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# FROM ANALOGUE TO DIGITAL: CREATING SIMULATIONS THROUGH CONCEPTUALIZATION BOARDS

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## ABSTRACT

We explore how to use conceptualization boards to familiarize students, teachers, parents, and the community in general with discrete-event simulations. We raise the question: how can we make simulations accessible to non-simulationists? We argue that with the use of tactile tools users can not only conceptualize but also create simulations. We developed a prototype board that captures discrete-event simulation's blocks like arrivals, queues, processes and resources. The board applies the concept of gamification to engage users. The board is simple to replicate and can be created with accessible material or 3D printing capabilities. Further, we propose the board be used simultaneously with software applications to facilitate the transition from analogue to digital tools. Future work investigates 1) extended simulation, 2) universal access to simulation and 3) insight generation.

## 1. INTRODUCTION

Simulations provide an efficient and effective way to learn. According to Alessi (2000) "studying by using a simulation is quite different than studying a book, listening to a lecture, or doing a computer drill. In a scientific discovery simulation, for example, the learner is performing experiments, varying input variables in a systematic fashion, observing and recording output, and (if the simulation is designed well) reflecting on the results" (p. 185). Simulation learning is more than a single activity and can be seen as a series of activities that move between using and building simulations fulfilling different advantages for learning. Simulations engage the participants in different types of actions and decision-making processes (Gredler 1994; Kriz 2003; Martin 2000; Yaman et al. 2008). Learners perceive simulations as more interesting and motivating than other methodologies for learning because they provide a real-world perspective (Alessi 1988; Alessi and Trollip 2001; Martin 2000). Through simulations, learners acquire new knowledge and apply this knowledge in a variety of situations (Curtin and Dupuis 2008; Eckhardt, et al. 2013). Overall, simulations can increase students' critical thinking, decision making, and problem solving skills (Curtin and Dupuis 2008). It is important to note that simulations are not technology, but rather an educational strategy (Anderson et al. 2008). As such, simulation can effectively enhance cognitive, affective, and psychomotor learning (Anderson et al. 2008). Yet, while we know the potential benefits of learning how to create models and simulations, these activities are usually learned at college and graduate-level courses. In addition, learning how to use and create models and simulations requires knowledge about methodologies, tools and, as important, knowledge about the domain of interest. As such, new easy to use methods and tools to facilitate the modeling and simulation process should be made available to students of all ages.

One way of bridging that divide is through gaming: expose students to games that underlie a learning experience. Games introduce complex concepts in a non-threatening way with the premise of learning by playing.

According to Oblinger (2006), games in learning provide advantages such as: creating social environments which often involve distributed communities; acquiring necessary knowledge for playing; exploring problem solving techniques; transferring learning by bridging reality and games; and providing an experiential (multiple sense) and immersive learning understanding. The motivational effect of digital games, for instance, comes from the emotional appeal of fantasy and the sensory and cognitive components of curiosity (Aldrich 2009). According to Van Eck (2006), a game can be suitable for use in the classroom if the game aligns with the class content and the game is not so easy that it is not engaging. Additionally, the optimal learning state is that of being in a state of “flow” (Csikszentmihalyi 1997). This refers to a mental state of immersion and clarity (Csikszentmihalyi 1990). Many individuals call it “being in the zone.

Discrete-event simulation (DES) was selected as it is one the easiest modeling paradigm to learn and one that we are most familiar with the representative systems. According to Robinson (2005), “Discrete-event simulation is one of the most commonly used modelling techniques” (p. 619). DES has been used in studying a wide range of queueing systems in museums (Gunal and Sezen 2014), airport terminals (Guizzi et al. 2009), healthcare (Findlay and Grant 2011; Gunal and Pidd 2010), manufacturing (Semini et al. 2006) and road constructions (Lu 2003), among others, with the goal of optimizing system performance, diagnosing issues, and evaluating alternatives.

