The Impact of the Use of Educational Board Games on Student Engagement and Understanding in the High School Science Classroom

Collette Valerie Louise Heskett

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Overview

Being raised in an upper middle social and economic class, in the Peak District in England, I had experiences and opportunities that many of my current peers did not have. Our community, like myself and my family, were predominantly white. I grew up with two parents who were equally present in my life. My father, who is American, and my mother, who is British, raised me and my brother with dual United States and United Kingdom citizenship. I grew up with many privileges, white privilege being most prevalent. White privilege, combined with middle class socio-economic status, afforded me the opportunity to travel extensively and experience first hand numerous different cultures. My family, and teachers considered traveling to be a more valuable way to learn about the world than textbooks or classroom learning.

My teachers, who were also white and supportive of the value travel can bring, permitted me to take a three month gap from school to travel the world with my family. On this trip we went to multiple countries, learnt about different cultures, and spent time in non tourist regions of each country. On this trip there was one experience that started my journey to become a teacher. It was when we went to Molatedi, South Africa, and were able to visit a local school called Tlhageng Primary School. The primary school I attended in England had electricity, multiple forms of technology, numerous classrooms for each grade, and mixed gendered classes - Tlhageng was very different. At Tlhageng Primary School, there were only two classrooms, one for boys and one for girls. In each classroom the students were mixed grades, ages four to eleven years old. There was one teacher per class, and they were instructed to teach the children all of the subjects, while simultaneously differentiating between the ages of the students. I was only seven years old when I saw this, but even then it amazed me with how complex and difficult this was for the teacher. What I noticed however, was that the teacher was managing to meet the

learning needs of all pupils and the culture of the classroom prioritized participation, allowing teaching to be more efficient and engaging.

When approaching the classroom, being guided by the principal, one thing that stood out was the amount of laughter from both the students and teacher. Stepping into the classroom - one without a secure roof, walls made of tin, and no electricity - the most noticeable thing we saw were smiles on students' faces while they were working hard to better their education. The students were genuinely interested in what the teacher was saying, physically leaning in to hear and learn more from the teacher. Seeing how much the students and teacher were enjoying the class and the level of learning taking place was where the seed of teaching science germinated.

As a science teacher my goal is to have a classroom environment similar to that of the class in Tlhageng Primary School. I aspire to have a classroom where all pupils are engaged in the lesson, feel safe enough to be themselves, and to be the teacher that students *want* to learn from and interact with.

In the University of Colorado (CU) Teach Program, we have learned that there are two key ways to create an environment that supports student and teacher relationships, and they should be used in tandem. The first is focusing on and utilizing the diverse student body, incorporating different cultures and ethnicities into the classroom. This is the focus of multicultural awareness in education, recognizing that society is becoming increasingly more diverse, and this diversity should be reflected in the educational environment (Alismail, 2016). Examples of this could be, sharing articles by authors with similar backgrounds, cultures, and ethnicities to the students, or using images, pictures, and videos that represent the diverse student body and global population. Students are more likely to succeed in a subject or classroom when they see people they can relate to, people who represent them, their culture, and their ethnicities,

rather than a classroom that lacks this representation (Neal, 2023). This highlights the practice of teaching for equity and justice, instead of simply teaching the subject. By reaching out and understanding the students, it can help the students discover that the classroom is a space for learning and being themselves.

The second way is to make the lessons more engaging and personalized to each student. This can be as easy as using student interest based analogies to explain a topic or choosing group work over individual work focusing on discussion based learning. There are multiple research articles that discuss the importance of engagement in the classroom and how to achieve it, assess it, and utilize it to help increase student understanding (Chen et al., 2021). One strategy to make lessons more engaging, is to gamify lessons through board games. Gamifying lessons, like using board games, can help students get hands-on experience with the subject and topic, making the lesson feel more tangible for the students. Additionally, board games are able to increase group participation while also helping develop communication, collaboration, critical thinking and problem solving skills (Noda et al., 2019). Board games are not only a fun family activity but can be an educational tool to help students of all ages and backgrounds explore topics through a different perspective

The benefit of using board games is that they are ubiquitous throughout multiple cultures. Board games have historical importance as they have been used in numerous cultures for many decades. The earliest known board game was created over 5,000 years ago by the Egyptians, and since then over 100,000 different games have been created world wide (Kumar et al., 2022; Georgiev, 2023). In O'Neill and Holmes's paper, *The Power of Board Games for Multi Domain Learning in Young Children*, they discuss the historical importance of board games and how they are successful as educational tools, as they can span multiple cultures and are easily understood

by many (O'Neill et al., 2022). By representing the student body's culture, ethnicities and race, and personalizing the lessons through gamifying topics, students are likely to feel more appreciated in the classroom.

Students who see themselves represented in the lesson, through their interests and cultures, are more likely to participate. Connecting with the students through content that they can relate to increases the likelihood that the teacher can grab and hold the students' attention for the duration of the class. Doing this helps increase student engagement and interest in the lesson. These two professional development strategies, teaching for engagement and representation, can both be present when using an educational board game and likely results in an increase of student participation as they engage with the content through the board game.

Reflection on Learning

When I first joined the CU Teach program, I took a class called Step 1, where we were first introduced into a classroom setting. During this class we had a final project where we got to teach a lesson, focusing specifically on engagement. I decided to make a board game, in the hopes that this would mimic the classroom environment of Tlhageng Primary School - one full of laughter, participation, and group work. I made the first board game and worked with a handful of eighth grade students, being taught by Annica Schnatwinkel at Monark Middle School. When reviewing the board game lesson plan with Ms. Schnatwinkel, her first response and comment on this lesson plan was "FUN!" (Appendix 1 & 2). During this lesson, I taught different weathers and climates, through a review based board game. The main goal I had during this lesson was to help reinforce and reteach these students the concepts that they were not understanding. Ms. Schnatwinkel and I also had the additional goal of improving their group work skills, as these students tended to work in isolation and not participate in group work.

Referring back to the reflection assignment completed during and after the board game, it was noted that after a couple of minutes the students became highly engaged in the activity, and were taking it upon themselves to ask questions to deepen their own understanding when they got a question wrong (Appendix 3).

Seeing the success of incorporating a board game into an eighth grade lesson both from a perspective of engagement and knowledge acquisition, I shared the results of this lesson with my professor, Dr. Jeff Writer. Dr. Writer stated it was “a really cool idea” and encouraged me to continue making these board games for more assignments. With this positive feedback from Ms. Schnatwinkel, my peers, my students, and Dr. Writer, I decided to pursue the idea of creating and using board games as educational tools.

During the next three years of my studies at CU Boulder, I created and used two more board games as final projects and presentations, with a focus on getting feedback on how to improve the engagement portion of the board game (Appendix 4 & 5.a-b). The most common feedback I received led me into a deep dive into reading about the different types and levels of engagement that students experience in the classroom. There are three main types of engagement with each helping the students maintain a high level of attentiveness and interest in the lesson (Foster & Ambrose, 2023). The first type of engagement is cognitive engagement, which is when students are using their own brains to complete tasks. Some examples of this would be students being inquisitive or participating in group discussions. Cognitive engagement ensures students deepen their own understanding of a subject, where they take it upon themselves to learn more about the topic. The second type of engagement is behavioral. This is where students are actively listening and participating in the class. Behavioral engagement is when students are actively working in class and responding to tasks given to them. The third type of engagement is affective

engagement, which is when students are demonstrating their engagement through body language, speech patterns, and overall tone of voice. This can be seen in students who are enthusiastic about the topic, productive and politely debating with other students, or actively willing and wanting to participate in projects and tasks. Over the course of three years, the board games have been modified to encompass the different types of engagement through tasks, group discussions, and participation.

To enhance the educational impact of these board games, I reached out to experts in their field to get advice on how to convey information about different science subjects. I worked with them to design and improve the lessons that went along with the board games to ensure that they would be the most useful in the science classroom. These experts include: the founder and executive director of Mission Zero - Scott King, a highschool science teacher and science curriculum author - Dr. Paul Strode, the head of the CU Teach program at CU Boulder - Dr. William Lindsay, and two middle school science teachers, both with a Masters in Education - Elena DeAndrea and Sophie Friedman.

