THE EFFECTIVENESS OF SIMULATION-BASED LEARNING FROM THE PERSPECTIVE OF KNOWLEDGE STRUCTURE: A CONCEPTUAL FRAMEWORK

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Full Paper
Simulations Track

ABSTRACT

Prior research on the use of simulations and serious games for teaching sustainability, as well as simulation-based learning in general, has rarely distinguished between different types or structures of knowledge when assessing learning outcomes. This paper aims to offer a conceptual framework and provide examples that can assist researchers and practitioners in developing and assessing the effectiveness of simulation-based learning in relation to knowledge-related outcomes: declarative knowledge, procedural knowledge, and conditional knowledge. The significance of this paper is to emphasize the necessity of rigorously conceptualizing and measuring knowledge as learning constructs in empirical research that utilizes simulation and gaming, which hopefully contributes to the research on the effectiveness of simulation-based learning.

INTRODUCTION

It has been demonstrated that simulation-based learning, the adaptation of simulations and serious games for educational and other formal purposes, is effective in teaching and learning sustainable development (Choomlucksana & Doolen, 2017; Lohmann, 2020). Particularly, knowledge constructs on sustainability have been widely explored in the experimental studies of simulation-based learning research (Nguyen & Hallinger, 2022a). Multiple studies have found positive effects of simulation-based learning on sustainability-related knowledge (e.g., Mulcahy et al., 2020; Su, 2018; Yeung et al., 2017). For example, a recent study showed that graduate students at a management institution demonstrated a significant gain in their knowledge of sustainability concepts after learning with a computer-based simulation (Chatpinyakoop et al., 2022). Moreover, simulation-based learning is well suited for capstone business policy or strategy programs in which users consolidate their knowledge across all functional areas of management (e.g., Manring & Moore, 2006; Thompson, Purdy, & Fandt, 1997). Users are trained on how to make decisions when solving conditional and practical challenges with reflective realism and receive feedback on simulated decisions they make in response to changing circumstances (Adobor & Daneshfar, 2006; Faria, 2001). Therefore, simulation-based learning becomes a potential means of helping people understand what relevant knowledge can be used to address sustainability issues.

However, previous studies in the relevant literature have tended not to differentiate between the types or levels of knowledge gained by students as a result of the specified interventions (Sitzmann, 2011; Urquidi-Martín et al., 2019). For example, Su (2018) found a positive change in students' conceptual knowledge about the environment. Juan and Chao (2015) found that simulation-based learning generated a large effect on students' knowledge of green building. However, the studies were not explicit about the levels of knowledge gained by the students. This deficit in the literature is significant because part of the rationale behind the use of simulations and games in educating for sustainability lies in the assertion that these approaches produce significant results in developing higher-order thinking and the ability to apply knowledge (Gokhale, 1996; Rice, 2007; Sitzmann, 2011; Wouters et al., 2013). Yet, studies too often fail to analyze the types of knowledge gained by learners.

The utility of this distinction was observed in an experimental study published by Dib and Adamo-Villani (2014). They defined declarative knowledge of sustainable construction as, "the capacity for memorizing and recalling information and procedural knowledge as the capacity for applying acquired knowledge to specified tasks" (p. 8). When simulation-based learning was compared with a traditional learning method, the researchers found no differences between the groups on declarative knowledge but significant and positive differences in favor of simulation-based learning on procedural knowledge (Dib & Adamo-Villani, 2014). Few studies have supported the efficacy of simulations to develop one form of higher-order thinking (Gokhale, 1996; Huang et al., 2022; Rice, 2007).

These trends in the literature indicate a need for more precision in conceptually defining the nature of the knowledge gained in studies of education for sustainable development (Dib & Adamo-Villani, 2014; Nguyen & Hallinger, 2022a). This represents the gap to be addressed in this paper. Therefore, this study advocates a more differentiated approach to conceptualize and evaluate the effects of simulation-based learning on knowledge of change management for sustainability.

