ZOMBIE BRAINS: DESIGNING A TRAVELING SCIENCE PROGRAM FOR ENGAGEMENT IN SCIENTIFIC EXPLANATION

By

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Written under the direction of

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Abstract

Informal science institutions like Liberty Science Center (LSC) aim to get learners excited about science, technology, engineering, and math (STEM) by creating fun and interactive exhibits. LSC also offers traveling science programs (TSPs) that bring some of the fun and interactive aspects of the museum to schools. Yet schools often seek programs that are more formal and engage students in the authentic practices outlined in the Next Generation Science Standards. TSPs fall somewhere between informal and formal learning—utilizing a bit more structure than museum exhibits, but are still relatively short (45-minute), one-time events. Thus, the challenge is to design TSPs that engage students meaningfully in authentic science practices while still being fun and exciting, all within a short amount of time.

As a Senior STEM Educator at LSC, I designed *BRAAAAINS: You & the Zombie (BYtZ)*—a TSP to engage students in the difficult practice of constructing scientific explanations. The purpose of this dissertation is to explore the effectiveness of *BYtZ* at engaging students and improving their ability to construct scientific explanations. I used a modified version of the experience sampling method (ESM) to collect engagement data using a clicker voting system. A pre/post-test analysis was used to examine improvements in scientific explanations. A total of eight 7th grade classes from three schools participated in the program. Data analysis revealed that students were engaged with all three major elements of the program, that their explanations improved, and that those who were more engaged with the program were more likely to demonstrate improvements in their explanations. The dissertation document is presented as a portfolio that seeks to make the study findings practical with the following three products: (1) the complete curriculum for the new TSP titled *BRAAAAINS: You & the Zombie (BYtZ),* (2) an academic journal article reporting on the research study for a science education researcher

audience, and (3) a professional development seminar for STEM Educators at LSC so they can learn how to present *BYtZ* with fidelity to its design intent and about general lessons learned during the design and research of the TSP.

Dedication

I dedicate this dissertation to my family, without whose encouragement I would never have gotten through it. I especially want thank you my husband for your constant love, never letting me give up, and keeping me on track even when it may have felt like your wife had abandoned you because I was sequestered in the office working. Thank you Mom and Dad for always believing in me, and Mom for letting me get away with not calling you when I was in the thick of things. Thank you family for always having the uncanny ability to send a funny picture or video to our group texts just when I needed a break, and also understanding my lack of responses during the most stressful times when I may have had to mute the group.

I would also like to acknowledge and thank my dissertation chair Dr. Eli Silk and the rest of my committee Janice McDonnell, and Dr. Harold Clark. Thank you Eli for all of your help and support during this process, I would not have made it this far this fast without such a dedicated advisor who pushed me to stick with it. Thank you Janice for all of your additional help with finding and revising the right measures for my study. Thank you Harold for supporting me in my endeavors both at work and in graduate school. Thank you to my dissertation group, Nancy, Natalie, and Kim, I would not have been able to do it without such an awesome group to work and brainstorm with. Thank you especially to Nancy for meeting me at the library or Panera on those days when we both really needed a push to get it done! Thank you also to my friends and family who went the extra mile and helped me revise various documents through the different stages of this journey. I would especially like to thank Jess, Sharon, Judith, and Ian for your insightful comments and for being far better at grammar than I am! Finally I would like to thank my constant study buddies, my dogs Cody and Whisky, for making me get up and get out of the house from time to time while working and keeping me company in between.

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Chapter 1: Introduction to the Study

Zombies. They fascinate us humans, and if the massive success of zombie related films, television shows, and even zombie walks has taught us anything, it's that we continue to be spellbound by anything to do with these undead creatures. Some educational institutions—such as PBS, Texas Instruments, and Liberty Science Center (LSC), where I work as a Sr. STEM (science, technology, engineering, and math) Educator, have realized they can capitalize on this public interest in zombies and use it to engage people in learning. The use of an interesting hook—such as the premise of a zombie outbreak—may work well as a hook to grab learner attention initially, but an interesting hook on its own is not enough to sustain interest or achieve learning (Blumenfeld, Kempler, & Krajcik, 2006). The learners' interest must be continuously engaged throughout the learning experience and that engagement needs to be directed toward the cognitive aspects of the experience that are likely to promote learning. Maintaining this level of engagement is no trivial task (Loukomies, Juuti, & Lavonen, 2015; Palmer, 2009).

Liberty Science Center (LSC) is an informal science institution (ISI) and our exhibits are designed to engage visitors in fun and exciting learning experiences. When most people think of museums, they think about the exhibits within the museum that they engage with. Indeed, there is a long history of research on the best way to design museum exhibits to grab the attention of the guest and hold it long enough for them to learn something before they move on (S. Allen, 2004; Bell, Lewenstein, Shouse, & Feder, 2009; Falk & Dierking, 2000; Sacco, Falk, & Bell, 2014; Schwan, Grajal, & Lewalter, 2014). Yet these exhibits are far from the only exciting learning experiences offered by most ISIs. Most ISIs, including LSC, offer a variety of longer programs in addition to their exhibits. The exhibits within the building itself are only one part of the total educational offerings from LSC. In addition to visiting the LSC museum exhibits, when they are in the building, schools and other groups can choose to add on to their experience by participating in a Live From Surgery or one of our in-house laboratories. Alternatively, LSC can come to the school or institution virtually with one of our electronic field trips, or in person with one of our traveling science programs (TSPs). Liberty Science Center offers two kinds of TSPs: assembly programs for large groups of students and classroom workshops for individual classes of 30 students or fewer. One design challenge that all of LSC's learning programs share whether it is one of the museum exhibits, a 20-minute live science demonstration on the museum floors, a 45-minute traveling science program (TSP), or a weeklong summer camp, is how to catch and hold learners' attention toward meaningful science learning for the entire duration of the learning experience.

Each kind of program comes with its own unique aspects to that shared design challenge. Live science demonstrations are shorter and therefore rely heavily on the "wow" factor of various experiments, but it can be challenging to ensure the program is also getting across a learning message. Summer camps allow campers to delve deeply into topics of prior interest, yet it is still important to include a variety of activities to engage the campers with the topic in different ways while maintaining a fun camp atmosphere. Traveling science programs fall somewhere in between, at 45 minutes they are more like a class period and therefore long enough to address a topic in more depth than a live science program. However, as one-off programs that are only 45 minutes they are not long enough to go into the same kind of detail as one might over the course of a multi-week lesson in school or even in a summer camp. One way to help bridge this gap is by designing a TSP that targets a curriculum standard so that it can complement what students are already learning in school.

Currently, schools are seeking programs to enhance their students' learning not only of content, but also of the practices of science. Here I have taken on the task of designing a TSP that complements that focus. It is particularly difficult to get students to engage with challenging scientific practices such as creating scientific explanations. It is even more difficult when one only has 45 minutes with the students in which to do it. In this abbreviated time frame, a TSP must grab the students' attention with an interesting idea and then hold it with activities that scaffold their engagement in key aspects of the authentic practices in order to give them a meaningful learning experience in a short lesson. Therefore, I have designed a traveling science program that draws on problem-based learning (PBL) to trigger and maintain students' situational interest as a way to engage them with the practice of forming scientific explanations (Belland, Glazewski, & Richardson, 2011; Palmer, 2009; Savery, 2006). To scaffold their explanation practice, I have built the claim, evidence, reasoning (CER) framework into the program (McNeill, Lizotte, Krajcik, & Marx, 2006). By bringing together these best practices, I hypothesize that students will improve their understanding of and ability to form scientific explanations as a result of maintaining a high level of engagement throughout the 45-minute program.

Statement of the Problem

This dissertation focuses on the design and implementation of a classroom workshop TSP because this setting provides the opportunity to explore how to design a one-time experience that balances making progress on a standards-based science practice while maintaining interest and engagement. Given the considerable research based on how students learn science both in formal classroom settings (Duschl, Schweingruber, & Shouse, 2007; National Research Council, 2012) and in informal out-of-school settings (Bell et al., 2009; Fenichel & Schweingruber, 2010; Sacco et al., 2014), the design of any TSP would undoubtedly benefit from drawing on this research. However, these TSP classroom workshops are a bit difficult to classify on the informal-formal science education spectrum—they fall somewhere in between, often referred to as non-formal (Eshach, 2007) or semi-formal (Jones, Scanlon, & Clough, 2013) learning experiences—and so there are challenges and opportunities that are particular to this context.

Being an informal science institution, we at LSC always strive to ensure our programs are fun and engaging as well as educational (Bell et al., 2009). However, since LSC classroom workshops take place inside a classroom, there is an opportunity to take advantage of that more formal setting to specifically target some of the more critical and challenging science standards. The challenge is creating a semi-formal program that simultaneously (a) meets the schools' desire and need to address science standards, (b) stays true to the LSC's informal learning mission of making science fun and engaging, and (c) keeps within the 45-minute time frame of a one-time classroom workshop. Fortunately, the new science standards, called the Next Generation Science Standards (or NGSS), were designed using some of the ideas about how to make science engaging from informal science practices, and so there are clearer connections for incorporating them into LSC's classroom workshops. The NGSS bring about a major change in the way science is taught in schools because, instead of primarily content memorization, they focus heavily on three dimensional learning that targets the scientific practices, crossing cutting principles, and the interdisciplinary big ideas that connect all science disciplines together (Bybee, 2013). The problem of practice I will address with this dissertation is how to create a 45-minute semi-formal traveling science program that meets the needs of schools through its alignment with the NGSS, while staying true to Liberty Science Center's mission "to get learners of all ages excited about the power, promise, and pure fun of science and technology" (Liberty Science Center, n.d.).

Purpose of the Study

There is room in the literature for additional data on the impact of one-time semi-formal lessons on students' ability to form scientific explanations. Additionally, there is room to explore whether such semi-formal lessons engage students with the learning, and further, whether the engagement may be responsible for improving the learning. This is an important area of study because as it becomes more challenging for schools to plan field trips, they are turning to programs such as LSC's TSPs to engage the students with science in new and different ways than their every day classroom experience. They are looking for opportunities for the field trips to come to them. Therefore, it is important for institutions providing such programs to assess the value of these programs for the students, and learn how they can be improved. It is not expected that students will become experts at skills, such as forming scientific explanations, from one 45-minute classroom workshop. Rather, TSPs are designed to introduce students to new content and practices, or strengthen their current understanding of topics they have already learned.

The purpose of this study was to design and test a program that met all three key goals for a TSP: (1) it fits into the medium-length, 45-minute, time frame (semi-formal TSP perspective); (2) it targets a key science practice (formal school perspective); and (3) it maintains student engagement throughout (informal science institution perspective). An additional purpose of this study was to assess whether engaging students in learning by evoking situational interest through an accessible PBL-like scenario with appropriate scaffolds for the key science practice was effective in improving scientific explanation skills in the TSP. *BRAAAAINS: You & the Zombie (BYtZ)* was the semi-formal TSP program designed for this study. *BYtZ* was designed to introduce students to and give them practice with the claim, evidence, reasoning (CER) framework for constructing scientific explanations. Engaging with the practice of scientific explanation during *BYtZ* was hypothesized to help make small improvements in students' ability to do so, and to also better prepare them to become experts in the practice as they move through school. Putting students in the role of Zombie Researchers in the 45-minute semi-formal traveling science program *BYtZ* was hypothesized to foster situational interest, which was hypothesized to, in turn, engage students in learning scientific explanation skills. A quantitative approach was used in this study to answer the following primary research question:

Did the short (45 min), one-time, semi-formal learning experience *BYtZ* engage students with the process of creating scientific explanations and improve their ability to do so? This overarching question was divided into the following specific questions:

1) Was there a positive change in students' construction of scientific explanations from the pre-test to the post-test?
2) Was there a positive change in student engagement as they progressed through the program?
3) Was there an association between students' level of engagement and their ability to construct scientific explanations?

Portfolio Description

The portfolio that follows includes three products that together encompass the same information and academic rigor found in a traditional dissertation format and fulfill the requirements thereof. I chose three products that have been and will be used, seen, and/or heard by students, teachers, and informal educators, to create a portfolio format dissertation that offers more to the community than the traditional format. The first product is a TSP curriculum that was designed for this dissertation but will continue to be offered as one of LSC's traveling science programs. The second product is a journal article that includes a review of relevant literature, outlines the research design and methods, and then reports on analyses of the data that evaluate whether students were engaged with and learned from the program. It will be submitted to *Science Education* where it will be accessible to both teachers and informal science educators to learn from. The final product is a professional development (PD) for my fellow LSC colleagues that was designed to enhance their understanding of how the program was designed and what lessons I learned through the process. The information could be helpful to LSC staff not only as they implement the *BYtZ* curriculum, but also as they design their own new TSPs and other semi-formal programs in the future. Altogether, the following three products support the goals of the Ed.D. program and the learning goals of the DLE concentration which are described for each product.

***BRAAAAINS: You & the Zombie* Curriculum.** The first product is the *BRAAAAINS: You & the Zombie (BYtZ)* curriculum. As a Design of Learning Environments (DLE) concentration student, I wanted a key component of my dissertation to revolve around designing a new learning intervention. As a Senior STEM educator at LSC, part of my professional responsibilities include developing new programs. Therefore, I chose to develop a new traveling science program (TSP) as part of my dissertation project. TSPs are 45-minute, semi-formal assemblies and classroom workshops that bring the learning resources of LSC to schools.

BYtZ is a 45-minute classroom workshop designed to teach middle schools students how to construct scientific explanations using the premise of a zombie outbreak to engage them with the material. I chose to design a program for middle school students because LSC currently offers fewer programs for those grade levels. I chose to design the program to help students learn how to construct scientific explanations because this is a skill that many students struggle with, and it is one of the science and engineering practices (SEPs) of the Next Generation Science Standards (NGSS). Explanations require evidence and gathering evidence can be an engaging process. However, coming from an informal science institution, it was also important to me that the designed TSP was not a typical formal, classroom-based evidence-gathering program. I wanted to make it fun and exciting, so that students were engaged with what they were learning. Therefore, I chose the premise of a zombie apocalypse because I knew it would grab students' attention, while also lending itself well to a program that required students to construct scientific explanations.

As informal science educators, it is important that the programs offered by LSC are fun, engaging, and different than the formal school learning kids regularly receive. However, to make our programs appealing and useful to the schools, it is also critical for us to build them based on the current science curriculum standards. Therefore, part of my professional responsibilities when designing new programs are to find creative, innovative, and rigorous ways to accomplish both of these tasks.

Journal Article. The second product is a scholarly journal article to be submitted to the journal *Science Education* in which I report the results of my study. I chose *Science Education* because I want to share my findings with the wider academic community of both formal and informal educators on how to effectively integrate the NGSS into semi-formal science programs without sacrificing the fun and excitement expected from informal science institutions. This product encompasses all of the key elements required by a dissertation. It includes a description of the context and problem of practice, a literature review, a methods section detailing data collection and analysis, a results section, and a discussion. Therefore, a research article supports the goals of the Ed.D. and meet the requirement for a more traditional scholarly item as part of the portfolio.

Professional Development for LSC Colleagues. The final product in my dissertation portfolio is a professional development seminar to supplement our normal training protocol for *BYtZ.* Ordinarily, when we are learning how to teach new programs, we observe other educators teach the program a few times. Once we are comfortable with the content, we then attempt to teach the program while one of the educators that is already an expert in that program observes us. The expert can provide just-in-time feedback, if needed, during the implementation of the program and give notes on areas of improvement after it. This has been a very effective method for learning to teach our programs. However, *BYtZ* has some key differences as compared to other LSC TSPs.

BYtZ is one of the first traveling science programs in the STEM Education department designed from the ground up to meet the NGSS, and the first to address one of the SEPs. Therefore, *BYtZ* has a practice-based emphasis as opposed to the more content-based emphasis of other LSC programs. This different emphasis is one of the main reasons I designed a PD to supplement the training of others how to teach this program. I believe it is important to break this program down into each component and describe why I have set it up to be taught in a specific way and order. My concern is that if I don't explain why the program is designed the way it is the emphasis will become the content instead of the practice of scientific explanations. While zombies and brain structures and functions are worthwhile things to learn, that information is not the purpose of the program. If the students walk away with a better understanding of how the brain works, that is positive, but the primary purpose of the program is for students to walk away with a better understanding of scientific explanations.

Additionally, since designing new programs is part of the STEM Educator's professional responsibilities, I thought it would be useful to my colleagues if I shared what I learned while designing *BYtZ* in case they find the information useful when designing their own programs. A discussion that has come up recently at work is whether students are learning from us and how we can quantify that so I have included my findings within the PD to share the knowledge with my colleagues. In order to best reach as many of my colleagues as possible to share why the program was designed the way it was, and what I learned through this process, it makes sense to hold a PD session to teach the entire team together.

Chapter 2: *BRAAAAINS: You & the Zombie* Curriculum

This chapter contains all of the documentation for the program *BRAAAAINS: You & the Zombie (BYtZ)*. The curriculum documentation is organized into five sections:

1. **Program Description -** The first item is the program description. This is an internal document that contains a brief overview and outline of the program for LSC educators to use as a refresher, and for LSC marketing staff to refer to when a potential client requests more information than the short advertising blurb (included in the program description) provided in the LSC program offerings booklet.
2. **Lesson Plan -** Next is the detailed lesson plan for *BYtZ* that LSC educators can use when learning the program and as a refresher if needed when a long time has elapsed since the last time they taught *BYtZ*.
3. **Presentation and Presenter Notes -** The next item is the PowerPoint presentation for *BYtZ* in its entirety. Additionally, select slides from key moments of the program and the accompanying presenter notes are provided.
4. **Student Worksheets -** The presentation is followed by the worksheets that students complete during *BYtZ*.
5. **Pre/Post-visit Packet -** The last item is the pre/post-visit packet. This is a standard LSC TSP document that is sent to the schools when they book one of our TSPs. This packet includes an overview of the program, a few day-of requirements, and a series of simple activities that the teachers can use. The activities can be used before we arrive to prepare the students for the content we will be presenting, as a follow-up to our visit to improve student understanding of some of the ideas learned, or a combination of the two.

Altogether these items make up the complete documentation for *BRAAAAINS: You & the Zombie* curriculum.

Program description

LIBERTY SCIENCE CENTER
WHERE THE FUTURE COMES TO PLAY

PROGRAM DESCRIPTION

Program Title: BRAAAAINS: You & the Zombie

Author(s): Kara Mann

Program Format: Classroom Workshop

Grade Level(s): 6-9

Overview:
Zombies are everywhere; at least they are in popular culture these days! While Zombies may not be real, they can help us learn real information about how our brains work. Students will join the Zombie Response Team as research scientists to help the CDC determine how a mutated strain of the Zombie Virus is altering zombie behavior, with special attention to whether these changes make the zombies more or less dangerous. To assess this students will first gain an understanding of the changes made by the unmutated virus to infected brains by comparing them to healthy human brains. Then they will compare brains from zombies infected with mutated strains of the virus to typical zombie brains. Students will be led through the process of creating a scientific explanation at each step of the way to become more proficient in this difficult science practice.

Rationale:
This program will help students improve their ability to construct scientific explanations by introducing them to the claim, evidence, reasoning framework. This is an area of the scientific endeavor that students classically struggle with therefore this program has been designed to help improve this skill. Additionally, this program will move students along in their understanding of the brain, its parts and functions, and how those functions affect our behavior. By taking on the role of Zombie Research Scientists participants will gain a deeper understanding of these brain functions through an anatomical and related behavioral comparison between healthy humans and zombies and predict the behavior of zombies infected with a mutated strain of the Zombie Virus.

Learning Objectives:
SWBAT:

1. Practice implementing the claim, evidence, reasoning framework for scientific explanation.
2. Explain why zombies behave the way they do and whether mutated strains of the zombie virus will change that behavior.
3. Describe how damage to certain areas of the brain can change behavior.

Big Ideas:

- Scientific explanations are a vitally important part of doing science, however, learning to make a claim and support that claim with appropriate evidence is not trivial, and it is something that students struggle with. Throughout this program students will learn to make a claim, support it with evidence, and give reasons as to how that evidence supports that claim.
- The human body is made up of interconnected organ systems that are regulated by the brain to keep us alive. The brain is not only running autonomously to keep our vital systems running, but it is also the part of our body that allows us to think, remember, make decisions, walk, talk, and interact with the people and the world around us.

Advertising Blurb for Web and Publications:
Zombies are everywhere these days! Join the Zombie Response Team as research scientists to help the government determine how a mutated strain of the zombie virus is altering zombie behavior. By identifying and explaining differences in behavior and capabilities of zombies and humans, gain a better understanding of how to construct a proper scientific explanation, and learn how the brain works along the way.

Resources/Materials Required:

iPads loaded with 3D Brain App http://www.g2conline.org/
XL 3D Printed Brains – Zombie and Healthy Specimens
Life size mutated zombie brains
Life size typical zombie brains for instructor
Handouts / worksheets
PowerPoint Presentation
Remote for PPT
Pencils

Background Information:
Some Basic Parts and Functions of the Brain

Amygdala: Emotional reactions, processing of fear, emotions, and rewards, fight or flight response.

Brain Stem: Involuntary functions, alertness, sleep, balance; connects brain to spinal chord.

Cerebellum: Muscle coordination, balance, posture.

Cingulate Gyrus: Self-regulation, pain processing, memory, emotions.

Frontal Lobe: Cognition, intelligence, decision making, problem-solving, language processing.

Hypothalamus: Regulates bodily functions such as hunger, thirst, body temperature, circadian rhythms, and sleep.

Motor Cortex: Voluntary movement, planning, executing, and coordinating movement.

Occipital Lobe: Processes vision.

Parietal Lobe: Touch, pressure, temperature, and pain perception; spatial reasoning.

Temporal Lobe: Learning and memory, sense of smell, language understanding.

Procedure:

<table>
<tr><td>Classroom Workshop</td><td>Introduction:

It’s a zombie outbreak! You are now part of the research team trying to solve the crisis!
We know the zombies are caused by a virus that attacks the brain, and that the virus is mutating.

Discussion and activity:

Since students aren’t neuroscience graduates, we need to review the brain!

Supplies:

iPads with 3D Brain App
http://www.g2conline.org/

Activity

Attempt brain structure and function matching activity in pairs
Complete & correct matching activity using 3D Brain app on the iPads
Review correct matches and discuss whether this gives us any ideas about zombie behavior
Introduce scientific explanations and CER framework

Discussion and activity:

Changes to the brain can result in changes to behavior
Need to gather evidence for zombie behavior

Supplies:

3D Printed Zombie and healthy brain specimens (extra large versions for front of the classroom)

Discuss

Odd zombie behaviors that make them different from uninfected humans

Activity

Compare the healthy and infected brains
Do observed differences make sense given zombie behavior?
Discuss CER for explanation of zombie behavior
</td></tr>
</table>

	Discussion and activity:
	• Mutations!
	Supplies:
	• 3D printed brains infected with mutated zombie virus
	  ○ One specimen per group of 4
	  ○ Worksheet to record observations
	Activity
	• Compare the brain specimen from a zombie infected with a mutated strain of the virus to the typical zombie brain
	• Determine whether those changes would result in a more or less dangerous zombie than the original
	• Write down a scientific explanation using the CER worksheet to explain how that zombie would behave differently than a typical zombie
	Whole Group Discussion
	• Review results of all mutations
	Review
	• Wrap up with review of brain parts and functions and understand of zombie behavior based on findings

NJ Student Learning Standards- Science/Next Generation Science Standards
This program helps build student competency toward meeting the following

Performance Expectations:

MS-LS1-3: Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

This program is primarily designed to support the following:

Science and Engineering Practices
Constructing Explanations and Designing Solutions:

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Engaging in Argument from Evidence:

- Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.

Additionally, this program supports the following:

Disciplinary Core Ideas
MS-LS1.A: In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.

Cross-cutting Concepts
Systems and System Models:

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions— including energy, matter, and information flows—within and between systems at different scales.

Pre-Visit Packet:
Available at: G:\Education\STEM Educators\TSP Programs\TSP Classroom Workshops\BRAAAAINS

References:

- 3D Brain App by Cold Spring Harbor Laboratory DNA Learning Center; Online version here: http://www.g2conline.org/
- https://www.biodigital.com/education

Lesson Plan

THIS DOCUMENT IS UNDER CHANGE CONTROL

DO NOT MAKE ANY MODIFICATIONS TO DOCUMENT WITHOUT PROVIDING DATA REQUESTED BELOW

TITLE: *BRAAAAINS: You & the Zombie*
DATE CREATED: March, 2017
AUTHOR: Kara Mann

CHANGE RECORD

Date	Reason for Change (short description)	Person making changes

BRAAAAINS: You & the Zombie

Overview:
Zombies are everywhere; at least they are in popular culture these days! While Zombies may not be real, they can help us learn real information about how our brains work. Students will join the Zombie Response Team as research scientists to help the CDC determine how a mutated strain of the Zombie Virus is altering zombie behavior, with special attention to whether these changes make the zombies more or less dangerous. To assess this students will first gain an understanding of the changes made by the unmutated virus to infected brains by comparing them to healthy human brains. Then they will compare brains from zombies infected with mutated strains of the virus to typical zombie brains. Students will be led through the process of creating a scientific explanation at each step of the way to become more proficient in this difficult science practice.

Learning Objectives:
SWBAT

1. Practice implementing the claim, evidence, reasoning framework for scientific explanation.
2. Explain why zombies behave the way they do and whether mutated strains of the zombie virus will change that behavior.
3. Describe how damage to certain areas of the brain can change behavior.

Materials:

- Large 3D Printed healthy brain
- Large 3D Printed zombie brain
- 3D printed mutated virus zombie brains
- 3D printed typical zombie brains for educators
- PowerPoint presentation (available on flash drive in the kit as well)
- iPad minis loaded with 3D Brain app
- Student worksheets
- Pencils

Next Generation Science Standards

This program will focus on building students' competence in the **Scientific and Engineering Practice** <u>Constructing Explanations and Designing Solutions:</u> *Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena; construct an explanation using models or representations.* Additionally, the program will build knowledge toward the **Performance Expectation** *MS-LS1-3: Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells* and the **Disciplinary Core Idea** *LS1.A: Structure and Function - In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.*

Procedure:

1. Zombie Response Team and Goals of the Day

- Explain to students that there has been a zombie outbreak and that the Zombie Response Team (ZRT) unit of the CDC (centers for disease control) needs as much help as they can get, therefore, they have been recruited as junior CDC agents as part of the ZRT trying to solve this crisis.

