Agent-Based Modeling Games – Teaching Situation Specific Science Topics

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Abstract

Agent-based modeling (ABM) offers learners the opportunity to actively engage in complex modeling situations. These range from the physical and natural sciences to those topics which are relevant in today's society under the auspice of a variety of socio-economic or cultural happenings. Minimal user interaction is required, as the simulation or game is designed and the outcome of the data on human behavior and logical thought processes. This encourages learners to work collaboratively in a multi-player gaming forum and to realistically apply scientific principles and properties in a low-threat matrix environment. The use of ABM within educational games key component in improving Critical Thinking (CT) and Cognitive Load (CL) abilities for a more realistic learning environment.

ABM propounds a practical application of identifying active entities by the modeler, of agents while defining the agents' behavior(s). The agents, in this learning forum, were the learner/users of the simulation game, while the behavior was the established connection(s) between scientific concepts and phenomena and the practical application(s) therein. ABM is a fairly new approach to the modeling of complex systems, in which autonomous 'agents' or users abide by 'behaviors' or rules of engagement. The users or agents interact with one another, thus influencing their behavior(s), therefore altering the outcome(s) of the simulation game. This in turn creates a more realistic view of general behavioral practices. These practices give rise to patterns and structural attributes that cannot be expressly or explicitly programmed into the game itself.

The research performed was a causal-comparative quantitative study with 150 learners enrolled at a two-year community college, to determine the effects of Agent-Based Modelling on learner behavior within science education. Data collection involved a quantitative analysis of pre/post-laboratory experiment surveys that included using a Repeated Measures ANOVA test for ABM or non-ABM for cognitive load and critical thinking modalities. By studying the manner in which learners comprehend information and reducing their cognitive load while conducting scientific experiments in Virtual Learning Environments (VLEs), we are provided with the information required to structure pedagogical changes and appropriate technology resources in applicable teaching modalities.

1. Introduction

Agent-Based Modeling (ABM) propounds a practical application of identifying active entities by the modeler, of agents while defining the agents' behavior(s). The agents, in this learning forum, were the learner/users of the simulation game, while the behavior was the established connection(s) between scientific concepts and phenomena and the practical application(s) therein. "The emphasis on modeling the heterogeneity of agents across a population and the emergence of self-organization are two of the distinguishing features of agent-based simulation as compared to other simulation techniques such as discrete-event simulation and system dynamics" [5, p.151]

The purpose of this quantitative quasi-experimental study was to determine how the use of ABM in virtual learning environments effected learner behavior choices, and how these systems are requisite of manipulating more than one parameter which can alter the complexity of a learning scenario. This yields an increase in cognitive load, specifically for inexperienced learners. The data revealed that the inclusion of ABM games can enhance the learning process in inexperienced learners. This was accomplished by and Cognitive Load (CL) among learner participants at a two-year community college. The Consumer-centric smart grid configuration describes the relationship between consumers and distributed power through renewable energy vectors. The version of the simulation presented in Fig. 1 uses icons to represent these vector components, which are essential to the learning process.

Energy consumption estimates were modeled and quantified based on indicidual behavior of users consuming energy in a variety of situations for residental use. The data was aggregated to demonstrate the choices user made based upon energy prices and energy output for each renewal energy resource chosen.A distinction exists between ABM for educational games and non-ABM games that is based upon taxonomic representations that amplify in their intricacy and generalization. Research has noted that a progressive development between learning contextual usage of terms based upon pictorial representation and abstract meanings used in vernacular culture [7, 13]. The use of consumer versus producer in science education reinforces the scientific method as to support ABM and ABMS through assumptions and believability. These factors are essential to users making decision-based analyses.

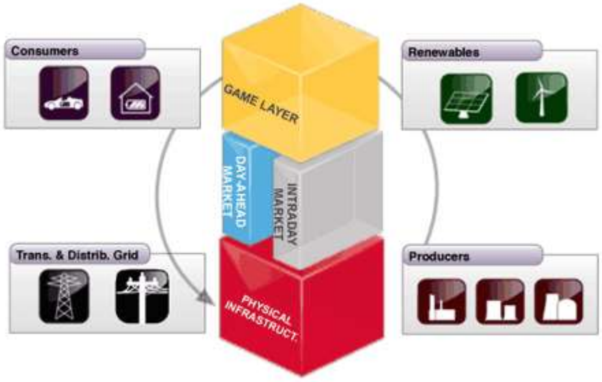

Fig. 1. Consumer-centric smart grid configuration
(Mihailescu, R., Vasirani, M., & Ossowski, S., 2013)

2. ABMS Hierarchy

By placing the importance on modeling the diversity of agents transversely against a populace and the materialization of self-classification, agent-based simulations are distinguished more thoroughly than other simulation techniques that focus on discrete events and system dynamics. ABM offers a feedback social system wherein agents are composed of interacting and instrumental behaviors and experiences. They adapt based upon their environment and what best suites that environment at an instant in time and over the duration of the game. Applications of ABM span broad ranges of disciplines and behavioral situations.