In DES, simulations provide a way of explicitly and tacitly exposing students to STEM: scientific (random number generators, computability), technical (simulation design and execution), statistical (probability distributions), mathematical (functions), and engineering (queuing) concepts. Therefore, the amount of specific domain knowledge required to study these systems is minimal. In other words, users familiarize with a useful method that can have real impact on their daily lives and that they may encounter in college or at the work place in the future.

It is important to note that while DES tools exist they do not necessarily convey how to model. According to Robinson (2005), “although software vendors provide training in the use of their packages, in general they do not train their users to be simulation modellers” (p. 625). Further, constructive simulations are of digital nature which makes it difficult to visually impaired individuals. Blenkhorn and Evans (1998) present the use of talking tactile diagrams to enable blind users to create, read, and edit flow diagrams. The simulation community need and must open new avenues to reach an underserved population.

Considering the importance of simulation in interactive learning as an educational strategy, the use of gaming in learning as a motivational and social component, and the prevalence of DES across domains and its relative ease of use, this paper explores the use of conceptualization boards towards learning DES and STEM concepts. The paper is organized thusly: section two provides the context for using board games in Modeling and Simulation (M&S), section three presents a proposed conceptualization board, section four proposes how the board can be used with simulation software and section five summarizes the paper while providing a way forward.

## 2. TOWARDS FAMILIARIZING USERS WITH M&S USING BOARD GAMES

The Beer Distribution Game is perhaps the best-known game that familiarizes people, mostly within M&S and Operations Research communities, with the concepts of delay and feedback using an easy to understand system (i.e. beer distribution) with clear learning objectives (Sterman 1989). The concepts of delay and feedback are key in the system dynamics modeling paradigm. How can we convey DES concepts like inter-arrival time and batching, for instance? Collaborating with high school students, we have come up with preliminary prototypes of board games. Figure 1 shows a game, named by the students Archipelago Anarchy. The game mainly focuses on highlighting the concept of batching where a minimal number of entities is required to form an attack group. The game uses cards to generate entities and provide the unexpectedly fun part of the game.

Figure 1: Archipelago Anarchy Board Game - Early Prototype.

Some of the preliminary rules of the game are:

- Player turns are decided by rolling a die; the highest number goes first, then in clockwise order.
- At the beginning of the game, every player starts with one island, one ship builder, and five randomly chosen cards from the top of the deck.
- Upon the Players turn, they will pick their respective number of cards from the top of the deck. The number of cards that can be pulled per turn is determined by how many islands the player owns. For example, if the player owns two islands, (including the starting island), then the player pulls two cards at the beginning of their turn.
- Cards do not have to be immediately played, but they can only be played during the players turn.
- When any troop type is initially placed, it cannot be used immediately. The player will wait until the next turn before the troop assigned is ready to be usable.

There have been two main challenges to the development of the game: first is the comprehensive integration of DES concepts and second the tradeoff between DES concepts and making the game fun. On challenge one, the idea is that the game reflects the most concepts of DES so more users can have the most comprehensive learning experience. Yet, while some of these concepts may be easily identifiable – batching for instance – others may not be, like entity processing. Further, if the concepts are not easily identifiable, the effectiveness of the game is reduced or nonexistent for learning those concepts and perhaps the paradigm as a whole. Challenge two is the tradeoff between DES learning and achieving enjoyment while learning. We have identified, so far, that the more DES concepts are faithfully captured the less fun the game becomes so there is a tradeoff decision that must be made and cannot be overlooked. Both challenges suggest the need for balance; what to keep in and out in order to make the game educational and fun.

To keep exploring on the potential uses of the game, it is being re-thought as an agent-based board game. We have relied on the use of activity diagrams to facilitate the transition and definition of game rules making the process of the game creation an educational one when conducted with simulation learners. It is important to note that games' design and their potential effectiveness depends on the "target market." Archipelago Anarchy, for instance, focuses on creating simulation awareness to a young population (middle school, high school, early college) that may not pursuing simulation education.

