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The Design and Use of Agent-Based Modeling Computer Simulation for Teaching Technology Entrepreneurship

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Abstract: Entrepreneurship is complex and dynamic. It involves continuously pursuing novel or better products and business models amidst constraints, uncertainty, and constant change among participants (or "agents") in the ecosystem. Entrepreneurship education, therefore, needs to be non-linear. Yet, traditional teaching methods in entrepreneurship came from business management education practices: lectures, case studies, and group discussions–mostly ineffective because entrepreneurship is more dynamic and non-linear. Recent entrepreneurial experiential learning attempts include starting and running a business and using computer simulations to reduce time and cost. This study focuses on the agent-based computer simulation approach. It aims to design and build, using existing open-source frameworks, a simulation environment specifically for technology entrepreneurship, with the choice of technology entrepreneurship forcing novelty and relative market uncertainty in product offerings. The design and selection of technologies will follow evaluation frameworks on the effectiveness of entrepreneurship teaching simulation environments: *fidelity*, *verification*, and *validity*. The expected output will be a simulation environment resulting from multiple design-build implement iterations. The simulation core engine shall interface with a Learning Management System (LMS). The study will also generate insights after simulation sessions with students through educational data mining (EDM) of the resulting logs.

Keywords: computer simulation, entrepreneurship education, agent-based modeling, serious games

1. Introduction and Context

Entrepreneurship is pursuing novel or better products or business models amidst constraints (Eisenmann, 2013). Entrepreneurial education is crucial in fostering economic growth, yet it lacks many aspects in making it more effective (Allegra, 2013). Entrepreneurship education needs to be flexible, but studies show that higher education does not have the flexibility necessary (Matlay and Mitra, 2002, as cited in Tasnim & Yahya, 2013). Entrepreneurship is a complex, chaotic, non-linear, and dynamic process of vision, change, and creation; therefore, it is more than business creation and management (Neck & Greene, 2011; Kuratko, 2005). There are gaps between current theories of the entrepreneurship process involving opportunity recognition, evaluation, and exploitation and how they are taught (Fox, Pittaway, & Uzuegbunam, 2018). The typical teaching methods in entrepreneurship classes are those used in business: lectures, case studies, and group discussions–all ineffective when teaching entrepreneurship (Bennet, 2006, as cited in Tasnim & Yahya, 2013). Educators can still teach entrepreneurship outside these methods (Neck & Greene, 2011; Kuratko, 2005). Previous sources of entrepreneurial understanding were publications, direct observation, and speeches or presentations by practicing entrepreneurs. Entrepreneurship education has expanded with business plans, consultation with practicing entrepreneurs, and computer simulations (Kurtko, 2005). This study focuses on the computer simulation approach.

A *simulation* is a self-contained immersive environment in which the learner interacts within the environment in an attempt to learn or practice skills or knowledge (Kapp, 2012). Simulations allow cost-effective training that would otherwise be costly and time intensive to set up in a real scenario (Kapp, 2014, as cited in Almeida & Simões, 2018). People in education define a *game* as any contest (play) among adversaries (players), operating under constraints (rules) for an objective: winning or pay-off (Tasnim & Yahya, 2013). *Serious games* are computer-based learning simulations that engage players in realistic activities designed to increase knowledge, improve skills, and enable positive learning outcomes (Prensky, 2001; as cited in Fox et al., 2018). Simulations and serious games have storylines and can be competitive and keep score (Almeida & Simões, 2018). Serious games, unlike entertainment games, focus on problem-solving tasks and incorporate the imperfect nature of interactions with the natural world (Susi, Johannesson, & Backlund, 2007; as cited in Fox et al., 2018). This study aims to design and observe the usage of a computer simulation environment specifically intended for technology entrepreneurship students, with the choice of technology entrepreneurship implying novelty and relative market uncertainty in product or service offerings.

An *agent* is an autonomous individual that can behave and decide independently. Agent-based Modeling and Simulation (ABMS) covers interactions among independent agents (Macal & North, 2005).

2. Research Questions

The following questions properly establish the significance of the study, all in the context of technology entrepreneurship learning: RQ1) What aspects of technology entrepreneurship education are fit for simulation? RQ2) What elements of computer simulations or serious games are critical for learning entrepreneurship? RQ3) What features must be present when designing and implementing a serious game platform for entrepreneurship education? RQ4) How would the efficacy of serious games be measured based on learning outcomes? For RQ1 and RQ2, consistency with the natural world is essential, so the study will consider a framework or a set of criteria for evaluating computer simulations and serious games. For RQ3, the study will include a technology scan of various computer simulation tools and techniques. For RQ4, the review will cover several assessment techniques and design criteria involving simulation for entrepreneurship education (not necessarily already covered by computer simulation and serious games).