CONCEPTUAL FRAMEWORK

Sustainable change is essential not only for the long-term survival of our planet but also for building the long-term competitive advantage of organizations (Henderson et al., 2015). Organizations have observed and experienced changes in sustainable development issues in recent years (Ingham & Havard, 2017). For example, the COVID-19 crisis has not only had a long-term financial impact on the global economy, but also changed how firms view and are viewed in terms of corporate social responsibility (CSR) (Manuel & Herron, 2020; Bae, Ghoul, Gong, & Guedhami, 2021). Change management is described as the process of continually renewing the direction, structure, and capabilities of an organization to serve the ever-changing needs of external and internal customers (Moran & Brightman, 2001). The CSR demands (i.e., workplace safety, working conditions, human rights, equity considerations, equal opportunity, health and safety, and labor rights, named in Jones, Comfort, & Hillier, 2005) may have been considered unnecessary in the past, but changes to meet these demands are now mandatory in competitive business.

Prior research has shown that a firm's individuals as stakeholders, especially its leaders and employees, are called upon to gain and apply sufficient knowledge of change management toward sustainability in specific business and social contexts (Dahlsrud, 2008; Van Marrewijk, 2003). In fact, leaders and managers are frequently unaware of the multiple aspects of consequences of the management and training practices that they design and conduct causing a decrease in the internal social sustainability of organizations (Grant et al., 2007; Pinzone et al., 2019). As knowledge has evolved into a major currency in enterprises, it is required that stakeholders obtain efficient management understanding, planning, and implementation (Buckman, 2004). In other words, knowledge for sustainable change requires strategic and complex levels of thinking (Poponi, Arcese, Mosconi, & Arezzo di Trifiletti, 2020), thinking in new ways, and engaging with different points of view (Sharma & Kelly, 2014).

Therefore, teaching and learning change management for sustainability should be perceived as complex rather than segmented ideas and practices (Hmelo-Silver, Duncan, & Chinn, 2007). They should produce not only conceptual knowledge but also flexible thinking abilities reflected in procedural and conditional knowledge (Hmelo-Silver & Eberbach, 2011). Hmelo-Silver and coauthors (2007) also believe that learning settings should allow learners to participate in scientific processes such as questioning, research, and reasoning while still acquiring knowledge in a stimulating and meaningful way. However, research on training has traditionally examined variables of declarative knowledge as a major learning outcome, ignoring knowledge structure, which is considered a sign of high-level understanding (Kozlowski et al., 2001; Kraiger et al., 1993).

Sugrue (2005) argues that the knowledge structure of a topic/problem is a function of the following three levels: understanding of concepts (declarative knowledge), understanding of principles (procedural knowledge), and application of linking concepts and principles to conditions and procedures (conditional knowledge). In this study, it is desired that knowledge of change management for sustainability be acquired as a coherent, logical, and comprehensive whole, beginning with an understanding of concepts and principles (e.g., Kraiger et al., 1993; White, 1984), and ending with their application in contexts (i.e., Garris et al., 2002; Sitzmann, 2011; Whitehill & McDonald, 1993). Insufficient knowledge of sustainable change management, on the other hand, is considered scattered, incomplete, and disorganized understandings, which might inhibit a person's ability to present relevant concepts and apply them to contextual environments. In other words, beginners have a limited or segregated understanding of the key concepts or might not recognize the patterns and rules that underlie the knowledge(Gijbels et al., 2005). In contrast, comprehensive knowledge is accurate representations of significant phenomena and their interactions are correctly depicted by a well-structured process of relevant concepts and principles (Gijbels et al., 2005). Regardless of the work, a capable trainee's knowledge appears to be organized around essential principles and rules that guide actions and judgments in a range of taske contexts (Dochy et al., 2003; Gijbels et al., 2005; Sugrue, 1995). Akibg wutg a task-specific process, the capable worker can revise different strategies to adapt to the changed features of tasks (Kozlowski et al., 2001).

