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Perceptions of the effectiveness of system dynamics-based interactive learning environments: An empirical study

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ABSTRACT

The use of simulations in general and of system dynamics simulation based interactive learning environments (SDILEs) in particular is well recognized as an effective way of improving users' decision making and learning in complex, dynamic tasks. However, the effectiveness of SDILEs in classrooms has rarely been evaluated. This article describes the construction, integration, and evaluation of an interactive learning environment in two educational settings. Subsequently, it explores how undergraduate business students perceive SDILEs and SDILEs-based course approach. This research draws on data obtained from two courses in undergraduate business program, over a period of three years. Results of this study suggest that students enrolled in the SDILE-based courses do indeed perceive important learning benefits and educational value. Further more, introduction of SDILE-bases courses at higher level are more beneficial than at the lower level introductory courses. However, there is need of more resources to be developed and deployed to harness fully the benefits of experiential learning provided through SDILE-integrated course approach.

1. Introduction

The use of simulations for teaching and leaning is becoming increasingly popular (Adobor & Daneshfar, 2006; Faria, 1987; Holweg & Bicheno, 2002; Moratis, Hoff, & Reul, 2006; Tao, Cheng, & Sun, 2009). Specifically, computer simulation-based interactive learning environments (ILEs) are often developed and used to improve people's decision making in the context of the dynamic complexity of business settings by facilitating user learning (Bakken, 1993; Issacs & Senge, 1994; Lainema & Nurmi, 2006; Lane, 1995; Qudrat-Ullah & Karakul, 2007; Romme, 2003). People learn from the experience. Learning is the process whereby knowledge is constructed by the transformation of experience (Adobor & Daneshfar, 2006; Kolb, 1984; Wall & Ahmed, 2008). Simulations in general and ILEs in particular are one form of experiential learning. In an ILE session subjects make a series of decisions and have access to the instantaneous feedback. Subjects also have the opportunity to evaluate and reflect on their performance in the after-the-simulation debriefing session. ILEs are found helpful in training people on decision making in complex tasks in several domains (e.g., The Business Networking Game in *mass customization* (Hoogeweegen, van Liere, Vervest, vand der Meijden, & de Lepper, 2006), The MERIT in *construction industry* (Wall & Ahmed, 2008), INTOPIA in *decision support systems* (Ben-Zvi, 2010), *Realgame* (Lainema & Nurmi, 2006) in *manufacturing decision making*). Prior studies have demonstrated some notable advantages and benefits of the use of traditional business simulations in science and management education and training (e.g., Adobor and Daneshfar (2006) and Anderson and Lawton (2009) provide excellent reviews on this topic).

However, developing skills in dynamic decision making, a *raison d'etre* of business education, is a challenge. Fragmented subjects taught in each functional area (e.g., finance & accounting, strategy, marketing, operations management, human resource management) hardly prepare our students to develop coherent mental models and strategies about the business world (Lainema & Nurmi, 2006; Sterman, 2000). Developing expertise in dynamic decision making requires the decision maker to develop the structural understanding of the task system i.e., how do the decisions and the consequences from them are causally related over time? (Bravo, van Joolingen, & de Jong, 2009; Spector, 2000; Sterman, 1989a; Yasarcan, 2009). System dynamics based ILEs purport to rise to this challenge (Forrester, 1961; Lane, 1995; Sterman, 2000).

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The basic premise of system dynamics is that "structure drives its behavior" (Forrester, 1961). An ILE based on a system dynamics simulation model, therefore, allows the users to "see" how their decisions lead to the particular outcomes, over time. However, majority of the evaluation research on the promise of system dynamics based simulations, including those with the explicit purpose of improving dynamic decision making skills (e.g., Maani & Maharaj, 2004; Tan, Anderson, Dyer, & Parker, 2010; Yasarcan, 2009) are based either on experimental studies (Moxnes, 2004; Parush, Hamm, & Shtub, 2002; Spector, 2000; Tan et al., 2010; Wheat, 2007) or on professional training and workshop settings (Gröbler, 2004; Gröbler, Maier, & Milling, 2000; Lane, 1995; Qudrat-Ullah & Karakul, 2007). Classroom use of system dynamics based ILEs has been limited to teaching of system dynamics modeling skills (Bravo et al., 2009; Plate, 2010; Wheat, 2007). Thus, despite the promising potential and an increasing interest, system dynamics based ILEs benefit to the business education learning process in the classroom has rarely been investigated empirically.

