

# **A Taxonomy of System Dynamics Models of Educational Pedagogic Issues**

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## **Abstract**

*A number of papers have been published describing various pedagogic techniques for the dissemination of the System Dynamics (SD) approach at various Education institutions and academic levels ranging from schools (K-12 in the US) to higher education. This paper builds on previous papers by this author that provided a 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. The findings from these investigations are briefly described.*

## **1. Introduction**

The SDS Education 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 Taxonomy of publications of relevant SD work and pedagogical 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 the curriculum 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, 2008) by separating these SD Pedagogic Techniques from the Policy Aspects (described in a sister paper). The objective of this paper is to facilitate and structure debate on the use appropriate Pedagogic Techniques for the dissemination of system dynamics (SD) (Forrester 1961) in Educational establishments.

## **2. A Taxonomy of System Dynamics Pedagogic Techniques**

From a survey of completed SD investigations in higher education management three areas of concern (Teaching Quality, Teaching Practice, Microworlds [including {Interactive} Learning Environments & Management Flight Simulators]) have been identified. Four hierarchical levels (National/ All level, University/ Institute, Faculty or Department and School/ K- 12) have identified. 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, 2002 and 2008). Brief descriptions are summarised from the earlier papers.

	Hierarchical Level				
	National/ All level Issues	University Wide Issues	University Department	School, K-12	
Specific Area of Concern	Teaching Quality		Kennedy (1998a) Kennedy (1998b) Eftekhar & Strong (2005) <i>McKeachie (1990)</i> <i>Schneider Fuhrmann &amp; Grasha (1994a)</i> <i>Schneider Fuhrmann &amp; Grasha (1994b)</i> <i>Fincher (1994)</i>		
	Teaching Practice	Richardson with Andersen (1979) Richardson with Andersen (1980)	Forrester (1974) Saeed (1997) Frances (2000) Arndt (2007) Friedman et al (2007) Perez Salazar et al (2007) Potash, with Heinbokel (2005)	Runge (1977) Shaffer (1976) Senge (1988) Saeed (1990) Morecroft & Sterman (1992) Sterman (1992) Saeed (1993) <i>Anderson &amp; Sosniak (1994)</i> Saeed (1997) Frances (2000) Nodenof et al (2004)	Costello & Fisher, et al (2001) Fisher, D. M. (1994) Foster (1972) Roberts (1976) Roberts (1978) Forrester (1989) Niles (1991) Halbower (1993) Forrester (1995) Forrester (2002) Sweeney and Sterman (2007) Hopper and Stave (2008) Nuhoglu with Nuhoglu (2008) Richardson (2000) Stuntz with Lyneis (2007) Thompson with Reimann (2007)
	Microworlds	Maier, F. H. and A. Gröbler (2000).	Barlas and Diker (1996a, 1996b) Barlas and Diker (2000) Sterman (1992) Virtual University (2005a) Virtual University (2005b) <i>Blumenstyk (2000)</i> <i>Conte (2003)</i> <i>Dekkers &amp; Donatti (1981)</i> <i>Sawyer (2002)</i>	Sterman (1992) Virtual University (2005a) Virtual University (2005b)	Sterman (1992)

Table 1: Classification of System Dynamics Pedagogic Techniques. Plain items refer to descriptions and evaluations of System Dynamics models. Items in italics refer to underpinning educational and other theory (not exclusively System Dynamics).

### 3. System Dynamists' Work in Higher Education Management

A number of system dynamicists and others have examined some of the issues associated with the Pedagogic Techniques suitable for the dissemination of SD. I shall briefly describe a selection of completed investigations and key findings.

#### 3.1 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”.

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***

Kennedy 1998a, 1998b developed an SD model to examine quality management issues at a UK University.

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.

## **3.2 Teaching Practice**

### ***Richardson with Andersen (1979 & 1980)***

In these papers Richardson and Andersen lay the foundations for the development of the pedagogy of System Dynamics and consider aspects of combining SD teaching and research.

### ***Teaching Practice aspects of SD in Schools***

As well as examining the wider Pedagogical issues described above, Roberts (1976) describes some practical teaching practice aspects of SD in Schools.

Niles (1991), evaluates the UROP programme of Pre-College Education and Halbower (1993) describes the practical pedagogical aspects of teaching SD in Schools- especially the importance of “The First Three Hours” of tuition.