## 3. CONCEPTUALIZATION BOARD 1

The conceptualization board started as another game board initiative to capture as many DES elements as possible. After several iterations, the board game was deemed more appropriate as a conceptualization board, one that helps design DES without a software tool, with a minimal gaming component. The gaming component consists of putting together a puzzle-like board that would capture the necessary DES components to simulate a desired system. As such, the board can be used to generate simulation awareness and facilitate the training of students consciously looking for simulation education. Figure 2 shows the board and a minimal number of parts to represent a system.

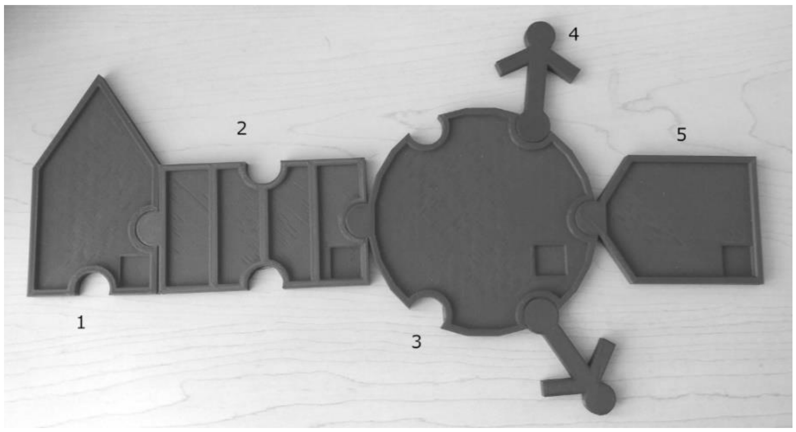


Figure 2: DES Conceptualization Board.

The model captured in Figure 2 has an arrival block (1), a queue (2), a process (3), two resources (4) and one exit (5). Note that the use of the board does not consider the model parameters. The idea is that those values are inputted in the digital version of the model. The analogue portion focuses on providing the learner the means of putting together a puzzle-like board and grow it to the point that serves as a conceptualization of a system. The system represented is a common example of a fast food restaurant where people arrive, are processed via available resources and leave the system. Figure 3 shows a slightly more elaborated model.

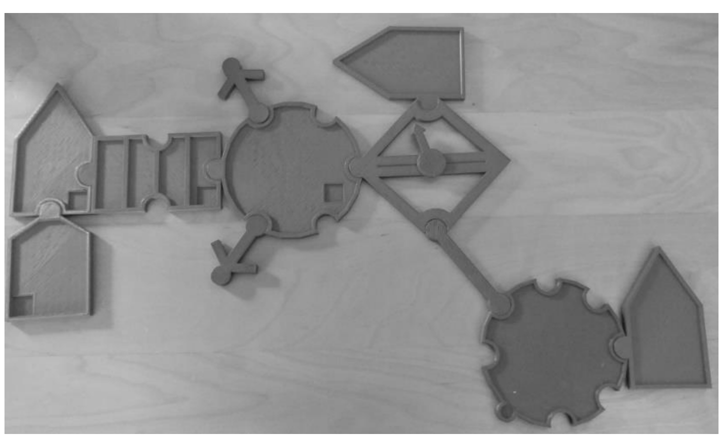

Figure 3: Board with more Blocks.

The model in Figure 3 contains a few new blocks namely, a decision block (diamond shape), a connector piece and a variation of the process block (one that allows for a larger number of resources). Following on the example, the decision block points to customers selecting one of two options (deciding): leaving the restaurant or going through a delay (process without resource) before exiting the system. It is important to note some design elements of the board. The little squares in some of the blocks were designed to initially hold a six-sided die that could introduce randomness when moving pieces through the system representation. But as was mentioned, those design options are not considered as of the latest iteration of the board. Figure 4 shows some of the dice considerations during the game design process.