- Inform students of what the ZRT has already discovered: that a virus that attacks key parts of the brain is responsible for the zombie outbreak, and we have just learned that the virus is mutating. Ask students what that word mutating means. Some students are not familiar with it outside of XMen and similar fantasy scenarios. It is important that they understand that mutation means change, so the virus is changing.

- Describe the key goals for the day: students will have to explain why zombies behave the way they do, determine whether the new strains of the virus damage the brain in different ways than the original virus, and whether those changes would alter the zombies' behavior, specifically would those zombies be more or less dangerous than the typical zombies.

2. Review of key brain structures

- Hand out worksheets and have students work in pairs to try and match each brain structure with its function. Give them a few minutes to work on this without the 3D brain app.

- Regain student attention and explain that you are going to give them a tool now to help them correct any mistakes they might have made and finish matching the structures and functions.

- Demonstrate and explain how the 3D brain app works, make sure to call students' attention to the structures list, the information section (marked with a T, maybe for Text?), which subsections of the information they should look at (overview, associated functions, associated with damage), and what the passcode is if the iPads falls asleep (5867 / JUMP).

- Give students time to work on finishing the matching on their own, but circulate to ensure that they all understand how to use the app and where to look to get the info that they need. Demonstrate how to locate a specific structure and the info about that structure if necessary. Continue circulating and guide students in the right direction where needed. If many students are making similar mistakes, give the whole class clues.

- When most students seem to be finished bring the group back together and go over the matching to make sure everyone has everything matched correctly. Let them know this paper will be useful to them for the rest of the program so they should make sure to pay attention and correct any mistakes they might have made.

3. Hypotheses and Scientific Explanations Intro

- Now that they know a little more about the brain, students are asked to give some hypotheses about what parts of the brain they think might be damaged by the zombie virus.

- Agree that these are all good guesses, but we need to be good scientists and give our answer as a good scientific explanation.

- Go over the CER framework. Explain that every good scientific explanation has 3 components:
    - Claim*:* A conclusion that answers the original question
    - Evidence: Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.
    - Reasoning: A justification that links the claim and evidence. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.

- Ask the students what the first thing we need to know to answer a question about zombie behavior is. We need to make sure we're all on the same page about how exactly zombies behave. Some ideas about zombie behavior should have already come up with the hypotheses, but note we don't know for sure exactly what kind of zombies these are. So we need to find out.

4. Behavior

- Review the "footage" of the zombies

- Note how they walk – uncoordinated, slow, stumbling

- Note that the zombies in the second clip are not very smart, they are fooled by healthy humans stumbling through the crowd acting like zombies

- Finally review the zombies' key behaviors from our knowledge and the videos: they are aggressive, always hungry, never sleep, uncoordinated, and unintelligent.

5. Brain Comparison – Healthy Human vs. Typical Zombie

- Remind students that we are trying to answer the question "why is zombie behavior so different than human behavior"

- Now we know exactly how zombies behave, and we've made some guesses as to why based on what we know of the brain. But to construct a scientific explanation that requires a claim, evidence, and reasoning, what do we need? Evidence!

- Show students the healthy human brain and the typical zombie brain. Explain that these are oversized 3D printed models based on compiled data from many human and zombie brains, so these are models of the average healthy human brain and the average zombie brain infected with the original strain of the virus. (You will probably want to tell them the one is red because that was the color filament in the printer. Also hold the brains up to your head to demonstrate that they are XL and not life size.)

- Ask the students what the first thing is that they notice that is different between the two brains.
    - The frontal lobe is missing. Have them remind you what the function of the frontal lobe is (intelligence / problem solving / planning / etc.).
    - Point out though that the motor cortex is in tact. Ask whether this makes sense given that zombies are not coordinated. Take answers but wait to put it together

- Next compare the healthy cerebellum to the zombie cerebellum and ask what is different
    - The zombie cerebellum is all shriveled up and damaged.
    - Ask if this makes sense. It does because zombies are not coordinated (cerebellum damaged), but they can move (motor cortex in tact)
    - Note that the primary motor cortex is like the engine and the cerebellum like the steering wheel.

- Next compare the brain stem of the healthy to the zombie brain
    - Ask students what they notice
    - Amygdala – the amygdala is all but gone and as we learned a damaged amygdala can lead to aggression.
    - Hypothalamus – this too is all but gone, and as we learned it controls things such as hunger and sleep.

- Now do we have evidence to support our hypotheses? Yes. So let’s put it all together.

6. Scientific Explanation – Why is zombie behavior so different than human behavior?

- Ask students to give you a really general claim for why the zombies behave like they do.
    - The virus damages key parts of the brain.
- Ask them for our evidence.
    - The cerebellum, prefrontal cortex, amygdala, and hypothalamus are all severely damaged.
- Ask them for some reasoning. Remind them they have already been doing some of this all along when they made their hypotheses.
    - The brain controls everything, when it becomes damaged it can’t function properly anymore which leads to changes in behavior. When the cerebellum is damaged we see loss of coordination. When the hypothalamus is damaged, we see constant hunger and failure to sleep. A damaged amygdala leads to the aggression we see. And finally, a mostly missing prefrontal cortex means the zombie no longer possesses the ability to problem solve, plan, or reason; it is unintelligent.

7. Virus Mutations

- The final task for the day is to determine whether the new strains of the virus are having different effects on the brain than the original virus. Is the brain more damaged? Less damaged? How would this change the behavior of those zombies? Would they be more dangerous or less dangerous?

- Explain to the students that they will be working in groups of 4, and that each group will get a brain that has been infected with one of the four identified strains of the zombie virus. They have 3 goals, they are to
    - Determine whether any part of the brain looks different than the normal zombie brain we looked at together as a group. Are any parts more damaged? Less damaged? Changed in another way?
    - Assess whether and how these differences would change the behavior of the zombie, and whether that would make the zombie more or less dangerous.
    - Explain their findings to the CDC in the form of a scientific explanation that follows the CER framework.

- Remind them that they are looking for differences between the brains they were given to look at, and the typical zombie brain we looked at together.

- Circulate through the room and help students recognize how their brain specimen is different than the typical zombie brain. Prompt them to tell you how that would change that zombie's behavior and whether that would be more or less dangerous than a normal zombie. Remind them to write it up as an explanation.

- Go over each mutation, have the students give their explanations and revoice what they said and pick out the claim, evidence, and reasoning to review those concepts one final time.
    - More dangerous mutations:
        - Prefrontal cortex is less damaged – more intelligent zombies
        - Cerebellum is less damaged – more coordinated zombies
    - Less dangerous mutations:
        - Hypothalamus is less damaged – zombies can control hunger, will sleep
        - Amygdala is less damaged – less aggressive zombies

Wrap-up and Clean Up

- Remind students that scientific explanations are an important part of doing science, and that they have done a great job getting started on constructing them.

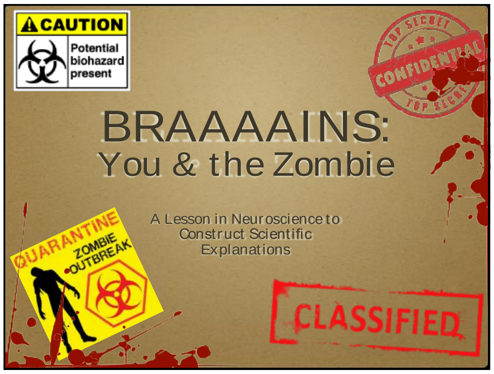
- Have the students carefully put the brains back together (if they are apart) and place them back in the correct specimen container.

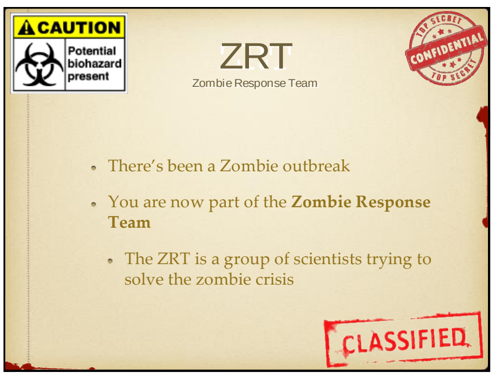
- Collect the brains and iPads. Students can keep the worksheets.

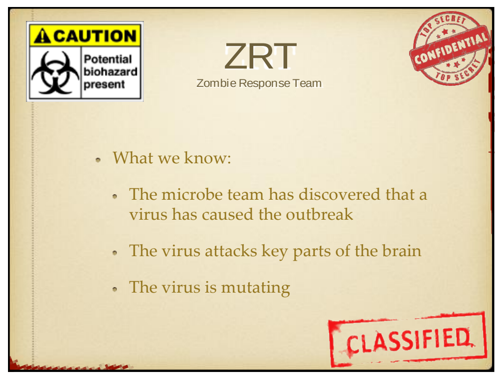
Some Basic Parts and Functions of the Brain

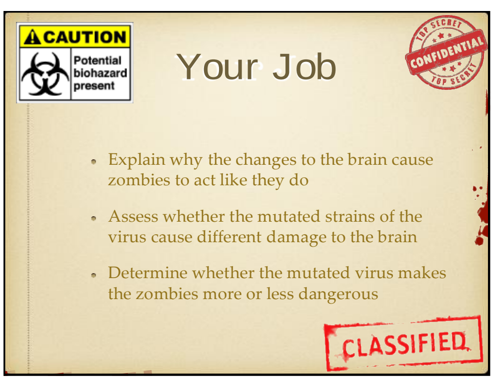
Amygdala:	Emotional reactions, processing of fear, emotions, and rewards, fight or flight response. Damage to amygdala leads to aggression and irritability.
Brain Stem:	Connects brain to spinal cord. Amygdala and hypothalamus are part of the brain stem.
Cerebellum:	Controls coordination, balance, and posture; damage to it causes loss of coordination and inability to walk
Frontal Lobe:	Cognition, intelligence, decision making, problem-solving, language processing.
Hypothalamus:	Regulates bodily functions such as hunger, thirst, body temperature, circadian rhythms, and sleep.
Motor Cortex:	Voluntary movement, planning, executing, and coordinating movement.
Occipital Lobe:	Processes vision.
Parietal Lobe:	Touch, pressure, temperature, and pain perception; spatial reasoning.
Prefrontal Cortex:	Planning, reasoning, and judgment; personality and emotion
Primary Motor Cortex:	Critical for initiation of movement; associated with some coordination
Temporal Lobe:	Learning and memory, sense of smell, language understanding.

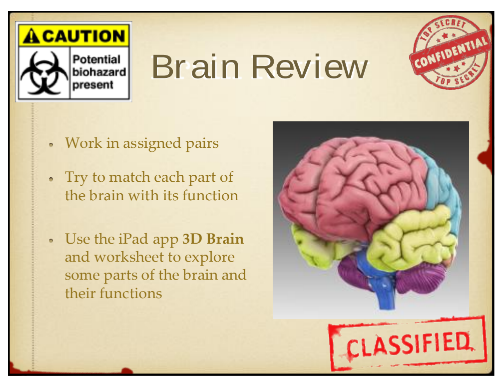
Presentation and Presenter Notes

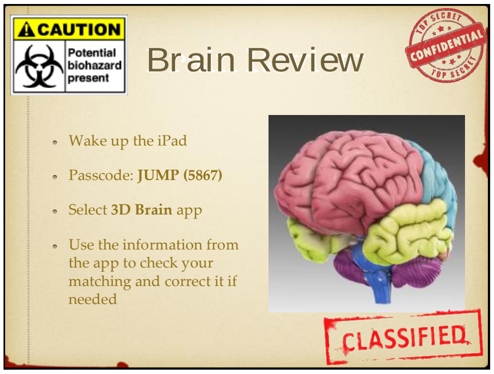











CAUTION
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Brain Review
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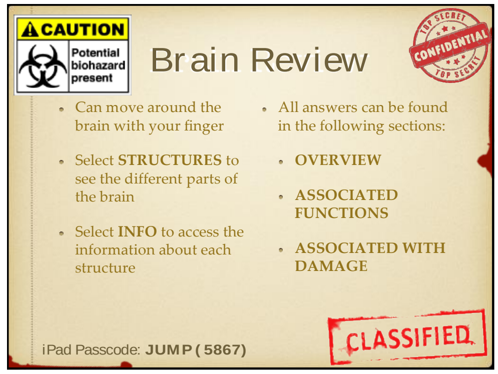
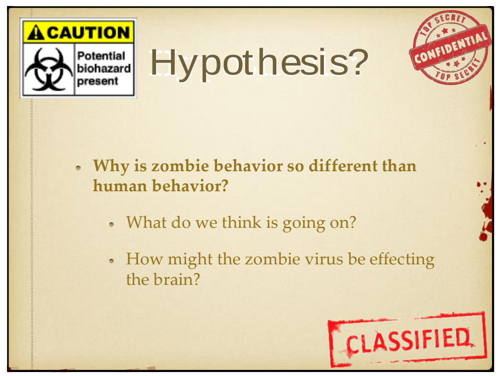
Wake up the iPad
Passcode: JUMP (5867)
Select 3D Brain app
Use the information from the app to check your matching and correct it if needed
CLASSIFIED


CAUTION
Potential biohazard present
Brain Review
TOP SECRET CONFIDENTIAL TOP SECRET
Can move around the brain with your finger
Select STRUCTURES to see the different parts of the brain
Select INFO to access the information about each structure
All answers can be found in the following sections:
OVERVIEW
ASSOCIATED FUNCTIONS
ASSOCIATED WITH DAMAGE
iPad Passcode: JUMP (5867)
CLASSIFIED


CAUTION
Potential biohazard present
TOP SECRET CONFIDENTIAL TOP SECRET
Experience Check-In
CLASSIFIED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Hypothesis?
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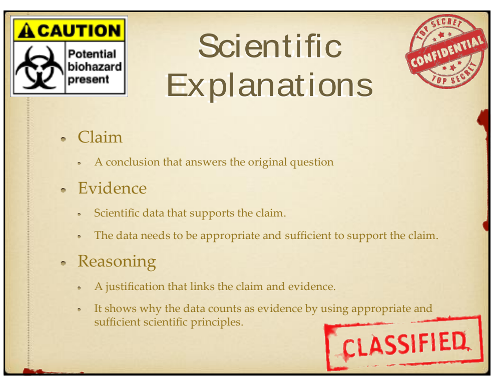
Why is zombie behavior so different than human behavior?
What do we think is going on?
How might the zombie virus be effecting the brain?
CLASSIFIED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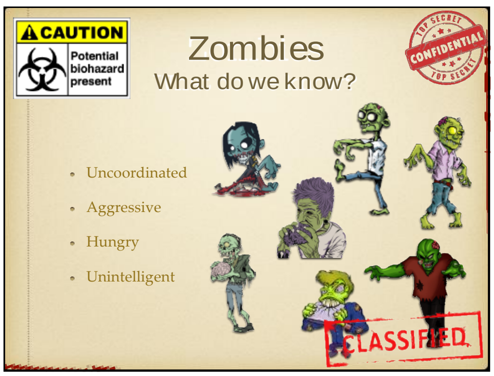
Scientific Explanations
TOP SECRET CONFIDENTIAL TOP SECRET
Claim
A conclusion that answers the original question
Evidence
Scientific data that supports the claim.
The data needs to be appropriate and sufficient to support the claim.
Reasoning
A justification that links the claim and evidence.
It shows why the data counts as evidence by using appropriate and sufficient scientific principles.
CLASSIFIED


CAUTION
Potential biohazard present
What we know: Behavior
CLASSIFIED


CAUTION
Potential biohazard present
Zombies
What do we know?
TOP SECRET CONFIDENTIAL TOP SECRET
CLASSIFIED


CAUTION
Potential biohazard present
Zombies
What do we know?
TOP SECRET CONFIDENTIAL TOP SECRET
CLASSIFIED


CAUTION
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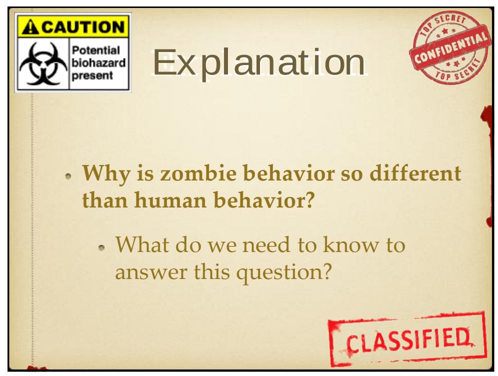
Zombies
What do we know?
TOP SECRET CONFIDENTIAL TOP SECRET
• Uncoordinated
• Aggressive
• Hungry
• Unintelligent
CLASSIFIED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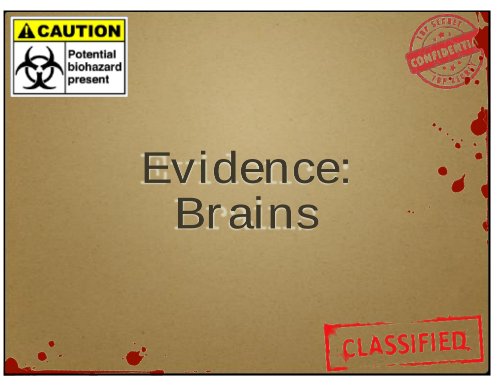
Explanation
TOP SECRET CONFIDENTIAL TOP SECRET
• Why is zombie behavior so different than human behavior?
• What do we need to know to answer this question?
CLASSIFIED


CAUTION
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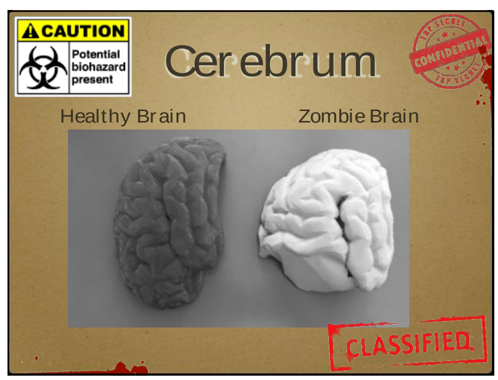
Evidence:
Brains
CLASSIFIED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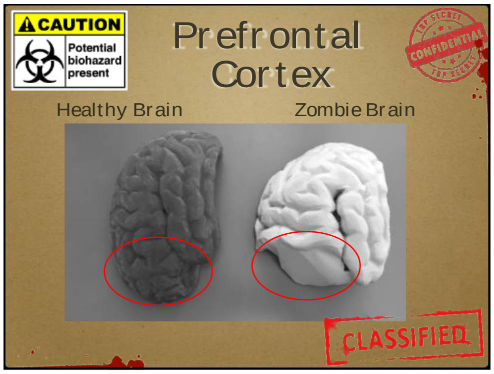
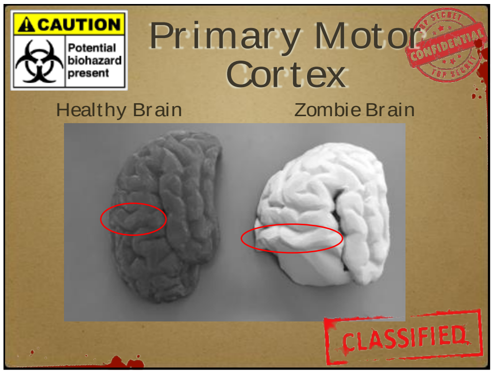
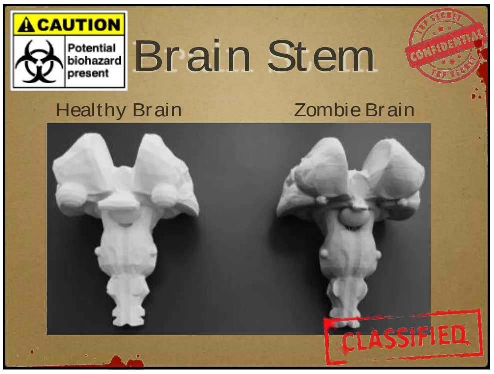
Cerebrum
Healthy Brain
Zombie Brain
CLASSIFIED


CAUTION
Potential biohazard present
Prefrontal Cortex
Healthy Brain
Zombie Brain
CONFIDENTIAL
CLASSIFIED


CAUTION
Potential biohazard present
Primary Motor Cortex
Healthy Brain
Zombie Brain
CONFIDENTIAL
CLASSIFIED


CAUTION
Potential biohazard present
Cerebellum
Healthy Brain
Zombie Brain
CONFIDENTIAL
CLASSIFIED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Brain Stem
Healthy Brain
Zombie Brain
CONFIDENTIAL
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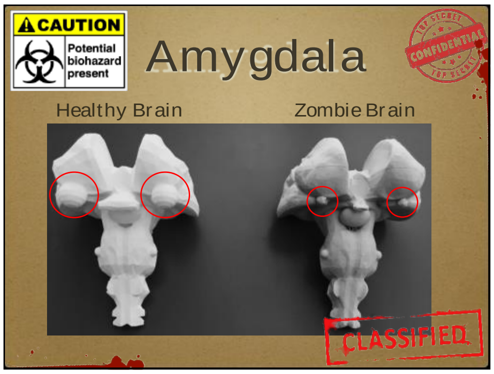
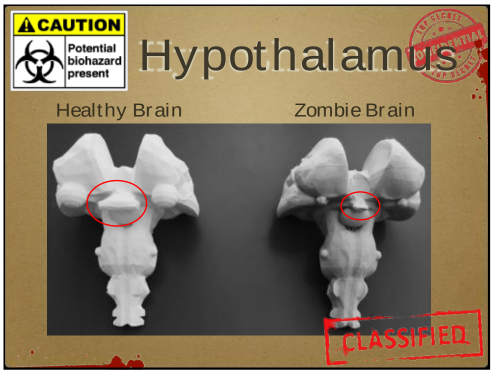

CAUTION
Potential biohazard present
Amygdala
Healthy Brain
Zombie Brain
CONFIDENTIAL
CLASSIFIED


CAUTION
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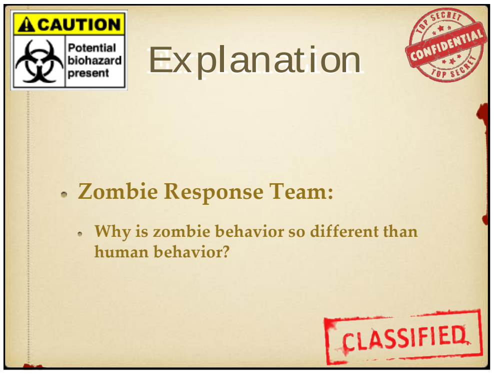
Hypothalamus
Healthy Brain
Zombie Brain
CLASSIFIED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Explanation
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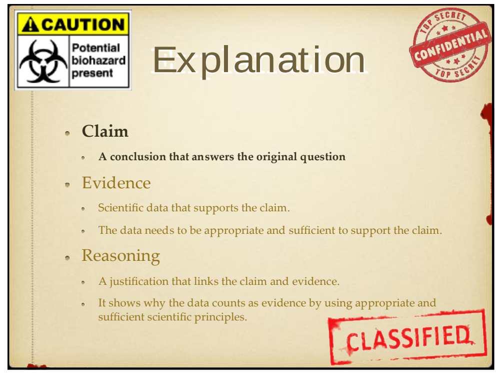
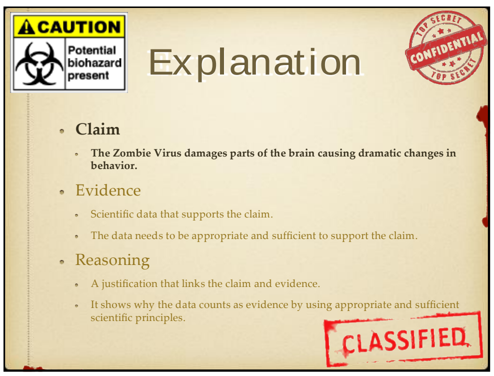
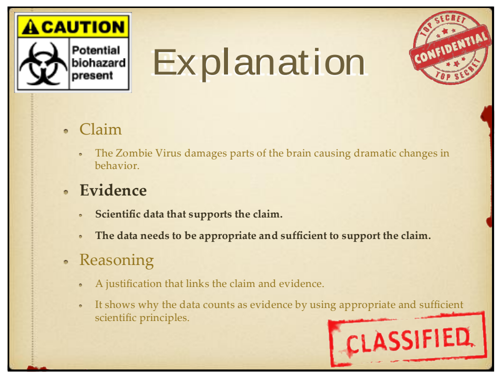
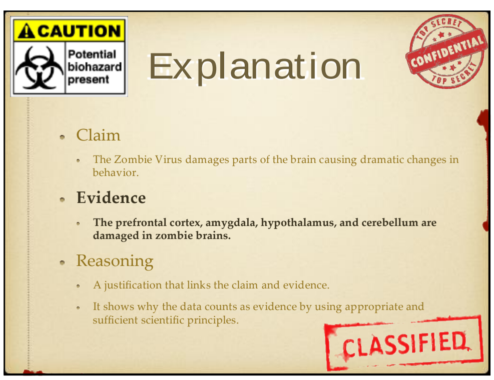
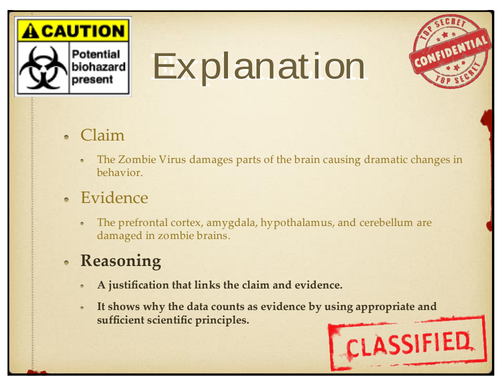
Zombie Response Team:
Why is zombie behavior so different than human behavior?
CLASSIFIED

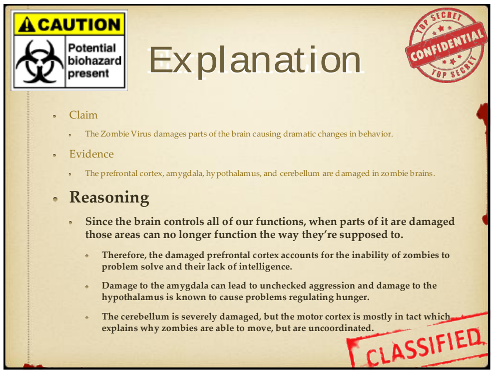

CAUTION
Potential biohazard present
Explanation
TOP SECRET CONFIDENTIAL TOP SECRET
Claim
A conclusion that answers the original question
Evidence
Scientific data that supports the claim.
The data needs to be appropriate and sufficient to support the claim.
Reasoning
A justification that links the claim and evidence.
It shows why the data counts as evidence by using appropriate and sufficient scientific principles.
CLASSIFIED


