Proceedings of the 2017 Winter Simulation Conference
W. K. V. Chan, A. D'Ambrogio, G. Zacharewicz, N. Mustafee, G. Wainer, and E. Page, eds.

STORYTELLING AND SIMULATION CREATION

Jose J. Padilla
Christopher J. Lynch

Virginia Modeling, Analysis, and Simulation Center
Old Dominion University
1030 University Boulevard
Suffolk, VA, 23435 USA

Hamdi Kavak

Modeling, Simulation, and Visualization Engineering Dept.
Old Dominion University
1300 Eng. & Comp. Sciences Bldg.
Norfolk, VA 23529, USA

Shawn Evett
Devon Nelson
Calvin Carson
Joshua del Villar

The Pruden Center for Industry and Technology
4169 Pruden Blvd.
Suffolk, VA 23434, USA

ABSTRACT

When learning to create simulations, we rely on real systems to emphasize their importance on reality. However, for younger students, reliance on reality is not always engaging. Reality provides context, but students' interest quickly fades. Through the use of four case studies, we explore the idea of having students create stories in order to engage them in learning to create simulations. Applying a narrative/story context provides a mechanism for learning and maintaining student engagement. Stories can be based on original/existing games, movies, or other sources rich in narrative. Our approach includes four components: create a game/story narrative; discuss, evaluate, and expand the narrative; implement the narrative into an animated storyboard; and implement the narrative into a simulation. Lastly, we briefly discuss the utilization of sounds on both the animated storyboard and the simulation. Future work will empirically explore the effectiveness of narrative storytelling for learning simulation creation.

1 INTRODUCTION

How do we teach simulation creation to non-experts? Like many, we have pondered this question in relation to *engagement* and *learning*. Traditionally, the focus lies on learning. This means, teaching non-experts the way we learn to create simulations. We rely on systems (Checkland 1989; Lightsey 2001; Mitroff et al. 1974) or modeling and simulation (M&S) methodologies (Robinson 2011; Tolk et al. 2013) to provide structure to learning about simulation creation. In addition, we rely on observable systems to create context for the introduction of new M&S concepts. The challenge is twofold: (1) engagement is often ignored, as 'we are not here to entertain people' or 'there is no other way to do it'; and (2) we assume that non-experts, like high school students, rely on "a" structure for learning.

In order to overcome these challenges, we look into narratives and storytelling. We aim to explore the use of storytelling to facilitate student engagement and to learn simulation creation by having the students create game narratives. In this case, non-experts participate in a process of generating narratives about

games or stories that they find interesting. Then they create simulations that reflect their narratives with respect to a specified modeling paradigm being taught.

According to Dahlstrom (2014), "although storytelling often has negative connotations within science, narrative formats of communication should not be disregarded when communicating science to nonexpert audiences." The author continues: "narratives often increased comprehension, interest and engagement. Nonexperts get most of their science information from mass media content, which is itself already biased toward narrative formats." The simulation creation process can also be considered biased toward narrative formats. Mathematics, being one of the means through which we express models, is always presented as a prerequisite to understanding simulations. Although mathematics for the non-expert is not always narrative friendly, there are concepts such as inter-arrival and service times that convey relevant information so that non-experts can familiarize with these concepts.

Ultimately, simulations, although technical, are the result of a storytelling process conveyed through their conceptualization and implementation. Simulations tell stories about systems or phenomenon, such as bottlenecks due to limited resources or unexpectedly segregated neighborhoods resulting from small preferences on acquaintances. These are stories that take the form of models in the areas of discrete event simulations (DES) and agent-based models. Non-experts may not be interested in the technical details of these models, but they may very well be interested in the story by the model; therefore, we hypothesize that this narrative aspect can increase non-experts' level of interest in creating models and simulations.

We present four use cases to demonstrate our approach. The first two use cases, *Pickle Wars* and *Space Pirates*, are developed as new game narratives utilizing themes of fiction, fantasy, war, and space. The last two use cases, *Wrath of the Deep One* and *Control of the Realm!*, are developed using publicly accessible material based on themes of adventure, medieval history, war, and fantasy. For *Wrath of the Deep One*, we frame a game narration around a monster from the fictional literature of H. P. Lovecraft (Lovecraft 1999). For *Control of the Realm!*, we frame a medieval-themed narrative based on the "Lords of the Realm" computer game by Impressions Games (1994). The use cases focus on engaging non-experts to learn basic DES concepts and does not currently expand into the topics of model verification or validation. We detail our approach in Section 2. Sections 3, 4, 5, and 6 present each of our four use cases and we provide a discussion and conclude in Section 7.

2 STORYTELLING AND SIMULATION CREATION

According to O'hara (2014), "Every storytelling exercise should begin by asking: Who is my audience and what is the message I want to share with them?" In our case, our audience is high school students. The message? Games, and the stories they convey, become the message. Students, in this case, should narrate stories that they find interesting. In doing so, they will ultimately include the constraints needed to comply with their simulation goals. The story provides the means for learning through creation and discussion while simultaneously providing encouragement and maintaining motivation for the learner. A resulting hypothesis from this exploration is that students embrace learning simulation concepts indirectly through tool utilization instead of directly through studying simulation concepts and abstractions.

Games provide engaging links for educators in capturing and maintaining the interest of students (Bowen 1999). Gaming enhances the cognitive, skill-based, and affective abilities of the students/players by focusing on game attributes such as challenges, rules, assessment, and sensory stimuli (Bedwell et al. 2012; Landers 2014; Wilson et al. 2009). For instance, the Beer Distribution Game serves as a well-known game within M&S and Operations Research for teaching the System Dynamics' concepts of delay and feedback using an easy to understand system (i.e. beer distribution) with clear learning objectives (Sterman 1989). Kapp (2012) makes a direct case that games serve as abstractions of reality that connects players, abstract thinking, and interactivity to facilitate learning and instruction. This is similar to the converging goals of M&S. Padilla et al. (2016) provides an example of using games to provide the context for learning to model, for teaching specific DES components, and for familiarizing students with the tools of the trade.