Simulation-based learning is viewed as an effective tool for teaching not only the concepts but also the higher levels of knowledge required to solve real-world problems (Gokhale, 1996; Sitzmann, 2011). The simulation-based learning approach in this paper provides a potential opportunity that encourages the production of knowledge identified as learning and analyzes the effects of a simulation-based learning program on strategic knowledge in change management for sustainability (see Figure 1).

The effectiveness of simulation-based learning on the learner's knowledge structure can be categorized and demonstrated as shown in Figure 2.

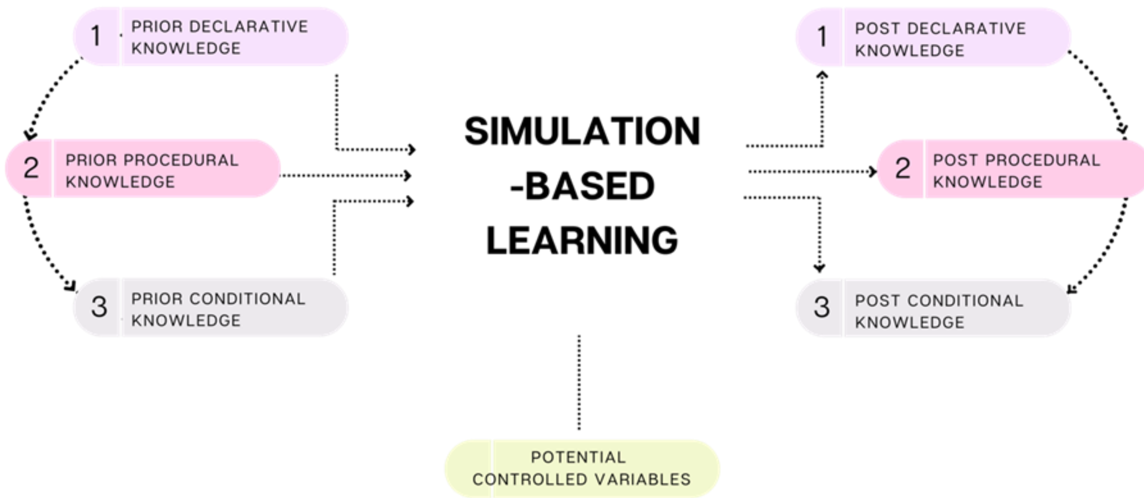

Figure 1. Conceptual framework of the effect of simulation-based learning on knowledge structure