CAUTION
Potential biohazard present
Explanation
TOP SECRET CONFIDENTIAL TOP SECRET
Claim
The Zombie Virus damages parts of the brain causing dramatic changes in behavior.
Evidence
Scientific data that supports the claim.
The data needs to be appropriate and sufficient to support the claim.
Reasoning
A justification that links the claim and evidence.
It shows why the data counts as evidence by using appropriate and sufficient scientific principles.
CLASSIFIED

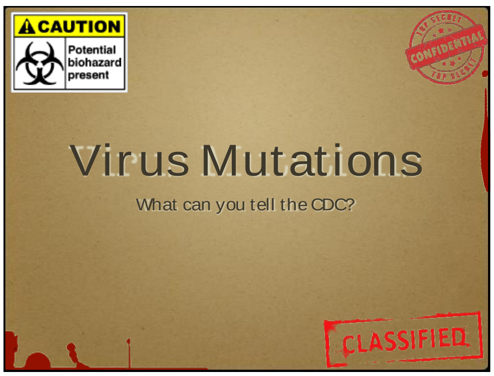

CAUTION
Potential biohazard present
Explanation
TOP SECRET CONFIDENTIAL TOP SECRET
Claim
The Zombie Virus damages parts of the brain causing dramatic changes in behavior.
Evidence
Scientific data that supports the claim.
The data needs to be appropriate and sufficient to support the claim.
Reasoning
A justification that links the claim and evidence.
It shows why the data counts as evidence by using appropriate and sufficient scientific principles.
CLASSIFIED

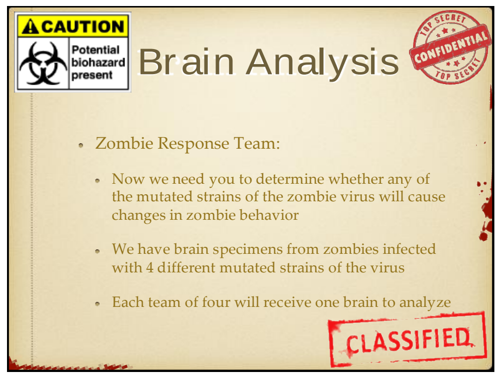

CAUTION
Potential biohazard present
Explanation
TOP SECRET CONFIDENTIAL TOP SECRET
Claim
The Zombie Virus damages parts of the brain causing dramatic changes in behavior.
Evidence
The prefrontal cortex, amygdala, hypothalamus, and cerebellum are damaged in zombie brains.
Reasoning
A justification that links the claim and evidence.
It shows why the data counts as evidence by using appropriate and sufficient scientific principles.
CLASSIFIED

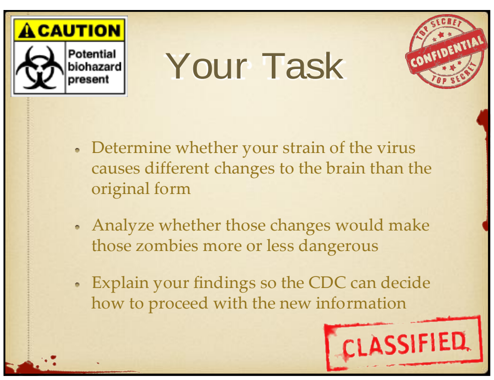

CAUTION
Potential biohazard present
Explanation
TOP SECRET CONFIDENTIAL TOP SECRET
Claim
The Zombie Virus damages parts of the brain causing dramatic changes in behavior.
Evidence
The prefrontal cortex, amygdala, hypothalamus, and cerebellum are damaged in zombie brains.
Reasoning
A justification that links the claim and evidence.
It shows why the data counts as evidence by using appropriate and sufficient scientific principles.
CLASSIFIED

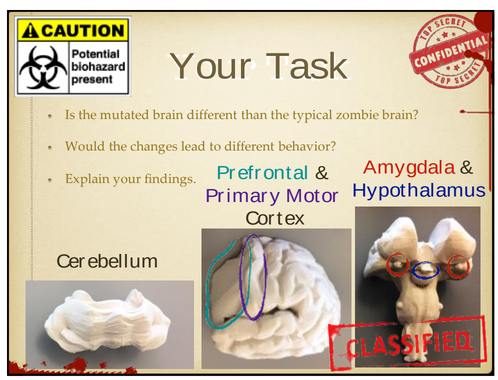

CAUTION
Potential biohazard present
Explanation
TOP SECRET
CONFIDENTIAL
TOP SECRET
Claim
The Zombie Virus damages parts of the brain causing dramatic changes in behavior.
Evidence
The prefrontal cortex, amygdala, hypothalamus, and cerebellum are damaged in zombie brains.
Reasoning
Since the brain controls all of our functions, when parts of it are damaged those areas can no longer function the way they're supposed to.
Therefore, the damaged prefrontal cortex accounts for the inability of zombies to problem solve and their lack of intelligence.
Damage to the amygdala can lead to unchecked aggression and damage to the hypothalamus is known to cause problems regulating hunger.
The cerebellum is severely damaged, but the motor cortex is mostly in tact which explains why zombies are able to move, but are uncoordinated.
CLASSIFIED

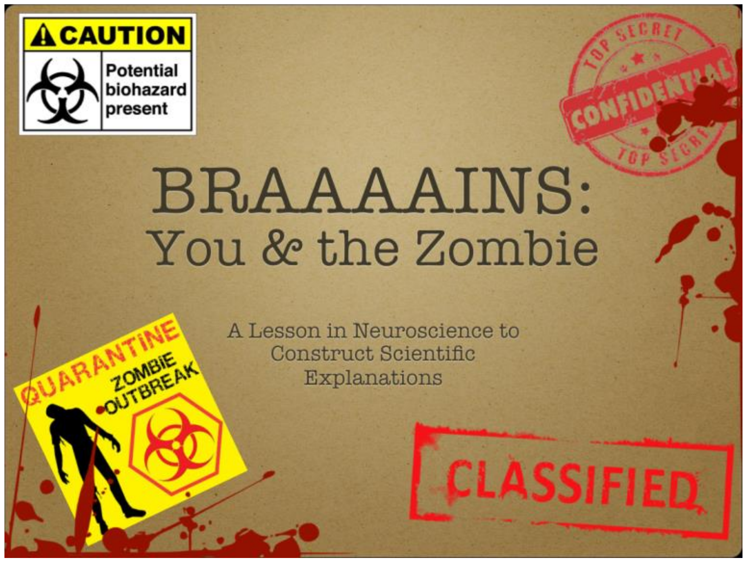

CAUTION
Potential biohazard present
Experience Check-In
CLASSIFIED


CAUTION
Potential biohazard present
Virus Mutations
What can you tell the CDC?
CLASSIFIED

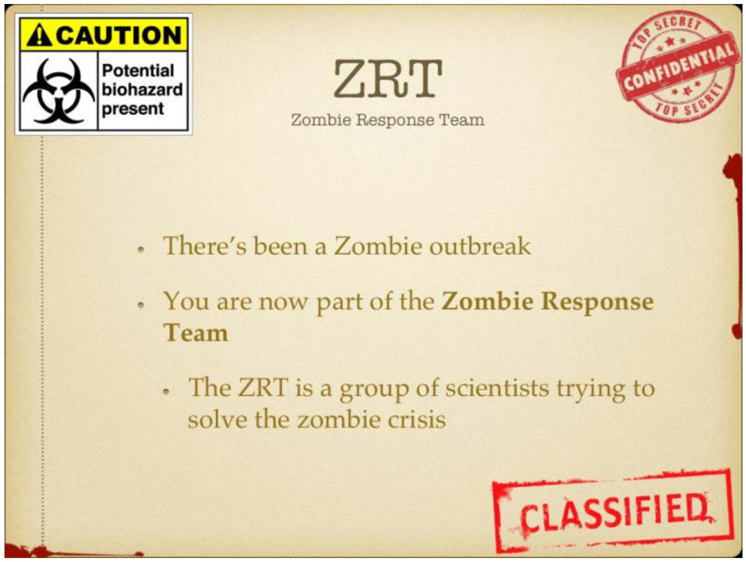

CAUTION
Potential biohazard present
Brain Analysis
CONFIDENTIAL
Zombie Response Team:
Now we need you to determine whether any of the mutated strains of the zombie virus will cause changes in zombie behavior
We have brain specimens from zombies infected with 4 different mutated strains of the virus
Each team of four will receive one brain to analyze
CLASSIFIED


CAUTION
Potential biohazard present
Your Task
CONFIDENTIAL
Determine whether your strain of the virus causes different changes to the brain than the original form
Analyze whether those changes would make those zombies more or less dangerous
Explain your findings so the CDC can decide how to proceed with the new information
CLASSIFIED


CAUTION
Potential biohazard present
Your Task
CONFIDENTIAL
Is the mutated brain different than the typical zombie brain?
Would the changes lead to different behavior?
Explain your findings.
Prefrontal & Primary Motor Cortex
Amygdala & Hypothalamus
Cerebellum
CLASSIFIED

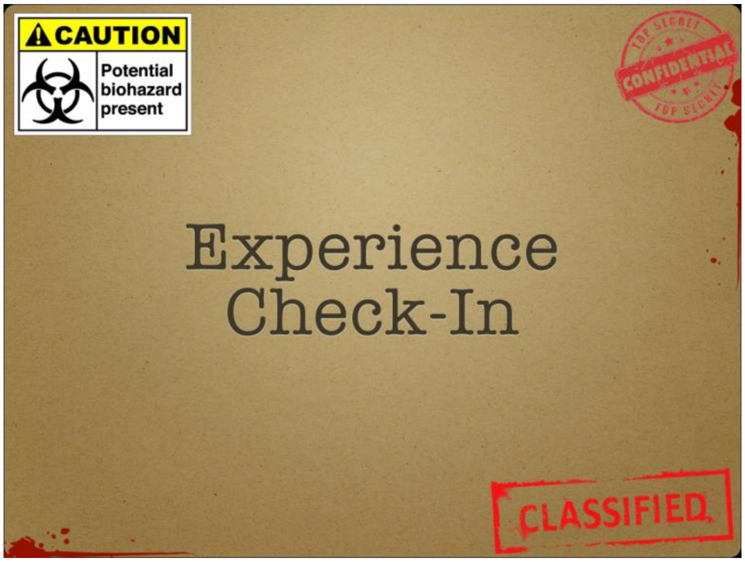


Kara Mann
STEM Educator at Liberty Science Center
Rutgers Graduate School of Education
Liberty Science Center Traveling Science Program
January, 2018

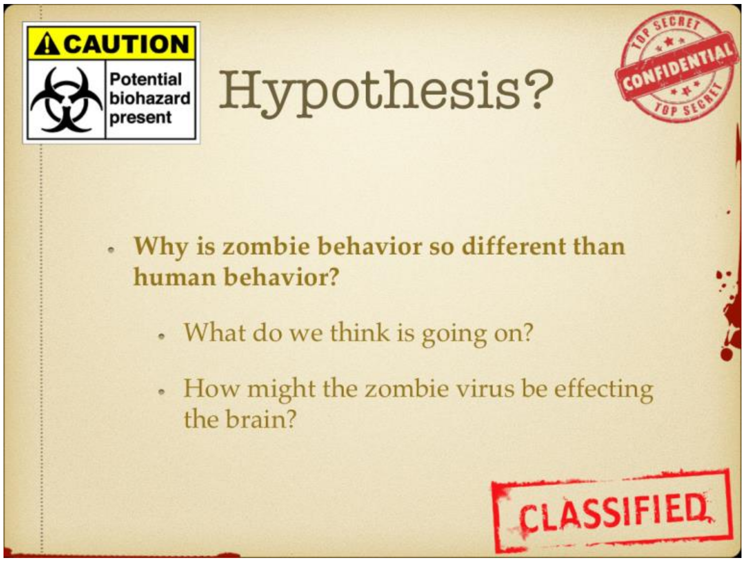


Slides 3- 5: Introduction to the premise and the problem students will be solving.

- Students learn:
- That we're in the middle of a zombie outbreak, and they have been recruited to be part of the Zombie Response Team, a faction of the CDC and they are now junior CDC agents on the team

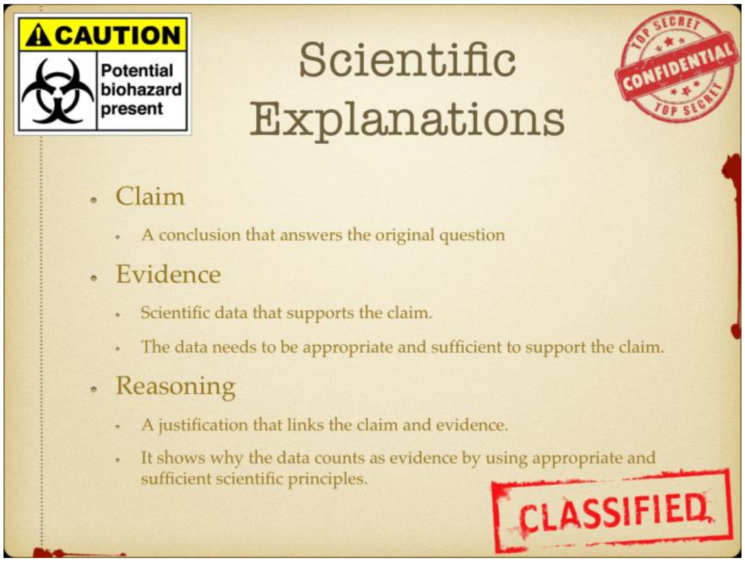


Program is paused to assess student engagement with the iPad activity during data collection.



Slide 10: Begin thinking about possible explanations

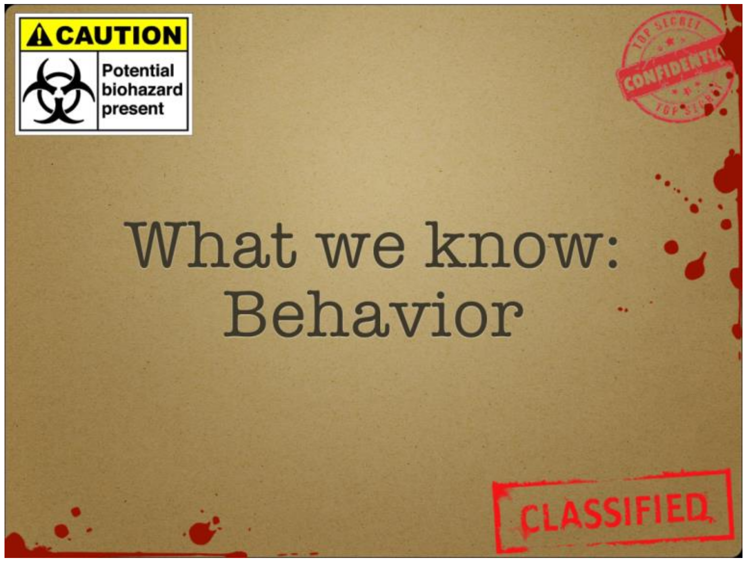
Students are asked to give preliminary hypotheses based on what they have just learned about the brain, and what they may already know about zombies



Slide 11: CER Framework Introduction

Students are introduced to the claim, evidence, reasoning framework for constructing scientific explanations

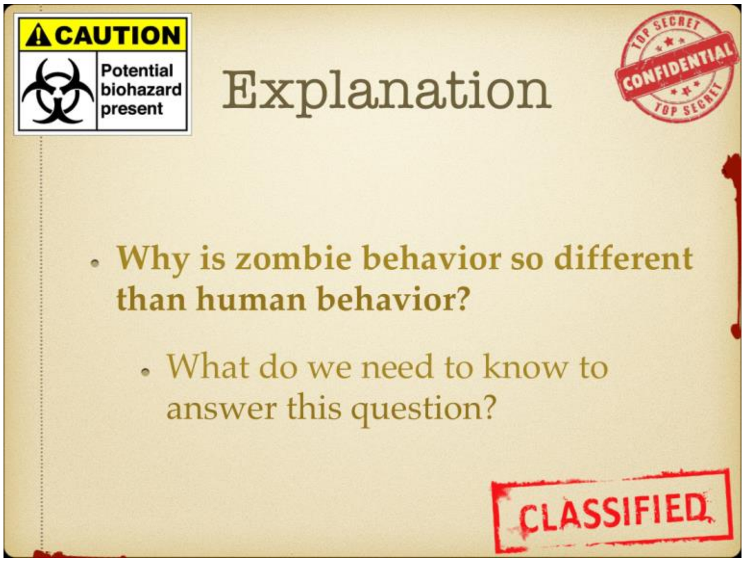
- They are reminded that they were just asked for some hypotheses (guesses) about why zombie might behave the way



Slides 12-15: Zombie behavior

To explain why zombie behavior is different, we need to know how zombies behave.

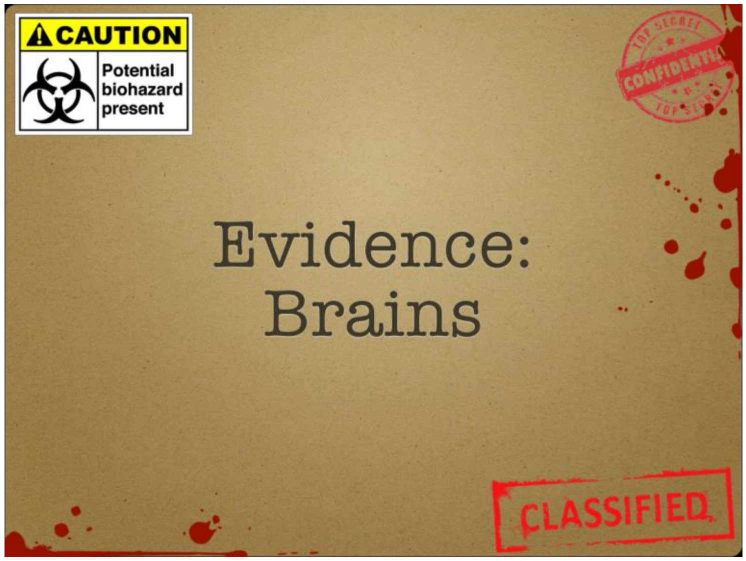
- Students are shown 2 video clips of “footage” of the zombies in this outbreak
- The videos demonstrate that these are the slow moving, uncoordinated kind of zombies



Slide 16: What else do we need to know?

Now we know how these zombies behave. What else do we need to form a scientific explanation to answer our question?

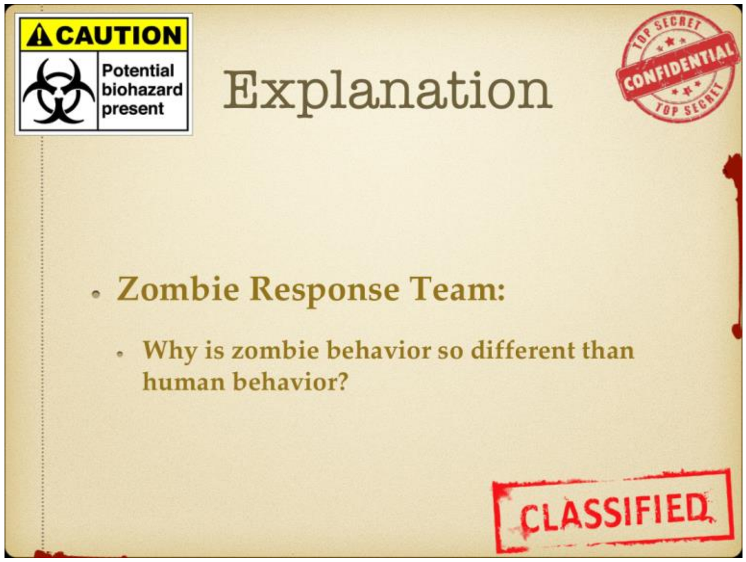
- We need evidence.



Slide 17-24: Healthy human brain vs. typical zombie brain comparison

Students are shown an oversized 3D printed model of an average healthy human brain and an average typical zombie brain and asked to point out the difference and each difference is discussed

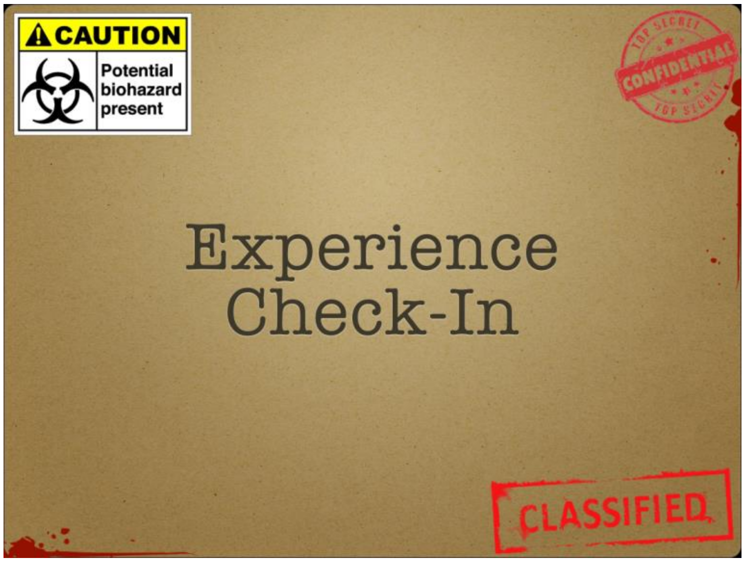
- The zombie brain is all but



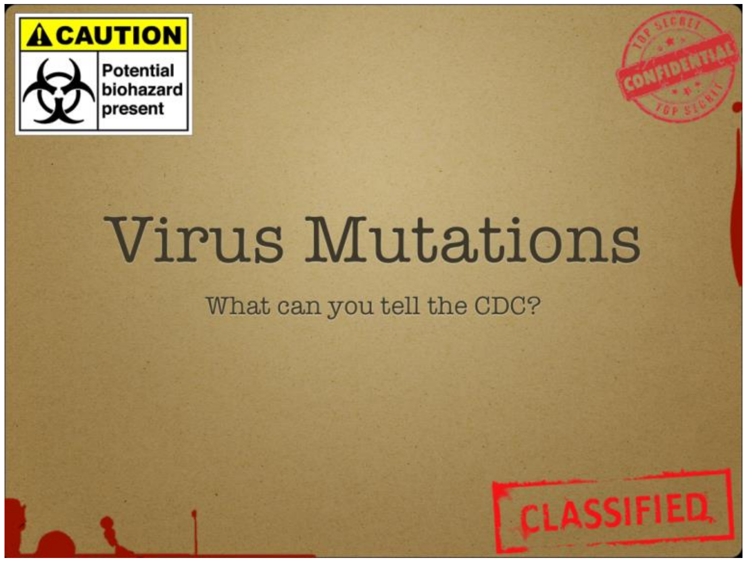
Slide 25-31: Putting together a Scientific Explanation

Here we revisit our question "why is zombie behavior so different than human behavior?"

- Now that we know exactly how zombie behavior looks, and have gathered evidence about the brain, it is time to put together a scientific explanation



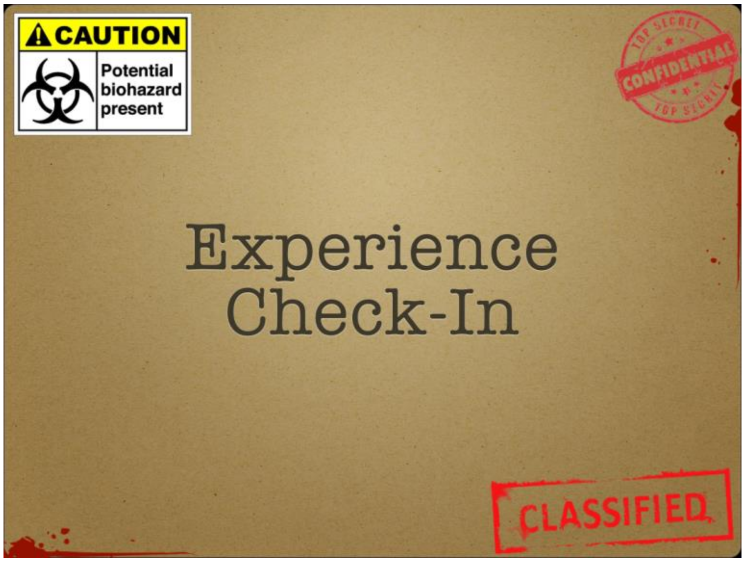
Program is paused to check student engagement with the brain comparison and explanation.



Slide 33-36: Mutated virus strains

Students examine zombie brains infected with mutated strains of the virus to determine whether the brains are damaged in different ways and how that would change the behavior of those zombies

- Students are reminded that one of their tasks is to determine whether the mutated strains of



Final experience check- in to check level of student engagement with the virus mutation brain comparison activity.

Student Worksheets

Let's review some key functions of the brain!

Match each structure of the brain to its function

Brain structure	Function
Prefrontal Cortex	Controls coordination, balance, and posture; damage to it causes loss of coordination and inability to walk
Cerebellum	Critical for initiation of movement; associated with some coordination
Hypothalamus	Damage to this part of the brain leads to aggression and irritability
Amygdala	Regulates functions necessary for survival including: hunger, thirst, and sleep
Primary Motor Cortex	Planning, reasoning, and judgment; personality and emotion

Recommendation to the Centers for Disease Control

Zombie researchers have noticed that the Zombie Virus is mutating, and they are concerned that this may cause changes to how it affects the brain of infected people. Work in groups of four to look at a brain infected with a mutated strain of the virus and determine whether or not there is need for concern.

Use the following Claim-Evidence-Reasoning format to take notes to help you convince the CDC that your conclusion is correct. We will discuss your conclusions as a group.

Zombie Virus Mutation #:_ZV-___________

Claim
(Would this zombie behave differently, if so, how?)

Evidence
(Provide scientific data to support your claim. Use evidence from your group's investigation of the brain infected with an altered strain of the virus.)

Reasoning
(Explain why your evidence supports your claim. How did the evidence allow you to determine whether this zombie would behave differently?)