Simulations are proving to be an effective resource for educating students about a diverse range of topics, including STEM, by exposing students to systems that they may not normally have direct access or to systems that do not exist. By creating simulations, students are required to think in more depth about the system that they are creating. The act of narrating a game to design and create a simulation allows the student to switch from the perspective of having to *identify* characteristics of some system to the perspective of having to *create* the system in order to expand their game. This forces students to expand their level of thinking about the game to a great enough level to then create an executable simulation.

Further, if we make storytelling and simulation creation a group activity, we can rely on activities like communication and collaboration to enhance learning. Collaboration in creating and using simulations has been suggested as a means for increasing the effectiveness of learning (Sanders et al. 2016). Along a similar avenue, Hodkiewicz (2015) utilizes a board game approach to teach asset management strategies by requiring managers to focus on designing board layouts by: (1) identifying strategies to advance the player; and by (2) identifying risks that move the player backward. This game-based approach to teaching asset management works by getting participants to engage with each other to identify strategies and their potential outcomes instead of focusing on the game's win criteria. A similar study puts players into the roles of employees within sectors of an organization, highlights player communication, and uses sector growth as a win condition for teaching management (Van den Boomen, Duifhuizen, and Staverman 2012).

Our proposed approach to storytelling through simulation creation is simple. Step 1 is to create a narrative for a game of interest. Step 2 is to discuss (if in group) or evaluate (if individual) the narrative and inquire into how it reflects simulation concepts. Step 3 is to implement the narrative in the form of animations/storyboards. Step 4 is to implement the narrative into a simulation. No requirements are offered for length requirements on the narratives. All four steps may need to be iteratively revisited as storyboard or simulation development may reveal additional elements that are missing from the narrative.

Step 1 - Creating the Narrative. Narratives can be based on games that the learners have played, games they are striving to create, or a combination. Movies are also an appropriate source for initiating narrative discussions. The learner needs to come up with a topic for a game that they find interesting. By framing the narrative in the form of a game, the learners are directed towards the identification of elements necessary for the construction of the eventual simulation. In order to create their visions, the learners need to identify an objective for the game, the actors that enter, exit, or interact, the behaviors or actions that the actors can make, and any entities or resources that the entities or players need to progress through the game.

The objective should reveal the outputs that need to be collected from the simulation runs. The actors should reveal the entities that arrive to and exit from the simulation. The interactions between actors or the behaviors that the actors can make should reveal any needed batches and separators. Any actor-actor dependencies indicated may reveal the presence of model resources.

Step 2 - Discussing, Evaluation, and Revising the Narrative. The discussions on the narrative should consider the narrative itself, how it can be implemented into a simulation, and how someone else might use the narrative and its simulation for learning. These discussions should yield insights into underspecified areas of the narrative, contradictory elements, and assist in specifying the simulation requirements. Revisions to the narrative are made and this step is repeated as needed.

Step 3 - Creating the Storyboards. Creating a visual storyboard to illustrate the narrative serves the roles of facilitating communication and collaboration, helps to pin down how game actors progress through the game, and helps to maintain engagement during the process of capturing additional assumptions and constraints that assist in simulation building. Animations further enhance the storytelling activity by forming dynamic storyboards. These animated storyboards can provide better representations of the actions that the game actors can make, reveal decision points in the game, and illuminate gaps in how game progression occurs. Ultimately, the storyboards also provide an effective means for sharing models.

Step 4 - Implementing the Simulation. Implementing the simulation ties the learner back to the M&S objectives. Up to this point, the learners create model specifications through the narrative development without having to know exactly how this connects to the model. However, now they have the task of

converting their narratives into a simulation through the use of a tool. If a specific paradigm is being taught, then objectives specific to this paradigm should be focused on during Step 2. Otherwise, a modeling paradigm should be selected which best fits the narrative based on guidance from the instructor.

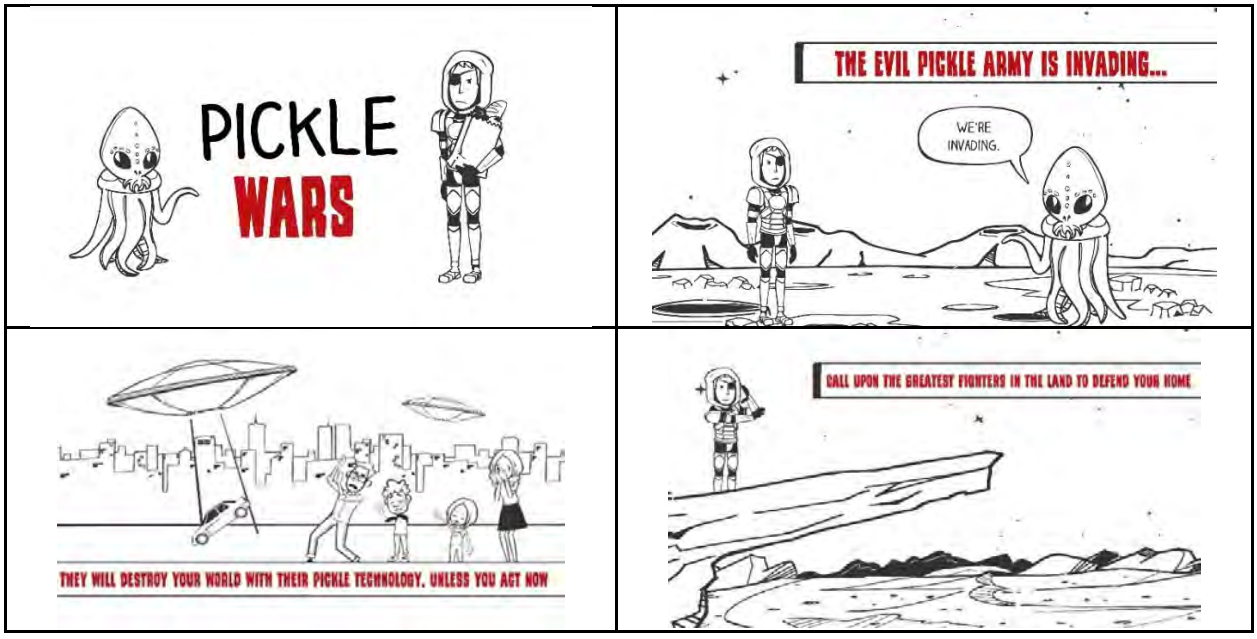
The remainder of the document highlights two considerations: storytelling with new narratives and storytelling with existing narratives. We speculate that some learners may be more comfortable leaning on an existing story than creating a new one. The authors collaborated on four games: two with new and two based on existing narratives. All games were implemented using the web-based DES tool CLOUDES (Padilla et al. 2014). Storyboards are screen capture of animations created in goanimate.com.