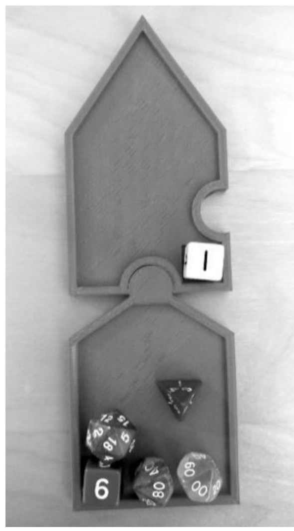

Figure 4: Dice Considerations for the Board.

It is also important that the board can be used or modified to effectively create good practices and avoid mistakes that may be overlooked in the digital world. For instance, the connecting points could be sized in the manner that they cannot be connected to other pieces if the design and/or software calls for that.

## 4. BOARD AND SOFTWARE

Talking about software, the conceptualization board was designed to complement the instantiation of the model as a simulation, ideally through semi-automated means. As it currently stands, the pairing is manual (meaning the model needs to be replicated in the software). The board was designed as generic as possible to pair to most DES software available. In this case, we paired the board with CLOUDES. Figure 1 implements the Basic example (Figure 5) in the CLOUDES environment. CLOUDES (Padilla et al. 2014) is a cloud-based discrete-event simulator supporting multiple languages and offering a library of models for browsing and learning. CLOUDES is designed to help users without simulation knowledge and domain expertise model systems that most people across ages are familiar with: queuing systems. CLOUDES can be executed across operating systems including mobile platforms such as tablets and Chromebook. CLOUDES' users access and interact with the environment through a web-browser based front end composed of JavaScript and HTML. The HTML components provide the interactive form components allowing the user to access, modify, construct, and share Discrete-Event Simulation (DES) models through web-browsers. Users have a variety of options when using CLOUDES, including: logging in, building models, running simulations, saving models, collaborating, sharing models, and loading existing models.

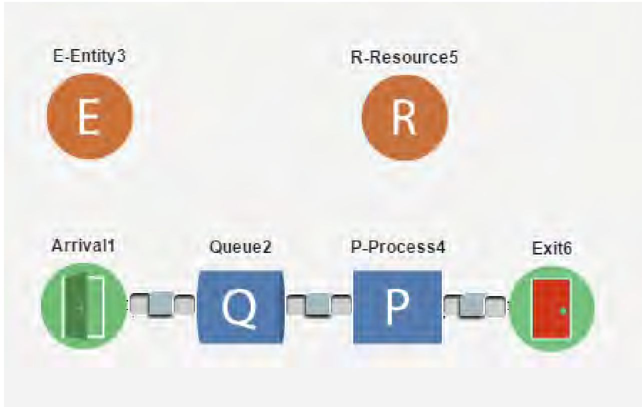


Figure 5: Basic Example – CLOUDES.

Pairing the board model with the simulation is crucial as to convey equivalence between analogue and digital blocks and to explore the simulation through different parameter initialization. As such, the board fulfills the function of introducing and transitioning non-simulationists to a simulation world.

It is important to note that, as it was in this case, the simulation platform evolved by adding new functionality. CLOUDES' conceptual modeling option provided an opportunity for the creation of new board options or board improvements. CLOUDES' conceptual modeling capability relies on the identification of "steps" in queuing systems and defining those steps as potential simulation blocks. Figure 6 shows a CLOUDES conceptual model of the Basic Example. Further, CLOUDES has the capability of automatically converting the conceptual model into a simulation model. In this case, the model from Figure 5 is the result from the conversion of the model from Figure 6.

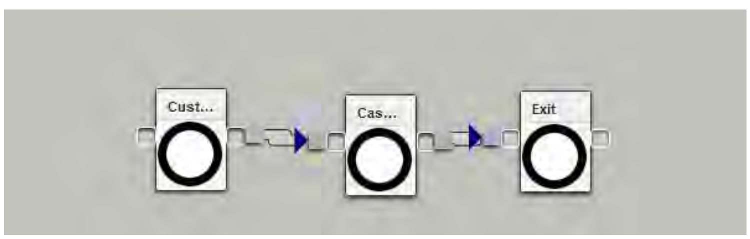


Figure 6: Basic Example – CLOUDES Conceptual Model.