Pre/Post-Visit Packet – For Schools

BRAAAAINS:
You & the Zombie

Come join the Zombie Response Team and help us understand how the zombie virus affects the brain of its victims. Through this research you will gain an understanding of how the brain regulates the different functions of our bodies, controls our mood and behavior, allows us to think and remember, and most importantly what separates us from them!

Recommended Grade Level: 6-9

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BRAAAAINS: You & the Zombie

Program Information

NJ Student Learning Standards- Science/Next Generation Science Standards

This program helps build student competency toward meeting the following

Performance Expectations:

MS-LS1-3: Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

For a detailed list of the Dimensions of Learning supported in this program, please refer to the end of this document.

Learning Objectives:

By the end of the presentation, the students will know and be able to:

- Describe how damage to certain areas of the brain can change behavior.
- Explain why zombies behave the way they do and how that relates to how the brain normally works in healthy humans.
- Defend their scientific explanation by supporting their argument with appropriate evidence.

Program Overview:

Zombies are everywhere; at least they are in popular culture these days! While Zombies may not be real, they can help us learn real information about how our brains work. Students will join the Zombie Response Team as research scientists to help the CDC determine how a mutated strain of the Zombie Virus is altering zombie behavior, with special attention to whether these changes make the zombies more or less dangerous. To assess this, students will first gain an understanding of the changes made by the unmutated virus to infected brains by comparing them to healthy human brains. By identifying differences in behavior and capabilities of zombies and humans, students will gain an understanding of how the brain regulates various functions, controls our mood and behavior, and allows us to think, learn and remember. In addition, students will become more proficient in their scientific explanation and argumentation skills.

Special Instructions:

- Please see Equipment Requirements below

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Thank you for reserving **BRAAAAINS: You & the Zombie**

There are just a few things we will need:

1. Parking:

- Safe, legal parking with easy access to our vehicle must be provided.

2. Space:

- Our program requires a regular-sized classroom with one large table set up for our materials. Additionally students will be working in groups of 2-4 and will need desks or tables to sit and work at. ***(For safety reasons, we cannot have students in the area while we are engaged in the set-up or breakdown of programs.)***

3. Equipment:

- A Smartboard, projector, or whiteboard we can project on, and access to electrical outlets.

4. Restrictions:

- The group size is limited to a maximum of 30 per workshop.

5. Directions:

- If you know that GPS or online directions to your location are inaccurate**, please provide correct directions to your site**. You may inform your reservation specialist using the phone number below.

Please contact 201.253.1310
if any of these outlined criteria present an issue.

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BRAAAAINS: You & the Zombie
Pre-Visit Activity Guide

This packet contains some simple classroom activities utilizing everyday, inexpensive (or even free!) items. Please feel free to duplicate these pages as needed - they are sent on plain white paper to ensure the best quality of reproduction.

We suggest that these activities be conducted before our visit in order to familiarize students with some of the concepts we will explore together during our **BRAAAAINS: You & the Zombie** presentation. However, they may be performed after our visit to serve as a reinforcement of the concepts covered in the program. If and when you choose to use these activities, or whether or not the activities are appropriate for your class, is entirely at your discretion.

If you have questions about any of the enclosed activity procedures, please call the Associate Director of STEM Educators and Offsite Education at 201.253.1472 .

We thank you for your interest in our program and eagerly look forward to visiting your school!!!

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Brain Charades

Objectives:

- Recognize the numerous functions and actions the brain controls.
- Identify the parts of the brain and what functions are associated with each region.
- Differentiate voluntary and involuntary functions and actions of the human body.

Materials:

- Handout with cross-section image of human brain (see step 4c under Procedure)
- Pencil, colored pencils or crayons
- Computers with Internet access
- Index cards.

Background:
Every time you breathe, sweat, dance, feel pain, recall a favorite memory, and even solve a math problem, you are using your nervous system. Our brain regulates all the behavioral, physiological and emotional functions of our bodies. It receives information from our environment, interprets it, determines the correct response, and then relays the information through our spinal cord and nerves to the appropriate body area. In this activity, students will recognize just how extensive a role our brain plays in our daily lives.

Preparation:

1. On 6-10 index cards, write down one action on each card that is controlled by the brain. Examples include:
   a. Hop up and down on one foot
   b. Sweating (Pretend to be hot and sweaty)
   c. Walk around the classroom
   d. Heartbeat (hand on heart)
   e. Sing, “Mary Had a Little Lamb”
   f. Do a math problem out loud (give them an example)
   g. Recall and describe how to get to the cafeteria from this classroom
   h. Pretend to be sleeping
   i. Dance
   j. Pretend to cry

Procedure:

1. Ask for 6-10 volunteers (one for each task) to come to the front of the class. Hand one index card to each student. One at a time, ask each to act out what is written on their index card. Remaining students will try to guess the action. Write down the actions on the chalkboard as it is identified.

2. When complete, ask the students which organ system of the body is involved in all of the actions performed (*answer: nervous system*).
3. Students will need to log on to a computer with Internet access to continue with the lesson. If not enough computers are available, students can work in pairs.
4. Using the Internet, go to www.kidshealth.org/kid/ and follow directions below or use desired website to learn about the brain.
   a. Click "*How the Body Works*" button on the left side of the screen.
   b. Click on picture of brain.
   c. Pass out a large cross-section picture of the brain (click on Activity).
      i. Instruct the students to label: *cerebrum, cerebellum, thalamus*, and *brain stem*; add *hypothalamus* since it is discussed in the website.
      ii. If your copy is in black and white, have them color-code each section of the brain, to differentiate the areas.
   d. Have your students research the site on the brain to find out what the main functions of the cerebrum, cerebellum, hypothalamus, thalamus and brain stem are. They can write in bullets next to each label on their picture. Possible websites include:
      i. Your Brain & Nervous System http://kidshealth.org/en/kids/brain.html
      ii. Anatomy of the Brain https://www.mayfieldclinic.com/PE-AnatBrain.htm *(Internet addresses current as of September 2017)*

Follow-up

1. Go back to the chalkboard and have the class identify which part of the brain was responsible for each action the students performed. There can be more than one possible answer for some. (*Answer key on next page*).
2. Review the terms *voluntary* and *involuntary action* (*definitions below*). Ask the class to decipher which actions written on the chalkboard would be voluntary and which would be involuntary. Have them explain their reasoning.
3. Discuss with your students that certain functions controlled by the brain were demonstrated in front of the class, but they were less noticeable. Every student was breathing, circulating blood, digesting food, maintaining the correct body temperature and showing balance and coordination. Highlight that our brains are working constantly, whether we "see" it or not.

Definitions

Voluntary: Under conscious control; proceeding from one's own choice or desire to do something.

Involuntary: Not under conscious control. Most of the biological processes in animals that are vital to life, such as contraction of the heart, blood flow, breathing, and digestion, are involuntary and controlled by the autonomic nervous system.

Brain Charades Answer Key

If students think of other actions happening, have them identify which part of the brain helped to do that action. There can be many answers.

Task	Involves	Part of Brain	Voluntary/Involuntary
Hop up and down on one foot	Movement, balance, coordination	Cerebrum, cerebellum	Voluntary
Sweating	Movement, sweating	Cerebellum, hypothalamus	Voluntary (movement) & involuntary (sweating)
Walk around the classroom	Movement, sight, balance, coordination	Cerebellum, cerebrum	Voluntary
Heartbeat	Breathing, heart rate	Brain stem	Involuntary
Sing, “Mary Had a Little Lamb”	Speech, memory	Cerebrum	Voluntary
Do a math problem out loud	Information processing, thinking, memory, speech	Cerebrum	Voluntary
Recall and describe how to get to the cafeteria from this classroom	Memory, information processing, speech, solve problem	Cerebrum	Voluntary
Sleeping	Breathing, heart rate	Brain stem, hypothalamus	Involuntary
Dance	Movement, balance, coordination, sight, breathing (panting), sweating	Cerebellum, cerebrum, brain stem, hypothalamus	Voluntary and involuntary (breathing & sweating)
Vomiting	Movement, coordination, sight, vomiting	Cerebrum, cerebellum, brain stem	Voluntary & Involuntary

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Stroop Effect

Objectives:

- Comprehend that your brain responds to both color and written stimuli
- Explain the role that the frontal lobe plays in problem solving

Materials:

- Stroop effect worksheets (included below – print in color and cut in half, OR can create your own power point and conduct the activity as a class)
- Stop watches or timers

Background:

Named for John Ridley Stroop, the Stroop Effect is a phenomenon that occurs when your brain receives two pieces of information. In this case, you are processing not only the color, but also the meaning of the word. If both stimuli (color and meaning) are congruent or compatible, we will respond with the correct answer rapidly. But if the color and the meaning do not agree we will have to make a decision as to which one to pay attention to. Since reading is more 'automatic' for most people, it takes longer to pay attention to color of the word, rather than its meaning. Hence the delay in response. Imaging methods such as MRI and PET have shown that the Stroop test causes the subject's frontal lobe to become activated during the task. More specifically, since your brain is trying to resolve the difference in the color and meaning of the word, specific areas of your frontal lobe that are responsible for conflict monitoring and resolution become active.

Special Considerations:

Students who are color blind will not be able to properly view the colors included in this experiment, and will have difficulty completing the activity. You may want to suggest that they play another role, such as a designated timer.

Procedure:

1. Explain to students that you will show them a list of words, and you would like them to tell you the <u>colors</u> of the words that they see.
2. Pass out or display the Stroop Effect Worksheet #1. Have students time each other – how long does it take to say all of the colors? Record this time.
3. Pass out or display the Stroop Effect Worksheet #2. Have students time each other – how long does it take to say all of the colors? Record this time.

Follow up:

Discuss the results. Which list took longer to read? Why? Use the background information to explain the science behind this "test".

Try this: Use Stroop Effect Worksheet #2, but turn it upside down. Repeat the experiment. How much time did it take? Was it faster or slower than your previously recorded times? Alternatively, make a list of words, in color, that are not colors. For example, BOAT. Does this change your time?

Stroop Worksheet #1

RED	GREEN	BLUE
BLUE	RED	PURPLE
YELLOW	BLUE	RED
GREEN	GREEN	PURPLE
PURPLE	YELLOW	GREEN

Stroop Worksheet #2

RED	GREEN	BLUE
BLUE	RED	PURPLE
YELLOW	BLUE	RED
GREEN	GREEN	PURPLE
PURPLE	YELLOW	GREEN

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Smell Jars

Objectives:

- Compare and contrast scents contained within smell jars
- Explain the process of detecting scent

Materials:

- Plastic or Glass jars with lids (can punch holes in the lids, or have students remove lids to smell)
- Cotton Balls
- Scented extracts, oils, spices, or household items such as:
    - Vanilla Extract
    - Orange Extract
    - Peppermint Extract
    - Lemon Oil
    - Cinnamon (spice or extract)
    - Cumin
    - Nutmeg
    - Coconut extract
    - Ammonia

Background:

Summarized from: https://www.nidcd.nih.gov/health/smell-disorders#2

Your sense of smell, as well as your sense of taste, is part of your chemosensory system. Within your nose, you have specialized cells known as olfactory sensory neurons. They are found high inside of your nose, and connect directly to the brain. Each one of these olfactory neurons has one odor receptor; these receptors are stimulated by molecules in the environment. These receptors detect the molecules, send the message to your brain, and your brain identifies the smell.

There are two pathways to reach the olfactory sensory neurons. The first is through the nostrils and the second is through a channel that connects the roof of the throat to the nose. It is through this channel that smells released from the food that you are chewing will travel. This is also why it is harder to taste food, or food tastes different when you have a cold; not as many of the odors can reach the sensory cells through this channel.

We also have what is known as common chemical sense, which can influence our sense of smell. On the surfaces of the eyes, nose, mouth and throat we have thousands of nerve endings, which help us to sense "irritating" substances, such as onion and menthol.

Preparation:

- For oils and extracts, place cotton balls in the bottom of the jars and place a few drops on the cotton balls.
- For spices, can sprinkle at the bottom of the jar, or on top of cotton balls so that the jars are consistent (they all have cotton balls). If the jars are clear, be aware of visual clues such as the spices may provide.
- Be sure to "label" the jars in such a way that you know which scent is contained within!

Procedure:

1. Hand out jars, have students identify smells within each, using the scientific **wafting technique**. This means that students should cup their hand above the container and waft the air (and therefore the scent) towards their face. They should never place their nose directly above the jar and smell!
2. Hand out second set of jars, all of which contain one of the "stronger" scents, such as the peppermint extract, cinnamon extract, or ammonia AND one other smell. Can students differentiate two smells within the jar? Why or why not?

Follow Up:

For the first set of jars, which smell was the "strongest", in your opinion? Which smell did you enjoy the most? For the second set of jars, was there one prominent scent? Discuss what each of these jars contained. Why could you only smell one odor, if there were really two?

In popular zombie culture, the zombie sense of smell is no better or worse than yours – which means they can be tricked! They don't attack each other because they can smell the decay of each other, just like you can smell your rotting garbage in the garbage can. Therefore, one method of avoiding zombie attack is to cover yourself in zombie blood and innards to mask your own body smell! Doesn't that smell great?!

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Round and Round We Go

Objectives:

- List which senses help us maintain our balance
- Explain how we can confuse our brain's sense of balance

Materials:

- Pool Noodles (one per student volunteer – suggest 2 volunteers)
- Bottle of water (a large water cooler bottle is great, but if not available, any transparent bottle of water will work!)
- Food coloring (to make the water more visible)

Equity Considerations:

Students who have balance issues, or are prone to severe motion sickness should not volunteer for this experiment. They can enjoy watching others get dizzy!

Background:

Three of are our senses are responsible for conveying our movements to our brain – our sense of touch (via our muscles and joints), our eyes and our ears. While it may be logical that our sense and sight can provide this information, many people do not realize what an important role our ears also play! Ears contain a series of structures that make up what is known as the vestibular system. Within your vestibular system is a fluid filled chamber known as the semicircular canal; this is what provides information to your brain about your rotational movement as the fluid moves inside the canal. Information from these three inputs are sent to the brain stem, where it is categorized and then integrated with previously learned information provided by the cerebellum – the cerebellum is the part of the brain that is responsible for balance, coordination and posture.

Preparation:

- Have an open, and safe, space in which to perform this experiment.
- Put a small amount of water at the bottom of the water bottle. Add food coloring if you think it will be difficult for students to see it.

Procedure:

1. Have each volunteer lay the pool noodle on the floor in front of them horizontally, and then jump over it. Ask: Was that difficult to do?
2. Next, ask them to pick up the pool noodle, and hold it vertically against their torsos. One hand should grip the bottom of the pool noodle against their belly button, and the other hand should hold it gently against their chin.
3. Have the student's tip their heads back so that they are looking at the top of the pool noodle, while still gripping it against their bodies. They should focus their eyes on the top of the pool noodle.

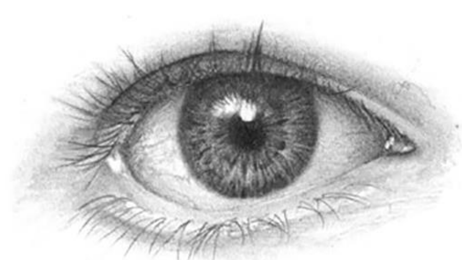
4. Ask students to slowly start spinning in place. Carefully watch them to see when they begin to get dizzy. Use caution with dizzy students!
5. When they appear dizzy, ask them to put the pool noodle back on the floor and jump over it again. Ask: Was it difficult to do this time?
6. Ensure that students are no longer dizzy before sending them back to their desks. *Tip: You may want to have them sit on the ground for a moment while you discuss what happened*

Follow Up:
Why do we get dizzy?! Discuss with the class the three senses that are responsible for our balance and coordination, including the vestibular system. Explain that sometimes we can confuse these senses!

When you spin in a circle, all of your senses are conveying the same information to your brain – I'm moving in a circle! But in this experiment, the brain, specifically the cerebellum, is given mixed signals! When the volunteers started to spin, the liquid in their ears starts to spin too - like the water in the bottle *(Hold up and swirl water in bottle for the class to see, then stop.)* Ask the students: Does the water stop spinning immediately? No! It continues to spin inside of the bottle. The same thing happens with the volunteers. Even when they stop spinning, the fluid in their ears continues to circle, telling the brain that they are in motion. However, their eyes can sense that nothing is moving, and tell the brain that they are standing still. The brain doesn't know which input to believe, so you get dizzy, and it can be hard for the cerebellum to keep you balanced because your eyes and inner ears are giving it different information. Actually, because it's getting such weird signals, the brain thinks you are being poisoned and it's getting your body ready to throw up the poison. That's why your stomach gets that sick feeling.

In a zombie brain, even though the eyes and inner ears might not be affected by the zombie virus, the cerebellum, which keeps us balanced based on that input, has been damaged. This is why zombies cannot walk upright or complete basic balance functions like climbing up a flight of stairs even though their eyes and ears still work.

Resource: http://vestib ular.org/understanding-vestibular- disorder/human-balance-system



NJ Student Learning Standards- Science/Next Generation Science Standards

This program helps build student competency toward meeting the following

Performance Expectations:

MS-LS1-3: Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

Dimensions of Learning Supporting the above Performance Expectations are:

Disciplinary Core Ideas

MS-LS1.A: In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.

Science and Engineering Practices

Constructing Explanations and Designing Solutions:

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Engaging in Argument from Evidence:

- Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.

Cross-cutting Concepts

Systems and System Models:

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions— including energy, matter, and information flows— within and between systems at different scales.

Chapter 3: Research Article for Science Education Journal Submission

Zombie brains: Designing a traveling science program for engagement in scientific explanation

Kara D. Mann

Rutgers University

May 2018

Abstract

Informal science institutions (ISIs) offer traveling science programs (TSPs) that bring some of the fun and interactive aspects of the ISI to schools while engaging students in authentic science practices. This study investigates the design of *BRAAAAINS: You & the Zombie (BYtZ)*—a TSP to engage students meaningfully in the science practice of constructing scientific explanations while being fun and exciting, all within a one-time, 45-minute, semi-formal learning experience. The TSP captures and maintains students' situational interest by putting them in the role of zombie researchers whose goal is to generate explanations for the behavior of zombies with mutated viruses that impact the brain differently compared to typical zombies. The claim, evidence, reasoning (CER) framework was included to scaffold the construction of scientific explanations (McNeill et al., 2006). The program was implemented at three middle schools with 149 participants. Engagement was measured as a composite of students' self-reported interest, enjoyment, and concentration once as a baseline and then three times throughout the program. Scientific explanations were assessed using a written pre- / post-test and scored using a CER rubric. The data indicate that students were more engaged in the program activities compared to the baseline, that they made small gains in their ability to construct scientific explanations, and that those students who were more engaged were also more likely to score higher on the post-test explanation. This research indicates that it is possible to design one-time semi-formal learning experiences that have a meaningful impact and engage students with science learning.

Introduction

To prevent students from losing interest in science, it is important to make their science learning experiences engaging. This is, perhaps, one of the reasons that science museums and other locations and opportunities for informal science education are so popular (Bell et al., 2009). With a decrease in budgeting for field trips, opportunities for science museums to bring programs to schools are becoming more prevalent, such as the traveling science programs (TSPs) offered by Liberty Science Center (LSC). Liberty Science Center offers two kinds of TSPs: assembly programs for large groups of students and classroom workshops for individual classes of 30 students or fewer. Both kinds of TSPs are approximately 45 minutes long to ensure they fit into a single class period. These programs are designed to engage students in science learning through a combination of interesting topics and hands-on activities. The use of an interesting premise as a way to initially grab learners' attention is useful, however, it is not enough on its own to sustain interest or achieve learning (Blumenfeld et al., 2006). It is also critical to continuously engage the students with the learning and this is not a trivial task (Ainley & Ainley, 2011; Hidi & Renninger, 2006; Renninger, 2007).

It is rarely easy to get students to engage with challenging scientific practices such as creating scientific explanations. It is even more difficult when one only has 45 minutes with the students. In this abbreviated time frame, the students' attention must be caught with an interesting idea and held with engaging activities to give them a meaningful learning experience in a short lesson. Additionally, it is important to consider the best scaffolds and tools to help channel that interest into productive learning (Belland et al., 2011; McNeill et al., 2006; Sandoval & Reiser, 2004). Designing a program that holds the interest of the learners while giving them the tools they need to learn productively is important when designing any learning environment, however, it can be particularly challenging within the constraints of a program such as one of LSC's classroom workshops. Therefore, designing a classroom workshop comes with a unique set of challenges.

Classroom workshops are not typical learning environment because they are neither truly informal nor formal science learning experiences. Like field trips, in-school programs like TSPs present opportunities for students to learn science in fun and engaging ways that are different from their regular classroom learning. However, because the programs take place inside of the classroom, they are harder to classify as informal learning experiences. Instead, classroom workshops are best classified as semi-formal learning experiences because they combine aspects of both formal and informal learning experiences (Eshach, 2007; Jones et al., 2013, Table 1). Traveling science programs fall into this semi-formal category (Table 1) because, for one, they are highly structured activities that take place during school time and in a school setting. At the same time, they strive to maintain the central themes of informal science institutions and informal learning, which are to engage learners of all ages with scientific skills and knowledge in fun and exciting ways (Bell et al., 2009; Fenichel & Schweingruber, 2010). Although there is considerable research on how to learn science both in formal, in-school contexts (Duschl et al., 2007; National Research Council, 2012) and in informal, out-of-school contexts (Bell et al., 2009; Fenichel & Schweingruber, 2010; Sacco et al., 2014), much less is known about how to effectively design programs for this middle category of one-time, semi-formal learning experiences. This is an important area of study because as it becomes more challenging for

Table 1: Comparison of categories on the spectrum of formal to informal learning

Formal	Semi-Formal	Non-Formal	Informal
Usually at school	Often occur at school, during school time	At institution out of school during school time OR at a school but out of school time.	Everywhere
May be repressive	Usually supportive	Usually supportive	Supportive
Structured	Structured	May be Structured	Unstructured
Usually prearranged	Usually prearranged	Prearranged or spontaneous	Spontaneous
Motivation is typically more extrinsic	Motivation may be extrinsic or intrinsic	Motivation may be extrinsic but it is typically more intrinsic	Motivation is mainly intrinsic
Compulsory	Usually Compulsory	Usually voluntary	Voluntary
Teacher-led	Educator-led	May be guide / docent or teacher-led	Usually learner-led
Learning is evaluated	Learning may be evaluated, but not for grading	Learning is usually not evaluated	Learning is not evaluated
Sequential	May be sequential	Typically non-sequential	Non-sequential

Adapted from Eshach (2007, p. 174) and informed by (Bell et al., 2009; Fenichel & Schweingruber, 2010; Jones et al., 2013; Sacco et al., 2014).

schools to plan field trips, they are turning to programs such as LSC's TSPs to engage the students with science in new and different ways than their everyday classroom experience. They are looking for opportunities for the field trips to come to them. Therefore, it is important for institutions providing such programs to assess the value of these programs for the students and learn how they can be improved.

From the perspective of the informal science institutions (ISIs), a valuable program engages learners and sparks their curiosity and interest in the STEM (science, technology, engineering, and math) fields (Bell et al., 2009; Fenichel & Schweingruber, 2010). At the same time, ISIs seek to design their TSP programs such that they also fit into the students' learning context at school by being designed around the same set of standards as the rest of their science learning. Although it is not expected that learners will develop expert-level science competencies from a 45-minute classroom workshop, traveling science programs can trigger and maintain learners' situational interest. This interest could evolve into an emerging personal interest in a STEM discipline and open up new ideas to them for future career goals (Hidi, 1990; Hidi & Renninger, 2006; Renninger, 2007; Renninger & Hidi, 2011). Engaging with scientific practices during TSPs could help make small improvements in learners' competence with those practices, but may also help prepare them for future learning of those practices as they continue to encounter them in their formal school experiences.

Any semi-formal program designed to complement the formal science learning in school ought to be aligned with the Next Generation Science Standards (NGSS), which are a reformed set of standards that bring about a major change in the way science is taught in schools (Bybee, 2013; NGSS Lead States, 2013). Recognizing that understanding is a key component to knowledge retention and the ability to find and use information instead of just repeating it, the authors of *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas* on which the NGSS are based took a new approach to science standards (Bransford, Brown, Cocking, & National Academy of Sciences - National Research Council, 2000; National Research Council, 2012; Simon, 2000). The authors of the *Framework* proposed that school science standards should focus on science and engineering practices and crosscutting concepts as a way to understand a few core ideas (National Research Council, 2012; Pruitt, 2014). Thus, the NGSS focus on a set of eight Scientific and Engineering Practices (SEPs) as well as Crosscutting Concepts (CCs) that are applicable across all scientific disciplines. The goal is to help students reach a deep understanding of a much smaller set of Disciplinary Core Ideas (DCIs; Golan Duncan & Cavera, 2015; National Research Council, 2012; NGSS Lead States, 2013; Pruitt, 2014). The goals are no longer as simple as students acquiring isolated facts; the learning goals are now to have learners' master difficult science practices. While this makes the new standards exciting it also makes it more challenging to meet those standards. The current study explores the design challenges in creating a program that simultaneously (a) meets the schools' desire and need to address science standards, (b) stays true to the LSC's informal learning mission of making science fun and engaging, and (c) keeps within the 45-minute time frame of a one-time, semi-formal classroom workshop. To inform this design work, I will review the literature on interest and learning, the contribution of fun to learning, and design strategies for supporting these goals. This review will be the basis for the design of a semi-formal TSP that targets the learning of a science practice and the subsequent evaluation of that design.

Background

Situational Interest for Engagement in Science Learning

Interest is an emotion that motivates people to learn and explore, therefore, it can be capitalized on as a way to engage people in learning experiences (Palmer, 2009; Schraw, Flowerday, & Lehman, 2001; Silvia, 2008). However, not all interest is the same, and the same things don't interest everyone. There are two main kinds of interest commonly described: situational interest and personal (or individual) interest (Hidi, 1990; Hidi & Renninger, 2006; Linnenbrink-Garcia et al., 2010; Linnenbrink-Garcia, Pugh, Koskey, & Stewart, 2012). Situational interest refers to transient interest stimulated by something in a person's environment that focuses attention (Dohn, 2011, 2013; Hidi, 1990; Loukomies et al., 2015; Palmer, 2009). On the other hand, personal interest refers to an enduring interest that will cause a person to seek more information and put more time into learning about that topic on their own and that may or may not relate to learning in the classroom (Hidi & Renninger, 2006; Linnenbrink-Garcia et al., 2012; Palmer, Dixon, & Archer, 2016). In an educational setting, it is difficult to try and account for every student's personal interest because the range of interests is so varied.