One of the board games that was discussed with experts was the Ocean Acidification Board Game. To see the effects of board games in the high school classroom, in 2022 I used the Ocean Acidification board game with my junior and senior students, who were in an environmental science class, at Northglenn High School. On the average day these students were typically quiet, low energy, and easily distracted. My mentor teacher at the time, Valerie Franzke-Munro, tasked me to teach a mini unit of Ocean Acidification in a way that would increase student participation and engagement in the class. I taught a five day unit and at the end we played the Ocean Acidification Board Game as a tool for review. While the students were playing this game, we were able to observe the three types of engagement with my students. As

part of the board game students were tasked with looking up why their organism has specific behaviors or habits and reporting this information back to their board game groups. This encouraged cognitive engagement. Students displayed behavioral engagement when playing the game and we observed high levels of group discussion and laughter. Affective engagement occurred while playing the game as students competed against their peers to win, which created a light hearted competitive environment causing higher levels of excitement and enthusiasm. I was able to see a class grow from a quiet, low participation environment to a classroom full of high energy and engaged, happy students (Appendix 6). It was evident that the engagement of these students increased.

After seeing my own students' engagement increase with these board games, and hearing about the successes that others have had, I presented the Carbon Capture Board Game, one that I worked closely with Scott King to review, and the Ocean Acidification Board Game at two different events. The first was the Climate Action Expo at CU Boulder, where I shared how these board games can teach students complex ideas around climate change and the effects of climate change on our world, in a way that is easy to understand and engage with. A few months later, I presented the same board games at The Denver Museum of Nature and Science, where I talked to many families, elementary teachers, and middle school teachers, who all shared a similar interest in using board games to increase engagement in their classrooms (Appendix 7). Many professors and guests listening to both presentations shared their previous successes of using board games as review and the subsequent increase of student engagement in the classroom.

As a result of these presentations, as well as writing an abstract for CU Scholar University Libraries website discussing my presentations and project that was reviewed by David

Vasquez and CU's Micro-credential Manager (Appendix 8.b), I have received a Sustainability Innovation Micro-Credential for Teacher-CV Board Games[1] (Appendix 8.a).

During the past fourteen years I have had many opportunities to expand upon this idea of engagement, from observing a class in South Africa, to talking to experts on science topics and education. I have incorporated this learning into making the board games as beneficial to the education environment as possible. My goal is to be able to support other teachers who want a classroom environment full of laughter, participation, and understanding. Much research has been done on how board games can increase the engagement of students in elementary and middle school, however, very little research has been completed to understand the efficacy of board games and increasing engagement and science comprehension for high school students. For the rest of this Practice in Process (PIP) Capstone Project, I am focusing on the research question: How does the use of educational board games impact student engagement and understanding in the high school science classroom?

Annotated Biography

Chen et al. write about the effects of board games on the skill of problem solving. This research paper discusses how using educational board games can improve and strengthen different transportable skills[2] needed for the majority of students and their future careers. The authors of this paper determine that there is a motivation difference between people playing the game to learn and summarize the concept, versus people not playing the game. In this paper they talk about the importance of developing transportable skills starting in high school, as they are used in all careers. The research conducted by Chen et al. is used in this paper to state that educational board games help motivate and engage students in non-traditional ways, while also ensuring they understand the concepts at a higher level.

Chen, S., Tsai, J., Liu, S., & Chang, C. (2021). The effect of a scientific board game on improving creative problem solving skills. *Thinking Skills and Creativity.* https://www.sciencedirect.com/science/article/pii/S187118712100136X

Foster et al. writes about the ways that teachers are able to measure and determine student engagement. They highlight the three main types of engagement: behavioral, emotional and cognitive, and how to determine which one is being employed in the activity and classroom. The authors later go on to suggest common types of activities that can improve engagement in the classroom while also being educational, one of them being interactive games, such as board games. They go on to discuss the different types of engagement and how to test/observe each type, mostly through surveys, quizzes, and self-assessments. This reference assists in the analysis portion of this project to determine which form of engagement the students are displaying, while also assisting in developing ways to collect qualitative and quantitative data from the students and teacher.

Foster, S., & Ambrose, K. (2023). Facilitating and assessing student engagement in the classroom. *Center for Teaching & Learning.* https://www.colorado.edu/center/teaching-learning/2023/01/23/facilitating-and-assessing-student-engagement-classroom

Noda et al. review the importance of board games by comparing and contrasting multiple studies around the effects of group participation and board games. One study they review concludes that board games can help focus and motivate people with AD/HD. Another study Node et al. reviews studied a wide range of both participant ages as well as topics. One such game focused on improving students' communication skills with the board game offering students the opportunity to practice their communication and critical thinking skills. The age of

these specific participants are unknown, but other similar studies state that participants were from young children to older adults, and had similar outcomes. This review paper assists in emphasizing the use of board games to deepen knowledge and illustrate how effective board games can be in the classroom.

Noda, S., Shirotsuki, K., & Nakao, M. (2019). The effectiveness of intervention with Board Games: A Systematic Review. *BioMed Central*. https://bpsmedicine.biomedcentral.com/articles/10.1186/s13030-019-0164-1

O'Neill et al. consider the use of board games in relation to multi domain learning in youths. In this paper they discuss the effects that COVID-19 has had on youths, ages 2-12, and how that has affected their development. When the authors conducted the research they determined that driven by how engaging and educational board games are, the use of board games has been historically important, throughout multiple cultures. This paper is used to emphasize that board games can be used across different cultures and are able to be used by anyone, irrespective of background, making educational board games an equitable educational tool.

O'Neill, D., & Holmes, P. (2022). The Power of Board Games for Multi Domain Learning in Young Children. *American Journal of Play, Volume 14, Number 1*. https://files.eric.ed.gov/fulltext/EJ1357958.pdf

Lesson Design

To test the efficacy of board games as a means to increase engagement and understanding in the high school science classrooms, an eight day lesson plan was created to teach ecology, specifically forest ecology. The lessons created align with, and are designed to target, multiple NGSS Standards. Appendix 10 identifies the specific NGSS standards within this unit and

includes the lesson plan, lesson story line, and the link to the lesson slides. This unit was primarily in Life Sciences and covers sections 1 (From Molecules to Organisms: Structures and Processes) and 2 (Ecosystems: Interactions, Energy, and Dynamics) of the NGSS Standards.

The specific NGSS standard for this board game was HS-LS2-7, where students are required to "design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and ecology" (NGSS, 2013). The students needed to think about how invasive species affect the ecosystem and species interactions of others. Later, students were asked to explain how humans could get involved to help control the invasive species population, and come up with examples on how this could be done. By participating in the worksheets and board game, the students were able to meet this NGSS standard while also completing two other learning objectives: students are able to explain the importance of wildlife conservation and biological control, when it comes to invasive species control, and, students are able to apply the knowledge learned from the prior week, to a specific example that relates to themselves and the community around them. These two learning objectives and more lesson details are provided within the lesson plan for Forest Ecology Board Game (Appendix 11.a).

To build this lesson there was a lot of background information that must be taken into consideration, specifically the demographics of my students. The 2021-2022 year breakdown of the Northglenn High School student body population, of 2,012 students, is seen to be built up from… (NORSE, 2021). The breakdown of the student body in my biology class, periods 1, 3, 4, and 7, are in Table 1.

- Diversity: 73% Hispanic students, 19% white students, 3% Asian students, 2% Black students, and 3% other. 47% male and 53% female.
- Economic: 62% of students are eligible for free lunch and reduced lunch.

- Proficiency tests: 16% were proficient in math and 38% were proficient in reading.

Table 1

Student Body Breakdown for Biology Class

Class Name	**Period**	**Grade Level (number of students)**	**Infinite Campus Flags (number of students)**		
General Biology	1	9th grade: 31	IEP: 11 504: 0 SPED: 11	LIT: 12 STEM: 4 Intervention Services: 4	NEP: 3 LEP: 7 FEL: 7
CP Biology	3	9th grade: 32 11th grade: 2	IEP: 1 504: 0 SPED: 1	LIT: 0 STEM: 14 Intervention Services: 1	NEP: 0 LEP: 1 FEL: 17
CP Biology	4	9th grade: 31 10th grade: 1 11th grade: 1	IEP: 1 504: 2 SPED: 1	LIT: 1 STEM: 22 Intervention Services: 0	NEP: 0 LEP: 1 FEL: 14
CP Biology	7	9th grade: 29	IEP: 1 504: 2 SPED: 1	LIT: 2 STEM: 18 Intervention Services: 0	NEP: 0 LEP: 1 FEL: 14

Based on Table 1, it was important to make sure that my lessons and instructions were clear with multiple sensory learning, specifically for the students in the NEP, LEP, and SPED programs, and students with an IEP or 504[3]. To make sure the lessons were differentiated to each student's abilities, the use of images, hands on activities, and strategic seating charts allowed for the most efficient and productive classroom.