3 GAME ONE: PICKLE WARS

This game was developed as a single player game with the objective of forming an army in order to repel an invading force. Multiple game actors are revealed along with resource requirements, decision points, and a run length for the simulation. The narrative follows:

> *The evil pickle army is amassing at our gates, ready to turn the world into one giant lobster dish - form an army and repel the invaders! Call the Mascar drivers, assemble the herd, find out if the Jordan Remseys care or not, then battle your foes! If you take too long, the pickles will overrun your defenses. Each section of the army needs resources to be called:*
>
> *Mascar dudes need fuel to drive their cars, Cowboys need time to gather the herd, and it takes lamb sauce to get the attention of the Jordan Remseys - but they might not care about your mortal conflicts anyway, so it's still a gamble. You have 4 hours!*

The narrative contributes five different entities, including Pickles, Cows, Cowboys, Jordan Remseys, and Mascars as well as Lamb Sauce as a required resource. Additionally, several events, a timeline, several intertwined paths, and an objective are identifiable. The storyboard (Figure 1) helps to sequence the narrative's events and reveals that a number of events occur in parallel, such as gathering the player's forces. Figure 1 helps to convey the main points in the game; however, the animated version conveys greater depth into the specifications that lend themselves towards conversion into a simulation. These include clearer looks into how and when the different forces come together and expands upon pickle army's role.



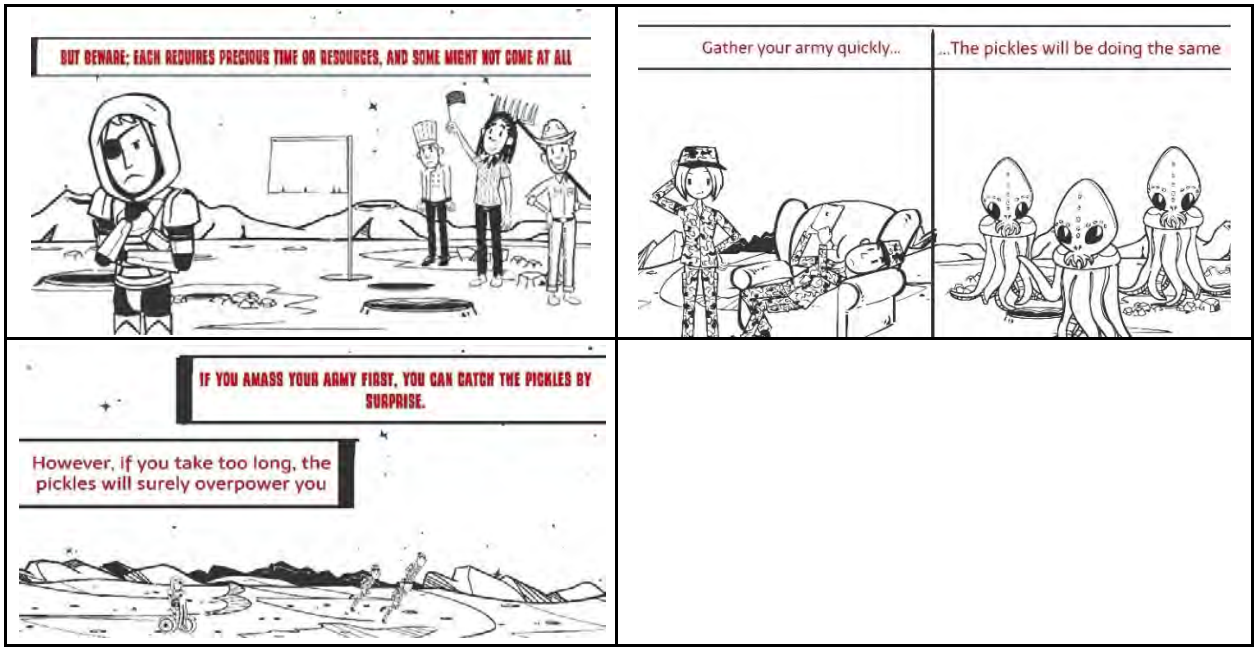


Figure 1: *Pickle Wars* storyboard.

In *Pickle Wars*, all forces needed to form the allied army spawn from the left and merge together within the "Grouping army" Batch. Cowboys have to collect their herds before joining the army. The Jordan Remsey's can decide not to join the army and result in an automatic loss. The Pickles enter from the top of the simulation and merge into an army within the "Mustering for attack" Batch. The first army to reach and exit the "Fite" Process becomes the winner. Figure 2 provides a view of the completed simulation. The simulation can be accessed at: https://beta.cloudes.me/loadShare?simId=10923.