However, since situational interest can be triggered by the environment, it can be used as a motivational factor for learning. Not all situational interest is equal though. Some researchers have broken down situational interest into those experiences that *catch* interest and those that *hold* it (Krapp, 2002; Mitchell, 1993). Similarly, Hidi & Renninger (2006) have proposed a model of interest that consists of four phases: situational interest is first triggered (catch) and then maintained (hold) and this can lead to an emergent personal interest, which in turn can become a well-developed personal interest. Catching and holding situational interest can be a good way to enhance learning by engaging the learners in the task (Hidi, 1990; Rotgans &

Schmidt, 2011; Tapola, Veermans, & Niemivirta, 2013). For example, in their study Tapola and colleagues (2013) examined whether students found concrete or abstract tasks more interesting, as well as how much the students learned. They found that the students maintained a higher level of interest in the concrete learning tasks, and that those students also learned more from the lesson (Tapola et al., 2013). Similarly, in their study of college students participating in a one-day problem-based learning activity, Rotgans and Schmidt (2011) found that higher levels of situational interest were predictive of academic achievement. Therefore, even though it may not be possible to take each individual's interests into account when designing a learning experience, there are ways to trigger and maintain interest with the program activities.

Situational interest in the classroom. Triggering and maintaining students' situational interest is valuable in education because not all students have the same personal interests, but studies have found that there are certain aspects of activities that seem to be universally interesting (Bergin, 1999; Mitchell, 1993; Silvia, 2008). Silvia (2008) contends that, even though individuals have their own personal interests and that an individual's interests may change over time, most people appraise situations that are novel and complex but comprehensible as interesting. Supporting this conclusion, researchers studying situational interest in the classroom have found that novel, unusual, surprising, or unexpected content and experiences can stimulate situational interest (Bergin, 1999; Palmer et al., 2016; Renninger & Hidi, 2011; Schraw et al., 2001). To move from triggered to maintained situational interest, however, lessons require something other than just interesting opening phenomenon.

Previous studies of situational interest have found that giving students a certain amount of autonomy and the ability to work in groups can help trigger and maintain their interest by adding a social aspect to the learning (Bergin, 1999; Mitchell, 1993; Rotgans & Schmidt, 2011).

In their study of a college zoophysiology class, Dohn and colleagues (2009) found that the social aspect was not very important to those students, but they note that this could be related to the age of the students because most of the other studies that have found the social and group-work aspect to be important were done with students in grades K-12. However, their study did find that some amount of background knowledge was important to maintaining situational interest, which is also supported by other studies (Bergin, 1999; Palmer et al., 2016; Renninger & Hidi, 2011; Schraw et al., 2001). When there is relatively low background knowledge, though, it has been found that more concrete problems will keep students' interest compared to abstract problems (Tapola et al., 2013). The Tapola et al. (2013) found that when students were faced with a task on a topic they had low background knowledge on (circuits) they maintained a higher level of interest when given concrete problems to solve, rather than abstract ones. However, concrete problems are not the only thing that helps maintain student interest.

Hands-on activities have also been found to catch and hold the interest of students (Bergin, 1999; Dohn, 2013; Loukomies et al., 2015; Palmer, 2009; Rotgans & Schmidt, 2011). Maintaining situational interest can also be achieved by creating a problem or puzzle for the students to solve (Linnenbrink-Garcia et al., 2010; Loukomies et al., 2015; Mitchell, 1993; Palmer, 2009) and this can be enhanced by presenting those problems within a fantasy context or narrative (Bergin, 1999; Lepper & Cordova, 1992; Parker & Lepper, 1992). Loukomies and colleagues (2015) chose to include a combination of interactive demonstrations, teacher-led conversations, and group work in an attempt to maintain student interest in different ways throughout the lesson. They chose to do this because novelty along with choice and social interaction are some things that increase engagement with learning (Loukomies et al., 2015; Palmer, 2009). Altogether the literature demonstrates that it is indeed possible to trigger and maintain students' interest in the science classroom even though they may have dissimilar personal interests. However, LSC is not a school, therefore, it is also important to design programs that incorporate the fun and excitement that learners experience when participating in informal science learning experiences. This is an important aspect to include in the design not only because it is part of LSC's mission, but also because fun and learning have been demonstrated to enhance each other.

Fun and Learning are Complementary

Science can be difficult to learn, even more so because in formal settings it is often presented in tedious ways, or as monotonous memorization. But it does not have to be this way; learning science can be fun, engaging, and exciting depending on how it is presented. Research suggests learning experiences that are fun or part of a leisure experience can result in better knowledge retention over time, and that the learning enhances the fun (Ballantyne, Packer, & Hughes, 2009; Mann-Lang, Ballantyne, & Packer, 2016; Packer, 2006; Packer & Ballantyne, 2004). When questioned why they visit informal science institutions or participate in informal science learning experiences, many visitors state that the reason for doing so is specifically because the experiences are both educational and fun (Bell et al., 2009; Falk & Dierking, 2000). In their study of six educational leisure sites – "museum sites (museum, art gallery); interpretive sites (wildlife centre, aquarium, guided history tour); and natural sites (guided forest walk)", Packer & Ballantyne (2004, p. 59) found that visitors to the different sites felt that they learned more because the information was presented in an entertaining way and that learning new things kept them entertained. They concluded that learning and entertainment are not mutually exclusive, but instead are complementary (Packer & Ballantyne, 2004). In fact, education and leisure have been found to be so mutually enhancive that Packer (2006) coined the phrase

"Learning for Fun" to describe the experience that most visitors have at places of informal science learning. This is not only true at science museums, but also of other spaces where informal science learning takes place. Visitors to zoos and aquariums have indicated that they believe entertainment and education are the two most important things those institutions provide to their visitors (Ballantyne & Packer, 2016). Additionally, in a study of two dolphin shows, research found that tourists preferred the show that was educational over the one that was mostly just theatrical (Mann-Lang et al., 2016).

This phenomenon is not only seen in classic informal science institutions such as museums, zoos, and aquariums, but learning for fun is further supported by eco-tourism research. Research inquiring into tourists' motivation for participating in eco-tours have found that many chose to go on the excursions because they were seeking an experience that was both fun and educational; some participants were even disappointed that there was not a heavier emphasis on education during the trip (Ballantyne et al., 2009; Lück, 2003). In his study of tourists on dolphin and whale watching expeditions, Lück (2003) found that the most common suggestion by tourists for improving the trip for future participants was to make education a larger emphasis. This finding is based on responses to an open-ended survey card that did not mention learning, indicating this is an important aspect to people participating in these kinds of excursions (Lück, 2003). This suggests that people participating in such excursions believe the educational aspect to be an integral part of the enjoyment. Similar results have been found in studies of tourists visiting the Mon Repos Conservation Park in Queensland, Australia (Ballantyne et al., 2009; Tisdell & Wilson, 2005). In these studies, tourists support the educational aspects of the trip and believe they enhance rather than detract from the experience (Ballantyne et al., 2009; Tisdell & Wilson, 2005). Altogether, these studies demonstrate that informal science learning experiences provide a unique opportunity to engage students in learning by providing an experience that is both fun and educational so that these two aspects can work synergistically to enhance one another.

The importance of the complementary nature of fun and learning goes beyond informal settings and into the classroom as well. It is just as important for students to be engaged with their learning in the classroom as it is for informal learners. One model for measuring engagement asserts that engagement requires a simultaneous experience of concentration, interest, and enjoyment (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003). This model of engagement is based on Flow theory (Shernoff et al., 2003). Flow is described as “a state of deep absorption in an activity that is intrinsically enjoyable” (Shernoff et al., 2003, p.160) such as when an artist is performing, a person is immersed in a video or computer game, or an athlete is focused on their sport. This model for engagement with learning includes enjoyment as a necessary part of the equation, further supporting the idea that fun and learning are complementary, and when the two are working in sync learners are more likely to remain engaged by the experience. When learners are engaged with what they are learning, their interest is also sustained at a higher level. Therefore, incorporating some of the fun from informal learning with the methods of triggering and maintaining interest in science learning can be useful for the design of programs that are short, one-time semi-formal learning experiences.

Designing Fun Programs to Catch and Hold Interest

One of the benefits of the longer informal science learning experiences like TSPs is that they often present the students with a chance to engage in hands-on, inquiry-based activities and authentic practices (S. Allen, 2004; Barab & Hay, 2001; Edelson & Reiser, 2006; Gibson & Chase, 2002; Lindemann-Matthies & Kamer, 2006; Satterthwait, 2010). These types of learning experiences give the students a chance to engage in the scientific process. Engaging in the scientific process requires the students to gather evidence and support their claims, making the experience more authentic by putting the students in the shoes of a scientist which, in turn, increases engagement in the learning process (Edelson & Reiser, 2006; Pruitt, 2014; Schwan et al., 2014; Tawfik, Trueman, & Lorz, 2014; Torp & Sage, 2002). The need to gather evidence to support claims can promote scientific reasoning skills and give students a sense of ownership over the material they are learning (Barab & Hay, 2001; Edelson & Reiser, 2006; Palmer, 2009; Satterthwait, 2010). For example, Gibson and Chase (2002) studied a summer program in which the students designed and implemented their own experiments to give them autonomy and ownership over their work. This sense of ownership over their work in turn made the experience more engaging and engagement led to increased learning (Gibson & Chase, 2002). Similarly, Dresner and Gill (1994) examined knowledge retention in students that participated in a two-week nature camp in which they learned about the environment and how to protect it by learning low-impact camping and outdoor skills. They found that the campers were engaged and maintained their knowledge and interest in nature long after the camp was over (Dresner & Gill, 1994). While these are both studies of longer programs, they demonstrate that when students are involved in their learning, they become engaged with and interested by it. The lessons learned from these longer-term studies can be applied to learning in the classroom with problem-based learning.

Problem-based learning. Problem-based learning (PBL) is an instructional approach that is learner-centered in which the learners take ownership of their work by applying theory and practice to solve an ill-structured problem (Savery, 2006; Torp & Sage, 2002). A key component of PBL is that it is experiential and so it engages the students in problem-solving and allows them to be self-directed learners (Torp & Sage, 2002). The goals of PBL for students include helping them to become effective collaborators and self-directed learners, and to develop a flexible knowledge base to become effective problem solvers (Hmelo-Silver, 2004). Hmelo-Silver (2004) also notes that PBL should help students become more intrinsically motivated to learn, which is similar to situational interest leading to personal interest over time.

The problems posed in PBL are typically designed to take the students days or weeks to learn the required background information and come to a solution, but this is not something all students are used to doing so they must first learn to collaborate effectively (Ertmer & Simons, 2006). One way to improve collaboration skills and introduce the classroom to PBL is through posthole activities (Ertmer & Simons, 2006). Posthole activities are essentially mini PBL units that introduce students to the problem-based learning method but with problems that can be resolved in a short amount of time such as a single class period (Ertmer & Simons, 2006). This gives students a chance to learn how to collaborate on short projects to prepare them for longer units. Another way that Ertmer and Simons (2006) suggest developing a collaborative classroom environment is by debriefing as a whole class after the group work is complete to give students a chance to reflect on both the problem and the process. This debriefing process is similar to the revoicing advocated by Hmelo-Silver and Barrows (2006) as a method of scaffolding the learning at steps during the completion of longer PBL units. Along with posthole activities, anchored instruction is another kind of problem-solving instruction that builds in some content learning before delving into the problem scenario (Hmelo-Silver, 2004). With both anchored instruction and posthole activities, the role of the teacher is somewhere in between the true facilitator of a classic PBL unit and the lecturer of standard classroom instruction. Altogether, these smaller PBL units could serve as models for the units that informal science institutions bring to schools to teach in their classrooms, such as TSPs. While PBL and PBL-like activities are an excellent way to engage students in learning, when designing a semi-formal learning experience, one must take into consideration the best practices for program design from both formal and informal education.

Strands of Science Learning Inform the Design of Semi-Formal Learning Experiences

Some researchers contend that there is not a single, coherent set of best practices for informal educators to adhere to (L. Allen & Crowley, 2014; Tran & King, 2007), which is not necessarily surprising given the diversity of such learning opportunities. However, there is a framework that consists of six strands of science learning that can be used for program design and assessment and move informal science educators toward a set of best practices (Table 2; Bell et al., 2009; Sacco et al., 2014; Fenichel & Schweingruber, 2010). Noting a need for a comprehensive tool for informal science institutions and educators to use as a guide when creating learning experiences, Bell and colleagues (2009) proposed the 6 strands of informal science learning that were later expanded upon by others (Fenichel & Schweingruber, 2010).

These six strands were developed based on the 4 strands of science proficiency developed by Duschl and colleagues (2007) in *Taking Science to School: Learning and Teaching Science in Grades K-8* (Table 2). These 4 strands of science proficiency were proposed as a way to improve science learning in the formal classroom and begin to move away from the classic content-knowledge-only pedagogy of schools by indicating that students should understand scientific explanations, be able to generate evidence, reflect on science knowledge, and productively participate in science (Duschl et al., 2007; Michaels, Schweingruber, Shouse, & National Research Council (U.S.), 2008). In both of these cases, the strands emphasize participation in science instead of only a focus on content knowledge. In fact, strands 2-5 demonstrate a nearly complete overlap between the goals of the two (Bell et al., 2009; Duschl et al., 2007; Fenichel & Schweingruber, 2010; Michaels et al., 2008). However, strands 1 and 6, in particular, set the informal learning strands apart from the formal school learning strands (Table 2).

Strand 1 reminds informal educators and institutions that the generation of excitement and interest are what set informal science experiences apart from learning in schools and are an integral part of an engaging and enjoyable learning experience (Bell et al., 2009; Fenichel & Schweingruber, 2010). Strand 6 emphasizes learners identifying with the scientific enterprise and seeing themselves as scientists whether that is their profession or not and having the knowledge to understand science and its importance in the world around them (Bell et al., 2009; Fenichel & Schweingruber, 2010). Strands 1 and 6 especially work together to promote sustained interest in science and changes in beliefs about science and scientists in a positive manner (Bell et al., 2009; Schwan et al., 2014). While excitement (Informal Strand 1) and identity as a scientist (Informal Strand 6) are important ideas in the formal science classroom, they tend to be secondary due to various constraints, whereas they are an integral part of the informal science learning experience. However, the new Next Generation Science Standards work to bring some this together in the classroom.

The NGSS were developed based on the recommendations in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which introduced the three dimensions of science learning: disciplinary core ideas, science and engineering practices, and crosscutting concepts (National Research Council, 2012). The three dimensions from the framework adopted in the NGSS were developed from the four strands of classroom science learning (Table 2) and informed by informal science ideas and strands laid out in *Learning Science in Informal Environments: People, Places, and Pursuits* (Bell et al., 2009; Duschl et al., 2007; National Research Council, 2012; NGSS Lead States, 2013). The strands and dimensions do not align perfectly, but they cover the same basic principles (Table 2). This overlap in the goals of the new science standards and the goals of informal science educators further highlights the importance of engaging in the practices of doing science. However, it is important for informal science educators to remember not to only focus on the overlap when designing new programs, because making the programs exciting and different and promoting interest in science (Strand 1) is an integral part of those experiences. Engaging in scientific practices provides a program design opportunity where the goals of informal and formal science educators overlap. Yet engaging in these scientific practices can be difficult for students. Therefore, it can be challenging for educators, both formal and informal, to design programs that meaningfully engage students with them. One practice that is particularly difficult for students to master is constructing scientific explanations. However, there are excellent scaffolding techniques that can help build students' competence with this practice without overwhelming and frustrating them in the process.

Table 2: Aligned Comparison of the 6 Strands of Informal, the 4 Strands of Formal Science Learning, and the 3 Dimensions of the Framework

Strands of Informal Science Learning (Bell et al., 2009, p. 4)		Strands of Formal Science Learning (Adapted from Duschl et al., 2007, p. 37)		Dimensions of the Framework (Adapted from National Research Council, 2012, p. 254)	
Strand 1:	Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.				
Strand 2:	Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.	Strand 1:	Know, use, and interpret scientific explanations of the natural world	Disciplinary Core Ideas Crosscutting Concepts	Specify big ideas, not lists of facts.
Strand 3:	Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.	Strand 2:	Generate and evaluate scientific evidence and explanations	Practices	Learning is defined as the combination of both knowledge and practice, not separate content and process learning goals.
Strand 4:	Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.	Strand 3:	Understand the nature and development of scientific knowledge		
Strand 5:	Participate in scientific activities and learning practices with others, using scientific language and tools.	Strand 4:	Participate productively in scientific practices and discourse.	Practices Crosscutting Concepts	Practices are defined as meaningful engagement with disciplinary practices, not rote procedures.
Strand 6:	Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.				

Constructing Scientific Explanations is a Difficult Skill to Learn

Explanations are a key component of the scientific endeavor, but constructing them is not a trivial skill for children to learn to do properly. Students struggle with putting together appropriate and sufficient evidence and with giving the logic that explains why they think their selected evidence supports their conclusions (McNeill & Krajcik, 2008; McNeill et al., 2006; Sandoval, 2003). Students tend to have a hard time understanding what counts as evidence and what evidence is appropriate, instead tending to rely on their personal beliefs to draw a conclusion (McNeill et al., 2006). Additionally, students often will fail to provide multiple pieces of evidence to support their claims, and will often discount data that does not support their theory instead of revising that theory (McNeill et al., 2006). Students also struggle with the task of justifying how specific pieces of evidence support a certain conclusion: this process is referred to as the reasoning portion of a scientific explanation (Berland & Reiser, 2009; McNeill et al., 2006; Osborne & Patterson, 2011). Even once they learn how to collect sufficient and appropriate evidence to justify a given claim, students often do not articulate the scientific principles that helped them make those connections (McNeill et al., 2006). The inability to provide the logic for why the claim is supported by the evidence given therefore makes it difficult for students to make persuasive explanations (Berland & Reiser, 2009). Helping students learn to effectively justify their claims can be difficult, but there is a good model to help scaffold their learning.

Claim, evidence, reasoning framework scaffolds explanation construction. One way to help students learn to create scientific explanations is by scaffolding students' construction of them using the claim, evidence, reason model (McNeill & Krajcik, 2008; McNeill et al., 2006; McNeill & Martin, 2011). In this model, students are asked to make a claim about why a certain phenomenon occurs, gather evidence that supports this claim, and then give reasons why that evidence supports their claim (McNeill et al., 2006; McNeill & Martin, 2011). The scaffold itself is the breakdown of a scientific explanation into three core components of a claim, evidence, and reasoning. It is usually presented as a worksheet, paper or digital, that has prompts for students to write out their claim, supporting evidence, and reasoning to help the students understand that a good explanation requires all three of these key elements (McNeill et al., 2006; McNeill & Martin, 2011). When students are first learning to construct explanations, the prompts can be more detailed by asking for an answer to a question (claim), a certain number of pieces of evidence the students must give (evidence), and alerting them that they must give reasons why that evidence supports their claim (reason) (McNeill et al., 2006). In their 2006 study, McNeill et al. questioned whether it was more effective to provide one scaffold for explanation construction over time, or gradually fade that scaffold over time. They found that fading the scaffolds appeared to better prepare students to construct explanations in general. However, because one of the challenges for creating a TSP workshop is to design a program that will move students forward in their scientific explanation skills in an abbreviated time frame, a faded scaffold design is not possible. However, McNeill et al. (McNeill et al., 2006) found that students' scores increased significantly from the pretest to just the first explanation they made with a scaffold, which suggests it may be possible even in a shorter, one-time intervention to impact students' explanation abilities.

Additional studies using the claim, evidence, and reasoning model have also shown success in improving students' abilities to form well rounded scientific explanations (McNeill & Krajcik, 2009; McNeill & Martin, 2011). Similarly, a scaffolding tool called ExplanationConstructor has been used to successfully improve students' ability to form scientific explanations (Sandoval & Reiser, 2004). ExplanationConstructor is a digital tool that prompts students to answer a question by selecting pieces of evidence and then linking those to causal claims (Sandoval & Reiser, 2004). The two scaffolds are set up differently, but both guide students towards answering a question by using evidence to support their claim and providing logic for how the evidence supports that claim. The success of both scaffolding frameworks demonstrates that breaking up scientific explanations into the key parts is a useful way to help students become more proficient in this scientific practice. Given the abbreviated time frame of TSP classroom workshops, it may not be possible to have students become familiar with a new software tool like ExplanationConstructor. Nevertheless, simpler tools could be utilized as long as the tools focus students' attention on differentiating the key components of a complete scientific explanation.

A classroom TSP workshop is a semi-formal learning experience that combines the excitement of informal learning experiences and the more structured content of formal classroom lessons. TSPs balance the fun and the learning while taking place in the classroom during school time and with the goal of complementing the formal science curriculum. Much of the literature reviewed on learning scientific practices involves studies that take place over weeks, months, or even years. TSPs, on the other hand, are one-time, 45-minute classroom workshops. It is not expected in a TSP that students will make the same kind of progress as they would with a longer-term formal curriculum. However, by providing an exciting and fun experience it may be possible to catch and hold students' interest during that time, and potentially trigger personal interest in pursuing science in the future. Additionally, scaffolding students' construction of scientific explanations using the claim, evidence, reasoning model has the potential to support short-term learning gains, which may help students be better positioned for future learning.

Therefore, while the improvements may not be large, it is possible that even one, exciting and interesting 45-minute program could improve students' ability to form scientific explanations, while laying the foundation for developing interest and ability to participate in science in the future.

Learning Environment

This study focuses on the design and assessment of a new 45-minute TSP classroom workshop called *BRAAAAINS: You & the Zombie (BYtZ).* The program was designed to teach middle school students how to form scientific explanations as they learn some of the parts and functions of the human brain. The premise of a zombie outbreak was used to grab student interest initially, and students take on the role of zombie researchers to maintain a high level of engagement throughout the program. Given the short (45-minute) time frame of TSP classroom workshops, this program was designed using some of the overarching principles of PBL, but it is more akin to a Posthole or mini-PBL activity as described by (Ertmer & Simons, 2006). Therefore, the program contains key elements of PBL such as the students having a problem to solve (mutated zombie virus), collaborating with each other and, to some extent, the opportunity for student-directed learning (Savery, 2006). However, the design includes considerable guidance from the educator to ensure students complete the activities in the allotted time. In addition, the problem is posed as a fantasy narrative to further increase student engagement with the material (Bergin, 1999; Lepper & Cordova, 1992; Parker & Lepper, 1992). The problem is semi-authentic and falls generally into the diagnosis-solution problem category (Jonassen & Hung, 2008; Torp & Sage, 2002). However, given the nature of the narrative, the solution is not to cure a patient, but rather to determine the danger level of the new mutations so the CDC can decide if new safety protocols should be put in place.

During *BYtZ*, students complete a simple matching activity to begin learning about some key structures of the brain (Table 3). This is followed by a comparison between a healthy human brain and one infected by a zombie virus (Table 3). The anatomical differences are then related to the behavioral differences between humans and zombies. This contrast between the healthy brain and zombie brain helps students gain a deeper understanding of the behaviors associated with each brain structure, as well as what can happen when the structures are damaged. Once students understand how the original zombie virus damages the brain, they work in teams to look at brains from zombies that were infected with new, mutated, strains of the zombie virus (Table 3). Their task is to determine whether the damage to the brain caused by these new strains of the virus will make that zombie more or less dangerous than those infected with the unmutated virus. Throughout the program, students are introduced to the claim, evidence, reasoning framework of forming coherent scientific explanations (Table 3).

Students are first introduced to the CER framework in the third activity (Table 3). In this activity the educator explains the framework and what each component of the explanation should include. After gathering evidence, the CER framework is revisited in the sixth activity (Table 3) during which the educator leads the class through the process of constructing a scientific explanation. Students are asked to raise their hands and attempt to form each component, and then the educator reviews the claim, evidence, or reasoning that they came up with on the PPT slide. In the seventh activity (Table 3) the students work in groups of four to compare the mutated zombie brains to the typical zombie brains and construct a scientific explanation that states whether that zombie would be more or less dangerous than the typical zombie. There is a worksheet to guide them through the explanation construction (Appendix D). Finally, at the end of the program during the wrap-up the educator reviews the findings of each group and revoices them as scientific explanations where needed. The premise of a neuroanatomical comparison between healthy brains and zombie brains was chosen as a way to get students interested in the program from the start. Since zombies are something students are likely to be familiar with, and hopefully intrigued by, the topic should captivate their attention and engage them with the learning.

Embodied Conjecture

The embodied conjecture (Sandoval, 2004, 2014) for the TSP learning environment design consists of three main components: the tools the students use during the workshop, the structure of the activities, and the overall learning environment (Figure 1). The main tools used are the 3D brain application, the physical brain models, the CER framework, and guiding worksheets. Together, application of these materials leads to the intermediate outcomes by engaging the students with the material, demonstrating good explanations, fostering critical thinking, and improving content knowledge. The PBL post-hole structure of the program puts the students in the role of scientists as zombie researchers. This scenario combines collaborative inquiry with modeling of scientific explanations to further increase their engagement and critical thinking and demonstrate how to construct a good scientific explanation. The learning environment of the novel fantasy scenario of a zombie outbreak further enhances student engagement and provides a reason for improving their content knowledge of the brain. Altogether these intermediate outcomes are hypothesized to lead to the students' improved ability to construct scientific explanations and to increased knowledge of the brain as well.