Based on Adams 12 District policy, it was seen to be more important to incorporate more figures into the lessons we teach the students, than translating the entirety of the lessons into their chosen language. To work with district policy, we incorporated more images and made a seating arrangement where the NEP students sit together, next to their friend who is in the FEL program, in the front row of the class (refer to Table 1). By placing these students in the front row, they have a better view of the figures and English words we are using, increasing the likelihood of them understanding the content when learning new content. However, during class

instructional time, before a class based activity, we communicated with these students through google translate, in their preferred language, as they have been seen to participate more when they understand both the activity and rules. In addition to this, we previously translated the class materials and gave the students an option if they would like the English or the Spanish version of these documents, for missing and makeup work.

For our students with an IEP and 504, the lessons were modified to accommodate their individual needs. Amongst all of my students with an IEP or 504, it is fairly common for the students to request the ability to move around or doodle while learning, as it helps them focus. To support these students in their modifications, we allow students to do just this, as long as it does not disrupt other students' learning environments, or go against Adams 12 District rules.

What these students have self identified as tools to help them focus and stay engaged in the lesson, is a tool called multisensory learning. Multisensory learning has an emphasis on encouraging students and participants to use more than one sense when learning new topics and information. This multisensory learning environment is the secondary product that the board games aim to provide (Heskett, 2022). The main senses that are targeted through this style of learning are sight, sound, touch, and movement (Anupma, 2020). In the traditional classroom there is usually one sense occurring - listening to the teacher (sound). However, board games, like Teacher-CV's Board Games, include multiple senses for the students to participate in while learning about the topics. These can include: listening to group members (sound), moving to new groups (movement), reading the cards and looking at the pictures (sight), and playing with the board game and pieces (touch). Having these different senses help all students, but especially SPED students as there is a greater need for multisensory tools when teaching these students. As each SPED student is different, and has different needs, providing an environment where the

students can use their main senses can allow the students to choose how they want to learn, resulting in the lesson being more accommodating and effective for these students (Velazquez, 2018). Depending on the topic and type of board game, different senses may be used, but, using educational board games in the classroom encourages a multisensory learning environment that can increase student engagement and likely their understanding in the specific subject matter.

Lesson Logistics

The specific learning objectives for each day are outlined below. Every day the students write down the learning objective on their warm up sheets. This allows the students to comprehend the goal for the end of the day, each day. The original lesson was designed to only take seven days; however the students were having great conversations and were highly motivated to continue learning, above what was expected of them, so it ended up exceeding the expected duration.

Table 2

Learning Objectives Each Day

Day #	**Learning Objective**
1	I can come up with definitions of different types of interactions in biology.
2	I can give good feedback to my peers and think of examples for types of interactions in biology.
3	I know the difference between the three ecological pyramids and apply this knowledge to my mars project.
4	I know the difference between food webs and chains and apply this knowledge to my mars project.
5	I can explain how predators and prey populations impact each other and also what a keystone species is.
6	I can apply my knowledge that I have learned this week to different interactions and use it to play a board game.

7	I can use the topics we have talked about this week and give a group presentation based on the organisms I am for the board game.
8	I can use the topics we have talked about this week and give a group presentation based on the organisms I am for the board game.

To get to know the students, they were requested to fill out a survey that consisted of a few different opinion based questions. The first section asked the students about their preferred name and pronouns and in what context we are allowed to use these preferred names and pronouns. The second section asked the students about their favorite snacks, sports, activities, just as a way to connect with the students. The final section talked about science concepts and things related to science that they may know the name of or understand (Appendix 9). I have used the results of this survey to help make my lessons and the board game more relevant for the students (Appendix 9). There were two possible versions of the ecology board game that could be used; one based on the ocean and the other based on the forest. In the survey, a majority of my students mentioned they enjoyed hiking or hanging out with friends outside, but none of them mentioned anything about water sports or water activities. This helped make the decision to use the Forest Ecology Board Game with all of my students.

The lesson spanned over eight days, where we discussed topics of: interactions in biology, conservation of energy and matter, food webs and food chains, keystone species, and predator and prey population interactions (Appendix 10.a & 10.b). For each of these topics there was an activity that was either group or individual based. Following this, there were three formative assessments that occurred: after the topics of interactions in biology and conservation of energy and matter, during the food web and food chain lesson, and after the mini unit, used as a summary based assessment. Each of these assessments helped dictate whether the students were ready to move forward onto the next topic, or if they needed more revision on a specific

concept. At the end of this mini unit, students participated in the board game as a tool for reviewing the concepts discussed during the eight days.

The week and a half of learning that the students covered, led directly into the background knowledge that they needed to play the board game and complete the board game related assignments and presentation. The board game lesson plan was designed to take approximately two days, where they worked through a mini phenomenon and story line relating to the organisms in the board game (Appendix 11.a-b). The students worked in groups of four, of their choosing, as student-choice groups result in higher quality of work (Weimer, 2011). Since this is a board game that leads into the end of the unit summative exam, it was most beneficial to the students if they were able to choose their own groups, to produce a higher quality of knowledge and understanding at the end of the lesson.

The layout of the board game is fairly simple. There are four organisms that the students choose to represent, one organism per student. During the game the students read the game cards with scenarios on how the different organisms are interacting. Sometimes the organisms benefit from the scenario, while sometimes the scenario is a disadvantage. The students are unaware that the board game has a consistent predicted outcome, making the invasive species win the majority of the time. This is to imitate what occurs in the real world where invasive species usually dominate the realized and fundamental niche of an ecosystem. The students are then asked to determine why the invasive species won and how this is representative of the real world.

To determine the level of engagement of the students, as well as how much information they are able to retain and understand, students took a survey directly before playing the board game, and then again after the board game. The two surveys are very similar and ask the same questions about comprehension of the material, but the questions around engagement change

slightly from before and after the board game (Appendix 12.a-d). Similarly to this, the students were videoed while playing the game, to capture the conversations, group participation, and engagement of the students during the game. This allowed a comparison between the original videos of students working in groups and independently versus during the game (Appendix 15). This categorical data assisted in determining the engagement of the students during the board game, compared to the engagement of the students during an average week of biology in this classroom. This helped further assess whether the engagement in this high school science classroom has improved.

To end this mini unit, students completed a CER paragraph after the board game where they must demonstrate their understanding of the lesson from the board game and the days before (Appendix 13). This was used as a formative assessment that helped demonstrate what the students were able to retain from both the lessons and the board game.

Routines and Continuation of Knowledge

Throughout the duration of the lesson, the routine of each day looked the same. The first 5-10 minutes of class were discussing the warm up questions, copying down the learning objectives and homework, refer to *Table 2: Learning Objective Each Day*. Next there was instructional time, the duration of this depends on the lesson. Following and during this, students were required to write notes down in their notebooks or a handout we provided them. The last few minutes of class is clean up time and putting the materials away. This routine has been in place since the first day of school, and the students were accustomed to getting started on the warm up as soon as they entered the classroom and sat down. This routine was heavily utilized during this time as the students were being exposed to new teaching strategies like: playing an educational board game, or being taught by a student teacher; both of which could cause some

unease. Having a routine such as this can help students feel more comfortable in our science classroom, while also being able to explore teaching activities and strategies that they may not have seen or been a part of before, like the use of a board game.

When using the board game as a tool for review and to reinforce specific terms and concepts, the goal was that the students were able to recall this information and apply it to future concepts. Two weeks after this was completed, they had a unit exam, with forty multiple choice questions and short answer questions. This exam lasted two days, and covered everything from the first day of school up until the exam, including the information shared through the board game. When the students were playing the game, the hope was that they were reviewing and reinforcing concepts that we have been discussing. Going beyond the exam, there were three more units in the biology class which have a mix of topics that all relate back to this first unit of ecology. Since the knowledge that students were obtaining through this year is built upon in future topics, it was vital that students were able to understand the terms and concepts explained before and during the board game.