3. Related Work

Neck & Greene (2011) present three traditional different "worlds" used to teach entrepreneurship: *entrepreneurial* (teaching and observing the entrepreneurial personalities, attitudes, discussing exemplars), *process* (business plan writing, case method), and *cognition* (mindsets, ways of thinking entrepreneurially, and knowledge structures to assess, decide, and make judgments on opportunities, creation, and growth). They also offer a fourth approach involving entrepreneurship as a *method* in contrast to a *process*, which implies predictability. Some methods are starting a business, design-based learning (observation, fieldwork, and understanding value-creation), and reflective practice. Another method uses *serious games*, simulations, multimedia instruction, and interactive activities to compact the business creation process. Serious games are innovative tools for developing entrepreneurial skills such as strategic management, leadership, communication, negotiation, or decision making (Almeda & Buzady, 2019; Tasnim & Yahya, 2013).

An *agent* is an autonomous, self-contained, and self-directed individual with characteristics and rules governing behaviors and decision-making capability. In complex social processes (including entrepreneurship), agents represent people or groups of people, and agent relationships represent processes of social interaction (Gilbert and Troitzsch, 1999, as cited in Macal & North, 2005). Agent based Modeling and Simulation (ABMS) covers interactions among independent agents (Macal & North, 2005). Examples of recent work involving ABMS with critical complex environments during COVID-19 involve supply

chain recovery (Rahman, Taghikhah, Paul, Shukla, & Agarwal, 2021) and economic activities (Kano, Yasui, Mikami, Asally, & Ishiguro, 2021).

Low et al. (1994) and Hindle (2002) are early attempts at using computer simulation in entrepreneurship education (Fox et al., 2018). Hindle (2002) finds that experiential learning and the generation of empathy for the "real-life" situation are vital components of entrepreneurship education. Hindle (2002) also raises the issue involving the timeframe of a business venture exceeding an academic subject's term duration. This difficulty is why a simulation game could address this issue. Allegra et al. (2013) used PNPVillage for students to manage a simulated tourist resort. Other tools mentioned in the literature include SKY HIGH (Hindle, 2002), Virtual Business Retailing (VBR) software (Yen & Lin, 2020), SimVenture (Bellotti et al., 2014; Fox et al., 2018), FLIGBY (Almeida & Buzady, 2019), and GoVenture (Fox et al., 2018). ABMS software packages like NetLogo (Wilensky, 1999) and Python-based MESA (Kazil, Masad, & Crooks, 2020) are free, open-source, come with example models, are customizable, and extensible.

Centralized decision engines, where rules and functionalities reside, become problematic as rules become more complex. The resulting delays in feedback make it difficult for users to see the repercussions of their decisions. Artificial intelligence, new programming paradigms, and the ability to decentralize the running of agents may help alleviate these problems (Allegra et al., 2010).

Feinstein & Cannon (2002) propose an evaluation framework for entrepreneurship serious games with three criteria: *fidelity* (realism of the simulation), *verification* (the model operates as intended), and *validity* (the model and the natural world reach the same conclusions). Hindle (2002) proposes success criteria: *adequate suspension of belief, unambiguous communication, technical reliability, and cost benefit assessment*. These attributes and success criteria are the combined theoretical framework for the simulation environment design in this study.

It has been challenging to look for literature on integrating a computer simulator and a Learning Management System (LMS), especially related to entrepreneurial learning, with Allegra et al. (2013) being one of the exceptions. Most serious games for entrepreneurial education also do not include an integrated assessment process of the developed entrepreneurial competencies (Almeida and Buzaidy, 2019), implying a lack of LMS integration as observed in other areas (Queirós, Leal, & Paiva, 2016). In addition, most of the simulation software packages mentioned in the studies are off-the-shelf with minimal room for customization. This study aims to fill the gaps in work on the following: 1) customizing ABMS software to support additional entrepreneurial concepts, 2) extending the opensource ABMS software to allow competition, 3) integrating these ABMS platforms with LMS, and 3) providing educational data mining capabilities for the simulation environment.

4. Research and Implementation Method

The study will take at least two cycles, with additional ones to allow enhancements as new findings and insights emerge. The design, based on past work, must align features with the learning outcomes of the B.S. Information Technology Entrepreneurship (BS ITE) Program of the Ateneo de Manila University in the Philippines. The early prototypes will involve entrepreneurial concepts that are "architecturally significant." A candidate concept is Rogers' (1995) theory of diffusions of innovation (Meade & Islam, 2006). Early prototypes will use NetLogo and then migrate to MESA. The simulation engine will connect to an LMS. Students will then use the prototype to compete against each other for top scores in various business metrics. Each session will have at least three rounds with a debrief and assessment of participants by facilitators in between. Students will reflect on the experience and submit their insights through the LMS. At the end of the session, simulator logs and student insights captured in the LMS will go through analysis using exploratory educational data mining (EDM) techniques, which will feed into the subsequent iterations of the simulator build.

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