Role of agricultural simulation games to promote youth-adult discussions related to agricultural sustainability

Nathan C Rice, University of Nebraska, Lincoln

Nathan Rice is a 4-H Youth Development Extension Educator located in the Panhandle of Nebraska. Currently he helps run the 4-H program in Scotts Bluff, Kimball, and Banner Counties of Nebraska. His emphasis is in STEM and entrepreneurship program development for K-12 students.

Dr. Jennifer Keshwani, University of Nebraska - Lincoln

Jenny Keshwani is an Assistant Professor of Biological Systems Engineering and Science Literacy Specialist in the Institute of Agriculture and Natural Resources at the University of Nebraska-Lincoln. She is active in promoting science and engineering education in both formal and informal settings through her research, extension, and outreach activities. Dr. Keshwani is actively engaged in several cross-disciplinary regional and national efforts related to STEM education and outreach. Most recently, she was part of a team that received NSF funding to engage youth in STEM through wearable technologies.

Dr. Deepak R Keshwani, University of Nebraska - Lincoln

Dr. Deepak Keshwani is an associate professor of Biological Systems Engineering at the University of Nebraska-Lincoln. In addition to research in the area of bioprocess and biosystems modeling, Dr. Keshwani is engaged in teaching and advising students across two academic colleges and is involved in numerous campus-wide student success initiatives including leading a civic-engagement program for first-year students.

Role of agricultural simulation games to promote youth-adult discussions related to agricultural sustainability

1. Introduction

The 2006 publication by the Food and Agriculture Organization of the United Nations (FAO) sparked an initiative on how to feed the world by 2050 [1]. This report looked at population growth estimates which illustrated that the global population would reach 9.1 billion people by the year 2050, and asked the important question of how are we going to feed that many people. The report put tangible boundaries around a "Wicked Problem" that was otherwise difficult to grasp [2]. The topic of feeding a rising global population has since been at the center of the public attention, and is a primary driver behind this research project, which stemmed from the NSF initiative, Innovations at the Nexus of Food, Energy and Water Systems (INFEWS) [3].

The focus on providing for a sustainable future also had rippling effects into the world of serious games with over 60 video games coming out related to sustainability since 2006 [4]. The topics of these games are wide ranging but many adopt the model principles of the Triple Bottom Line of Sustainability: environment, society, and economics. This model states that in order for anything to be truly sustainable it must balance these three criteria. Serious games were chosen to teach on sustainability issues due to their ability to improve students' engagement [5], [6], [7] and represent scenarios that would be impossible to reproduce otherwise [8]. Research done on these games has focused on player engagement, motivation, and learning outcomes with relation to traditional teaching approaches. There have also been several model frameworks developed on how to develop a successful game [9], [10], [11]. A review of the literature shows little understanding on where the information goes following the game experience.

The goal of this research project was to investigate if the added engagement of the simulation game environment promoted the occurrence of youth-adult discussions related to agricultural sustainability. The study looked to discover first if discussions took place and if they did what were those discussions about and why did they occur. The following objectives were set forth to accomplish this goal.

1. Have rural youth with connections to agriculture play an agricultural sustainability video game.
2. Capture students' in-game actions to determine what content they focused on and their engagement level.
3. Perform a focus group one week following the intervention to determine the types of discussions that took place, and why they took place from the youth's perspective.

The agricultural world is at the center of the sustainability issue. Currently, 70% of global fresh water is used for agricultural production [12], and agriculture accounts for 52% of the United States land base [13]. Agriculture, food, and related industries also gross $1.053 trillion annually in the United States [13]. Agricultural truly encompasses all three sustainability pillars and thus must be a key player to attain global sustainability. If sustainability games promote youth-adult discussions, video games may prove to be an effective route to reach agricultural decision makers with new advances in sustainable agriculture.

2. Methods

This research project centered around a 3-D immersive simulation game on agricultural sustainability, Agpocalypse 2050. The simulation game was developed by a research team investigating the nexus of food, energy, and water systems (FEWS). The overarching topic of the game was to investigate how decisions within one FEW system have rippling effects into connected systems, and how this may influence the resiliency of the overall system. The corn, water, ethanol, beef (CWEB) nexus in the Midwest was used as an exemplary model in the game.