Analysis

This analysis portion of this PIP Capstone Project is broken into four separate sections. The first section illustrates the level of student learning and engagement before and after the board game. The level of student learning was captured by the completion of surveys that the students take to determine their content knowledge and engagement before and after the game. The second section summarizes the perspective of the co-teacher, asking how he thought the board game went, the implications of the board game, and any comments he had around the engagement of our students and the board game. The third section student feedback by considering how students received and interacted with feedback from teachers and their peers, to deepen their understanding. The final section discusses the language use and introduction of new language into the classroom. This section has references to student work from the first to last day of this mini unit to determine if there was a change in diction, by using the words and phrases we have discussed in class.

Student Learning and Engagement

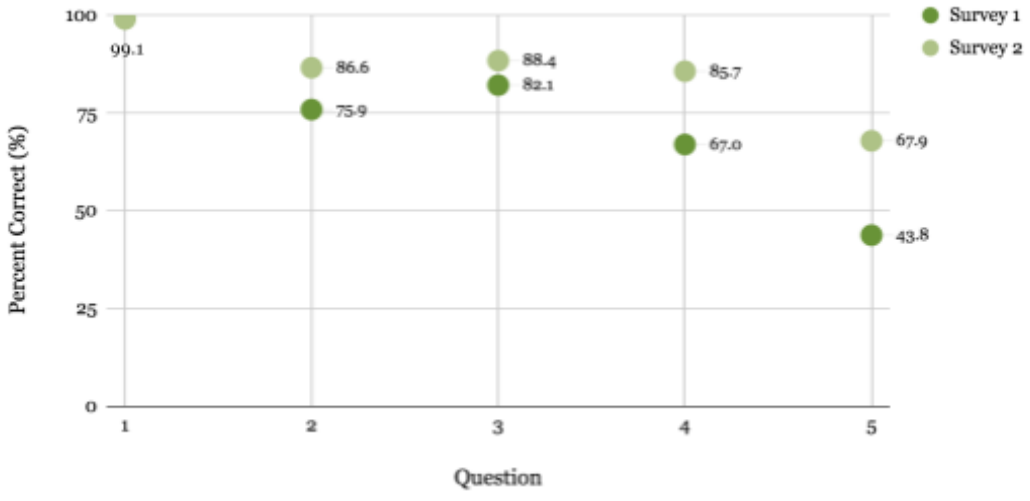
The two surveys that the students participated in before and after playing the board game, differ slightly. The survey named Biology Survey 1 (Appendix 12.a) was the survey given to the students before the board game, and the survey named Biology Survey 2 (Appendix 12.c) was the survey given after the board game. Both surveys were broken into two sections, the first being science content knowledge and the second section asking students to share how they feel about the lesson. It was explained to the students that the responses are anonymous to encourage students to be truthful in their responses particularly section two.

The first part of both surveys focused on the students comprehension of the science topics learned during the week leading up to the board game. See Graph 1 below, which depicts the

difference in responses from before and after the board game for this part of the survey. In the student responses it was evident that before playing the game students were confident in their understanding of what a keystone species was and how invasive species interact with endangered species. However, students were less successful when thinking about the 10% rule of energy and biomass ecological pyramids, how invasive and native species interact, and the correct order and arrow placement on a food web. After playing the board game - which specifically discussed interactions between keystone species, invasive, native and endangered species - students were seen to have an increase in science content knowledge. The extra review aspect that the students received when they played the game, giving them another example and opportunity to review the content discussed, likely impacted their science content knowledge. Similarly the board game and worksheets asked students to critically think about new ideas and concepts that they must look up themselves, and then present these ideas to the class, giving them yet another chance to review materials.

Graph 1

Students' Science Comprehension



Note. Students were asked equivalent science comprehension questions on both of the surveys.

Through this graph it can be seen that in four of the five questions, the students' science comprehension increased in accuracy for each question. It should be noted that on question 1, students had a 99.1% accuracy rate on both of the surveys. While the percentage of students who got question 5 correct is still lower than what would be ideal, the increase from pre to post the board game was greater than 20%. On average, there was a 11.97% increase in the number of students getting the answer correct for the science comprehension section. Using this graph, we can conclude that the board game does have some review benefits that assist in students retaining scientific knowledge.

The second part of both of the surveys asked students to share their feelings and thoughts about the lessons and activities (Appendix 12.b). Survey 1 asks the students how they felt about the topics and activities. Survey 2 asks students similar questions, while in addition asking the students how they felt when playing the board game and what they thought of the board game. Within both surveys students are asked to report how much they agree or disagree with a statement. These statements can be seen in Table 3. Some of these statements have positive connotations while others have negative connotations allowing the students the chance to really think about how the activities affected them. Students were given five different options on how to rate them: *really disagree, disagree, in-between, agree,* and *really agree*. After rating, students were asked to explain their reasoning to one of the statements that they agreed or disagreed to. (Appendix 12.d). Below are two graphs comparing the students' responses to these statements, before and after the board game. Answers have been combined into three categories: *disagree, in-between, agree*. To view the students' individual responses, their reasonings, and the raw data refer to Appendix 12.d.

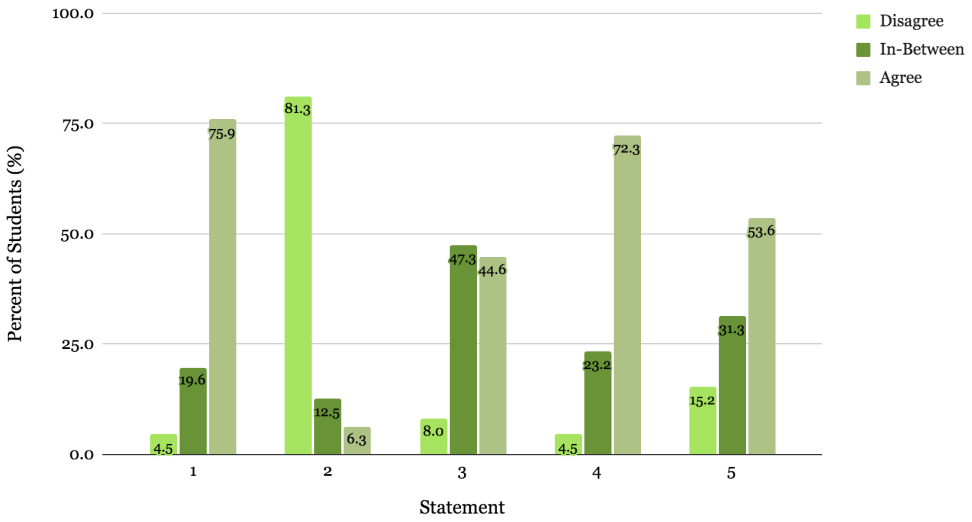
Table 3

Statements That Students are Responding To in Both Surveys

Number	Statement
1	I learned something new about how invasive species and keystone species interact.
2	I think I learned LESS by doing these activities than reading out of a textbook.
3	I felt like my ideas were shared and represented in the lessons.
4	I want to do more activity based learning instead of individual work.
5	I liked the different activities that we did in class.

Graph 2:

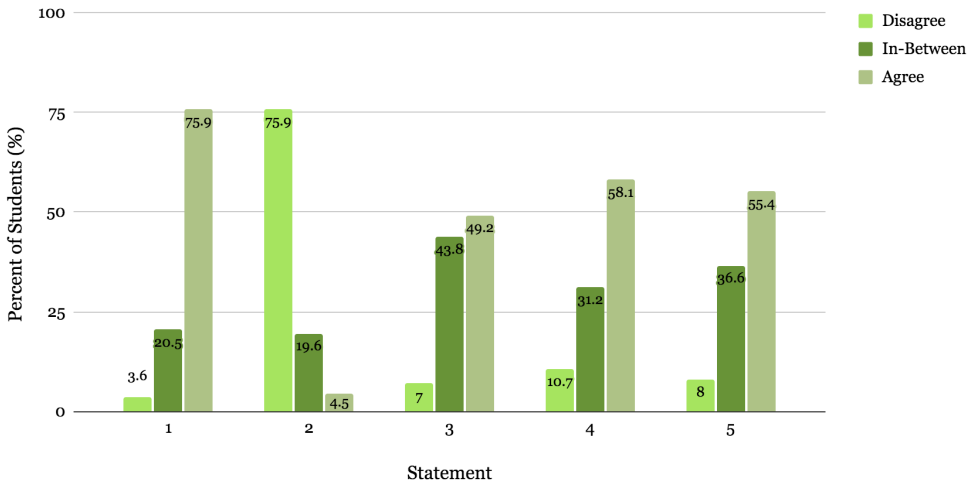
Percentage of Students Who Agree/Disagree with Statements Around Engagement on Survey 1



Note. These questions were provided to the students the day before playing the board game.