In common with several of the above Forrester (1995) is concerned with the provision of high quality teaching materials- in his case the “Road Maps” to teaching SD.

Forrester (2002) summarises the progress made over 25 years in K12 SD education provision and looks forward to future enhancements and again proposes a programme of action in order to realise the potential.

### ***Costello & Fisher (2001), Fisher (1994), Richardson (2000)& Stuntz with Lyneis (2007)***

In these papers (and may other publications by the same authors), teachers and other educators who have been implementing system dynamics and systems thinking in schools across the United States reflect on their progress in implementing Forrester’s vision of a more effective kindergarten through 12th grade (K-12) education based on System Dynamics. These authors have also organised numerous workshops and other events to promote effective (K-12) SD education.

***Sweeney and Sterman (2007)***

In a series of papers John Sterman and co-worker have reported on a number of experiments on the level of ability of school students (and in some cases teachers) in coping with various systems concepts such as feedback, stocks and flows, time delays and nonlinearities, prior and after formal training in these concepts. They report generally limited intuitive systems thinking abilities. They discuss the nature of students' and teachers' intuitive models of dynamic systems, explore potential barriers to understanding dynamic systems, and discuss implications for effective teaching of systems concepts.

***Hopper and Stave (2008)***

Hopper and Stave (2008) adds rigor to discussions around teaching practice aspects of SD in Schools by proposing methods for assessing systems thinking interventions.

***Nuhoglu with Nuhoglu (2008)***

Nuhoglu with Nuhoglu (2008) report on a number of experiments conducted with 81 students in middle schools in Istanbul, Turkey.

***Thompson with Reimann (2007)***

Year 9 and 10 students were given a system dynamics model of the impacts of visitors on a National Park. There was a significant increase in the environmental knowledge score for those students in the collaborative learning condition, but not in the individual learning condition.

***Teaching Practice aspects of SD in Universities***

One of the motives for suggesting changes or enhancement to SD teaching practice is the perceived need to improve better methods of teaching SD in order to counter critical responses to System Dynamics Models. An example is Forrester (1974).

As mentioned above, the earliest teaching of SD was almost exclusively to graduate students Runge (1977) makes an early attempt at suggesting methods for Teaching System Dynamics, while Shaffer (1976) suggests an early concept of organizing the system dynamics curriculum.

Later there have been many papers describing (asserted) advances in the methods of teaching SD in particular domains. Senge (1988) describes “New System Dynamics Learning Tools for Management Education and Training”, while Sterman (1992) describes the evolution of “management flight simulators” in general and the beer game in particular. Morecroft and Sterman (1992) describe a collection of “modelling for learning” examples.

***Saeed (1990, 1993, 1997)***

Saeed in a series of papers has investigated the role of System Dynamics in developing teaching practice in a number of academic disciplines, including social sciences generally (Saeed, 1990), economic development (Saeed, 1993) and for a “New Liberal Education” (Saeed, 1997).

***Frances (2000)***

In this paper Carol Frances introduces the important topic of assessing the impact of new educational technology.

***Nodenof et al (2004)***

The technology deployed is rapidly advancing. Nodenof et al (2004) state that their approach for the engineering of web based educational applications is grounded in software engineering research and that the applications “require advanced functionality for regulating and tutoring learners' activities (dynamics of learning)”.

***Arndt (2007)***

Proposes that integrated learning environments consisting of system dynamics models and additional didactical material have positive learning effects.

***Friedman et al (2007)***

This research was carried out in order to determine if a relationship existed between the use of specific system thinking tools and Kolb learning styles.

***Perez Salazar et al (2007)***

This paper shows a course design and its knowledge transfer process when teaching the changing paradigm of systems thinking, systems dynamics and simulation, through e-learning.

***Potash, with Heinbokel (2005)***

Describes an effort to build capacity through collaborative problem solving.

### **3.3 Microworlds**

***Maier, F. H. and A. Größler (2000)***

Maier and Größler have produced ‘A Taxonomy of Computer Simulations to Support Learning’ including Microworlds, Interactive Learning Environments and Management Flight Simulators.

***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.

***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. Sawyer (2002) describes “Serious Games”.

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.

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