2.1. Intervention

The intervention consisted of 1 hour and 45 minutes of classroom activities. The session was split into introduction (15 min) and gameplay (90 min). During the introduction, students were given a brief backstory on the video game, a paper survival guide containing typical game pathways, and an overview of the controls. For gameplay, students had the choice to play three different scenarios: combine harvesting, irrigation management, and grassland range management. This study only investigates the results of the irrigation management scenario as the combine harvesting and grassland range management scenarios were still under development at the time. Students were given little to no guidelines on what they had to do in the video game. They were asked to complete at least one year in the irrigation scenario, but after that could choose where they would like to go and how much time they would like to spend there. Students could also quit playing at any time if they were bored. Supplemental curriculum was not given before or after gameplay to ensure all findings could be linked back to the game content.

2.2. Sample

Youth were recruited from a rural school district with a K-12 population of 160 students. Total sample size was four students consisting of three boys grades 7 – 8 and one girl grade 9 – 12. All students were white Caucasian and grew up with an agricultural background (direct family ties to ranching or farming). The activity took place during an optional school day where students were offered a variety of hands-on activities. Students had to get parental consent to take part in the study. The study was given exemption status by University of Nebraska –Lincoln Institutional Review Board (IRB #: 20181018564EP).

The study had anticipated a greater turnout of students for the session. Unfortunately, the school program was completely optional and students had a variety of overlapping sessions to choose from which resulted in low attendance. A second session was planned with an additional school, but was postponed due to the breakout of COVID 19. Future work will look to address the limited sample size.

2.3. Gameplay

During the irrigation management simulation, students were tasked with producing the most corn with limited water resources and a varied climate. Inputs beyond irrigation were auto applied for the students to ensure only irrigation practices influenced the results. This included fertilizer, seed type, and planting date. There were two Non Playable Characters (NPCs) in the game world to help the students make wise decisions: Agronomist and Agricultural Engineer.

Students could talk to the NPCs to learn about sustainable cropping practices, irrigation management, climatic impact, and much more. Students could also go to a crop health screen that showed them what date their crop would hit certain growth stages (Figure 1). This helped them identify critical stress points in the crop's lifecycle. They could also see what the current moisture content was in their soil compared to the wilting point and the saturation point. Based on the information students could determine if they were irrigating too much resulting in poor agricultural sustainability or too little resulting in poor economic performance. The final screen the students could use was the irrigation management panel (Figure 1). This panel showed the students what the weather would be like for the remainder of the month. This included temperature high, temperature low, and moisture for each day of the month. Based on this information and the information from the plant health screen, decisions were made on how much and when to irrigate throughout the month. Students were limited to 12 inches of irrigation water for the year. These could be applied any time throughout the year in increments of 0.25", 0.50", or 1".