The main purpose of this study, therefore, is to evaluate whether students in post-secondary classrooms perceive any learning benefits from system dynamics based ILEs. Is it more beneficial to introduce such an ILE-based course to junior or senior undergraduate students? In this respect, the implementation of a system dynamics based ILE in several undergraduate courses in business education will be explored. This implies a focus on integrating ILE in standard undergraduate courses (e.g., introduction to operations management, and advanced decision making), without an explicit purpose in the area of systems thinking and system dynamics.

From a methodological point of view, this study draws on data gathered based on action research in authentic educational settings (Romme, 2004). Data captured by the ILE's programmed module, questionnaire and other qualitative data obtained in these settings will serve to explore whether ILEs integrated in classroom settings generate any learning benefits.

We begin by discussing some background concepts related to system dynamics based ILEs and how do they support learning and decision making in dynamic tasks and by briefly presenting the FishBankILE. In Section 3, we describe the settings, methods, and measurements used in this study. We then report results from two educational settings. Finally, we offer some reflections on the role of human facilitator support, utility of system dynamics based ILEs in experiential learning, need for additional instructional resources in ILEs, and role of background education and experience in improving dynamics decision making skills through these ILEs.

2. Background literature

2.1. Background concepts

We use "ILEs" as a term sufficiently general to include microworlds, management flight simulators, DSS, learning laboratories, and any other computer simulation-based environments – the domain of these terms is all forms of action for the facilitation of learning in complex, dynamic environments. In an ILE, the learning goals are clearly made explicit. Therefore, the computer games played for fun will not count as ILEs. An ILE consists of three components (i) a computer simulation model to adequately represent the domain or issue on hand with which the decision makers can experience and induce real world-like responses (Davidsen, 2000; Homer & Hirsch, 2006; Kriz, 2003), (ii) a user interface capable of allowing the decision makers to make decisions and access the feedback on interactive basis, and (iii) a human facilitator or a coach responsible for conducting briefing and debriefing sessions (Davidsen, 2000; Davidsen & Spector, 1997; Ledrman, 1992; Zydney, 2010). When an ILE's underlying simulation model is based on system dynamics methodology (Forrester, 1961), we call that ILE as SDILE. Examples are People Express (Sterman, 1988), FishBankILE (Qudrat-Ullah, Saleh, & Bahaa, 1997) and Healthcare Microworld (Hirsch, Immediato, & Kemeny, 1997).

Complex, dynamic decision-making situations differ from those traditionally studied in static decision theory in at least three ways: a number of decisions are required rather than a single decision, decisions are interdependent, and the environment changes either as a result of decisions are made or independently of them or both (Edwards, 1962). Researchers in system dynamics have characterized such tasks by feedback processes, time delays, and non-linearities in the relationships between decision task variables (Moxnes, 2004; Sterman, 1989a). Driving a car, managing a firm, and controlling money supply are all dynamic tasks (Diehl & Sterman, 1995). In these dynamic tasks, contrary to static tasks such as lottery type gambling, locating a park on a city map, and counting money, multiple and interactive decisions are made over several periods whereby these decisions change the environment, giving rise to new information and leading to new decisions (Forrester, 1961; Sterman, 1989b).

2.2. Learning with SDILEs

Learning about complex, dynamic tasks does not happen easily. There are some fundamental barriers to developing expertise in dynamic tasks (Sterman, 2000): (1) *dynamic complexity*: our limited ability to understand the impact of time delays between our actions and their consequences coupled with the interactions between feedback loops that are multiple and non-linear in character and are ever present in the most of the real world managerial tasks, (2) *information availability and quality limitations*: information we estimate, receive, and communicate is often oversimplified, distorted, delayed, biased, and ambiguous, (3) *information processing limitations*: when it comes to decision making people generally adopt an event-based, open-loop view of causality, ignore feedback processes, fail to appreciate time delays and are insensitive to non-linearities present in the feedback loop structures of the task system, perceive flawed cognitive maps of the causal structure of the systems, make erroneous inferences even about the simplest possible feedback systems, fall prey to judgmental errors and biases, defensive routines (Sterman, 1994, 1989a, 1989b). The effective SDILE, therefore, should allow the users to overcome such impediments to decision making and learning in dynamic tasks.

SDILEs meet this challenge through the provisions of (1) a representative simulation model of the task system, (2) powerful interface, and (3) human tutor support-the three fundamental components of any SDILE.

2.2.1. Learning and decision support through system dynamics simulation model

The primary premise of system dynamics methodology is 'the structure of the system drives its behavior'. This structure consists of feedback loops, stocks and flows, time delays arising from accumulation processes, and non-linearities arising from the interaction of these basic structures (Sterman, 1989b). The core of SDILE is a system dynamics based simulation model (Forrester, 1961). System dynamics based