic principles of systems thinking and system dynamics potentially provide a useful framework within which the issues of performance measurement, performance indicators and improvement initiatives should be considered…"

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