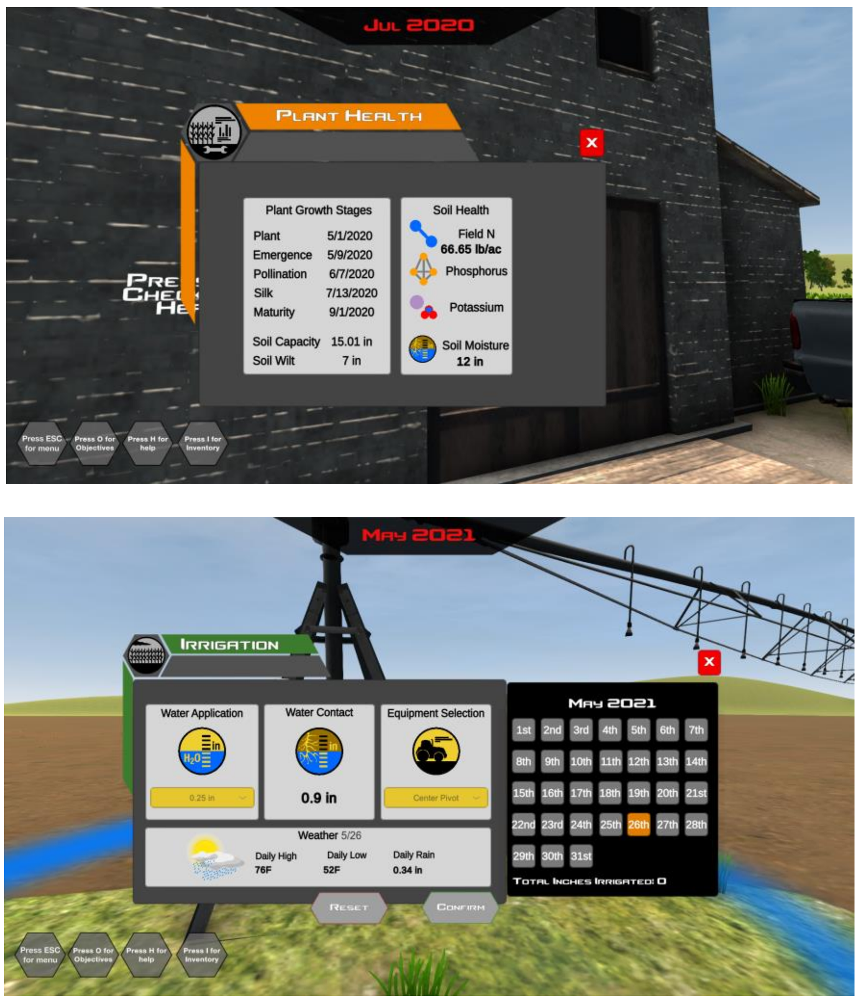

Figure 1. Top: Plant health screen used to inform students about crop growth stages and soil moisture in Agpocalypse 2050. Bottom: Irrigation management menu used to see the weather data throughout the month and set irrigation schedules in Agpocalypse 2050.

Once the students were satisfied with their irrigation schedule, they clicked next month ending their turn for that month. The decisions they made were then sent to the Decision Support System for Agrotechnology Transfer Model (DSSAT) to calculate how the decisions would influence crop growth. DSSAT sent back new information on the current growth stage of the plant and the soil moisture in the field. These would propagate the plant health screen allowing the students to gain feedback on how they did. Students continued this cycle of deciding irrigation schedules each month until the crop was ready for harvest. Once the students harvested their crop, they would receive a final yield for their field on a per acre basis thus ending the crop growth year. Each year they received a new random weather file taken from climatic model projections.

2.4. Data Collection

As the students played the irrigation game, their in game actions were recorded to determine where they spent their time. Actions recorded include entering and leaving the scenes, time spent talking to the NPCs, and when they harvested crops (signaling the end of the year). Students also took part in a focus group one week after the game session. The focus group investigated how information was transferred following the game activity, general knowledge retention, and how the game could be improved. The focus group was held in a group format.

3. Results

3.1. Game Actions

The game action data was collected using timestamps. How long students spent on each action was calculated by subtracting when they started an activity from when they ended (Table 1). On average, the students played the crop scene for 48 min before switching to another scene. They spent 2 minutes talking to the agronomist and 6 minutes talking to the agricultural engineer. The time spent talking to the agricultural engineer was weighted heavily by Player 1 who talked to the NPC significantly longer than the other students at 19 min. Students completed an average of 2.5 harvests with a medium of 2. It took students 7 min on average to hit the first game marker, which was to talk to the agronomist. Player 1 had a heavy weight in this category taking 17 min. The second milestone was completing the first harvest year. Time for Harvest 1 varied greatly between students with a STDV of 10.84 min, but became more consistent in Harvest 2 with a STDV of 2.86 min. Yield data was supposed to be collected, but there was an error in the code preventing the collection from occurring. A timeline is given in Figure 2 illustrating how the players progressed through the irrigation activity.

Table 1. Students' in-game actions for the irrigation simulation. All times and numbers are displayed in minutes.