Graph 3

Percentage of Students Who Agree/Disagree with Statements Around Engagement on Survey 2



Note. These questions were replicas of Survey 1. This survey was given to the students the same day as playing the board game.

Comparing the responses to statement 1 and 2, from graphs 2 and 3, it can be seen that students believe they learned a similar amount of new information from before and after the board game. Although a lower proportion of students indicated that they learned less. It is also apparent that students felt like their ideas and thoughts have been more represented in the class after the board game (statement 3). Similarly, students seemed to enjoy the different types of group work we did in class, more so after the board game (statement 5). Statement 4 is inconclusive as there were both more students who disagree and agree with the statement on Survey 2 than Survey 1.

In the second survey, students were asked to provide feedback on how much they actually enjoyed the board game itself, by rating six more statements. They had the use of five different ratings: *really disagree, disagree, in-between, agree,* and *really agree*. They were then asked to explain why they rated one of the statements, in a short answer response. Table 4 outlines the

different statements that are correlated to the different numbers for Graphs 4. Below is a graph showing their responses, combining five ratings into three: *disagree, in-between, agree*. Refer to Appendix 12.d to see students' individual responses and reasonings.

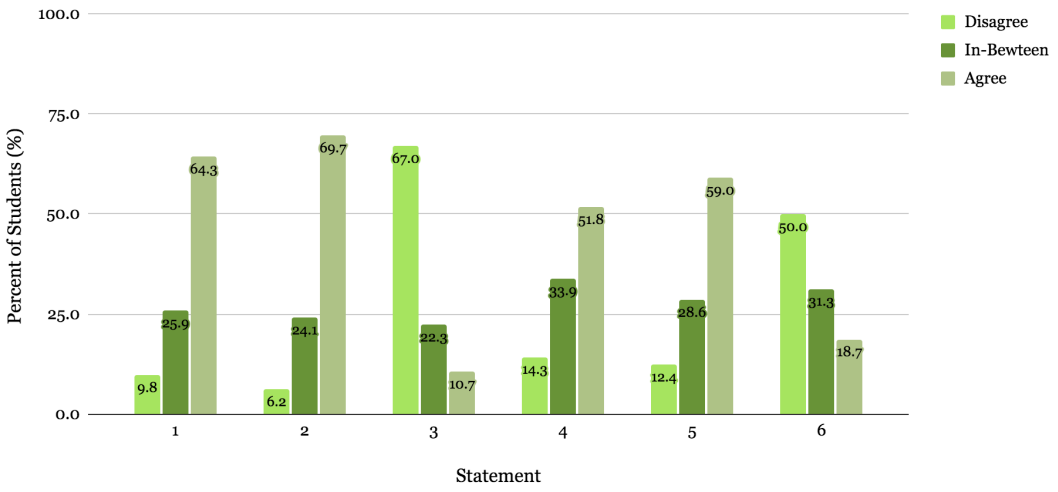
Table 4

Statements That Students are Responding To in Both Surveys

Number	Statement
1	I liked the board game and it was easy to use.
2	I learned something from the board game.
3	I found the board game to have no purpose.
4	I want to do another board game.
5	I found the board game useful for my understanding of science.
6	I would rather do a different activity than play a board game.

Graph 4

Statements on Student Engagement Around the Board Game on Survey 2



Note. Students were asked these questions the same day as playing the board game.

In this graph it can be seen that a majority of the students stated that they liked the board game, thought they learned something from the board game, and wanted to play another board game in class (statements 1, 2, 4, and 5). Similarly, many students stated that they would prefer to play board games over other group work and that they thought the board game had a purpose (statements 3 and 6). Based on this graph it can be summarized that the majority of students enjoyed the board game and found that it was helpful to their understanding of science.

Usually, a loud classroom could be considered disruptive, however, an indicator of increased student engagement is an increase in the number of student conversations, and subsequently an increase in the noise level in the classroom. The moments during the day when the average decibels were recorded occurred when the students were having productive conversations. Productive conversations can be defined as any type of conversation where the students are talking about the topic or relating to the topic, as these conversations assisted in their development of science knowledge while also maintaining engagement in the class.

To determine the noise level of the students' conversations, the average decibels were recorded for activities such as individual work, group work, and the board game. A baseline was established by recording the decibels for individual work, where the expectation is to only hear the teacher's voice. This was recorded once throughout this mini unit. This baseline was to determine how loud and how much conversation the students were having when participating in individual work to compare it to regular group work and to the conversations around the board game.

Below are two tables and one graph comparing the data collected, for the different activities. The noise level was recorded during each period, comparing the amount of student

conversations between the group work and board games. For the majority of the time that the decibels were being recorded, the students were videoed to have a visual comparison of the students working to the decibel meter (Appendix 15). The decibel meter was placed in a similar location in the room and was recorded for 5 minutes during each activity.

Table 5

Daily Decibels (dB) of Students During Different Activities

Period	**Individual Work (dB)**	**09/26 Group Work (dB)**	**09/28 Group Work (dB)**	**09/29 Group Work (dB)**	**Board Game (dB)**
1	57.9	72.1	71.0	72.5	75.2
3	57.7	73.6	74.2	72.1	84.1
4	65.1	71.4	79.2	76.6	82.3
7	65.4	73.8	74.1	76.5	83.3

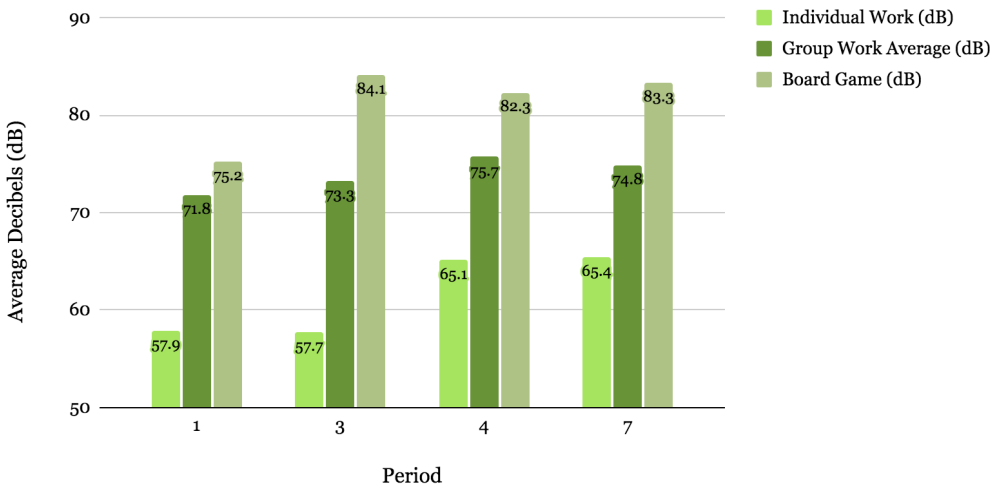
Table 6

Average Decibels (dB) of Students During Different Activities

Period	**Individual Work (dB)**	**Group Work Average (dB)**	**Board Game (dB)**
1	57.9	71.8	75.2
3	57.7	73.3	84.1
4	65.1	75.7	82.3
7	65.4	74.8	83.3

Graph 5

Average Decibels (dB) of Students During Different Activities



Note. The average decibels (dB) were recorded for when students were participating in individual work, group work, then the board game group work.

It is evident through Tables 5 and 6, and Graph 5, that students were having a greater amount of discussions during the board game compared to participating in group work. The data illustrates that there is an increased range of 3.4 dB to 10.8 dB, when students are playing the board game versus participating in group work. This increase in the noise level of the classroom can be correlated with the use of the board game. The board game provided a space for the students to engage with the material and work together. In addition, per the student interest survey that they completed in the beginning of the semester, most of these students enjoy some form of competition, usually through extracurricular activities (Appendix 9). The board game fostered this sense of light hearted competition in the classroom, resulting in students being more engaged in the topic and more likely to participate in group discussions, which, in turn, increased the noise in the classroom.