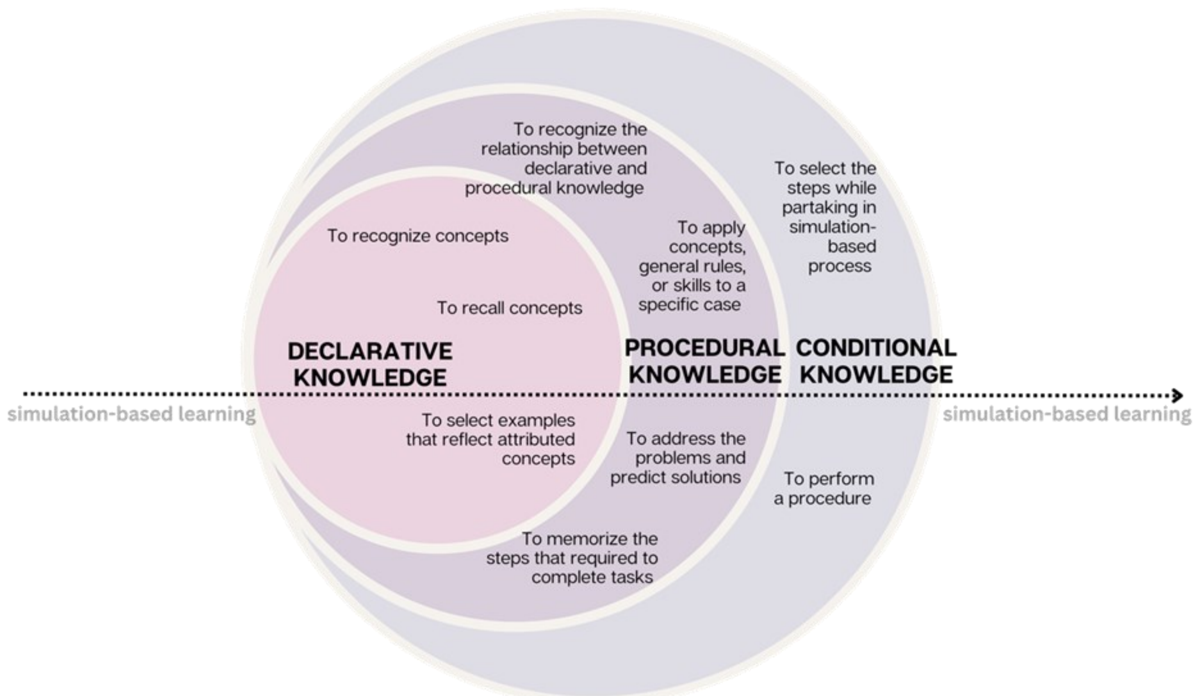

Figure 2. A classification of knowledge outcomes for simulation-based learning evaluations

At the first level of the knowledge structure, the understanding of concepts is the subject of the learning process. An individual's knowledge of a concept is specifically examined by presenting them with various instances of the concept and asking them to recall and identify those that belong to the category. Additionally, participants could assess related ideas concurrently by matching concept labels with a variety of examples. For example, declarative knowledge is the ability of the participants to recognize and recall concepts presented during learning and training (Chatpinyakoop et al., 2022; Kraiger et al., 1993, Nguyen & Hallinger, 2022b) or to select examples that reflect attributed concepts (Sugrue, 1995).

Because principles are rules that imply relationships between concepts, the second level of the knowledge structure assesses an individual's understanding of the principles of the relevant knowledge that links to the concepts. In fact, a person can be trained to understand specific concepts but may have little or no understanding of the broader principles that govern the relationships between those concepts. While individuals play a simulation or a serious game, dealing with several problematic and unexpected events, they are often requested to make different decisions from which they learn to choose the most suitable predictions or solutions. Therefore, individuals will be able to identify problems in the associations with relevant concepts and then predict accurate solutions, which requires a concise understanding of the principles in that specific knowledge.

For instance, researchers have defined procedural knowledge as the ability to recognize the relationship between declarative and procedural knowledge (Hong et al., 2018), to apply concepts, general rules, or skills to a specific case (Garris et al., 2002), to address the problems and predict solutions (Dib & Adamo-Villani, 2014), or to memorize the steps that are required to complete tasks (Kraiger et al., 1993; Sitzmann, 2011). It seems that these explanations are not consistently or explicitly addressed in current research. The relationship between the variables of knowledge structure is complex and intertwined with thinking types or skills such as systems thinking, anticipatory thinking, critical thinking, and strategic thinking, as named in Kioupi, Vakhitova, and Whalen's work (2021). In one study of the positive impact of simulation-based learning on high-order thinking skills (creativity, critical thinking, and problem-solving), procedural knowledge can be reflected as a problem-solving skill, which Huang and coauthors (2022) refer to as the ability to identify problems and collect and analyze relevant information. Besides the cognitive capacity to reason and think analytically, including comparing feasible solutions for a problem, is critical thinking. Creativity is the capacity to generate and cultivate novel concepts (Huang et al., 2022). The potential limitation of this conceptual approach is that it struggles to explain some aspects of the interdependent relationships between the concepts.

