UNDERSTANDING DIGITAL LEARNING FROM THE PERSPECTIVE OF SYSTEMS DYNAMICS

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ABSTRACT

The System Dynamics approach can be seen as a new way of understanding dynamical phenonema (natural, physical, biological, etc.) that occur in our daily lives taking into consideration not only single pairs of cause-effect variables, but the functioning of the system as a whole. This approach also provides the students with a new understanding in learning. This conceptual paper discusses how various online learning tools promote systems thinking and concludes that they not only bring the subject-related concepts to life, but also help especially the visual learners to see the reactions in easy schematics so that the related thought process is made simpler.

Keywords: Systems Thinking, Dynamic Thinking, Web 2.0, Simulations, Computer Modeling.

INTRODUCTION

System dynamics combines the theory, methods and philosophy needed to analyze the behaviour of systems in various fields ranging from management to engineering. It provides a common foundation for understanding how things change through time. System dynamics offers a framework for giving cohesion, meaning, and motivation to education at all levels from kindergarten upward (Forrester, 1994). This paper discusses how various online tools such as simulations, micro worlds, mindtools can foster systems thinking and the development of other related skills by providing a detailed literature review.

Some Useful Definitions

A system is defined as a collection of parts organized for a purpose. It is expected to perform as well as the circumstances allow, regardless of what the circumstances are.

A model is a new world that someone constructs to represent things from our world (or an imaginary one). These models represent a simplification of the modelled world and we can interact with them to explore and understand how things work both in the model world and in the modelled world (Coyle, 1996; Sampaio, Santos, Ferracioli et al., 1999). Consequentially, models not only allow the students the opportunity to develop some cognitive abilities such as formulating and testing hypothesis, idealisation and abstraction, but also facilitate their recognition of the structural and functional similarities between different dynamic structures and processes (Sampaio, Santos, Ferracioli et al., 1999). Yet, as Sampaio, Santos and Ferracioli et al (1999) state, models are not much used by teachers because not all of them are well prepared to use this idea and because students may not have the necessary mathematical background to work with these ideas.

The traditional educational sequence normally progresses through the following steps (Roberts, 1978): Learning facts, comprehending meaning, applying facts to generalizations, analyzing to break material into constituent parts and synthesizing to assemble parts into a whole.

Yet, such a deterministic model is not sufficient to deal with the complexity in today's world. Complexity-derived from the Latin root complexus-means embraced or entwined. In order to have a complex, two or more distinct parts should be joined in such a way that it is difficult to separate them. Examples are a living cell, a society, an ecosystem, the Internet, a brain which all consist of numerous elements whose interactions produce a global behaviour that cannot be reduced to the behaviour of their separate components. So, there are complex dynamical interactions of the components. Classical thinking assumes conserved distinctions whereas complex systems are entangled in such a way that their components can no longer be separated.

We don't live in a unidirectional world in which a problem leads to an action that lead to a solution. Indeed, we live in an ongoing circular environment in which each action is based on current conditions, such actions affect conditions and the changed conditions become the basis for future action (Forrester, 1994).

Forrester (1992) claims that answers to questions about how things change through time lie in the dynamic behaviour of social, personal, and physical systems rather than the static snapshots of the real world as taught by education. Education is compartmentalized into separate subjects that in the real world it interact with each other. Yet, a framework for understanding the social and physical environments cannot be synthesized without teaching dynamic behaviour. The cornerstones for a more effective education would be system dynamics and learner-centered learning.

In order to gain the s-thinking systems education students must get actively involved and relate what they are learning to systems they already now in families and school for a deeper understanding. System dynamics modelling refers to learning by doing and learning through being surprised by the mistakes one makes.

Systems thinking seeks structural explanations that will help learners see the dynamic complexity of situations in which cause and effect are not readily apparent and that take considerable time for the effects to manifest themselves. Systems thinking leads to a robust awareness of the interconnections behind complex systems. Mastering systems thinking is a lifelong endeavour and it can contribute to the learners' development of critical awareness of how the complex systems we live and work in operate.