Co-Teacher Perspective

The day after the board game took place, the Co-teacher, Aaron Pidek[5], was interviewed to capture his opinions and observations regarding how the students reacted to the board game. The interview comprised of eight questions focusing on whether he noticed if there was an increase in demonstration of knowledge and engagement/participation prior to and post the board game (Appendix 14.a & 14.b). The transcript from this five minute interview is below.

Heskett:	How do you think the board game added value to the lesson?
Pidek:	I liked the board game, how it brought the… it was a good review. It brought everything together that we have been talking about, and had kids think about the application of it to… a real life situation that we haven't talked about in class.
Heskett:	Did you notice any changes in student behavior when they played the board game versus any other group activity?
Pidek:	Yes and no… There are activities that kids are motivated and excited about but the thing I found interesting about the board game is that they were excited about the board game. I don't mean that in a bad way, it was interesting because they were asking about it "oh we get to play the board game today" "can we do the board game today" and that sort of thing. They showed some excitement over this where other group activities don't show this, it depends on the activity.
Heskett:	How would you describe the students' engagement before, during and after the board game?
Pidek:	There was an increased engagement when the board game began, as all the students were trying to participate and be a part of the board game. Whereas before it there were some students who were kind of checked out, some who were engaged, some who were in between. But I definitely saw a much higher engagement when the board game started.
Heskett:	Did the board game change the environment of the classroom?
Pidek:	It got much busier, during the board game, a lot more excitement, the noise volume came up, you could see the kids were engaged.
Heskett:	Do you think that the students' understanding of the topics, the week prior to, increased because of the board game?
Pidek:	Absolutely, it put them into a situation of organisms that we haven't talked about and they had to think about those organisms in a new situation and apply what they have learned prior to that new situation. And for the most part successfully do that, based on my observations.
Heskett:	What is something you would change about the board game or layout of the lesson?

Pidek: Well it would have been nice to have more time, we ran out of time, but that has nothing to do with the board game itself. I liked how the board game worked and played within the lesson, as a review and bringing everything together.

Heskett: If given the chance and time would you use the board game again?

Pidek: Absolutely. I enjoy using games all the time throughout the unit. I have contemplated the idea of gamifying the entire class, so… (laughs). It's just a different level of engagement for the kids.

Heskett: Do you have any comments around the board game or engagement?

Pidek: The only thing that comes to mind is watching the kids that were less engaged, disengaged. And watching them re-engage during the board game. And the fact that they were not engaged for the stuff leading up, but they got the little piece and they were able to learn from their peers and so I'm pleased to see that.

When co-teaching with him, and based on the interview, it is clear to see the passion he has for the subject and the desire that he has to get his students engaged and participating in the work. Pidek often gets students laughing and moving to increase participation in the lesson. He prioritizes students' learning through experimentation and group work over individual work and lecture style lessons. To him, it's vital that students feel comfortable enough to be themselves in his class and have fun with the lesson and friends. This is one of the goals of the board game, to create an environment of engagement and participation, so that students are able to have fun with the learning material. After the interview, during a biology department meeting at Northglenn High, Pidek mentioned to his colleagues that he will be using more board games in the future to convey different information to students in a way that increases the participation level of his students. Based on the interview with him, it is evident that he prioritizes student engagement, and using the board game is an effective way to satisfy the requirements of that priority.

Student Feedback

To make this lesson most impactful for students, the use of the Instructional Leadership for Science Practices (ILSP) strategies were woven into the lesson, to help with the concept of

peers as resources. The specific instructional strategy that was implemented was the constructing of explanations by asking questions and using feedback. Based on this specific strategy, students were tasked to help each other by giving feedback, then revising their own work using the feedback of others. This lesson plan contained activities where writing and reading feedback were one of the main learning objectives for them to practice giving feedback and receiving it from their peers. Each day students received verbal feedback from the teachers, but there was also one main instance where students received written feedback from the teachers on their work.

The first was day two of the interactions poster activity, slides 6 and 7 of Appendix 10.b for the instructions. This activity asked students to guess on definitions of scientific terms, and participate in a group discussion and feedback. Then this activity tasked students to correct their original definitions with the correct definitions. During this time students were giving each other feedback by reviewing their original definitions with each other, giving each other examples, and then sharing examples of the terms with the class. To see the students' poster work, refer to Appendix 13.

The second instance where this ILSP strategy was implemented was during the Conservation of Energy within Interactions Slides Activity, slides 22 and 23 of Appendix 10.b. This activity asked students to find another example of the types of interactions in biology and relate it to the Law of Conservation of Energy and Matter. Students were then tasked with reading three of their peers' slides and writing feedback on their slides. After they wrote the feedback, they were asked to read through the feedback they received, and add to their slides in another text color based on the feedback. To see the student's work and feedback refer to Appendix 13.

The final activity for feedback was during the group presentations for the Forest Ecology Board Game. During this game students were regrouped into groups of similar organisms and asked to present their findings from the game to each other. They then worked together to complete an analysis worksheet that assisted in students' understanding of the “why” we played the board game and the purpose of the invasive species winning. Afterwards, each group was tasked with presenting their findings to the audience, during which time the audience was required to write down one question and one fact they heard from the presenting group.

The last main instance of planned feedback was on the students’ Forest Ecology Board Game packet. This packet contained information and activities that occurred over three separate days. These three days consisted of individual writing time, group work, and group feedback. All activities quizzed students about information from the prior week’s lesson. The feedback that we provided occurred on the second day of this three day board game activity. It was written directly on their papers when they needed to either rethink a question or if it was correct, students got some form of feedback. On day three of this activity, students were able to change their answers in class, based on the feedback provided, and then were tasked to write a CER. Once turned in, we wrote more comments on the CER, and gave the students an opportunity to rewrite it or add to it to improve their understanding and score on the assignment. This can be viewed in Appendix 13.

After each round of feedback, students were given the chance to change or modify their original work. This also assisted in getting the students to review information and topics from the week prior, to assist with studying for the upcoming exam. It was seen in class that after each round of feedback leading up to the board game, more students were asking questions on topics covered in the class. These questions were very standard and did not demonstrate a deeper level

of understanding, as they consisted of “Is this a food web not a food chain?” or “Would a tick be an example of a parasite?”. These questions were introductory level questions that were covered in class the day prior, indicating that the students were not retaining much information for longer than a day. However, after the board game, the students were asking questions that indicated a deeper understanding of the topic. These questions were discussing future applications of this knowledge. For example, a few students asked “So the gray squirrels we see outside are terrible for the environment, how can I help stop them from hurting the red squirrels?” or “How can we start introducing more hawks into the area to stop the gray squirrels?”. These questions were not covered in the board game, but demonstrate the students questioning how to apply this knowledge into their own lives and futures as scientists. The change in level of questions that occurred after the board game was likely due to the students having another example of terms and topics discussed in class through the use of the interactive and multi sensory learning tool, the board game.

Language Use - Literacy Specific Standards

There are three literacy specific standards that last the duration of this mini unit. The first is working on a student's comprehension skills and implementing it into their own explanation - code: RST2-09-10.2. This is designed to take place within all activities, as students are required to look up information, summarize it, and restate it into their own words to then share with their group or class. The second standard is being able to examine the relationships between different terms and phrases - code: RST5-09-10.5. This standard is the main focus of the first activity where students are discussing new terms and concepts, and trying to determine how they are related to interactions in biology. The third literary standard that is focused on within this week is having students use evidence to make a statement - code: RST9-09-10.9. The last day of this

mini unit, students wrote a CER paragraph, where they must use information from the board game, notes from the last few lessons and their worksheets supporting the board game, all to convey the reasoning why they think invasive species won the board game.

Language Use - Repetition of Terms and Concepts

The strategy of learning that was implemented in this lesson is named “circle learning”. This is where terms mentioned at the beginning of the lesson or unit, keep being brought up again throughout the rest of the unit and lesson. Different terms and concepts were mentioned during different days and activities, and this section of the paper discusses where and how students use the terms again in later assignments and projects. For evidence to support the idea that the board game increases the chance for circle learning, photographs of students are provided in Appendix 13 that highlight the different terms used. Of the 130 students that participated in these board games, five student worksheets per period were selected at random and their work anonymously shared in this research project.