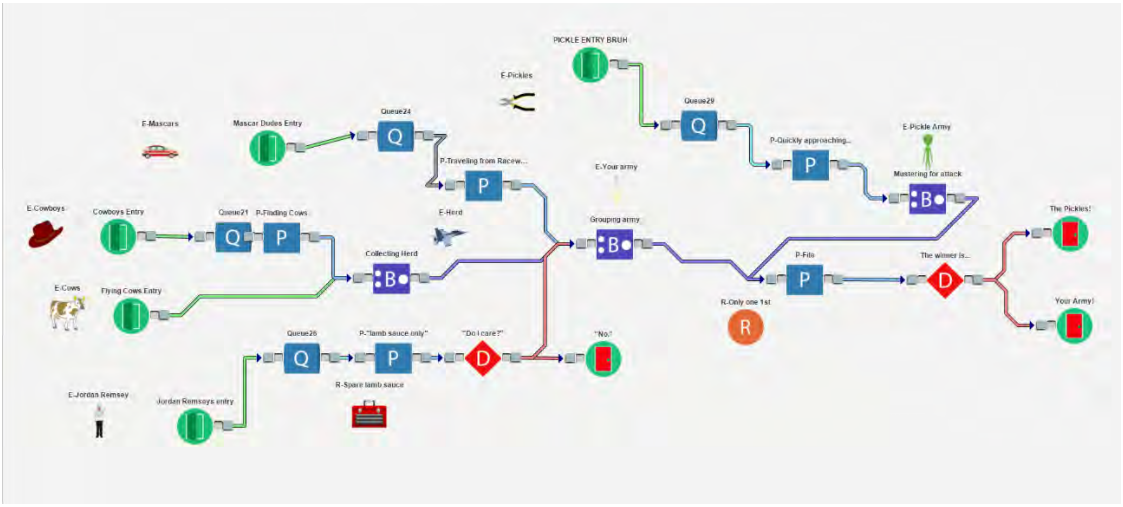


Figure 2: DES implementation of the *Pickle Wars* narrative in CLOUDES.

4 GAME TWO: SPACE PIRATES

This game was developed as a single player game set in space with the goal of conducting raids to steal loot. The objective is for the player to determine optimal arrival layouts so that ship crews are not idle and

unable to assist in the raids. Probabilities for decision outcomes are conveyed along with metrics of success that need to be monitored within the simulation. The narrative follows:

> *You are a member of the space pirates. Your captain has ordered you to steal the loot from trader ships. You can choose to either take a group of your fellow pirates to raid the ships or you can go solo and stealthily steal the loot. Your chances of stealing the loot in the raid are 45%. Your chances of stealing the loot solo are 30%. The goal of this game is to minimize the amount of people waiting for officers to arrive while also making sure that officers arrive fast enough to successfully complete the raid 5 times or steal the loot 3 times.*

The narrative lays out Officers and Group Members as the two entity types. The objective is defined along with two potential paths for achieving victory. The chances of victory along the two paths fixed values so that the player can experiment with the numbers of arrivals. The storyboard (Figure 3) sequences the game's events and visually establishes the space theme to situate the game.

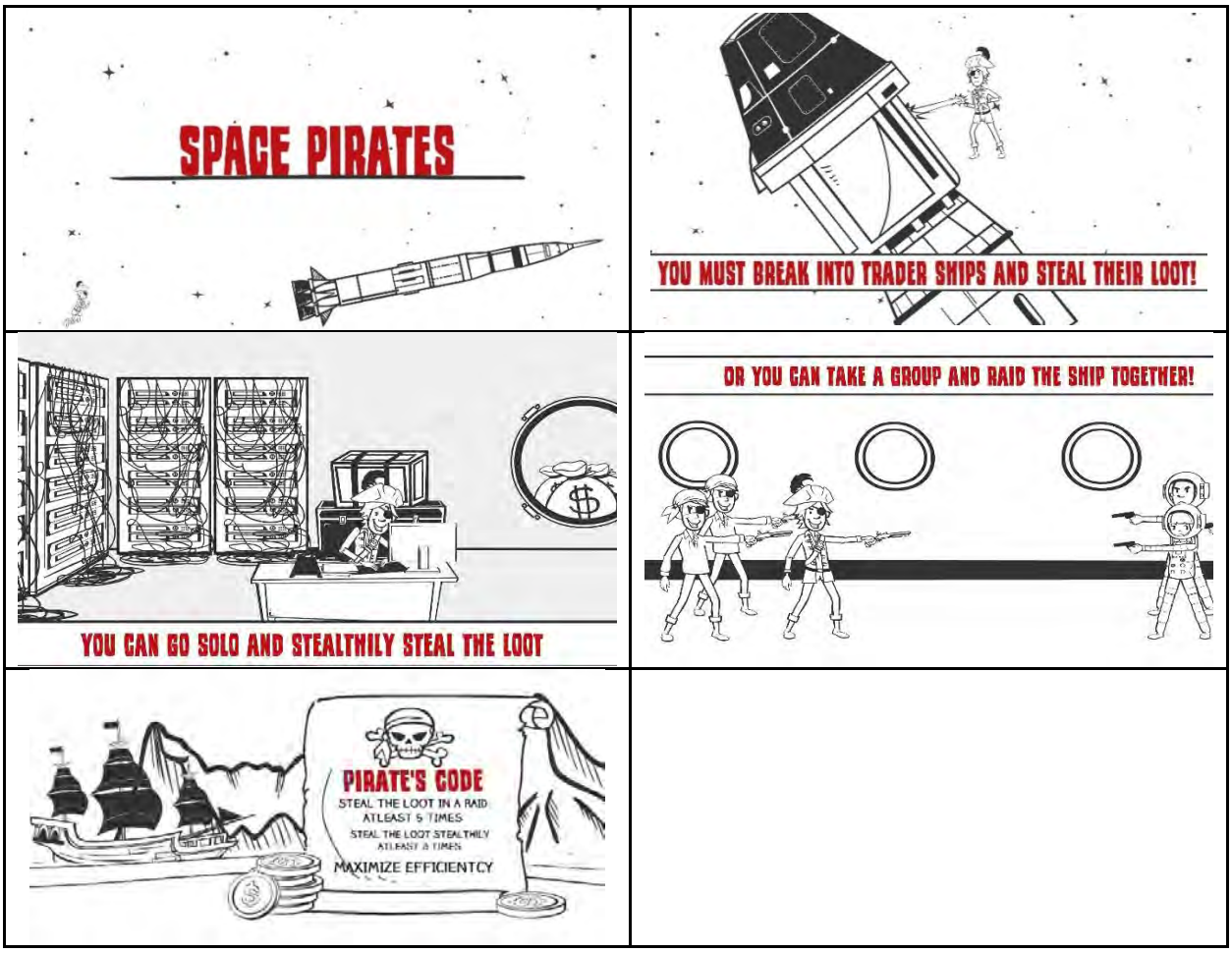


Figure 3: *Space Pirates* storyboard.