	Player 1 *(min)*	Player 2 *(min)*	Player 3 *(min)*	Player 4 *(min)*	Average *(min)*	Min *(min)*	Max *(min)*
Time in Crop Scene	56	58	37	40	48	37	58
Time with AG	3	5	1	0.5	2	0.5	5
Time with EN	19	3	1	0	6	0	19
Time for Harvest 1	42	32	13	22	27	13	42
Time for Harvest 2	11	15	7	12	11	7	15

Time for Harvest 3	-	-	8	-	8	8	8
Time for Harvest 4	-	-	8	-	8	8	8
Number of Harvest	2	2	4	2	3	2	4
Time to first marker	17	10	1	4	8	1	17

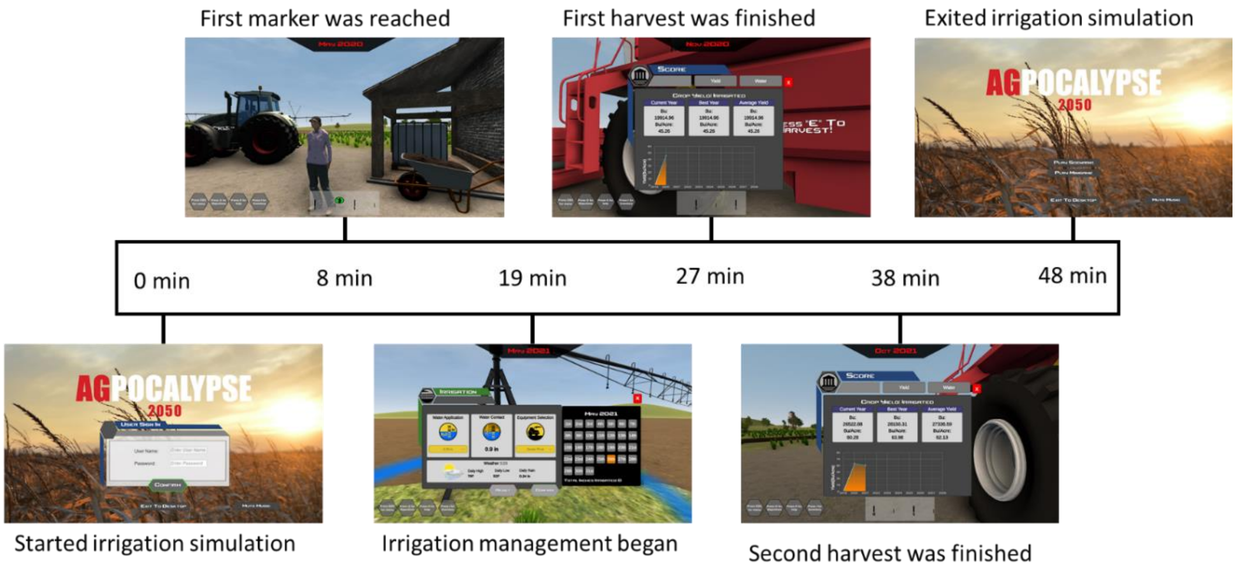

Figure 2. Timeline of average player movements through the irrigation simulation in Agpocalypse 2050.

3.2. Focus Group

The goals of the focus group were to discover what types of discussions took place, and the basic knowledge retention of the students. Students were asked if they discussed the game with someone else, their relationship with that person(s), the topic of the discussion, and what about the game caused them to discuss it with others. All four students discussed the game with at least one person. Four discussed with a parent/guardian and three discussed with at least one friend. The following responses were given when asked what the topic of their discussion was about (Table 2), and what about the game caused them to discuss it with someone else (Table 3). Themes that emerged for the discussion topics include game graphics and game actions. Themes for why they discussed the game include engagement and awareness of parents.

Table 2. Student responses when asked about the topics they discussed with parents/guardians on Agpocalypse 2050.

Question: What was the topic of your discussion?	
Player 1	What actions they did in the game. They described the game and what happened. The game scenes they saw and their graphics.
Player 2	Discussed how the scenes and graphics were developed really well. How much time it must have taken to make the game. How they managed their irrigation resources.

Player 3	Discussed the outcomes of the game. Discussed how their yield changed from year one to year two and why that might have happened.
Player 4	They talked about what the scenes looked like. The creepy looking NPCs in the scenes. The actions they took in the game.