Throughout the entirety of the mini unit, there were six terms that were introduced on the first day to these students. These terms were: mutualism, commensalism, parasitism, predation, interspecific, and intraspecific. Students were asked to discuss and introduce these terms and were tasked to guess what these words meant by writing down their personal definitions on a poster paper. Then they were shown the correct definitions that they needed to know and they corrected their posters to match the correct definitions (Appendix 10.b). This first day’s activity helped students remember these terms and get comfortable with using them later on in the unit. To determine if the students understood, remembered and were able to use these terms correctly, we looked at their board game worksheets where they were tasked to answer questions by using these terms (Appendix 11.b). In Appendix 13 there are images of these questions answered by

students, to illustrate how often these terms were used, the terms are underlined, in *green*. It was determined that on average, students were able to use these terms correctly and effectively to convey their understanding of what occurred during the board game.

The next time new terms were introduced to these students was on day three when we were talking about the three types of ecological pyramids. These terms are: trophic pyramid, energy pyramid, biomass pyramid, 10% rule, exponential growth, and logistic growth. These terms were written on a handout for the students to fill in the gaps on the paper and add any information that they think is important (slide 11 of Appendix 10.b). To test these terms, students were tasked to make an energy, trophic, and biomass pyramid for their Mars Projects[4] and then use this information on their board game worksheets. If the students were able to use the terms, they were underlined in *blue* (Appendix 13).

Day four of this lesson introduced the idea that there is a difference between food chains and food webs. These two terms were not new to these students but differentiating between the two was a new practice. The first time students are asked to differentiate between them was when they are asked to make their own food web of the species on their Mars Projects, then circle an individual food chain (slide 18 and 19 of Appendix 10.b). After this, students were tasked with completing the board game CER which asked students to prove their claim based on their knowledge of a food web and food chain (Appendix 11.b). Students proved to be successful in knowing the difference between food chains and food webs based on their work in the board game packet (Appendix 13). These terms were underlined in *yellow* (Appendix 13).

The final terms that were discussed in these lessons were: predator, prey, and keystone species. These three terms were discussed on day five of the lesson. To test whether the students could comprehend these terms they were asked to complete two activities. Students were asked

to complete quiz questions that covered all of the lessons talked about (slide 49 and 50 of Appendix 10.b). This was used to determine how much information the students have retained, while also being able to use their notebooks. The second activity, to check the students' understanding, was during the board game and worksheets that asked the students to think about the organisms and if one was a keystone species (Appendix 11.b). These terms were underlined in purple (Appendix 13). With all of these activities completed, it was evident that the students were proficient at using the terms correctly.

Combined, students used the terms underlined in green approximately 29 separate times; terms underlined in blue 100 times; terms underlined in yellow 80 times; and terms underlined in purple 77 times. Based on this, it is apparent that students are most comfortable using the blue underlined terms: the three different ecological pyramids, 10% rule, and the different types of population growth. Students had equal opportunity on the board game worksheets and CER to use all four categories of terms, but were using these terms most frequently and correctly.

By using the board game as an assessment tool to determine which concepts students are less comfortable using and understanding, future lessons can be tailored to compensate for the lack of understanding of specific terminology. The week following this unit provided time to review the board game CER and worksheet, where students were retaught the green terms (mutualism, commensalism, parasitism, predation, interspecific, and intraspecific) as they were used less frequently and accurately. Utilizing the board game and worksheets, not only as review but as a formative assessment, allowed the students to assess themselves and provided the opportunity to ask for help.

Summary and Recommendations

To conclude, this research paper discusses how to use educational board games in the classroom. The summary contains the results of this study and applies it to previously mentioned research articles to determine the effectiveness of educational board games in the high school science classroom. The recommendations include: how to introduce and teach the board games, outlines of each of Teacher-CV's board games, and how to find more educational board games like the one in this study.

Summary

The eight day lesson, focusing on the impacts of the board game on the students, illustrated that the students demonstrated an increase in the level of student engagement and overall participation from before to during the game. It can also be concluded that the board game had a greater impact on student engagement than individual work or other group work. This level of increased engagement and participation was observed at various stages throughout the lesson. The first evidence of increased engagement was seen by measuring the decibels recorded in this study. When students played the board game the classes were louder than regular group work, as students were talking and engaged in the activity. In addition to engagement levels there was also an increase in participation of all students. According to the interview with Mr. Pidek, students who normally choose to not participate, were participating and engaged in the board game and the corresponding work, subsequently increasing the noise in the class. The second observation occurred during and after playing the game as the students became excitable when reading the cards instructing players to move up or back, causing someone to win or lose. After the game and worksheets were completed when we revealed to the students that the game has a consistent predicted outcome, many students became rambunctious, voicing their

grievances by saying comments like: “That's cheating!”, “Not fair!”, and “Not cool, Miss!”. However, the smiles on their faces and the laughter that followed their comments indicated the increased level of engagement and enjoyment that the students experienced during the board game.

In addition to the positive impact on engagement and participation, it was also demonstrated that the students had an improved level of understanding around the topic as the board game acted as another form of review. As seen in the pre and post survey, students' science knowledge increased on the topic of ecology from before playing the board game to after. Analyzing student work throughout the week, it was evident to see that students were able to accurately restate and use key terms and phrases throughout the eight day lesson, but especially showed their increase of knowledge when writing the CER after the board game. Throughout the rest of this unit and future units, this game will be mentioned and brought up again when students need to be reminded of the key concepts and terms. Similarly, the posters the students completed before the board game and the worksheets completed during and after the board game, will either be on display around the classroom or accessible to them at all times.All of the concepts that were discussed during this mini unit are used in their larger PBL, and will be needed for their presentations at the end of the semester.

In the student interest survey, it was noted that a majority of the students enjoyed group work, games, and some form of competition. This board game provided the students with an opportunity to work in groups in a competitive setting, as the board game required groups of three to four students to compete for the winning spot. It was evident that there was an increase in students' willingness to participate in class and that they found the board game to be a fun alternative to other review tools. While this multisensory learning tool was seen as a fun activity

by the students, it had a greater purpose than just light hearted competition. It discussed the concepts and key terms that were previously mentioned during the week and provided another example of the phenomenon discussed.

This study was conducted on a population of freshman and sophomores at Northglenn High School While this study proved that educational board games will increase student engagement and understanding in the subject of Ecology for freshman and sophomores, more research needs to be conducted to determine how educational board games affect students of all years in high school, throughout multiple different topics within science.

Recommendations

Dear Educators,

Previous studies have mentioned the benefits of incorporating educational board games into the elementary school classroom, as it can help teach basic communication and collaboration skills. However, most of the studies have not determined if this can be the same for high school students. Within this research project it was concluded that the use of educational board games are a successful tool for reviewing concepts, increasing student understanding, and increasing engagement in the high school classroom

To further this research and provide a board game that is inclusive to everyone participating, more research needs to be conducted to uncover the impact of using board games on engagement and understanding in the high school science classroom. This would ideally be conducted in many different locations and across multiple curriculum designs, to determine if there is correlation or causation between board games and student engagement and science comprehension. Until this research is conducted, and applied to the general population of 14 to 18 year olds in the science classroom, it is fair to conclude that these 130 students benefited from

a board game as it increased engagement and participation, while also improving student's comprehension of science concepts.

Before playing the board game, I recommend first teaching the topics and lessons that use concepts and ideas discussed in the board game. Each board game is related to at least one NGSS Standard, so topics reviewed in the board game are relevant to the national curriculum. When playing the board game, I encourage you to not tell the students that the game has a consistent predicted outcome as this is a good discussion point for later use. Expect that students will be more energized than usual, as the students will actively participate when playing the game resulting in the noise level of the classroom increasing . After the board game, it is equally important that the students participate in the analysis worksheet or questions as this is the portion of the game that will help students review topics and concepts.

The Forest Ecology Board Game was created by Teacher-CV, who has also made four different board games that are able to be used for review. The first is Carbon Capture, for grades 9-12, that discusses how carbon dioxide is created by humans, and how humans can capture and use these emissions to improve the environment. The second board game is on Ocean Acidification, for grades 9-12. This encourages the students to investigate the effects of ocean acidification on specific marine organisms and how that will in turn affect humans. The third board game, Ocean Ecology, is, for grades 5-8, and discusses the impacts of human activity, keystone species and invasive species on other organisms. The fourth board game is Forest Ecology, for grades 9-12, where students will discover the impacts of humans and invasive species on keystone species, native species, and the environment. Each of these board games differ slightly with separate lesson plans and board game instructions that are provided to the teacher once downloaded.