Table 3: BYtZ Activities with number of participants, materials used, and time allotted

Activity	Participants	Materials	Time	Summary
1. Introduction	Whole class	PowerPoint slides	3 min	Students are informed of the zombie outbreak and their role in the research
2. Brain review with *3D Brain App*	Pairs	iPads with *3D Brain* app Worksheet	9 min	Students use a worksheet to guide them to key pieces of information about the brain
3. Introduction to CER	Whole class	PowerPoint slides	3 min	Scientific explanations and the CER framework are explained
4. Discussion of what is known	Whole class	PowerPoint slides Zombie "footage"	3 min	Class works together to make a list of typical zombie behavior based on video clips of zombies
5. Evidence: Zombie vs. Human brains	Whole class	3D printed Zombie and Human brains *3D Brain* app	3 min	A large model of an average healthy human brain and an average zombie brain are compared for differences
6. Explanation with CER	Whole class	PowerPoint Slides Evidence Gathered so far	6 min	Instructor guides class through first CER based on the behavior and brain anatomy evidence
7. Mutated virus investigation and explanation	Groups of 4	3D printed brains from zombies infected with one of 4 virus mutations CER worksheet PowerPoint Slide *3D Brain* app	12 min	Students work together to examine the 3D brain they are given and compare it to the model of the typical zombie brain and then use that information to write an explanation regarding whether that zombie would behave differently than a typical zombie
8. Wrap-Up and Review	Whole class	PowerPoint All other materials	6 min	Whole class comes back together to share their explanations and review them with each other and the instructor

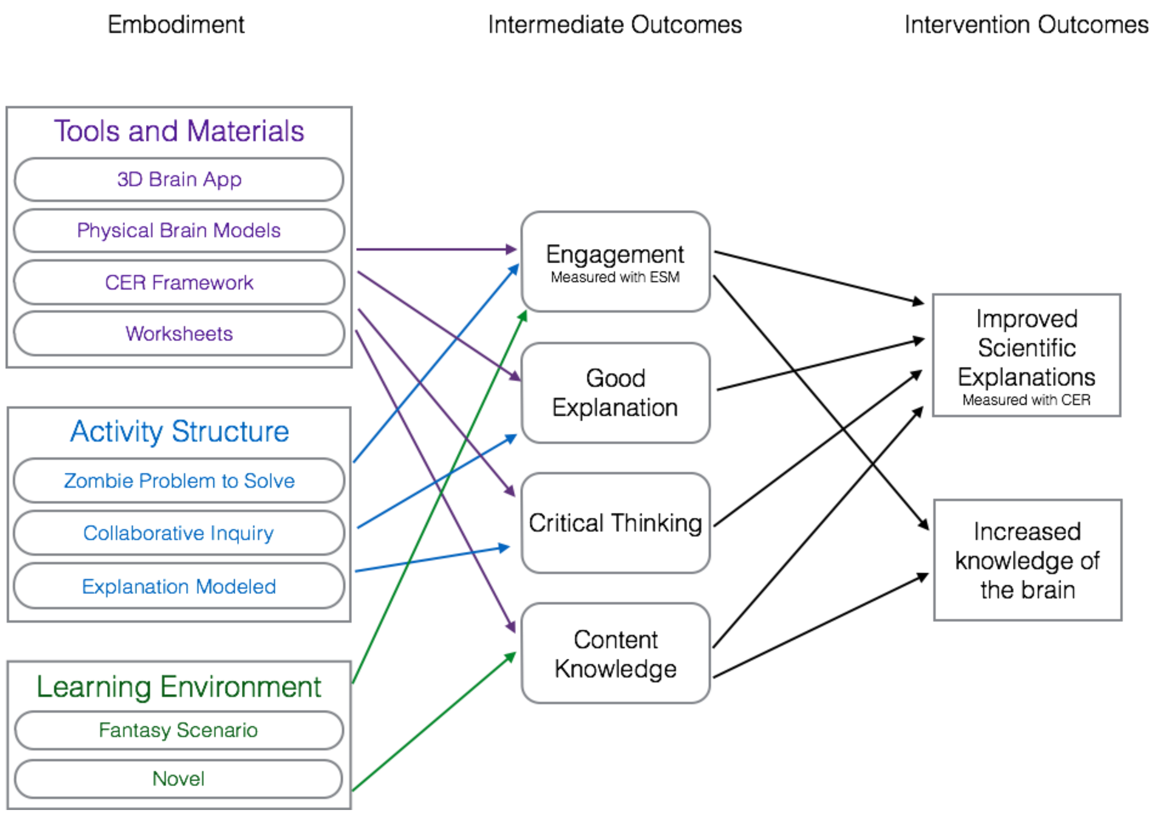


Figure 1. Visual representation of the embodied conjecture. This figure displays how the embodiment leads to the desired outcomes through intermediate steps (intermediate outcomes).

Methodology

The purpose of this treatment only pre-test / post-test study was to assess whether engaging students in learning by evoking situational interest while scaffolding their learning of the science practice is effective in improving scientific explanation skills in a short, one time, TSP. Putting students in the role of Zombie Researchers in the *BYtZ* TSP is hypothesized to foster situational interest, which will in turn engage students in learning scientific explanation skills. A quantitative approach was used in this study to answer the following primary research question:

Does the short (45 min), one-time, semi-formal learning experience *BYtZ* engage students with the process of creating scientific explanations and improve their ability to do so? This overarching question will be divided into the following specific questions:

1) Is there a positive change in students' construction of scientific explanations from the pre-test to the post-test?
2) Is there a positive change in student engagement as they progress through the program?
3) Is there an association between students' level of engagement and their ability to construct scientific explanations?

Students' scientific explanation skills were measured using a paper-pencil test before and after the program. The scientific explanations assessment required students to write a scientific explanation based on a data table. The assessment was scored with a rubric based on the claim-evidence-reasoning (CER) framework. Engagement was measured using an abbreviated form of the Experience Sampling Method (ESM) as a brief survey students completed with clickers just before *BYtZ* began, and again at 3 time points during the program. Improvements were investigated quantitatively in both the scientific explanation assessment and the engagement survey.

Participants

This study was conducted with 7th grade students from three different schools in three different school districts in New Jersey. The students in School A were 95% Hispanic, 4% African American, 1% Hispanic and White with 55% males and 45% females. The students in School B were 87% African American, 11% White, and 2% Asian with 45% males and 55% females. The students in School C were 47% African American, 44% Hispanic, 8% White, 1% Asian and Other with 52% males and 48% females. The schools were located in lower socioeconomic status towns with School B having 67% of students qualify for free or reduced price lunch, while 93% and 87% qualified for the same in Schools A and C respectively. At each school the program was taught to three classes of 18-30 students each for a total of 201 students participating in the program. Of those, 167 (83%) assented to having their work included in the study. However, 18 students failed to complete both the pre-test and the post-test, or had IEPs that could not be accommodated during the program, and so were excluded from the analyses. Additionally, the author failed to instruct the students in the first group from School B to write their clicker number on their packet, so the engagement survey responses from those 17 students were not scored and they could not be included in any analyses involving engagement. Therefore, n = 149 students are included in the analyses the involved the explanation data only, while n = 132 students are included in the analyses that involved the engagement data.

Materials

Scientific explanation assessment. To determine whether the students improved their scientific explanation skills, a paper-pencil pre- / post-test assessment was used (Appendix A).

The claim-evidence-reasoning (CER) framework and rubric were used to design the paper-pencil explanation assessment question (McNeill & Krajcik, 2009, 2012; McNeill & Martin, 2011). The explanation assessment included a data table that students used to write a scientific explanation to answer a question about whether any of several mutated forms of the zombie virus would result in more dangerous zombies (Appendix A). They were given an identical assessment question just before and just after the program. The explanations were scored using a rubric similar to the one used by the McNeill group (e.g. McNeill & Krajcik, 2009) with specific content adapted for this research (Appendix B). However, since this program is only 45 minutes long, large improvements in students' scientific explanations were not expected. Therefore, to make it easier to observe small changes, the McNeill rubric was further adapted by splitting up most of the categories. Therefore, instead of a score of 0-3, for each explanation, students received a score (0-7) for their claim, evidence, and reasoning separately for a total of 21 possible points across the full explanation (Appendix A; McNeill & Krajcik, 2009; McNeill et al., 2006). To ensure reliability in scoring, a second rater (a doctoral student with experience in data coding) scored a subset of 15% of the responses (McNeill & Krajcik, 2009). After a few rounds of adjustment to the rubric, the interrater reliability (IRR) was 90% or higher for each piece of the explanation. To ensure the reliability of the finer scaled rubric, the author and the second rater scored each explanation using both the originally designed 0-3 point scale rubric that maps closely onto the McNeill group rubric and the new 0-7 point scale rubric. All scores fell within the same portion of the rubric. The author scored the remaining 85% of the explanations. Using the CER rubric to score the answers generated quantitative data that allowed for comparison between the pre- and post-tests.

Engagement survey. There are many ways to measure engagement and interest. Some studies of situational interest have students fill out surveys on interest once or twice throughout a semester or school year (Linnenbrink-Garcia et al., 2010; Nieswandt, 2007). However, this approach gives only a broad sense of students' interest, but does not capture their interest in the moment of each lesson. To avoid this problem, other groups use multiple time points within a lesson to try and capture students' interest in the moment (Rotgans & Schmidt, 2011; Tapola et al., 2013). For example, Tapola and colleagues (2013) used a paper-pencil survey on the back of each of a series of worksheets that the students completed throughout the lesson. The survey they employed used a scale of sad to happy faces to make it easy for students to correlate their own level of interest with the material (Niemivirta & Tapola, 2007; Tapola et al., 2013). Loukomies and colleagues (2015) took a similar approach but used a modified version of the experience sampling method (ESM) and a clicker voting system to measure students' interest at multiple time points during a class.

The ESM is a survey measure that individuals fill out at a variety of time points to increase the amount of data gathered from each person and is therefore a useful tool for capturing participants thoughts and feelings in a given moment of interest (Csikszentmihalyi & Larson, 1987; Shernoff & Vandell, 2007; Vandell et al., 2005). This method of data collection has been used for many years and it has been validated and found reliable as a way to gather data on subjects' state of mind in real time (Csikszentmihalyi & Larson, 1987; Shernoff et al., 2003; Shernoff & Vandell, 2007; Vandell et al., 2005). This is critical for measuring student engagement with each activity throughout a lesson because you don't want their feelings by the end of the program to alter their perception of how they felt during an earlier part of the same lesson. Unlike some of the other engagement measures available, the ESM is not specific to formal learning environments. In fact, it has been used to measure engagement in after school programs (Shernoff & Vandell, 2007; Vandell et al., 2005), which are more similar to the semi-formal education program assessed in this study. For these reasons, a modified version of the ESM was an appropriate tool to gather data on student engagement for this study.

Since the ESM in full is designed for use over a longer period of time, this study used a similar approach as the Loukomies group (2015) and used a modified and significantly shortened version of the ESM to measure student engagement (Csikszentmihalyi & Larson, 1987; Loukomies et al., 2015; Shernoff et al., 2015, 2003). An ESM logbook used in a previous study in combination with information from other work by the Shernoff group were adapted into a brief survey for the present study (Appendix C; Shernoff, 2010; Shernoff et al., 2003; Shernoff & Vandell, 2007). Of the questions asked in other ESM surveys, only three of the subjective experience variables were tied to engagement: interest, concentration, and enjoyment. Therefore, these were the only three questions included in the survey for this study (Appendix C) and they were combined together to form a composite variable for engagement; this will be discussed further in the data analysis plan (Shernoff et al., 2003; Shernoff & Vandell, 2007). Student responses to these survey questions were collected using the Promethean ActiVote system which is a clicker voting system that allowed the students to quickly respond to the survey questions.

A clicker system was chosen for this study because though the program contains some worksheets, they are not used for every activity. Additionally, pilot testing indicated that the students enjoyed using the technology more than filling out paper surveys. Furthermore, since this study investigated engagement, not just interest, splitting up each survey question (level of interest, enjoyment, and concentration) allowed students to focus on each question, instead of just circling all of one number, which was seen in pilot testing with paper surveys.

Procedure

At Liberty Science Center, TSP workshops usually take about 45 minutes. An additional 15-20 minutes were added for data collection, resulting in a total of 60-65 minutes allotted for the entire program for schools that agreed to be part of the study. No identifiable information from the individual students was collected. All worksheets handed out on the day of the presentation of *BYtZ* were stapled together in numbered packets that were collected at the end of the program. Clickers were labeled with a number that students wrote on the front page of their packet. Students were specifically told not to put their names on their packets. The author taught all programs and collected all data the day of the program. The sessions proceeded as follows (see also Figure 2 and Table 3):

1. The oral assent script was read to the students and it was explained that they had the choice at the end of the program whether or not to include their work in the research.
2. Students participated in a practice round with the clickers to ensure they were comfortable working with them.
3. Students were asked to think about what they were doing just before they came into the classroom and asked to complete the ESM survey with the clickers (Appendix C). Then they completed the pre-test explanation (Appendix A)
4. Students were introduced to the zombie epidemic, and then they used an iPad to complete a matching activity to match a variety of brain structures with their functions as a way to learn some critical information about the brain.
5. Students completed the second ESM survey (Appendix C)
6. Students worked with the instructor to connect behavior of zombies to the parts of the brain while being introduced to the CER framework.

7. Students completed the third ESM survey (Appendix C).
8. Students worked in groups of 4 to determine whether the mutated zombie brain their team was given would have behaved differently than normal zombies. They were prompted to use the CER framework to help with their conclusion. Each of the four mutations was discussed as a group and the educator helped phrase students' answers as scientific CER explanations.
9. At the end of the program, students completed the final ESM survey (Appendix C) and the post-test explanation (Appendix A).
10. Finally, students were given the choice to opt in or out of the research by checking the corresponding checkbox on the last page of their packet.

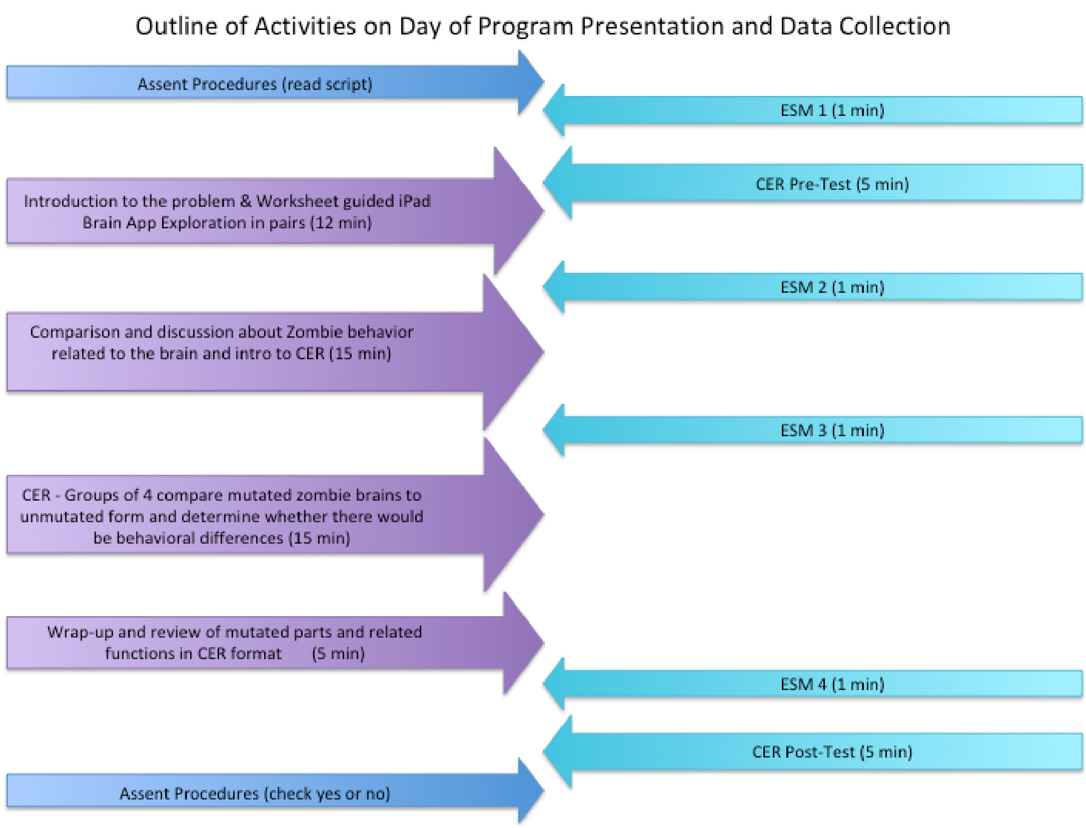


Figure 2. *Visual outline of activities on the day of the program including data collection.*

Results

Scientific Explanations

To determine whether the students made any improvements in their scientific explanations from the pre-test to the post-test, the quantitative data generated from the CER rubrics – individual scores for claim, evidence, and reasoning, as well as combined scores (Appendix B) – were input into and analyzed in both the statistical analysis software SPSS and Microsoft Excel. Each component was given a maximum possible score of 7.0 for a total possible combined score of 21.0. See Table 4 for means and standard deviations for all scores.

Table 4: Component and combined explanation performance for each school and across all schools

		Pretest[a]		*Posttest*[a]			
	n	*M*	*SD*	*M*	*SD*	*t*[b]	Cohen's *d*[c]
All Schools	149						
Claim		2.98	1.22	3.23	1.18	2.56**	0.2
Evidence		3.19	2.02	3.52	2.07	1.65*	-
Reasoning		2.21	1.90	1.85	1.87	2.28**	0.2
Combined		8.02	4.17	8.96	3.94	2.93**	0.2
School A	42						
Claim		3.55	1.13	3.70	0.87	0.72	-
Evidence		3.55	2.03	3.07	2.02	-1.14	-
Reasoning		2.00	1.89	1.88	1.70	-0.43	-
Combined		9.10	3.93	8.64	3.43	-0.73	-
School B	44						
Claim		2.70	1.30	2.84	1.31	0.86	-
Evidence		2.43	2.03	3.23	1.93	2.21*	0.3
Reasoning		1.89	1.73	2.41	2.06	1.72*	0.3
Combined		7.02	4.03	8.48	4.47	2.75**	0.4
School C	63						
Claim		2.79	1.11	3.19	1.18	2.60**	0.3
Evidence		3.48	1.90	4.02	2.11	1.97*	0.2
Reasoning		1.73	2.05	2.30	1.84	2.33**	0.3
Combined		8.00	4.30	9.51	3.85	3.03**	0.4

[a]Maximum score = 7 for claim / evidence / reasoning; 21 for combined. [b]one-tailed paired *t*-test.
[c]Cohen's *d* effect size only shown for differences with $p < 0.05$.
*$p < 0.05$ **$p < 0.01$

The data were analyzed by three one-tailed paired *t*-test analyses, one for each explanation component. The results indicate a small (Cohen's $d = 0.2$ for all components) but statistically significant increase in the average score for claim ($t(148) = 2.56$, $p < 0.01$), evidence ($t(148) = 1.65$, $p = 0.05$), and reasoning ($t(148) = 2.28$, $p = 0.01$) on the post-test compared to the pre-test (Figure 3A). When looked at individually, the schools have varying results. School A ($n = 42$) shows no significant differences between pre- and post-test scores, and in fact shows a trend of lower average scores on the post-test for evidence and reasoning (Figure 3C). School B ($n = 44$) has a significant increase on the post-test evidence ($t(43)=2.21$, $p < .05$) and reasoning ($t(43)=1.72$, $p < .05$) scores with a small effect size of Cohen's $d = 0.3$ (Figure 3B). School C ($n = 63$) shows small but significant gains on all aspects of the explanation: claim ($t(62)=2.6$, $p < 0.01$; Cohen's $d = 0.2$), evidence ($t(62)=1.97$, $p < 0.05$; Cohen's $d = 0.3$), and reasoning ($t(62) = 2.33$, $p = 0.01$; Cohen's $d = 0.3$) (Figure 3D). The results for a combined explanation score are similar to those for the all school results in each component of the explanation (Cohen's $d = 0.24$; $t(148)=2.93$, $p < 0.01$; Figure 4).

A frequency analysis was performed by plotting the number of students that received each score (0-7) on bar graphs (Figure 5). The data show that on the pre-test, most students made claims, many students provided evidence, and some students gave reasoning (Figure 5A-C). In all cases there are improvements, but the most dramatic is for claims where there are quite a few students making inaccurate claims on the pre-test, whereas on the post-test most students are making accurate, if incomplete claims though not getting all the way to the highest level claim score (Figure 5A). The evidence and reasoning are more evenly distributed but the evidence skews more toward the middle scores (Figure 5B) while the reasoning skews more toward the lower scores (Figure 5C) over all. For claim, evidence, and reasoning, there are more students scoring higher on the post-test.

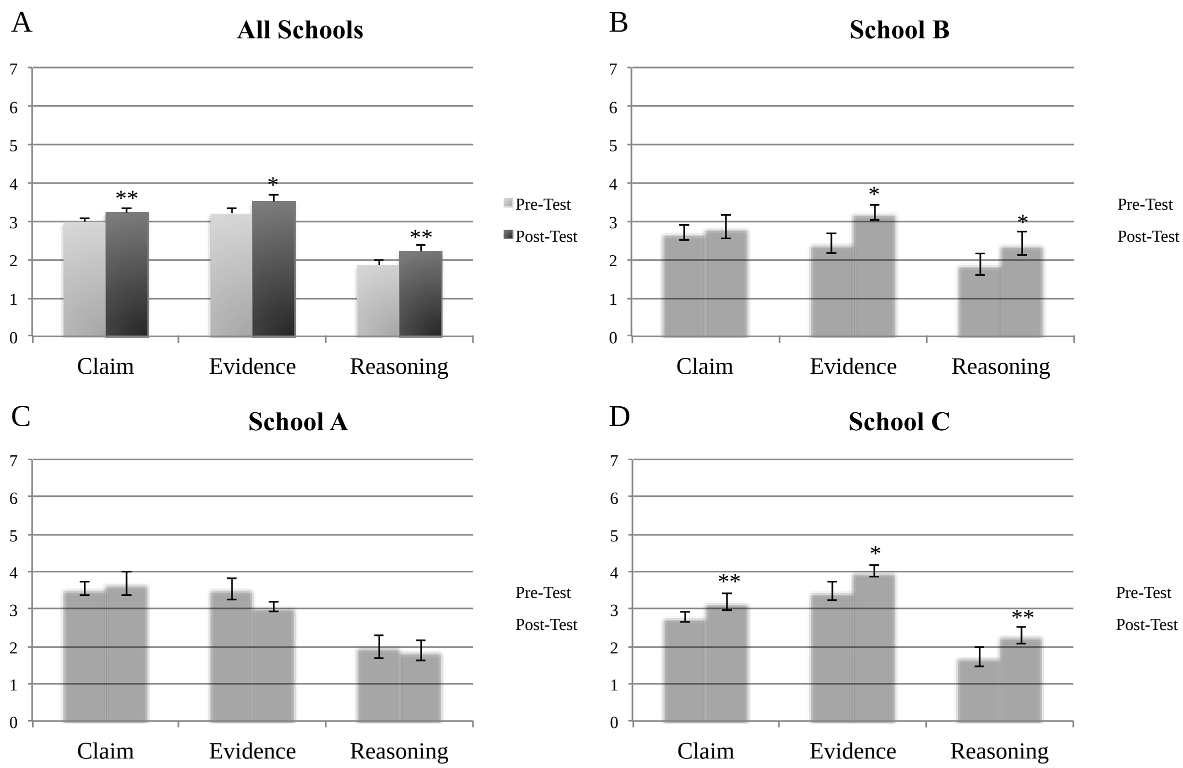


Figure 3: Graph of average explanation scores comparing pre-test to post-test. (A) This graph shows the average score on each element of the explanation for all schools. *p < *0.05.* **p ≤ *0.01. (B-D) Graphs showing the average score on each element of the explanation for each school.* *p ≤ *.05.* **p ≤ *0.01.*

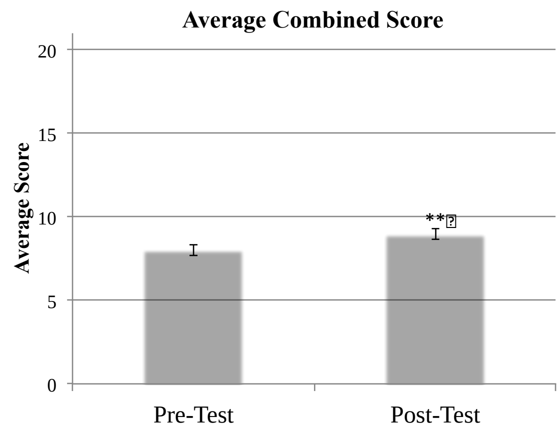


Figure 4. *Graph of average combined explanation scores comparing pre-test to post-test score for all schools. ** p < 0.01.*

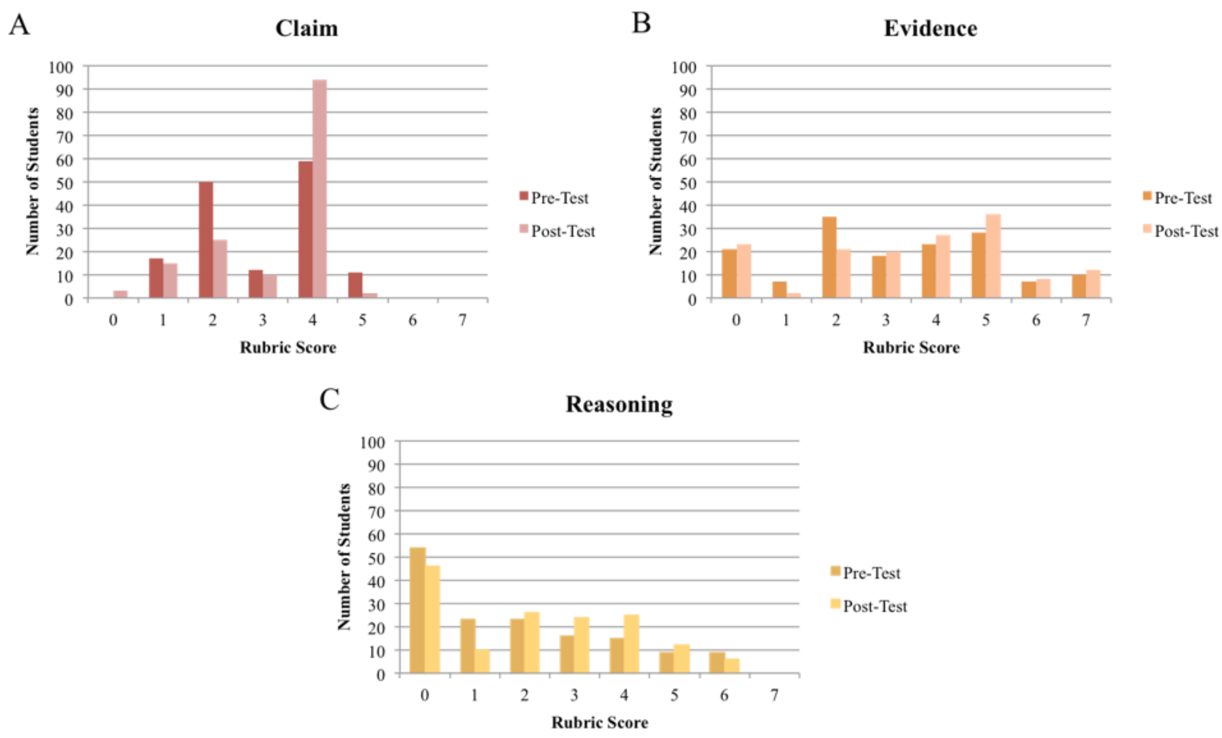


Figure 5. *Frequency graphs of each explanation component. (A-C) Comparison of the frequency of each score on the pre-test compared to the post-test for claim (A), evidence (B), and reasoning (C).*

Engagement

All survey data was exported from the Promethean software to a Microsoft Excel spreadsheet. This data was then consolidated into a master Excel spreadsheet file and reorganized for analysis. To generate the engagement data from the survey questions the composite variable for *engagement* described by the Shernoff group was used (Shernoff, 2010; Shernoff et al., 2015). This composite variable is a combination of the items for *concentration, enjoyment,* and *interest* (Shernoff et al., 2003; Shernoff & Vandell, 2007). The *engagement* variable is based on flow theory and “conceptualized students to be engaged only when all three [variables] were experienced simultaneously” (Shernoff & Vandell, 2007, p. 897). Once all of the responses were consolidated and averaged to generate the engagement data, the data were then imported into the statistical analysis software SPSS for analysis. The data were analyzed by repeated measures analyses of variance (ANOVA) with activity (baseline, brain review, brain comparison, mutated brains) as the factor and level of engagement (1 – 4) as the repeated measure. The ANOVA revealed a statistically significant difference in the level of engagement during the program, $F(3, 521) = 25.60$, $p < 0.001$, $\eta^2 = 0.128$.