Table 3. Student responses when asked what about the game caused them to discuss it with someone else.

Question: What about the game caused you to discuss it with someone else?	
Player 1	The game was exciting.
Player 2	It was their number one topic of the day.
Player 3	Most fun thing they did that day.
Player 4	Parents knew they were going to play the game that day and asked how it went.

4. Discussion

The goal of this research project was to investigate if the added engagement of the simulation game environment promoted the occurrence of youth-adult discussions related to agricultural sustainability. The study had four students with a rural background and connections to agriculture play an agricultural simulation game on sustainability within the Midwest's CWEB Nexus. The students' in-game actions were recorded as they played, and a focus group was performed one week following the intervention to determine if youth-adult discussions took place, the topic of those discussions, and why they occurred from the students' perspective.

4.1. In-Game Actions

The simulation game proved to be adequate from a usability standpoint, but could be improved. Students were able to navigate the game with minimal guidance completing the first marker in an average of 8 min and the first harvest in 27 min. The learning curve seemed to drop heavily following the first harvest with subsequent harvests averaging only 10 min. This indicates that students began to grasp the game mechanisms, and had increased confidence in setting irrigation schedules. In future sessions the research team would like to reduce the time it took students to identify game markers and increase the time spent talking to the NPCs. Eight minutes is too long for the students to be walking around without finding their next task. Ideally, this time would be 3 minutes with the majority of the students finding the marker in less than one minute. The reason for this adjustment is some game players enjoy the exploration of new game words. Their initial response to a game is not to finish the objectives, but to see what the world contains and the boundaries within the game. These players will have a much higher time to marker skewing the average to 3 minutes.

Student learning in the game was driven by trial and error. The NPCs contained the majority of content specific information, but were not highly utilized at only 2 minutes and 6 minutes respectively. Students also reported in the focus group that they did not understand the plant health menu which was their other major tool for making informed decisions. This indicates that the game designers need to develop different methods of displaying the information to make it clearer for the students to understand and more engaging.

The video game maintained a high overall engagement level with students playing for 48 minutes before quitting. They also reported in the focus group that they enjoyed the game and would play it again. These indicators show the simulation game was successful in engaging the students and is a viable tool for future studies.

4.2. Youth-Adult Discussions

The focus group showed that all four students discussed the game with a parent or guardian and three out of four discussed the game with at least one friend. Students clearly had motivation to talk about the game which supports the assertion that video games can be used to promote discussions between youths and adults. The majority of the students indicated that they discussed the game with others because it was the most exciting part of their day at school. This also supports the hypothesis that it is the engagement of games that causes discussions to occur. It is important to clarify that this did occur at school. If the students had played the game at home the results could vary.

The fourth student’s response that the discussion occurred because the parent knew they would be playing the game is challenging to address due to IRB requirements. Ideally, all conversations would occur or not occur due to the student motivations. However, since this is an at risk population, parents/guardians are required to give consent for the students to participate. This in turn can cause the parents to be intrigued about the study and instigate a conversation. This will remain a limitation to the research.

It was interesting that nearly every student discussed the game’s graphics with their parent/guardian in a positive manner, as the graphics would not match up to most commercial video games. The emphasis on graphics most likely stems from the fact that the students were told that undergraduate students designed the video game. The connection to other students seemed to make them less judgmental of the game’s quality and even comment on it as a strength.

The second main topic the students discussed were the activities they did in the game. Students did not elaborate in depth about what specific actions they discussed, and is an area that needs further exploration in future studies. To truly have an impact on stakeholders the discussions will need to be on the actual management or sustainability practices.

5. Conclusion

The goal of this research project was to investigate if the added engagement of the simulation game environment promoted the occurrence of youth-adult discussions related to agricultural sustainability. The study found that simulation games on agricultural sustainability are a viable option to promote youth-adult discussions with every youth having discussed the game with a parent/guardian. The study also showed that students discussed the game because it was the most fun part of their day supporting the assertion that engagement is the driving force. These findings set the stage for using sustainability games to reach agricultural decision makers with new advances in sustainable agriculture through youth-adult interactions.