Teacher-CV is in the process of creating more board games that review multiple different topics. There are three main styles of Teacher-CV board game: review, predicted outcome, and standard. The review board games are designed to be used as a tool for review, similar to Kahoot and Quizlet, helping students study and review concepts. The predicted outcome board games, like Forest Ecology, not only review material but are designed to mimic the real world, causing one player to win the majority of the time by rearranging the game to benefit them the most. The standard board game, like the Carbon Capture Board Game, is created to let students choose different outcomes that dictate who wins or loses after the game is over. The review board game usually lasts one to two days, where the first day is playing the game and the second day consists of students asking questions and revisiting topics they misunderstood. The predicted outcome and standard board games typically last three days, as these two game styles require students to write a CER, complete worksheets, and give a presentation. All three board game styles are used to review topics and terms discussed in class and apply them to different examples. Teacher-CV will be launching five more board games, previews available on Teacher-CV.com, each with the purpose of increasing student engagement and comprehension of science topics.

We hope this makes a positive impact in your classroom,

Collette Heskett

Teacher-CV

http://teacher-cv.com/

https://www.teacherspayteachers.com/Store/Teacher-cv

References

Alismail, H. (2016). Multicultural Education: Teachers' Perceptions and Preparation. *Journal of Education and Practice*. https://files.eric.ed.gov/fulltext/EJ1099450.pdf

Anupma. (2020). What is Multisensory Learning? *Empower Kidz.* https://empowerkidz.com/what-is-multisensory-learning/

Neal, D. (2023). The connection between belonging and representation. *AMLE*. https://www.amle.org/the-connection-between-belonging-and-representation/.

Chen, S., Tsai, J., Liu, S., & Chang, C. (2021). The effect of a scientific board game on improving creative problem solving skills. *Thinking Skills and Creativity*. https://www.sciencedirect.com/science/article/pii/S187118712100136X

Noda, S., Shirotsuki, K., & Nakao, M. (2019). The effectiveness of intervention with Board Games: A Systematic Review. *BioMed Central*. https://bpsmedicine.biomedcentral.com/articles/10.1186/s13030-019-0164-1

Kumar, J. M., Herger, M., & Dam, R. F. (2023). A brief history of games. *The Interaction Design Foundation.* https://www.interaction-design.org/literature/article/a-brief-history-of-games

Georgiev, D. (2023). 13 board game statistics - all you need to know in 2023. *Techjury.* https://techjury.net/blog/board-game-statistics/

O'Neill, D., & Holmes, P. (2022). The Power of Board Games for Multi Domain Learning in Young Children. *American Journal of Play, Volume 14, Number 1.* https://files.eric.ed.gov/fulltext/EJ1357958.pdf

Foster, S., & Ambrose, K. (2023). Facilitating and assessing student engagement in the classroom. *Center for Teaching & Learning.*

https://www.colorado.edu/center/teaching-learning/2023/01/23/facilitating-and-assessing-student-engagement-classroom

NORSE (2022) Northglenn High School (2023-24 ranking) - Denver, CO. *Public School Review.* https://www.publicschoolreview.com/northglenn-high-school-profile

NGSS. (2013). Read the Standards. *High School Life Science.* https://www.nextgenscience.org/sites/default/files/HS%20LS%20topics%20combined%206.13.13.pdf

Heskett, C. (2022). About Us. *Teacher-CV.* http://teacher-cv.com/about-us/

Velazquez, G. (2018). Multisensory Approach in Special Education – NJ Special Needs School. *The Gateway School.* https://thegatewayschool.com/multisensory-approach-special-education/

Weimer, M. (2011). Group work: Are student-selected groups more effective? *Faculty Focus | Higher Ed Teaching & Learning*. https://www.facultyfocus.com/articles/teaching-and-learning/group-work-are-student-selected-groups-more-effective/

Heskett, C., & Pidek, A. (2023). Mentor Teacher/Board Game Interview. Personal.

Footnotes

[1] Teacher-CV Board Games is the business that creates educational board games to explain specific science concepts. It was created in 2022. **Here** is the link to the website.

[2] Transportable skills are skills developed in a classroom setting that can be used in multiple workplaces. Some of these skills are: communication, collaboration, and critical thinking.

[3] 504 is a government plan that gives support for students with disabilities.

[4] The mars project is the PBL that the biology department is doing for the ecology unit. Students will learn the terms and phenomenons of earth and apply this knowledge to a science fiction biome, of their choosing, on Mars.

[5] Aaron Pidek is my mentor teacher for both General Biology and College Prep Biology classes.

List of Acronyms

AD/HD - Attention-Deficit/Hyperactivity Disorder

CER - Claim Evidence Reasoning

CP - College Prep

FEL - Former English Learners

IEP - Individualized Education Program

LEP - Limited English Proficient

LIT - Literacy Intervention Toolkit

NEP - Not English Proficient

NGSS - Next Generation Science Standards

PBL - Problem Based Learning

STEM - Science, Technology, Engineering, and Mathematics

SPED - Special Education

Appendix

1. Weather and Climate Board Game: This is the image of the first board game I had created during my college career, where I played it with a handful of eighth grade students who needed to make points back, and deepen their understanding on the topics of weather and climate. Click **here** for access to a photo of the board game.
2. Weather and Climate Game Questions: This is the link to the game overview, rules, questions, cards that we used to play the game. This game was review based so the students were unable to progress through the game if they got the question wrong. Click **here** for access to this document.
3. Weather and Climate Board Game Reflection Assignment: This assignment discusses the observations that I noted during this lesson in 2021, as well as answering some reflection questions about the lesson. Click **here** for access to the assignment.
4. Best Buddies Board Game: This is the rules and image of another board game I had during my college career, where I played it with my peers in the CU Teach class called School and Society. We were tasked with creating a presentation on organizations or companies helping with adapting our society to make it more accommodating to neurodivergent individuals. Click **here** for access to a photo of the board game.
5. Biodiversity Board Game: This was the first draft of the start of my board games, which tested my peer's knowledge on biodiversity of ecosystems, specifically mentioning keystone species, native species, and invasive species.
    a. Click **here** for access to the board game cards.
    b. Click **here** for the activity worksheet.

6. Ocean Acidification Board Game Video: In this video the students are working through the board game. It can be seen that they are laughing, talking, and participating in the group work. Click **here** for access to this video.
7. Presentation Videos: This is a folder of videos and pictures of myself presenting two board board games at both CU Boulder's Climate Action Expo and the Denver Museum of Nature and Science. Click **here** for access.
8. Sustainability Innovation Micro-Credential: CU Boulder awarded the Sustainability Innovation micro-credential to people who are creating new concepts and ideas that can help with problem solving new technologies, innovations, and ideas that can solve current and future issues pertaining to climate change and sustainability issues.
    a. Click **here** to see the credly site where I was awarded the micro-credential.
    b. Click **here** for the abstract I wrote about the board games qualifying me for the micro-credential.
9. Student Interest Survey: This is a survey that I gave the students to better get to know them. **Here** to see the student responses.
10. Unit Lesson Plan: This is the lesson plan/story outline and slides for the mini unit.
    a. **Here** is the link to the unit storyline, where each focus question, learning goal and activities are laid out day by day, for the duration of the mini unit, which also contains the specific NGSS Standards for this unit.
    b. **Here** is the link to the google slides for this mini unit.
11. Board Game Logistics:
    a. **Here** is the board game lesson plan, which outlines the two to three days that we will spend on the board game, analysis, and wrap up of the activity.

b. **Here** is the link to the blank board game worksheets and game board.

12. Survey Data: All of the completed and blank surveys used in this lesson are below.

    a. Click **here** is the link to the responses from my students.

    b. Click **here** to get access to the link to their responses.

13. Student Work: This is a folder with all student work in it from the week leading up to the board game, the board game worksheets, and the post board game CER. Click **here** to get access to this folder of student work.

14. Interviewing Aaron Pidek:

    a. **Here** is the link to the interview questions that I will be asking my mentor teacher, Aaron Pidek.

    b. **Here** is the voice recording of the interview.

15. Video Evidence: This is a folder that contains videos of the two to three day board game lesson and the video of students working independently and in group activities throughout the week. In this folder are videos of student activities, my instructions, observations, and interactions between students and teachers. Click **here** to get access to this folder of videos.