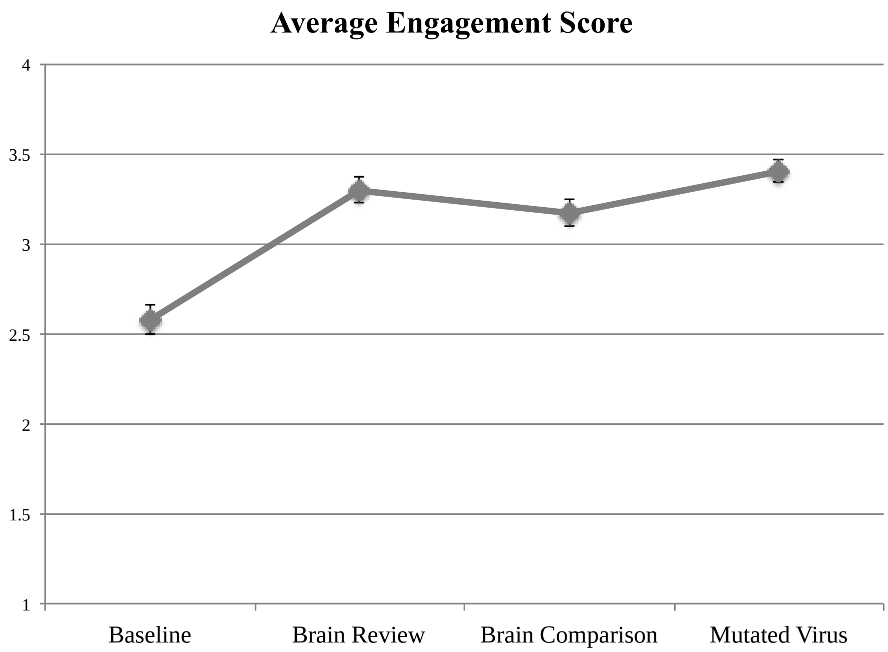


Figure 6. Graph of average level of student engagement at each data collection point.

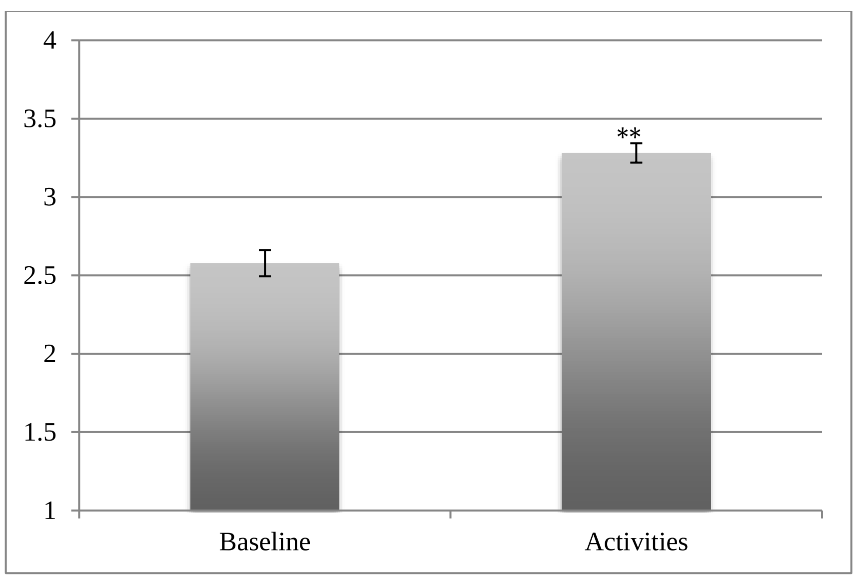


Figure 7. Graph of average baseline engagement value compared to the average total program engagement value with the *BYtZ* program activities. $**p < 0.01$

Post hoc comparison using the Hochberg's G2 test indicated that the mean scores for the program activities brain review (*M* = 3.30, *SD* = 0.79), brain comparison (*M* = 3.17, *SD* = 0.85), and mutant brains (*M* = 3.40, *SD* = 0.73) were significantly higher ($p < 0.05$) than the baseline level of engagement (*M* = 2.58, *SD* = 0.96; Table 5). A graph of the mean engagement values (Figure 6) shows this difference. To gain an understanding of overall engagement with the program activities the values to each time point were averaged to find a total program engagement value. When evaluated by *t*-test the difference between the average baseline engagement score and the total program engagement score is also statistically significant $t(131)=7.4$, $p < 0.001$ (Figure 7). When looked at individually, the average level of engagement with the *BYtZ* activities for each school is different; Figure 8 and Table 5 shows that School A has an overall lower level of engagement for each activity than Schools B and C.

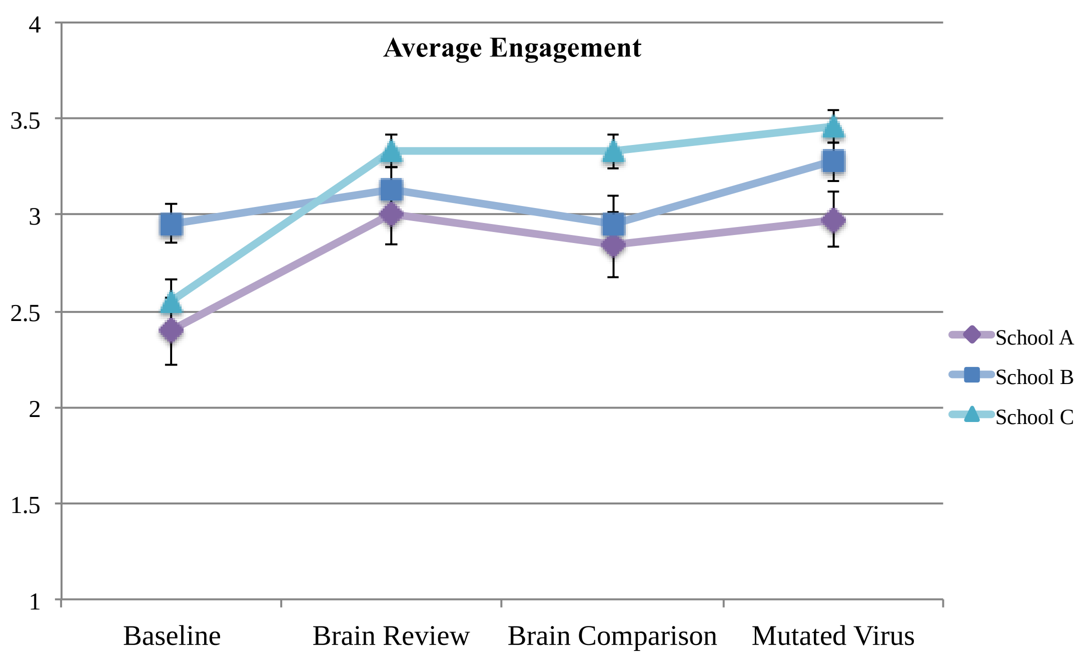


Figure 8. Graph of average level of student engagement with each activity separated by school.

Table 5: Mean values and standard deviations for baseline, total program, and individual activity engagement

	n	*M*	*SD*
All Schools	132		
Baseline		2.58	0.96
Program Activities		3.27	0.73
Brain Review		3.30	0.79
Brain Comparison		3.17	0.85
Mutant Brain		3.40	0.73
School A	41		
Baseline		2.38	1.12
Program Activities		3.08	0.94
Brain Review		3.08	0.98
Brain Comparison		3.00	1.08
Mutant Brain		3.21	0.91
School B	28		
Baseline		2.93	0.70
Program Activities		3.36	0.54
Brain Review		3.52	0.59
Brain Comparison		3.05	0.76
Mutant Brain		3.55	0.53
School C	63		
Baseline		2.55	0.91
Program Activities		3.38	0.57
Brain Review		3.34	0.70
Brain Comparison		3.33	0.69
Mutant Brain		3.47	0.67

Engagement and Scientific Explanations

Finally, to determine whether the level of student engagement with the program was correlated with improvements in their explanations the total program engagement value for each student was used for the engagement data. For the explanation data, the difference between the combined pre-test and post-test CER score was determined for each student. The data demonstrate a slight, but not significant positive correlation (Figure 9A). Additionally, the level of engagement was correlated with the change in each component (CER) score. The results demonstrate that the level of engagement was not correlated with changes in claim score (Figure 9B). However, there is a small but significant positive correlation between engagement and gains on the score for both evidence ($r = 0.25$, $p < 0.01$; Figure 9C) and reasoning ($r = 0.26$, $p < 0.01$; Figure 9D). The relationship between the average level of engagement and the change in total explanation score as well as the change in each component can be seen in the scatterplot diagrams in Figure 9.

The author was also interested to know whether there was a general positive correlation between high levels of engagement and high explanation scores. Therefore, the engagement data was also correlated with the combined post-test score for each student. The correlation analysis demonstrates a significant positive correlation between engagement and post-test combined score $r = 0.30$, $p = 0.001$. This relationship is also visible in the scatterplot diagram in Figure 10.

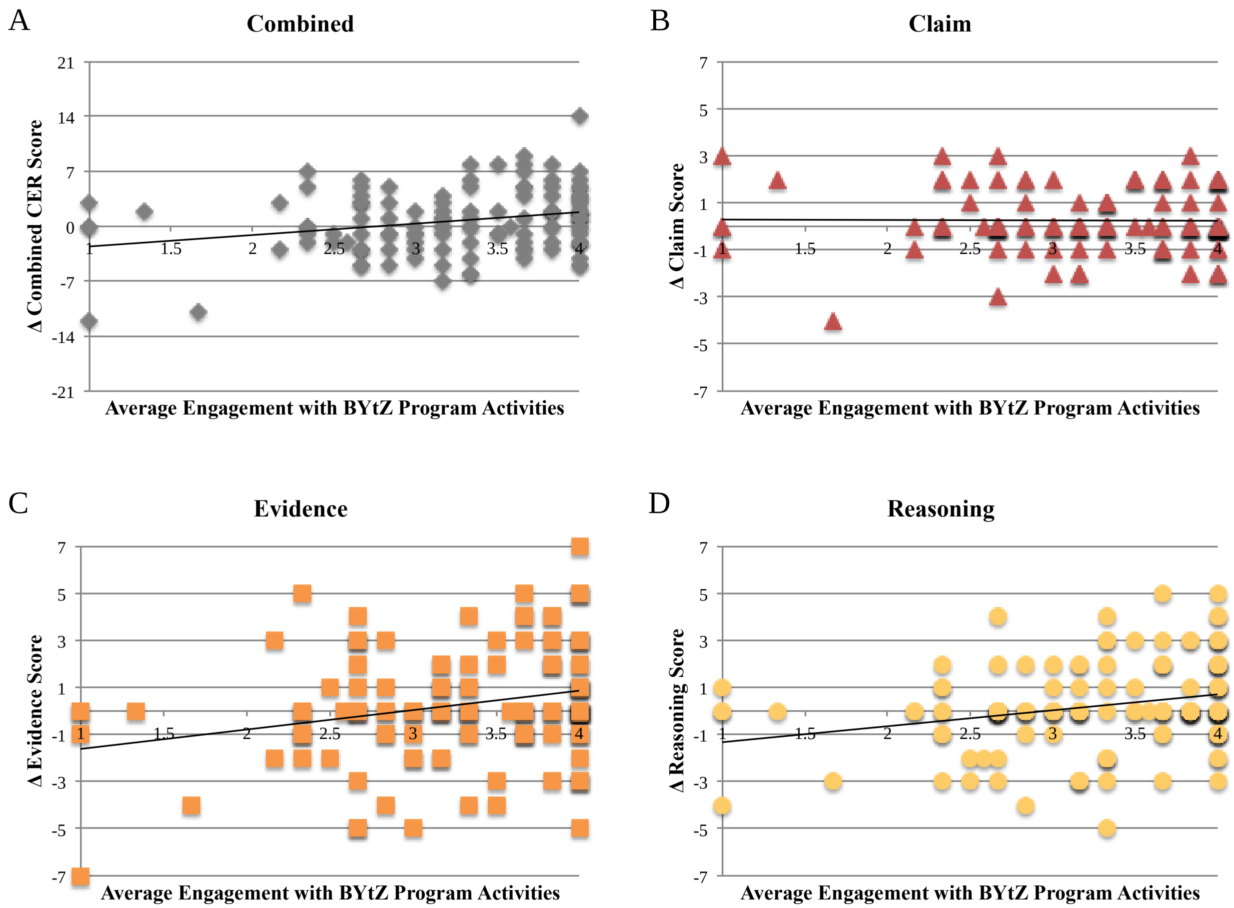


Figure 9. *Scatterplot diagrams of correlation between average level of engagement with BYtZ program activities and change in explanation score. (A) Engagement vs. change in combined explanation score. (B) Engagement vs. change in claim score. (C) Engagement vs. change in evidence score, r = 0.25, p < 0.01. (D) Engagement vs. change in reasoning score, r = 0.26, p < 0.01.*

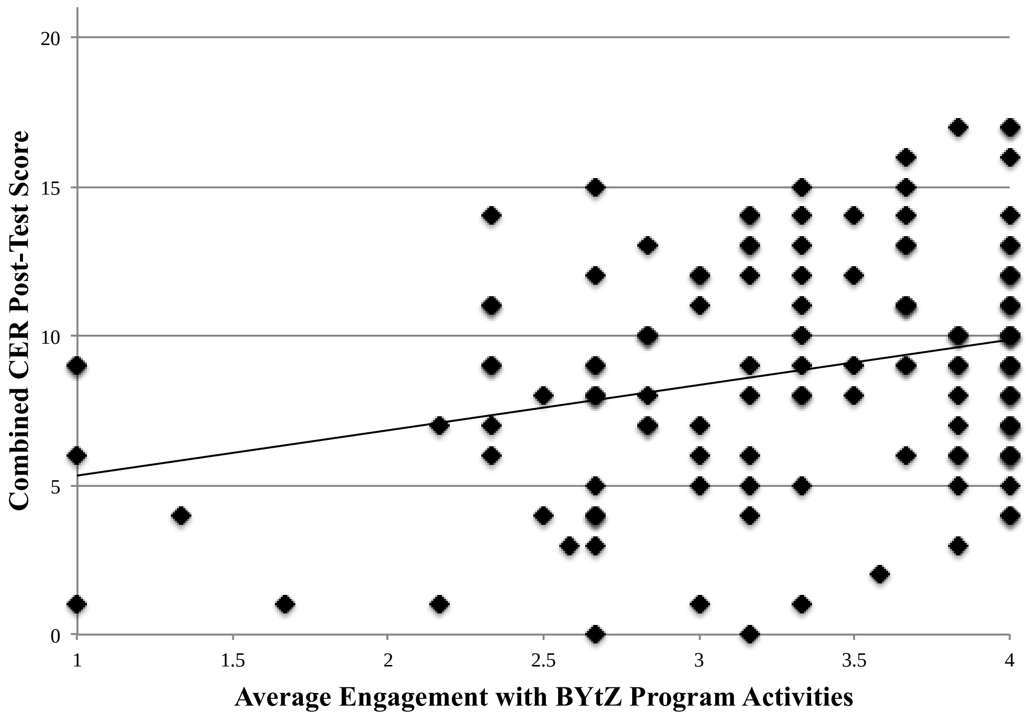


Figure 10. Scatterplot diagram of correlation between average level of engagement with *BYtZ* program activities and total combined post-test score for each student. $r = 0.30$, $p = 0.001$.

Discussion

This study set out to determine whether a one-time, 45-minute traveling science program could engage students in learning by putting them in the role of a zombie researcher to improve their ability to construct scientific explanations. Constructing scientific explanations is an challenging practice to become proficient at (McNeill & Krajcik, 2008; McNeill et al., 2006; Sandoval, 2003) yet it is a necessary skill for scientists to have, and it is one of the 8 SEPs of the NGSS. However, it is not always an easy thing to engage students with the process of constructing scientific explanations. While it can be easy to grab students' attention with interesting phenomena such as explosions, it is important to maintain their interest while they are learning more challenging practices such as scientific explanations. Therefore, the premise of a zombie outbreak was used to grab students' interest initially, and the activities in the program were designed to hold their interest by making them the zombie researchers and giving them hands-on activities to do throughout the program. In addition, the CER framework was employed to scaffold this difficult practice. The framework for breaking up the explanation into the claim, evidence, and reasoning was used as a scaffold providing structure to help the students complete the complex task of constructing scientific explanations. This scaffold was presented to the students as part of the PowerPoint presentation during the program and described verbally, and it was provided as a physical paper scaffold on their worksheet. The framework was explained, used as a group led by the instructor, and also used in small groups by the students. Altogether keeping the students engaged while scaffolding their learning of explanation construction helped them improve.

The data indicate that students were significantly more engaged with the program content compared to the baseline measurement. To gain a general baseline measurement, students were asked to think about what they had been doing just before they entered the classroom for *BYtZ*. Additionally, the data show small, but statistically significant increases in students' scientific explanation scores across all components (claim, evidence, reasoning; Figure 3). When the claim, evidence, and reasoning scores are combined to give an overall explanation score, the gain from pre-test to post-test is even larger (Figure 4). Given the abbreviated time frame of a traveling science program, large gains in explanation proficiency were not expected. In fact, there was a concern that on such a short time frame no differences would be visible. To see a statistically significant change, even if it was a small change, is evidence that students can and do learn from one-time 45-minute programs. Engaging the students with the learning through the premise of a zombie outbreak seems to have also been an important component as there is a significant positive correlation between level of engagement and the difference in score for both evidence and reasoning.

Anecdotal observations while delivering the programs may explain some of the differences between schools. Consistent with Figure 8, School B and School C appeared to be the most engaged with the program, there were fewer instances where the author had to work hard to regain the attention of the students. School A, on the other hand, had students that were more likely to lose focus and need to be recalled to the activity at hand. There were also more disruptions in School A due to an offset bell schedule compared with the program times, including one class that worked during part of their lunch break. For these reasons, the author looked at the explanation and engagement data by school as well as overall. Though not tested statistically, it is interesting to note that when the data are separated by school, School A shows no significant differences in explanation scores, and the students in that school also show the lowest level of engagement with the program content. On the other hand, School C which demonstrates significant gains on all three explanation components (claim, evidence, reasoning) has the highest level of engagement. This is further indication that when a program or instructor is able to engage students with what they are learning, they learn more. These results are exciting and support future development of programs of this nature because even though it takes a lot of time and energy to develop them, these programs have a positive impact on the students who have the opportunity to participate in them.

The Importance of the Iterative Design Process

It takes a lot of time and effort to design a one-time 45-minute classroom workshop. To make the best possible program, it is necessary to try out program components, or even sometimes the whole program, with students to find out which activities work well, and which ones need adjusting to maintain student interest. In pilot iterations of this program there were worksheets that involved a larger amount of writing. Those studies demonstrated that some of these activities needed to be altered because students were either not completing them, were copying things down *verbatim* and not necessarily paying attention to the content, and were spending so much time writing during the program that they were giving one to a few word explanations on the post-test. Two significant changes were made to combat this writing fatigue: the brain review activity that goes with the iPads, and the whole group scientific explanation. The iPad activity was originally a short answer worksheet, but is now the matching worksheet used in this program. The scientific explanation completed as a group to explain zombie behavior is now done orally, with no writing for the students. To help the students learn to construct the explanations, however, the task of putting the explanation together has mostly been transferred to them. The students are asked to give a claim, evidence, or reasoning. The educator will assist by asking questions to draw out the evidence or explanation, and sometimes rephrase the information the student gave them (revoicing) to put it into the explanation construct. After each piece has been reviewed, the educator advances the slide show to demonstrate the wording that they chose, but makes sure to inform the students that is not the only acceptable wording. Both of these changes proved to be valuable and helped move the program along more smoothly, however, additional areas for change also came up through the data collection process.

Most of the changes to the program that came up from the data collection process are minor changes to the PowerPoint presentation that will help with the review of data as a whole group. The first will be to put the matching activity on a PowerPoint slide with the correct brain structures and functions matched up so the students can triple check their work when they review with the instructor. The next will be a review slide of each of the 4 mutated brains that will include a photo of the normal zombie brain structure side by side with the same structure from the mutated brain to help students recall the differences as they go through their explanation out loud, and to allow all students to see all of the mutations. Finally, since the students are in the role of junior CDC agents during the program, the last slide of the PowerPoint will be a wrap-up slide with a note from the CDC thanking the students for their help. This will help give the end of the program a more finished feel than it currently has. The current iteration of the program showed promising explanation and engagement results, however, there are still opportunities for improvement.

Limitations

One limitation of this study is time. Much of the literature used to inform this study, especially regarding scientific explanation best practices, refers to studies that take place over the course of weeks, semesters, or entire school years. Therefore, students cannot be expected to make the same kinds of learning gains from one 45-minute program as they would from much longer and sustained programs. However, the purpose of this study was not to create a program that resulted in expertise at creating scientific explanations, rather, it was to get the students engaged with the practice of forming coherent scientific explanations. Another limitation of this study is that it is possible that the students who chose not to have their data used for the study were also less engaged with the program, therefore skewing the data toward a more engaged group. Finally, this study did not contain a control group for comparison, and to gather a baseline for engagement students were asked to think about whatever they were doing before they came to participate in *BYtZ.* This was the best baseline it was possible to get for this study, however, it leaves a lot of variability for the baseline data because students coming from their favorite class or recess are likely to score that activity higher than those coming from their least favorite class. Despite these limitations, the evidence is promising and hopefully future studies will help answer some of these remaining questions.

Conclusion

The main purpose of this study was to assess the effectiveness of a short (45-minute) semi-formal traveling science workshop in terms of student engagement and learning. This study demonstrated that students could make small improvements in their ability to construct scientific explanations using the CER framework in one-time 45-minute traveling science programs. Furthermore, the results show that student engagement is increased during the program activities, and that the level of engagement was positively correlated with an increase in both evidence and reasoning scores. Further studies would be needed to determine the generality of the design principles employed in *BYtZ* for the design of TSPs more broadly. It would be useful in future studies to conduct similar experiments in schools from a wider variety of socioeconomic backgrounds. It would also be beneficial to collect information regarding students' prior experience with scientific explanations and the CER framework.

Chapter 4: Professional Development Seminar for LSC STEM Educators

The following professional development (PD) seminar was designed to be a one-time, 90-minute seminar for the 8 full-time and 2 part-time STEM Educators at Liberty Science Center responsible for regularly bringing TSPs to schools. This PD was designed to bring a deeper understanding to those who will be teaching *BRAAAAINS: You & the Zombie* (*BYtZ*) of how and why this program was designed so that they can then deliver the best program possible. Additionally, it will be an opportunity to share what I have learned through this process and how I have used an iterative design process to improve *BYtZ* over time. Therefore, the main goals of this PD are twofold: (1) to ensure the program is taught with fidelity to its stated goals, and (2) to share with the LSC staff reflections and insights about the *BYtZ* design process they might use while designing their own new programs. Given the focus on the design process, it is also possible that this PD could be opened up to the rest of the LSC STEM departments, while they don't teach *BYtZ*, they may still gain useful information for program design. There are two main items included for the professional development:

1. **Program Outline and Notes –** The first item is an overall detailed outline of the program. This includes notes that go with each slide and the corresponding slide numbers and where to stop to allow the audience to try out the activities. There is additional background information included at the end of the outline.
2. **Presentation for PD Seminar –** The second item is the presentation that will be given during the PD in its entirety.

Program Outline and Notes for Presenter

Welcome! (Slide 1)

- Good afternoon and welcome
    - Feel free to ask questions throughout if any come up!

Introduction (Slides 2 – 10)

- (Slide 3) Why are we here?
    - To understand why I designed the program the way I did, and how it has changed and improved over time
        - I'll go over some of the literature
            - Why did I choose explanations?
            - What are best practices for engaging students?
        - I'll explain how this program has changed and improved over time
            - I have been working on some version of this program for quite some time, and many changes have been made. Some major, some minor, all for the best (I think).
    - To learn how this program is a little different than other programs we teach because it was designed to focus on a science *practice* not content
        - Yes there is content that is important for the program to progress, but the purpose of the program is for students to leave with a better understanding of constructing scientific explanations
            - If students leave with a better understanding of the brain that is great, and I hope they do, but it's not the point of the program
- (Slide 5) What are some key things we strive to incorporate into all of our programs at LSC?
    - Excitement, interest, meaning
        - We want are programs to be exciting, interesting, and meaningful to our audience so they learn something from them
    - How can we achieve these goals?
- (Slide 6) As an EdD student, I learned to go to the literature to make sure my ideas were grounded in peer-reviewed journal articles. And they ARE. What we know intuitively as informal science educators is supported by research.
    - Making science fun and exciting helps people learn
- (Slide 7) Situational interest, interest generated by the context, is what we strive to achieve to make the science exciting and fun to learn.
    - We catch interest with interesting phenomena or situations, but for TSPs in particular we want to hold onto that interest throughout the 45 minute program.
    - (Slide 8) One way to do this is to give problems and puzzles to solve.