ABMS principally began through a series of ideas, techniques, and implementations of computational modeling of complex but highly adaptive systems [5]. Throughout the evolution process of ABM, autonomy of the agents has been paramount from the inception, as to allow for the agents' responses to be unrestricted by external direction to situational encounters. This allows the agents to be active during the situation as well as independent in their behaviors. They are bestowed the ability to achieve learning outcomes, internal goals, and are no longer merely passive learners or mentors. Models include rather simplistic to the more complex 'if-then' rule, in which complex behaviors are modeled via adjustable artificial intelligence procedures [5].

3. Cognitive Load Theory

Cognitive Load Theory is a branch of instructional psychology, based upon the works of Sweller [12] that when applied as a cognitive science, enhances the effectiveness and efficiency of instructional design. The objective of instructional design involves providing instructional formats and procedures that maximize learning. The inclusion of inquiry-based instructional methods within science education, higher-education inclusive, has been extensively promoted as to raise national education standards in the STEM fields. While inquire is a vital component to education in total, science education directly benefits from the ability to form lasting connections between learner information through the inquiry process. This aids in learners care ting a learning environment that is demonstrative of the very essence of science, experimentation of concepts to establish an answer to a relevant scientific question. In conjunction, pedagogical design and architectural design of learning instruction are coupled as to maximize the efficiency of student comprehension, while limiting the over processing capacity of acquired and learned knowledge skills. A working memory individually processes visual and auditory information as to commit these concepts to long-term memory [6].

4. Results

The results of the presented study are based on data collected during an academic year. Each learner provided informed consent to the collection of this data. All data are anonymized as to avoid any personally identifiable information.
CL was assessed as to the extent in which they differed for learners who played educatioanl science games using ABM than those with no treatment. Results of the statistical analysis of the repeated measures indicated that the use of ABM games had some effect on the learning process and choices made by user throughout the game itself. The results indicated that the ABM in the treatment group does increase the use of CL and therefore used two main subscales, deep learning and surface learning learning. Fig. 2 represents the results in academic progress for those learners receiving treatment. There was moderate statistical significant changes for those learners without treatment.

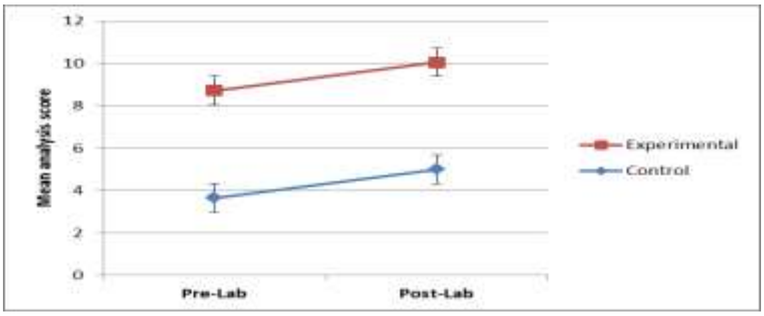

Fig. 2 RM-ANOVA for experimental and control groups at pre-lab and post-lab.

Cognitive Load (CL) capacity was assessed as to the extent in which they differed between the use ABM within the science education disciplines. The effective use of Cognitive Load with ABM games is marginally reduced and therefore, somewhat significant, as the within groups showed more efficient use of working memory than that of the between group results. The results showed that learners in the treatment group had moderately higher levels of CL usage and implementation than learners in the non-treatment group. The findings from this research are that those learners in the treatment group used similar levels cognitive load capabilities as did learners in the non-treatment group, is consistent with past research on the usage ABM games in science education within the science disciplines [7, 10 13, 14].

5. Summary and conclusion

The impact of ABM on Cognitive Load (CL) capabilities, was studied via apre/post survey methodology, as to distinguish learning events during experimentation. Statistical results are presented that show increased CL ability in ABM game learning environments. With the incorporation of these learning environments into laboratory courses, learners may increase their knowledge base within defined course content areas more expressly directed at the science disciplines. Instructional and educational design of a course aids in the determination of whether a learner utilizes deep or surface learning through Critical Thinking and Cognitive Load abilities [13, 14]. This study offered a discrete perspective for science educators with interests in simulation experiments and for educational technologists interested in creating these learning environments.

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