Another significant aspect of knowledge structure is conditional knowledge, a higher level of expertise, which extends beyond simply processing declarative or procedural knowledge. Conditional knowledge involves the integration of declarative (knowing what) and procedural knowledge (knowing how to perform certain tasks or procedures). Individuals with conditional knowledge not only possess the necessary information or concepts but also know how and when to apply them appropriately. It requires individuals to consider various possibilities, anticipate consequences, recognize the contextual factors that influence the application of their knowledge, adjust their thinking, and make well-informed decisions based on the specific circumstances they encounter. In the field of medicine, for instance, a doctor's conditional knowledge entails more than simply knowing medical facts. It includes his/her ability to apply this knowledge to the diagnosis and treatment of patients, considering the patient's medical history, symptoms, and other context-specific factors. Simulations and serious games often present participants with real-world scenarios or situations in which they are required to apply their knowledge under specific conditions. In one study, Fu, Sun, and Wang (2022) assessed participants' understanding of fundamental economic concepts and principles, which the authors considered to be a prerequisite for knowledge in this area. They did this as a means of evaluating their subject knowledge of money supply and policy. Furthermore, Fu and colleagues (2022) conceptualized and assessed systems thinking skills in three aspects of simulation-based learning tasks: pattern analysis, response identification, and the explanation of occurrences in a complex system. Their study would have been significantly more relevant if they had detailed and rigorously tested knowledge applications rather than simply asking participants to comment on this element.

Therefore, for conditional knowledge to be the focus, users are expected to show not only their conceptual or procedural understanding but also the applications regarding a variety of different procedures for accomplishing a specific goal (Canto de Loura, 2013). Conditional knowledge reflects individuals' ability to connect the dots between that information, the problems they are trying to solve, and the conditions under which they may act. A trainee with a lower level of knowledge will often have information, ideas, and principles, but they will not know how to put them to use in specific contexts in the best possible way (Gijbels et al., 2005; Glasser, 1990). Therefore, the evaluation of conditional knowledge focuses on learners' ability to select and perform the right steps and procedures under given problems and conditions while partaking in the simulation-based learning process (Gijbels et al., 2005; Sugrue, 1995; Wood & Stewart, 1987). This view is supported by Green, Molloy, and Duggan (2022), who proved that simulation-based learning has the potential to impact sustainability education by teaching individuals not only to recognize but also to apply patterns on their own. This eliminates the use of a fragmented approach where each sustainability issue is taught in an isolated condition or context (Green et al., 2022).

CONCLUSION

A growing body of literature on education for sustainable development acknowledges the value of simulations and serious games (Hallinger et al., 2020; Hallinger & Wang, 2020; Sterman, 2014). Researchers have additionally noted that simulations and games offer experiential learning environments that enable learners to acquire the skills needed to tackle intricate, multifaceted problems that demand the utilization of interdisciplinary knowledge and higher-order thinking (Astleitner, 2002; Gaber, 2007).

To address the need for a theoretical framework in the development and evaluation of the effectiveness of simulations or serious games, this paper proposes a hierarchical approach specifically targeting the organization of knowledge. Drawing on theory and research from various disciplines, the framework offers insights into understanding and assessing knowledge as learning outcomes. Future research is encouraged to explore the impact of simulation-based training on learner knowledge, investigating the variations in types or levels of knowledge variables acquired through simulation-based learning.

The anticipated contribution of this paper to the field of simulation and gaming research is significant. It advocates for a differentiated approach to conceptualizing and evaluating the effects of simulation-based learning on knowledge, particularly in the context of change management for sustainability. This paper is expected to support ongoing efforts by researchers and practitioners, advancing our understanding of effectiveness of simulation-based learning.

Furthermore, it addresses the significant gap in the existing literature by providing a more precise understanding of the nature of knowledge gained in studies related to education for sustainable developments. In summary, the research contributes by highlighting the effectiveness of simulation-based learning in sustainable development, addressing the deficit in knowledge structure analysis, and advocating for a more comprehensive approach to teaching change managemnent for sustainability. This comprehensive perspective is expected to enrich the discourse on education for sustainable development and enhance the design and assessment of simulation-based learning experiences.

Acknowledgement: The study was supported by the ASEAN Center for Sustainable Development Studies and Dialogues, College of Management, Mahidol University, Bankok, Thailand.

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