In *Space Pirates*, Officers arrive and wait for enough Group Members to join them to form Raid Groups and attempt to steal cargo from the trader ships. The Process nodes represent the length of time that each raid and stealth attack take to execute. The total number of successful and failed stealth and raid outcomes

are tallied to track success by the end of the game. Figure 4 provides a snapshot of the simulation which can be accessed at https://beta.cloudes.me/loadShare?simId=10926.

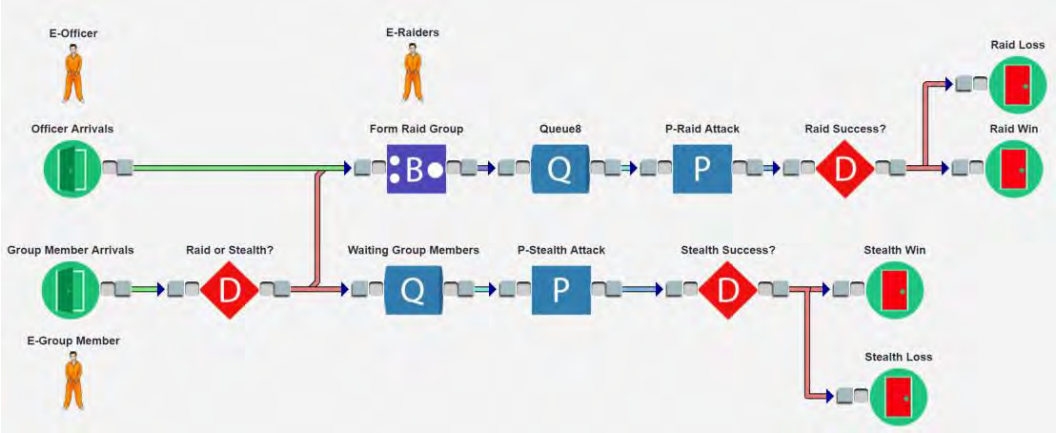


Figure 4: DES implementation of the *Space Pirates* narrative in CLOUDES.

5 GAME THREE: WRATH OF THE DEEP ONE

While original stories, such as *Pickle Wars* and *Space Pirates*, provide engagement, existing stories also provide a known and rich backdrop for creating simulations. We provide two narratives based on publicly accessible material, in this case, from fictional literature and variations of games. Storyboards are not provided as there exist abundant visual references and to avoid any potential legal infringement. *Wrath of the Deep One* was developed as a single player, adventurer style game with the ability to level up characters in order to improve the chances of defeating an evil monster. The narrative is based on concepts from the game Dungeons and Dragons and the Cthulhu character created by H.P. Lovecraft (Lovecraft 1999). Several paths for adventurer entities to progress are identified that each contain sets of unique challenges that manifest as combinations of batches, processes, and resources. Each route's chance for victory is clearly conveyed. The narrative follows:

> *Hear Ye! Hear Ye!*
>
> *The evil Lord C'thulu has evicted the King from his throne and taken over the Land of Nozgoth, and will destroy the world in 3 days!*
>
> *Henceforth, the King has issued a challenge to all able bodied heroes throughout the realm! Any hero able to slay the vile lord and return peace to the land shall be showered with the affections of the people for generations, as well as riches beyond their wildest dreams!*
>
> *All heroes must sign the release waiver given by the Quest Administrator, thereby releasing the kingdom from all liabilities concerning the life of any idiots-(ahem…) HEROES brave enough to undertake such a tremendous task.*
>
> *After the point of release, the adventurers' quests are up to their discretion. They can travel the Main Road and make a two hour walk to the Castle of The Deep One. It is at that point, where the Level 1 Adventurer may test his mettle against the powers of The Deep One. This path, however safe, shalt be a terrible gambit for an adventurer to take, for the Deep One's tremendous power will leave the Level 1 Adventurer with very little chance of victory.*
>
> *However, all is not lost, for along the path to the castle, there are dark and dangerous dungeons for adventurers to complete and collect powerful and valuable treasures! These increase the Adventurers' levels, as well as their chances for defeating The Deep One. These*

dungeons, however, do have a chance to kill the Adventurer and end their quest before reaching the Deep One. The Magic Sword, Magic Shield, and Magic Armor lie in wait for heroes to discover and don in the quest to rid the land of evil. After each dungeon, heroes can continue their paths toward the Deep One, or test their might in other dungeons. An adventurer, armed with the sword, shield, and armor has a cumulative level of Four, with each magical item adding a level to the Adventurer's stats, and each level adding increased chance of victory when finally facing The Deep One. Each dungeon has a set probability for an Adventurer to complete it and receive a Magical Item.

Finally, once at the castle of The Deep One, the adventurer is pitted against the Deep One himself! They will do battle and decide the fate of the kingdom. A meek Level 1 Adventurer shalt only have a measly one percent chance of victory. A mundane level 2 adventurer shalt have a modest thirty percent chance of victory. A surly Level 3 Adventurer shalt have an even fifty percent chance of victory. Lastly, a titanic Level 4 Adventurer shalt have a vast sixty-nine percent chance of victory, and a one percent chance to defeat The Deep One, devour his immortal soul, and become the king of the realm Himself!