6. Limitations and Future Work

The biggest limitation of this work was the low n for a sample size. Rural schools have the population demographics this project requires due to their close ties to agricultural, but make it challenging to find large volunteer numbers. In the future, the goal is to test through schools using FFA programs. This will still allow for similar demographics but increase class size capacity, and provide for an audience that has less bias towards enjoying video games compared to someone signing up for a video game trial.

A comparison is also needed between games played at school and games played at home to determine if it is the uniqueness of playing a game in a setting that it is not traditionally allowed that promotes the conversations to occur. If this is the case, the increasing number of games used in education may eventually remove this feeling of uniqueness causing youth to have less desire to share what they learned with others.

Finally, a perspective from the adult is also needed to determine if simulation games can be used to reach stakeholders. The perceptions of the adults following the discussion are critical to whether or not they will adopt the action. Will they immediately write off the conversation as a silly video game talk or mull over the topics that were brought forth?

References

[1] Food and Agriculture Organization of the United Nations, *World Agriculture Towards 2030/2050*, FAO, Rome, Italy, 2006. Available: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

[2] H. Rittel and M. Webber, “Dilemmas in a general theory of planning,” Policy Sciences, vol. 4, no. 2, pp. 155-169, Jun. 1973.

[3] National Science foundation, *Innovations at the nexus of food, energy, and water systems*. Accessed on Feb. 3, 2020. [Online]. Available: https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505241

[4] M. Stanitsas, K. Kirytopoulos, and E. Vareilles, “Facilitating sustainability transition through serious games: A systematic literature review,” *Journal of Cleaner Production*, vol. 208, nopp. 924-936, Jan. 2019.

[5] J. P. Gee, “Deep learning properties of good digital games: How far can they go?,” in *Serious Games: Mechanisms and effects*, U. Ritterfeld, M. Cody & P. Vorderer, Ed. New York & London: Routledge, 2009, pp. 65-80.

[6] F. Kem K. Xie, and Y. Xie, “Game-based learning engagement: A theory-and data-driven exploration,” *British Journal of Educational Technology*, vol. 47, no. 6, pp. 1183-1201, Nov. 2016.

[7] C. Dede, “Immersive Interfaces for Engagement and Learning,” *Science*, vol. 323, no. 5910, pp. 66-69, Jan. 2009.

[8] K. Madani, T. W. Pierce, and A. Mirchi, “Serious games on environmental management,” *Sustainable Cities and Society*, vol. 29, pg. 1-11, Feb 2017.

[9] W. Westera, R. J. Nadolski, H. G. K. Hummel, and I. G. J. H. Wopereis, “Serious games for higher education: a framework for reducing design complexity,” *Journal of Computer Assisted Learning*, vol 24, no. 5, pg 420-432, Oct. 2008.

[10] L. A. Annetta, “The “I's” have it: a framework for serious educational game design,” *Review of General Psychology*, vol. 14, no. 2, pp. 105-112, June 2010.

[11] J. Moloney, A. Globa, R. Wang, and A. Roetzel, “Serious games for integral sustainable design: level 1,” *Procedia Engineering*, vol. 180, pp. 1744-1753, 2017.

[12] Food and Agriculture Organization of the United Nations, *Water for sustainable food and agriculture: A report produced for the G20 Presidency of Germany,* FAO, Rome, Italy, 2017. Available: http://www.fao.org/3/a-i7959e.pdf

[13] D. Bigelow, *A primer on land use in the United States*, United States Department of Agriculture, Economic Research Service, Dec. 04, 2017. Accessed on: Feb. 3, 2020.

[Online]. Available: https://www.ers.usda.gov/amber-waves/2017/december/a-primer-on-land-use-in-the-united-states/

[14] United States Department of Agriculture, *Ag and food sectors and the economy*, Economic Research Service, Sep. 20, 2019. Accessed on: Feb 3, 2020. [Online]. Available: https://www.ers.usda.gov/amber-waves/2012/march/data-feature-how-is-land-used/