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Supporting the evolution and interoperability of organisational models with e-learning technologies

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ABSTRACT

Models are instruments that allow agents to gain understanding and plan future steps required for being sustainable. Unfortunately, social, economical and ecological systems are in constant flux. The modelling process in a dynamic environment is a never ending, ongoing concern. As a theoretical lens for the analysis of enterprise sustainability the theory of Complex Adaptive Systems (CAS) is used. This theory allows to capture dynamic aspects in models. Theoretical aspects of CASs are briefly introduced and used to analyse learning support for the active agents in the enterprise. A learning system is conceptualised. Support for enterprise models in general and the enterprises' active agents in particular is discussed to show how to support getting along with the dynamics of the overall system. Interoperability is derived as a key property of the overall system. Interoperability requires system-parts to be independent, while supporting the overall system's functionality. On the one hand multi-faced problems are independently analysed by active agents. On the other hand partial solutions realised by active agents need to be interoperable on the enterprise level. Taking a CAS point of view interoperability between system parts becomes a necessity, which, if not met, might bring the overall system to a halt. Requirements and properties for a support environment for organisations' agents to keep pace with permanent changes in their environments are described. Technologies are presented that fit to the used theoretical point of view and support both: the individual evolution and learning of agents who update local models and the interoperability between models.

1. Introduction

In order to build a sustainable system, a holistic approach is needed which takes into account multiple dimensions (Espinosa, Harnden, & Walker, 2008). System parts and relationships between heterogeneous systems of (at least) three types "environmental systems", "industrial systems", and "societal systems" have to be addressed in order to maintain sustainability (Fiksel, 2012). For example, enterprises take part in industrial economic systems, are interacting with the environmental system through the consumpition of resources, production of waste, and are driven by members of a social system – their employees.

For driving a sustainable enterprise, an understanding from a holistic point of view is needed. A theory that is capable of capturing a high number of complex relationships between independent system parts could support systemic modelling. Complex Adaptive Systems (CAS) theory is one such theory (Espinosa & Porter, 2011).

In CAS theory many independent agents interact with many other agents in great many ways (Waldrop, 1992). To permanently adapt to a changing environment and changing demands from the environment, the active agents need to learn individually and the organisation needs to learn as a whole. Agents, part of the organisations, require support to be able to meet resilience and sustainability criteria of the overall enterprise.

This paper is organised as follows. First basic requirements for handling the dynamics of modelling are discussed. This is followed by discussing Complex Adaptive Systems (CAS) theory as a conceptual foundation for further developments of the research presented. The theory is used to the need to support organisational agents' learning and the need for interoperable solutions/models.

2. Organisation of sustainable modelling

Diversity increases resilience of systems. In a system where many heterogeneous system-parts exist, a single cause impacting a certain type of part, will not impact all system parts, but only that

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fraction of parts, which are of a specific type. The persistence of individual agents or parts is dependent on its environment. Agents in natural systems fill niches, creating diversity (Holland, 1996). This diversity increases the systems's resilience further.

Dynamics in the environment requires a system where parts may be changed without effecting the whole system. The concept of interoperability of systems is of importance for sustainable development and is an ongoing concern for meeting the demands of sustainability of the overall system.

2.1. Evolution of models and sustainability

General discussions on sustainability show the dynamic nature of models (on a societal level). Which system-parts are to what extend of relevance is a matter of debate in the scientific and political communities. Involved experts have no doubt that models of sub-systems and linkages between system parts will evolve over time. Models for analysing sustainability are not, and never will be, finished once build. Any model forms a basis for further exploration and provides input to the next future model.

Even if the relevance of systems and their structures are a matter of debate, it is still of importance that a holistic and systemic view is taken (Fiksel, 2012). Besides the required overview, special attention is to be given in order to capture the dynamics of the system and of the modelling process.

- *Dynamics in the system* (to be modelled) implies that the system is evolving, and the model has to be able to re-produce the dynamic relationships. If there are non-deterministic relationships between subsystem parts, this behaviour is not easily reproduced. In such a case, the system's global behaviour may not be pre-determined by summing up behaviour of parts, but will emerge from the interactions of its parts. The other way around holds also true, its not possible to determine the system part's behaviour from observing the global behaviour.
- *Dynamics of the modelling process* implies that the system's model will evolve, because modellers change the system's structure and parts over time (cf. Espinosa et al., 2008).