The narrative sets up an intriguing theme, a timeframe, a complex leveling system, and the ability to experience the game from multiple perspectives ranging from a naïve to a properly prepared adventurer. A complex batching system is established in order to facilitate the conversion of the adventurer into higher levels over time. Clusters of decision nodes provide the differing chances of success based on the final level of the player before reaching The Deep One. The narrative and the simulation implementation contribute to a high level of engagement for players as well as for engaging discussions during the design phase.

Adventurers spawn individually and progress through the world. Each adventurer faces a series of decision points at which they decide if they continue adventuring and looking for gear to make themselves more powerful or if they are ready to take on the Deep One. Adventuring can be conducted a maximum of three times and yields a magical sword, shield, and armor upon the success of each respective adventure. These items are represented as entities which batch with the adventurer to form a higher level adventurer each time. Ultimately, an adventurer's level dictates the level of success in defeating the Great One and saving the land. Figure 5 provides a snapshot of the completed simulation. The simulation can be accessed at https://beta.cloudes.me/loadShare?simId=10927.

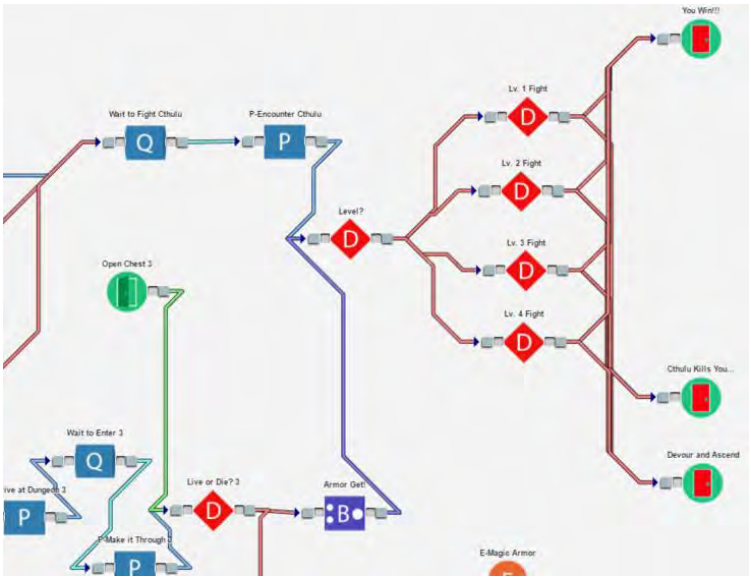


Figure 5: A portion of the DES implementation of the *Wrath of the Deep One* narrative in CLOUDES.

6 GAME FOUR: CONTROL OF THE REALM!

This game was conceptualized as a single player, strategy game taking place during medieval times and focused on internal waring within a kingdom. The narrative is inspired by the medieval strategy computer game Lords of the Realm (Impressions Games 1994), but similar scenarios are abundant within real history, fantasy novels, movies, and games. The quantities and arrival rates of attacking troops are left up to the game player to decide, but the defender's forces are restricted. The narrative follows:

> *Your uncle, the King, passed away during the night and left no direct heir to claim the throne. You are now the best person to rule over England. You have experience, allies, and the vision needed to improve the country beyond anything that it has been before. However, your cousin, the Duke of Wallex, also desires the mantle of King and is already maneuvering to steal control. He seeks to rule through fear and intimidation; yet, your reputation among the people is firm and they are sure to rally to your side if you can show them that you have power to lead them. The 16th Century will be remembered as your era!*
>
> *The time has come to lay siege to the Duke of Wallex's castle. Dozens of knights and archers stand ready to defend, so the battle will not be easy. You have two loyal allies willing to assist you! Summon their aid and mount an attack. Success in breaching the walls is likely to require multiple attempts. Regroup as needed and continue the onslaught for as long as possible. You do not have the time or knowledge required to construct large siege engines. Go! Claim your destiny!*

The narrative establishes a theme, a timeframe, and a recursion mechanism for reusing soldiers that survive each assault on the castle. A system of decision nodes provides the differing percentages of casualties based on the success level of the assault. A Castle Resource is utilized to ensure that only a single assault occurs at a time. In *Control of the Realms*, all of the allied forces spawn from the left side of Figure 6 and merge together to form an army within the "Prepare for Attack" Batch node. Each of the processes leading into the batch represent travel time required for the forces to arrive from their respective regions. The army then conducts an assault on the Duke of Wallex's castle at the center Process node.

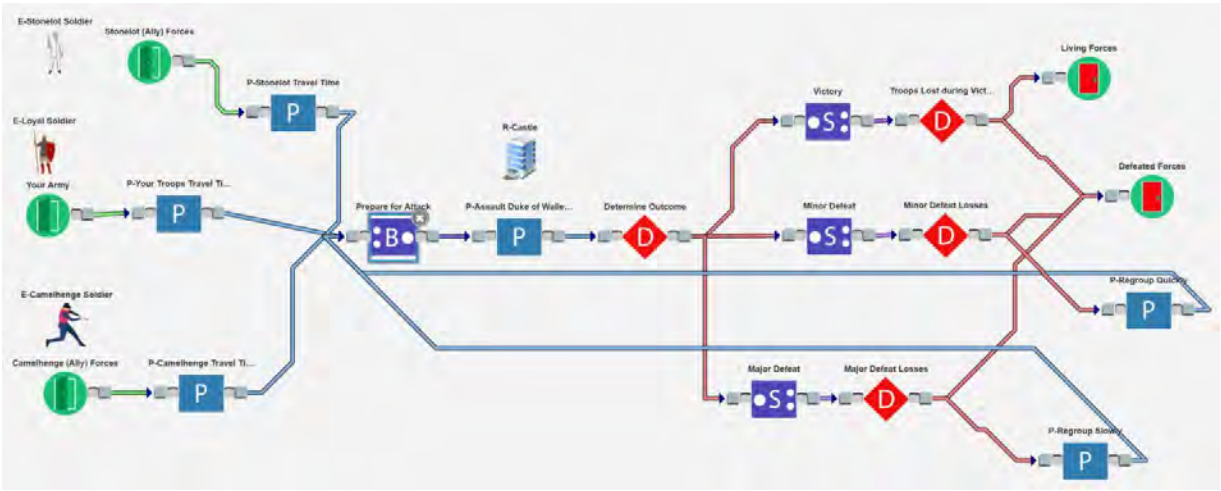


Figure 6: DES implementation of the *Control of the Realms* narrative in CLOUDES.