As such, a simpler board should provide the capability of creating "steps" and allow the user to capture those steps in the software and ask the software to create an equivalent simulation model. Figure 7 shows the 3D printed Simple Conceptualization Board that capture such conceptual model.

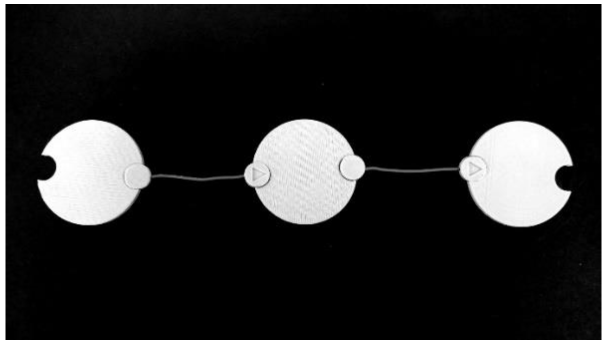

Figure 7: Simple Conceptualization Board.

## 5. DISCUSSION AND FUTURE WORK

Conceptualization boards provide a didactic way of creating awareness and engaging students in modeling and simulation creation. We postulate that the tactile nature of these boards provide a complimentary way for learning about modeling while providing a gaming value. Further, they have the potential of engaging people that are not participating in modeling activities like students with visual impairment, provided that blocks either have easily recognizable shapes or contain writing in braille.

It is important to note that while we have used boards in the context of DES, we could expand these to other paradigms. For instance, the board in Figure 7 can be extended with colored wires and multi-connector blocks to allow for building concept maps or causal loop diagrams. Figure 8 shows an extended version capturing a causal loop diagram capturing the well-known word of mouth – market adoption model. The board in this example has two block types (one with two and one with four connectors), two colored wires (one red capturing a link with negative polarity and one black capturing a link with positive polarity) and two "plugs" at the end of each wire (one with an arrow capturing the direction of the connection and one blank). Lastly, we rely on sticky notes to name the nodes.


Figure 8: Causal Loop Diagram - Simple Conceptualization Board.

This research endeavor is in its infancy considering the potential applications and ramification for making simulations accessible to the community in general. As mentioned, we are interested on developing the means for people with visual impairment or those within the spectrum to take full benefits of modeling and simulation. The Digital Senses group at VMASC, for instance, is developing hardware that can facilitate this by semi-automating the process of capturing data (that can apply to all) and designing models. We identify three main areas of future research

- Extended Simulation: The idea of extended simulation is to allow people to build simulations through a mix of physical and digital objects in a mix of physical and digital environments. Similarly, we would like to see people experience the simulation in extended reality where they can use multiple senses to experience the simulation during runtime, replay or analysis. We plan on linking the board game with our cloud-based discrete event simulation engine, so that users can use from physical to digital representations of model and data seamlessly

- Universal Access: Current simulation tools have interfaces that are limited to the sighted, hearing-able, neurotypical and physically-able users not to mention financial, social and cultural biases built-in to accessing the tools. The idea of universal access is to make the development and experience of modeling and simulation to accessible to all people across the board. It requires a pedagogical and methodological examination of simulation concepts that will benefit everyone across the spectrum.
- Insight Generation: Current simulations generate data and at most provide information through graphical user interfaces. These interfaces are mainly designed for analytically minded users who have a technical background. We need to move to simulation environments that aim at engaging users and provide a sense of presence so that they can make connections between the data streams generated by the simulation

Together, extended simulation, universal access and insight generation would allow users of all ages, experience level, background and physical ability to use simulations for entertainment, learning, exploration and care.

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