A theory that pays attention to dynamics on both of these levels is described in the following, and forms the basis for further developments.

2.2. Knowledge for the evolution of models

Systemic models often represent a *current* snapshot of abstract knowledge about relevant parts and linkages between system parts. Systemic models are build for gaining better understanding of real world aspects and effects. The dynamics of the modelling process requires support for learning about the current versions of models in order to continue the development of models.

A learning dimension of the modelling process needs to be considered and supported. To understand the required support, educational theories are briefly discussed. However, educational theorists hardly speak of models but of "organized bodies of information" (Dewey et al., 1938, p. 18). The modelling process is equivalent to a self-organised process of knowledge acquisition. For the following discussions, it is not distinguished between knowledge and models. A look on approaches supporting explorative and self-organised learning is taken.

Examples for progressive education approaches are *The Dalton Plan* by Parkhurst (Parkhurst, 1923, 2010), where students are supported in self-organising learning through the use of elaborated assignments. Maria Montessori is a well known scholar, where self-organisation and learning is supported through tangible learning materials (Lillard, 2007; Montessori, 1917). John Dewey described requirements for democratic education where students do not only acquire content but also become responsible members of the society (Dewey, 1903). Enabling self-driven acquisition of subjective experiences are key to progressive education approaches (Dewey et al., 1938).

Progressive Education focuses on supporting active and responsible students. Emphasis is given to the development of a learning environment. Through the developed methods and tools, together with careful and thoughtful design of a learning environment self-driven and social exploration of the learning topics are enabled (Eichelberger, Laner, Kohlberg, Stary, & Stary, 2008). In contrast to many existing teacher oriented approaches, progressive education puts emphasis on the learner's involvement in developing new knowledge rather than exact reproduction of existing knowledge (Dewey et al., 1938). Progressive education follows the following principles (Stary & Weichhart, 2012; Weichhart, 2013a):

- *focus on the individual learning styles*: learners are active and responsible agents; knowledge acquisition happens in individual and explorative processes
- *situated, complex, and challenging problems are provided in a prepared environments*: learning takes place through creative exploration of the problem space, authentic activities are building blocks that allow students to prepare for the future; teachers are not keepers of the single truth (materialised in text books) (Dewey et al., 1938) but are coaches that guide students, respecting their individuality
- *emphasising self-organised, social learning*: facilitated by the environment, individual agents interact during their learning processes; students support each other in their doing; knowledge is actively constructed in groups, new knowledge emerges during the interactive process

Overall the class of progressive education approaches provide a learning strategy which includes teaching of competencies that are required to allow responsible, active agents to develop heterogeneous and sustainable models.

More recently, learning environments have been analysed through the lens of systems theories. Complex Adaptive Systems Theory and Chaos Theory have been used to inform the creation of environments which enable active agents to self-organise their learning (Davis, Smith, & Leflore, 2008; Englehardt & Simmons, 2002; Hite, 1999; Siemens, 2005; Weichhart, 2013a; Weichhart, 2013b; Firestone & McElroy, 2005). The complex adaptive systems theoretical framework is discussed in the following.

3. Complex adaptive systems

Complex Adaptive Systems (CAS) theory places particular attention to dynamics in systems. In the following, the focus is placed on CAS theory. However, the properties of CAS are also discussed in other theories (Mitchell, 2009). The borders of CAS to Chaotic Systems and Cybernetic Systems are blurry. Common to these theories is the focus on the dynamics in the system. Common to them is also that they are rooted in General Systems Theory (GST) (von Bertalanffy, 1969). It is the intention of GST to abstract scientific fields for describing systems, subsystems and relationships. Of importance for the work here is that the referenced theories take either non-linear, deterministic, but chaotic behaviour or non-deterministic and dynamic relationships between system parts into account (Espinosa et al., 2008; Norman, 2011; Weichhart, 2013a).

For completeness, the following table briefly describes the distinguished system-types. Table 1 does not differentiate between