Three outcomes are possible from the battle: (1) victory; (2) minor defeat; and (3) major defeat. The army moves through a Separator node to break back into its base units so that casualties can be calculated. Major defeat has a high percentage of casualties and a long regroup period for survives to rejoin their

comrades. Minor defeat has a low percentage of casualties and a short wait time for rejoining their comrades. Victory has a medium percentage of causalities. In all three cases casualties are removed from the simulation. Figure 6 provides a screenshot of the completed simulation within CLOUDES. The simulation can be accessed at https://beta.cloudes.me/loadShare?simId=10932.

7 DISCUSSION AND CONCLUSION

The process of developing narratives and elaborating upon them through storyboards provides a fluid transition for creating simulations through storytelling. This approach provides an engaging environment through which non-simulation experts get to be creative and translate their ideas into executable simulations. This approach engages participants in constructive conversations for creating their simulations. Our approach does not currently expand into the topics of model verification or validation or explicitly provide a review process for evaluating the effectiveness or correctness of the implemented narratives. The objective of our approach is not concerned with producing games that are fair, balanced, or playable under specific time constraints; instead, the only concern is that the narratives facilitated engagement and learning of simulation concepts.

It is important for us to note the collaborative aspect of this work between the researchers and the students. This effort took place during a module with the students that focused on learning the CLOUDES DES tool. With similar modules conducted with high school level students in the past, we experienced sharp levels of decline in student engagement in learning the tool after the first week. By the end of the prior years' 3-4 week modules, we observed that the students had a general understanding of how to use the tools. However, they did not demonstrate depth into retaining DES information or demonstrate an understanding of how and why to conduct the abstraction process for identifying what to include and what not to include in their simulations at the completion of the modules. Therefore, our approach resulted from collaborating with the student co-authors to reach a level where the tool was being taught, DES concepts were being learned, information was being retained by the end of the module, and the students remained engaged throughout the process. We strove throughout this process to maximize the engagement level of the students with the tool in order to increase their overall level of learning of DES.

We found that the use of narratives in the form of games helped to facilitate transitioning between abstracting the relevant information from a system to then implementing that information using a tool. The process helped the students in what they described as "starting small and then going big" which encompassed several desirable aspects. First, it simplified the process of abstracting the needed information from the system (in the form of the narrative) by allowing the narrative to increase slowly in complexity during the development of the narrative, storyboard, and simulation. Second, the narrative served as a model specification that provided clear mappings from the intention of the game to the elements needed for implementation. Third, the games could be implemented one piece at a time, run, and observed to see what change occurred in the overall simulation. Finally, once an understanding of the basic nodes (such as the Entity, Process, and Exit) were understood with respect to the narrative, the remaining nodes (such as Batch and Separate) were explored with a higher level of interest to try and expand the model. Ultimately, the continued level of engagement appeared to greatly exceed the level of engagement from previous years and a greater understanding of DES was achieved. However, a formal study is needed to empirically confirm this result and to measure the level of effectiveness of using narratives.

In addition to narratives and storyboards, we briefly experimented with the use of sounds to drive the animated storyboards and to provide cues for entity locations in the simulations. Simple structures, like those in DES, provide a simple avenue for incorporating sound cues into individual parts of a model. Sound in the animations helped conceptualize and set the each narrative's tone. The background music in the *Pickle Wars* animated storyboard conveyed a comical war theme, while in *Space Raid* the background music helped to convey the thematic element of space battles occurring. Within the simulation, sounds were implemented at the entity exit point to reflect winning or losing actions. The selection and incorporation of

these sounds into the storyboards helps fuel engagement during model designing processes. As an additional benefit, the sounds also transferred the intended senses of urgency to the game players.

We explored attaching sounds to different nodes triggered by entities' entry. For the initial tests only a single sound was utilized by a simulation at a time. Potential challenges of incorporating sounds within simulations needs further investigation; however, its use shows initial promise towards further engaging non-experts for learning to create simulations as well as in enhancing the context of the narrative. This is a topic of related, ongoing research that we explore further in Duero et al. (2017).

It is noted that our approach requires basic knowledge of the simulation paradigm being learned. In this case, knowledge of concepts like batching and inter arrival times was required. Future work focuses on eliminating this requirement by integrating the learning of these concepts into the creation process of the narratives. Future work involves empirically investigating the impact that narrative storytelling yields towards student learning and whether it positively impacts activities like conceptualization. This requires conducting a formal study with control groups and empirically measuring the impact of narratives and storyboards towards increased learning among students. A study into the benefits of applying sound within the simulations as well as to the storyboards provides another avenue for future work.

REFERENCES

Bedwell, W. L., Pavlas, D., Heyne, K., Lazzara, E. H., and Salas, E. 2012. "Toward a Taxonomy Linking Game Attributes to Learning: An Empirical Study." *Simulation & Gaming*, 43(6): 729-760.

Bowen, A. P. 1999. "Using Games to Teach". *Journal of Emergency Nursing*, 25(5): 415-416.

Checkland, P.B. 1989. "Soft Systems Methodology". *Human systems management*, 8(4): 273-289.

Dahlstrom, M. F., 2014. "Using Narratives and Storytelling to Communicate Science with Nonexpert Audiences". *Proceedings of the National Academy of Sciences*, 111(Supplement 4): 13614-13620.