An important part of this systems approach entails seeking, identifying and appreciating the roles, timing and importance of different factors. It involves seeing not just single elements or parts of a process but the whole of the elements and interrelationships among these elements. A systems approach considers direct and indirect effects of change in any elements within or external to a system. According to Senge (1994), systems thinking requires the learner to use the following simultaneously operating levels within a system:

- *Events:* There are directly observable actions and behaviours.
- *Patterns:* These emerge as actions and repeated over time.
- *Systems:* These show the relationships between the patterns.
- *Mental models:* These are deep seated beliefs and values that hold systemic structures in place.

According to the systems theory, a system is made up of related and interdependent parts so that any system must be viewed as a whole. A system cannot be considered in isolation from its environment (Senge, 1994). A system that is in equilibrium will change only if some type of energy is applied (Senge, 1994). Players within a system have a view of that system's function and purpose and players' views may be different from each other (Senge, 1994).

According to Sterman (1999), systems thinking refers to the ability to see the world as a complex system in which we understand that one can't do just one thing and that everything is connected to everything else. This holistic worldview would enable one to learn faster and more effectively and identify the high leverage point in systems. A systemic perspective would also enable one to make decisions consistent with the long-term best interests and the long-term best interests of the system as a whole.

Major Tools for Systems Thinking

The major goal of systems thinking is to change the cognitive style of students and to equip them with an effective way of thinking about complex, dynamic systems. Students are encouraged to become critical users of models and to question assumptions underlying models. In this way, they can also gain respect for real life complexity and variety and question simple solutions to complex problems. Once an understanding of the basic dynamic processes are established systems of far greater complexity can be tackled that are characterized by feedback, delays, nonlinearities and noise (Davidsen, 1990).

Similary, Sampaio, Santos and Ferracioli (1999) assert that students are capable of engaging in system thinking when one or both of the following conditions occur: They use variables in reasonable causal links, in fully coherent models with at least one feedback loop. The second condition is that during the building of the model they have to ask for simultaneous graphs of variables, using the graphical inputs to improve the model structure and reach a reasonable level of discussion of the situation studied, and relate the model to reality.

Some of the major tools that encourage systems thinking can be summarized as follows:

Simulations

Simulations are virtual worlds or microworlds in which decision-making skills can be improved and experiments can be conducted. The model should be augmented to include important loops identified through causal mapping. Simulation experiments may be run to resolve uncertainties. Graphical user interfaces enable modellers to quickly sketch a causal diagram capturing the feedbacks and nonlinearities. Modelling can be done in real-time, and with groups whereas results can be viewed immediately via simulation. A model can also be converted into an interactive game with an intuitive interface.

Before doing a simulation, students can gather information, read references, work with computers in groups of 2 or 3 so that they actually have to use the material in a project simulating real life situations. In this way, they are not only taught about a specific subject, but also learn how to acquire and use knowledge whereas teachers' jobs shifted from conveyors of information to producers of environments that allow students to learn as much as possible.

According to Sampaio, Santos and Ferracioli et al.(1999), discussions with other students when observing the model running on the computer screen may also promote a better understanding of the situations studied, as well as their critical thinking issues.

Micro worlds

Micro worlds are simulation tools that are produced by the modellers using systems dynamics approach (Nuhoglu, 2007). They allow students to undertake experiments whereas these experiments can be repeated using various parameters and alternative scenarios. So, they can be considered as replacements for the real world so that students can see how the dynamics of the system works through experiencing it in the virtual world (Nuhoglu, 2007). System dynamics approach enables the students to focus on the causes of the events and help them to understand that there may be more than one cause and to effective relationship in a system (Nuhoglu, 2007). As system dynamics is a general approach for problem-solving the students may be able to use this approach throughout their whole lives once they learnt it (Nuhoglu, 2007). This approach also equip the students with the skills related to observation, discovery, modelling and investigation in a scientific way which is in contrast with the traditional educational methods. Nuhoglu (2007) claims that applying a system dynamics approach in the education is feasible as it allows the students to construct problems on their own by observing their environment critically and from unusual perspectives. In this way, students may be made aware that the truth changes with conditions and time and they can discover and suggest solutions for the hidden problems in the life (Nuhoglu, 2007). Nuhoglu (2007) makes the following statements concerning the use of microworlds:

- Microworlds enable the students to see how the dynamics of the system works by experiencing it in the virtual world and getting exposed to alternative scenarios.
- As the mental models may not always entail the correct representation of system interactions the student may not apply the principles taught in lectures to real life tasks. Simulations offer a source of immediate feedback for students to test their assumptions about their mental models of reality.
- Microworlds and simulations also provide the students with an understanding of the different dynamic

patterns and allow them to understand the logic of events in a deeper way.

- Through simulations and microworlds, the students understand that the behaviour of complex systems are determined by several feedback loops.
- Students can have the ability to actively observe their environment, discover new problems and model these problems in a scientific way.
- By approaching problems in a critical way student become aware that there is not a unique answer and that there might be different truths depending on the conditions.

By interacting with the code, students are performing an experimental tinkering that (Turkle and Papert, 1990) is not a part of the traditional means-end goal-oriented problem-solving. This experimental style allows students to interact with individual objects and treat computational entities as artefacts to be interacted with so that students become silenced tinkerers (Turkle, 1984).

Mindtools

Jonassen, Carr, Yueh et al.(1998) state that mindtools are computer applications engage learners in critical thinking about the content they are studying. Mindtools require students also to think deeply about what they know in different, meaningful ways. To exemplify, using databases to organize students' understanding of content organization engages the students in analytical reasoning whereas creating an expert system rule base requires them to think about the causal relationships between ideas (Jonassen, Carr, Yueh et al., 1998; Voss & Poss, 1988). In this way, learners functions as designers whereas they learn with technologies and utilize them as knowledge construction tools rather than learning from technologies (Jonassen, Carr, Yueh et al., 1998). Jonassen, Carr, Yueh et al. (1998) classify mindtools as semantic organization tools such as semantic networking, dynamic modelling tools which help learners to describe the dynamic relationships among ideas, information interpretation tools that help learners to access and process information, knowledge construction tools such as hypermedia and conversation tools: such as video conferencing, discussions and listser vs listserves.

Furthermore, computer modelling in education would facilitate the following skills:

- ■ *Dynamic thinking*

This refers to the ability to see and deduce behavior patterns rather than focusing on, and seeking to predict events. It is thinking about phenomena as resulting from ongoing circular processes rather than as belonging to a set of factors. Having students think about everyday events in terms of graphs over time might contribute to their dynamic thinking skills.

- *Closed-loop thinking*

This refers to seeing the world as a set of ongoing, interdependent processes rather than as a list of one-way relations between a group of factors and a phenomenon caused by these factors. So, the circular cause-effect relations are held responsible for generating the behavior patterns rather than external factors. This shift of viewpoint also facilitates the adoption of internal locus of responsibility and make one ask how one can be responsible for what happened rather than why such things always happen to one.

- *Generic thinking*

By apprehending the similarities in the underlying feedback-loop relations generic thinking skills can be developed. People can work with a series of generic structures that progress from simple exponential growth through S-shaped growth, to collapse and oscillation.

Conclusion

Using system dynamics in classrooms would make the students admit to being uncertain about a concept (Nuhoglu, 2007). The graphs and simulations bring the subject-related concepts to life and help especially the visual learners to see the reactions in easy schematics so that the related thought process is made simpler. While students' learning becomes more learner-centred and cooperative by using these tools system dynamics also encourages students to figure things out, put pieces together, look for similar patterns, work together to ask questions and find answers across disciplines (Nuhoglu, 2007). In contrast to the traditional approach, students can also take charge of their own learning while teachers become advisors and coaches rather than conveyors of information. Curriculum can be implemented in a constructivist sense in which learners and teachers collaborate to create elaborated understanding of systems and processes and to solve problems (Nuhoglu, 2007). Modelling is central to the doing and learning of science as it includes several important components such as data collection, data visualization and creating models to explain data.

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