Deuro, J., Lynch, C. J., Kavak, H., and Padilla, J. J. 2017. "Incorporating Sound in Simulations". In *Proceedings of the 2017 Winter Simulation Conference*, edited by W. K. V. Chan, A. D'Ambrogio, G. Zacharewicz, N. Mustafee, G. Wainer, and E. Page, 1-11. Piscataway, NJ: IEEE Press.

Hodkiewicz, M. 2015. "Designing SNAKES AND LADDERS: An Analogy for Asset Management Strategy Development". *Simulation & Gaming*, 46(5): 455-470.

Impressions Games. 1994. Lords of the Realm [Computer Game]. Cambridge, MA.

Kapp, K. 2012. *The Gamification of Learning and Instruction*. San Francisco, CA. John Wiley and Sons Inc.

Landers, R. N. 2014. "Developing a Theory of Gamified Learning: Linking Serious Games and Gamification of Learning". *Simulation & Gaming*, 45(6): 752-768.

Lightsey, B. 2001. *Systems Engineering Fundamentals*. Fort Belvoir, VA: Defense Acquisition University Press: 1-223.

Lovecraft, H. P. 1999. *The Call of Cthulhu and Other Weird Stories*. New York, NY: Penguin Books.

Mitroff, I. I., Betz, F., Pondy, L. R., and Sagasti, F. 1974. "On Managing Science in the Systems Age: Two Schemas for the Study of Science as a Whole Systems Phenomenon". *Interfaces*, 4(3): 46-58.

O'Hara, C. 2014. Managing Yourself: How to Tell a Great Story. Boston, MA: Harvard Business Review. https://hbr.org/2014/07/how-to-tell-a-great-story.

Padilla, J., Diallo, S., Barraco, A., Lynch, C. J., and Kavak, H. 2014. "Cloud-based Simulators: Making Simulations Accessible to Non-Experts and Experts Alike". In *Proceedings of the 2014 Winter Simulation Conference*, edited by A. Tolk, S. Diallo, I. Ryzhov, L. Yilmaz, S. Buckley, and J. Miller, 3630-3639. Piscataway, NY: IEEE Press.

Padilla, J. J., Lynch, C. J., Kavak, H., Diallo, S. Y., Gore, R., Barraco, A., and Jenkins, B. 2016. "Using Simulation Games for Teaching and Learning Discrete-Event Simulation." In *Proceedings of the 2016 Winter Simulation Conference*, edited by T. M. K. Roeder, P. I. Frazier, R. Szechtman, E. Zhou, T. Huschka, and S. E. Chick, 3375-3384. Piscataway, NJ: IEEE Press.

Robinson, S. 2011. "Choosing the Right Model: Conceptual Modeling for Simulation". In *Proceedings of the 2011 Winter Simulation Conference*, 1423-1435. Piscataway, NJ: IEEE.

Sanders, B., Shuttleworth, D., Deuro, J., and Padilla, J. J. 2016. "Learning Discrete Event Simulation Design Methodology via Interactive and Collaborative Projects." In *Proceedings of the 2016 Spring Simulation Multi-Conference - Annual Simulation Symposium*, 1-8. San Diego, CA: Society for Computer Simulation International.

Sterman, J. D. 1989. "Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment". *Management Science*, 35(3): 321-339.

Tolk, A., Diallo, S. Y., Padilla, J. J., and Herencia-Zapana, H. 2013. "Reference Modelling in Support of M&S - Foundations and Applications". *Journal of Simulation*, 7(2): 69-82.

Van den Boomen, M., Duifhuizen, J., and Staverman, T. 2012. "The Management Game: Asset Management". In *Proceedings of the Third International Engineering Systems Symposium (CESUN 2012)*, 1-10. Delft, The Netherlands.

Wilson, K. A., Bedwell, W. L., Lazzara, E. H., Salas, E., Burke, C. S., Estock, J. L., Orvis, K. L., and Conkey, C. 2009. "Relationships Between Game Attributes and Learning Outcomes: Review and Research Proposals". *Simulation & Gaming*, 40(2): 217-266.

AUTHOR BIOGRAPHIES

JOSE J. PADILLA is Research Assistant Professor at VMASC at ODU. He leads the Simulation Environments Lab at the Center. His research focuses on the understanding and modeling of problem situations. He received his Ph.D. in Engineering Management from Old Dominion University. His email address is jpadilla@odu.edu and his webpage is https://www.odu.edu/directory/people/j/jpadilla.

CHRISTOPHER J. LYNCH is a Senior Project Scientist at the Virginia Modeling, Analysis and Simulation Center (VMASC) at Old Dominion University (ODU). He received his M.S. in Modeling and Simulation (M&S) from ODU in 2012 and a B.S. in Electrical Engineering from ODU in 2011. He is currently pursuing a Ph.D. in M&S from ODU. His research interests include multi-paradigm modeling, conceptual modeling, and verifying and validating simulations. His email address is cjlynch@odu.edu and his web page is http://www.odu.edu/directory/people/c/clync008.

HAMDI HAVAK is a Ph.D. candidate in the Modeling, Simulation, and Visualization Engineering (MSVE) Department at ODU. He received his MS in M&S from ODU. His research focuses on data-driven agent-based simulations with an emphasis on human mobility and cyber security. His email address is hkava001@odu.edu and his web page is http://www.hamdikavak.com.

SHAWN EVETT is a high school student of the Pruden Center for Industry and Technology in Suffolk, VA. His email address is shawnevett@prudencenter.net.

DEVON NELSON is a high school student of the Pruden Center for Industry and Technology in Suffolk, VA. His email address is devonnelson@prudencenter.net.

CALVIN CARSON is a high school student of the Pruden Center for Industry and Technology in Suffolk, VA. His email address is calvincarson@prudencenter.net.

JOSHUA DEL VILLAR is a high school student of the Pruden Center for Industry and Technology in Suffolk, VA. His email address is joshuanordmeyer@prudencenter.net.