- (Slide 9) So we want to catch and hold situational interest and use PBL-like activities to make the learning fun and engaging. So far so good, none of this is really surprising to those of us in informal science education. So what topic can I use to get students interested in learning?
    - (Slide 10) Zombies!
        - The idea was percolating ever since learning about TI Zombie Apocalypse lesson
        - They're good for learning about the brain
    - My very first idea for this program was straight forward and fact based
        - It used Zombies as the hook, but then went on to be mostly fact-based with the two hands-on activities being building a neuron from pipe-cleaners, and comparing a zombie brain to a healthy brain.
        - As I did more research, took more classes, and learned more about the NGSS, this idea began to change
    - I learned about PBL and thought to myself making the zombie program more PBL would be a better way to engage the students
        - So I decided to make the students the zombie researchers and the problem they would solve would be to explain zombie behavior by comparing a healthy brain to a zombie brain.

Zombies and Standards (Slide 11 – 26)

- (Slide 11) But zombies are obviously not in any standards so now what?
    - (Slide 12) Well, the students are learning about the brain, so I found in the NGSS a life science PE and related DCI I could use
        - **Performance Expectation MS-LS1-3**: Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells
        - **Disciplinary Core Idea LS1.A:** Structure and Function - In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions (NGSS Lead States, 2013).
    - (Slide 13) These standards worked quite well for my original idea to have the students build a neuron and compare healthy brains to zombie brains.
        - This also worked well with my first idea for data collection, which was to have the students draw and label a brain before and after the program and score the drawings to look for improvement.
- (Slide 14) However, the more I read and the more I worked on the exact activities that would work for this program, the more I realized I was not designing a new TSP that was truly an NGSS program. Nor had I created an NGSS assessment.

- So I asked myself "What can I do that's a little different? How can I TRULY make this an NGSS program?"
- What I realized is that what sets the NGSS apart is the focus on practices to learn the content, so I decided focus on a practice, but which practice?

- (Slide 15) What will the students be doing?
  - Students will also be the *researchers* helping to solve the zombie crisis so there will be some practices happening!
    - Given the 45 minute time frame, need to hone in on ONE practice
  - (Slides 16 – 23) After eliminating some SEPs because they just didn't quite fit with the premise of Zombie Researchers I turned to 2 sources to figure out what practice to zero in on:
      - Teacher friends and relatives
      - The literature
    - I learned students really struggle with the related practices of constructing explanations and engaging in argument from evidence (Berland & Reiser, 2009; McNeill & Krajcik, 2012)
- (Slide 24) So how did I design the program to target this standard?
  - As I mentioned before, building off of a research base is critical for any program design as an EdD student. So, I hit the research again and found the claim, evidence, reasoning framework for constructing scientific explanations (Braaten & Windschitl, 2011; McNeill & Berland, 2017; McNeill & Krajcik, 2012, 2012; McNeill et al., 2006; McNeill & Martin, 2011)
    - Claim – answer to the question
    - Evidence – data that supports the claim
    - Reasoning – justification for how the evidence supports the claim
    - When first learning, scaffolding tends to be explicit but as they become more confident and comfortable with the practice, scaffolds can be faded (McNeill et al., 2006)
    - 45 minutes is not enough time to get to the faded scaffolds point so I decided they would stay explicit
  - So I had the idea to grab student attention with a zombie premise and keep it by making them zombie researchers and giving them a problem, I also knew I wanted to focus on scientific explanations using the CER framework – but how do I turn that into a program? What activities should I include?
- (Slide 26) Questions so far?
  - Before I get into how I chose and designed the activities, are there any questions so far?
    - What ideas have you used or wanted to use to design a new program?
    - How did you make that work as a lesson, or why haven't you created a program using that idea?

Program Design (Slides 27 – 78)

Activities (slides 27 – 60)

- (Slide 28) Activities
    - What problem will the students solve?
        - My original idea was to have them explain zombie behavior by comparing a healthy brain to a zombie brain, but now I realized I needed to build in more opportunities to do proper scientific explanations if that was going to be my focus, so that couldn't be the only problem to solve
        - So then I started thinking about what other problems related to zombies could they solve?
        - After much deliberation and discussion, I settled on "What happens if the zombie virus mutates?"
    - Before they can answer understand how zombie behavior relates to the brain, they'll need some background information the brain
- (Slides 29 – 43) Activity 1: Background info with iPads
    - Originally I was going to use a labeled paper diagram, but
        a. that's boring and
        b. it's not a good 3 dimensional representation to compare to the 3D brains later
        c. I no longer planned to do an assessment similar to this model, so why not go with something more interesting?
    - These kids are growing up in a digital world, so I found a 3D Brain app. This serves 2 functions:
        - Engages the students with a familiar technology (iPads) (Jones et al., 2013; Klahr, Triona, & Williams, 2007; Pallud, 2017; Triona & Klahr, 2007)
        - More relatable model to compare to the actual 3D brains when they look at those later on
        - Chose 3D Brain by Cold Spring Harbor specifically because the app is intuitive, easy to use, and the information is written in readily accessible language (layman's terms) (Cold Spring Harbor Laboratory, 2016).
    - There is still too much information, so I needed to focus the students on the key parts of the brain, and the most relevant information about each structure
        - I originally made a worksheet with short answer questions to focus the students' attention on key brain structures but I learned 3 key things from pilot studies with this activity:

1. Students are bad at bullet pointing and were writing down every piece of info they could squeeze on the paper whether it was answer the question or not
2. They weren't retaining the information, and there was too much to read through when they referenced the worksheet later on
3. It was too much writing

- So I discussed with my classmates and coworkers and one of my coworkers said "what about a matching activity like we do in Energy: Use It and Lose It"? And I said, YES!

- Matching activity that they complete with the app
  - Gives them more autonomy over the app while directing their attention to critical information related to zombies
  - Also gets them working in pairs which is part of PBL and increases engagement
- **COMPLETE MATCHING ACTIVITY**
  - Pause here to let the audience complete the matching activity with the iPads and then review the answers.
  - Now that they have some background information, we can get into the scientific explanations about zombie behavior
- (Slides 44 – 51) Activity 2: Why is zombie behavior different than human behavior?
  - To keep students engaged while making sure they have the required background information, they will learn what is known about zombies
    - They are given some basics at the very beginning:
      - There's been a zombie outbreak
      - It's caused by a virus
      - The virus damages the brain
      - The virus is mutating
  - To answer the question "why is zombie behavior different than human behavior" it is important to understand zombie behavior and it's also important to ensure that everyone has the SAME zombie behavior in mind
    - So they will watch zombie "footage" (which is also fun) and discuss what they see and what they already knew
- **(Slides 47 & 48) WATCH ZOMBIE FOOTAGE**
  - Watch and discuss the zombie footage as a group like you would with a class.
  - Discuss what behaviors are noticed and what hypotheses audience might have.
- To relate that to the virus and the brain, now we need to gather evidence to support our claim by looking at how the zombie brain is different than the healthy human brain
  - To do this we will view and compare large 3D printed models of a healthy human brain and a zombie brain as a group

- **(Slide 50) COMPARE BRAINS**
    - Pause here and go through the brain comparison as a group as you would do when presenting the program.
- (Slides 52 – 56) Activity 3: Hands-on with mutated zombie brains
    - Finally they work in groups of 4 to compare a brain from a zombie infected with a mutated strain of the virus to the typical zombie
    - Each group gets a 3D printed model of a zombie brain that is different from the typical zombie brain we reviewed as a class in one way
    - They have to determine which brain structure is different, and how they think that would change the zombie's behavior and would that make the zombie more or less dangerous
- **(Slide 54) MUTANT BRAIN COMPARISON**
    - Stop here and go through the mutant to typical zombie brain comparison in groups. Review and discuss as you would with a class.
    - There are 4 mutations:
        - Healthier cerebellum – more dangerous because the zombie would be coordinated
        - Healthier prefrontal cortex – more dangerous because the zombie would be able to think
            - Healthier Amygdala – less dangerous because the zombie would not be as aggressive
            - Healthier Hypothalamus – less dangerous because the zombie could control its hunger and would sleep sometimes

- (Slide 57 – 59) Those activities are designed to be engaging, and the data I collected shows that the students are engaged with them
    - At least, they are more engaged with the activities than with whatever they were doing before the program began, which is what I used as my baseline.
        - This did vary somewhat by school
    - However, while not statistically significant overall, they do seem less engaged by the human to healthy brain comparison.
        - My guess is this is because the activity isn't hands on the same way that the other activities are
    - (Slide 60) I would love some suggestions to make that better. Before we move on, are there any suggestions for making any of the activities more engaging? Especially Activity 2, the one where we compare the healthy brain to the zombie brain as a group.

Explanations (Slides 61 – 78)

- (Slides 61 – 64) To recap

    - We use the premise of zombie outbreak to hook the students' interest right off the bat
    - We use 3 activities to keep them engaged
        - 2 of those activities also involve group work
- (Slide 65 – 66) Those activities are fun and engaging, but the program is designed to teach students how to construct scientific explanations
- (Slides 67 – 73) So I built in 3 separate exposures to the CER framework over the course of the 45 minute program
    1. After the 3D Brain app and matching activity students are reminded that they are junior researchers for the CDC trying to answer the question "why do zombies behave the way they do" and they'll need to answer in the form of a scientific explanation. So we review the CER framework
    2. After ensuring we understand the question and gathering evidence, we put together one scientific explanation as a group.
        a. Students are asked to try and give a claim, some evidence, and reasoning. We want to engage *them* with the process, but go over each step the way we wrote it out before moving on to the next piece of the framework
    3. Students work in their groups of 4 to write a scientific explanation to the CDC to explain whether the mutated zombies would be more or less dangerous than the original zombie
        a. They are given a worksheet to scaffold the explanation and remind them to put in their claim, evidence, and reasoning
        b. These explanations are reviewed as a class so all students can learn about all of the mutations and get additional exposure to the explanations
- (Slides 74 – 78) The activities are not only designed to be engaging, but also to help students learn to construct scientific explanations.
    - The data shows that there are small, but statistically significant, improvements for both claim and reasoning across all schools. When looked at individually, School B & C show improvement on evidence as well, while School A shows no statistically significant improvements.
    - Why might that be? Let's look at engagement again.
        - Overall, School A was the least engaged, while School C is the most engaged.
    - But does that actually matter? Does engagement enhance learning as suspected?
        - There is a statistically significant positive correlation between engagement and improvement on the evidence and reasoning component of the scientific explanations.
- (Slide 781) Altogether, my research shows that YES we do make a difference. When we engage students with hands-on experiences with interesting topics they can make small learning gains even though we are only there for a short time. It is also possible

to design programs to target a science practice in only 45-minutes, it's not easy, but it's doable. However, it is important that we are cognizant of what is and is not working when we present our programs, and rework those things as needed.

- Students can and do learn in our short TSPs when they are effectively engaged
- Start thinking about practices that we can target and not just content, or think of a fun idea and then think about what practices it can target even if the content is not in the standards
- FIX what is not working to engage students in a more meaningful way
    - Bounce ideas off of each other and see what you can come up with

- Questions? Comments? Suggestions? Concerns?
    - In addition to discussing BYtZ, we can also discuss other programs and program ideas.
    - Does anyone have any program ideas they've been working on they would like to discuss? Let's think about how to target some of those practices?

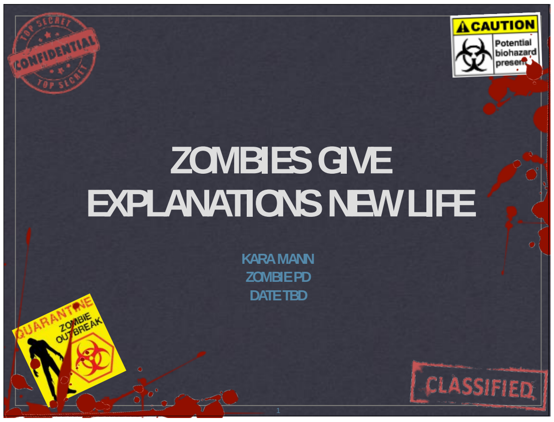
Additional Background Information that may be useful:

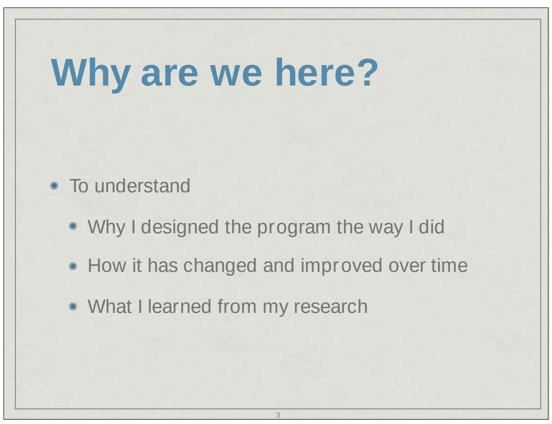
- Some background – research supports a lot of what we intuitively understand from doing this job so I'm just going to give a brief overview of some of that literature:
    - Making science fun helps people learn
        - Visitors learn and remember more when the experience is fun (Packer, 2006; Packer & Ballantyne, 2004)
        - Marine mammal watch tourists request more educational aspects BALL 09 LUCK TISDELL 05
        - Visitors prefer the educational dolphin show to the theatrical one (Mann-Lang et al., 2016)
    - Situational interest is something we strive to attain in all of our programs
        - It is interest generated by the context (Hidi & Renninger, 2006; Linnenbrink-Garcia et al., 2010)
            - For example experiences and content that are novel, unusual, surprising, or unexpected (Bergin, 1999; Palmer et al., 2016; Renninger & Hidi, 2011; Schraw et al., 2001; Silvia, 2008)
        - 4 Phases of interest, we focus on the first two – catch & hold (Hidi & Renninger, 2006)
            - Novel, complex, and comprehensible situations are interesting and good ways to catch interest, but you also need to hold interest especially when the learning takes place over a longer period of time like a classroom workshop (Bergin, 1999; Palmer et al., 2016; Renninger & Hidi, 2011; Schraw et al., 2001; Silvia, 2008). Part of being comprehensible includes that the situation should require a minimum background knowledge

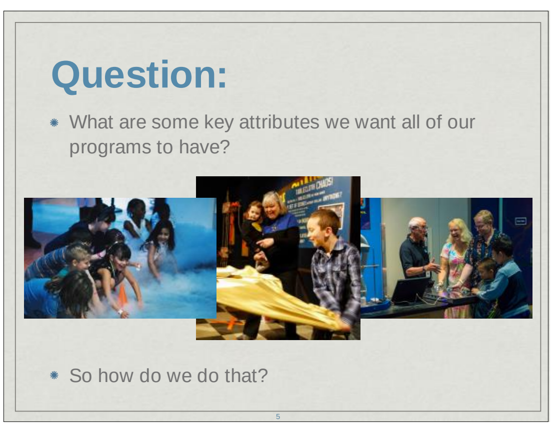
that most participants are likely to share (Dohn, Madsen, & Malte, 2009) OR focus on a concrete rather than an abstract problem (Tapola et al., 2013).

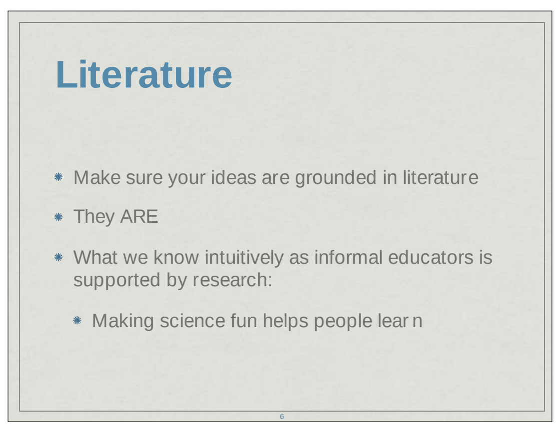
            - One way to hold interest after catching it is by presenting a problem or puzzle to solve (Linnenbrink-Garcia et al., 2010; Loukomies et al., 2015; Mitchell, 1993; Palmer, 2009), especially if they are presented as part of a fantasy scenario (Bergin, 1999; Lepper & Cordova, 1992; Parker & Lepper, 1992)
            - Additionally hands-on activities are a good way to catch and hold interest (Bergin, 1999; Dohn, 2013; Loukomies et al., 2015; Palmer, 2009; Rotgans & Schmidt, 2011)
    - Problem-Based learning scenarios embody SI ideas (Tawfik et al., 2014; Torp & Sage, 2002)
        - PBL is a learner-centered approach that gives learners ownership over their work by applying theory and practice to solve ill-structured problems (Savery, 2006; Torp & Sage, 2002)
            - PBL does usually take place over longer periods of time, so this is more akin to a posthole activity which is like a mini-PBL that gets students ready to work together in groups and think the way that is required for more extended PBL units (Ertmer & Simons, 2006). Similarly anchored instruction is another kind of pre-full PBL problem solving (Hmelo-Silver, 2004).
            - PBL also makes the learning experience more fun and enjoyable, and as we have already learned, fun and learning enhance each other
            - Enjoyment is also a necessary piece of engagement (Shernoff, 2010; Shernoff et al., 2015, 2003; Shernoff & Vandell, 2007)
    - Engagement is an important factor in holding students interest
        - Along with interest and concentration, enjoyment is a necessary part of engagement based on flow theory (Shernoff et al., 2003)
        - Flow is the experience of being “carried away by the current”, of being fully involved in an activity (Csikszentmihalyi & Hermanson, 1995; Csikszentmihalyi & Hunter, 2003; Csikszentmihalyi & Larson, 1987; Shernoff et al., 2003). Examples often include sports and gaming but it can occur in any environment from work to play or in between. It’s analogous to that moment when you’re in the groove or on a roll.

PD Presentation Slides









Presentation for PD Seminar

Situational Interest

- We achieve this through situational interest
  - Interest generated by the context
  - Catch and hold, especially during TSPs
  - Problems & Puzzles can help

Problem-Based Learning

- PBL is a learner-centered approach that gives learners ownership over their work by applying theory and practice to solve ill-structured problems
  - Gets students involved in the learning
  - PBL helps make learning fun
  - Fun and learning enhance each other

So…

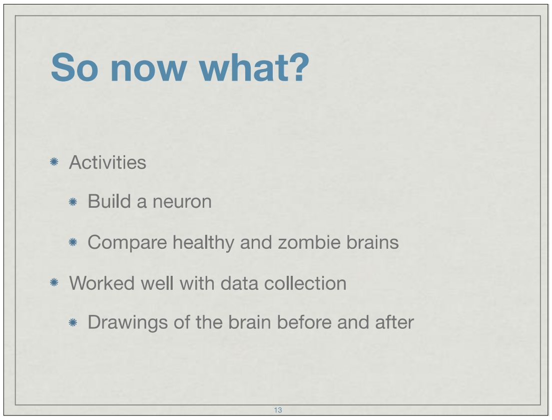
- Want to catch situational interest with a good idea
- Hold interest with some kind of problem
- But what's interesting to kids?

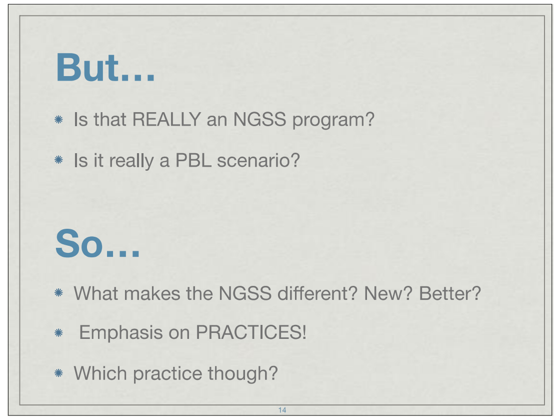
Sounds fun but…

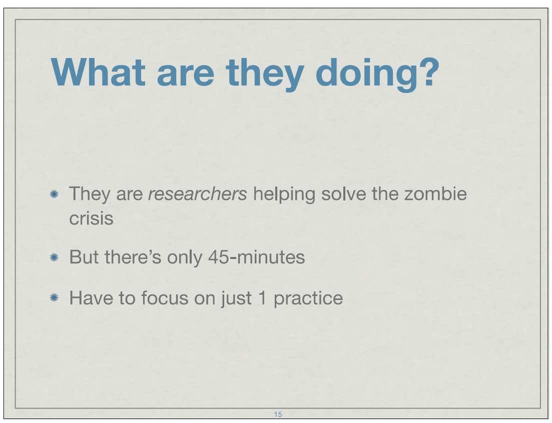
- Zombies are definitely NOT in any curriculum standard!
- No, but the program will be about the brain so that's probably in there somewhere…

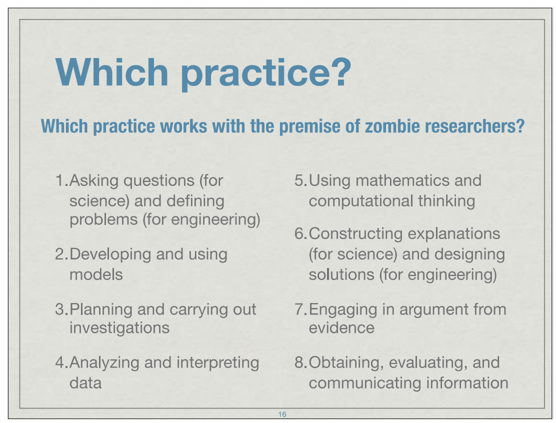
Standards

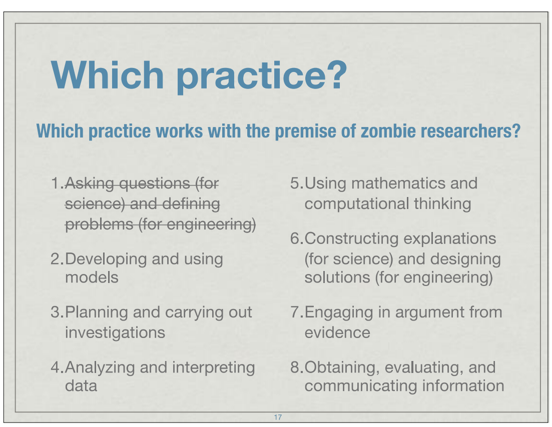
- **Performance Expectation MS-LS1-3**: Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells
- **Disciplinary Core Idea LS1.A:** Structure and Function - In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions (NGSS Lead States, 2013).

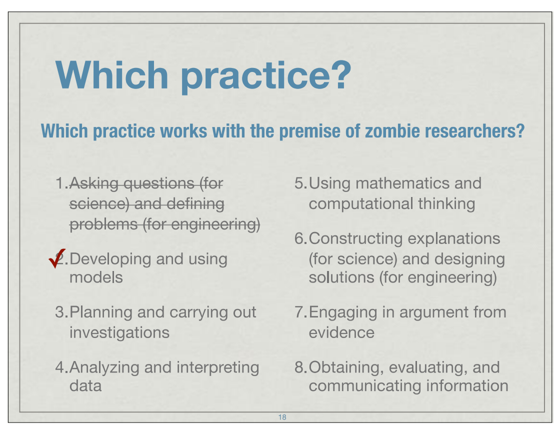

So now what?
Activities
Build a neuron
Compare healthy and zombie brains
Worked well with data collection
Drawings of the brain before and after


But…
Is that REALLY an NGSS program?
Is it really a PBL scenario?
So…
What makes the NGSS different? New? Better?
Emphasis on PRACTICES!
Which practice though?


What are they doing?
They are *researchers* helping solve the zombie crisis
But there's only 45-minutes
Have to focus on just 1 practice


Which practice?
Which practice works with the premise of zombie researchers?
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information


Which practice?
Which practice works with the premise of zombie researchers?
1. ~~Asking questions (for science) and defining problems (for engineering)~~
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information


Which practice?
Which practice works with the premise of zombie researchers?
1. ~~Asking questions (for science) and defining problems (for engineering)~~
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
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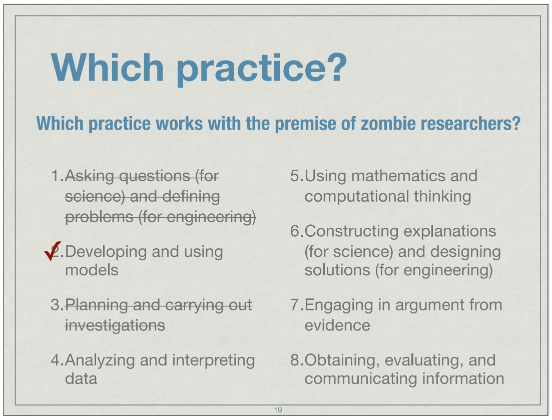
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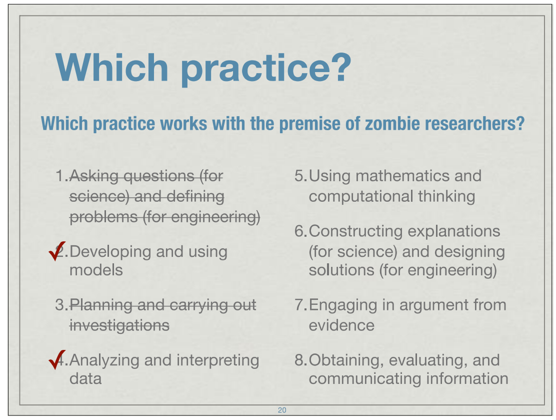
19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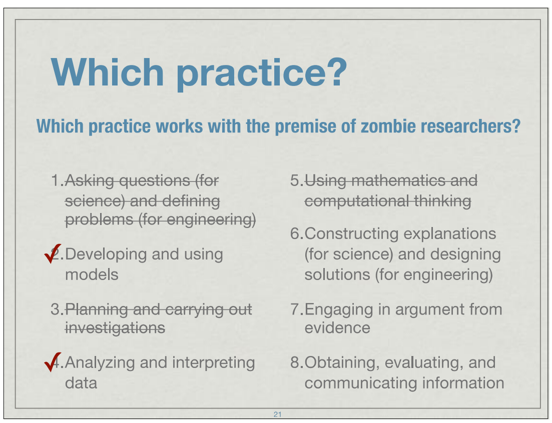
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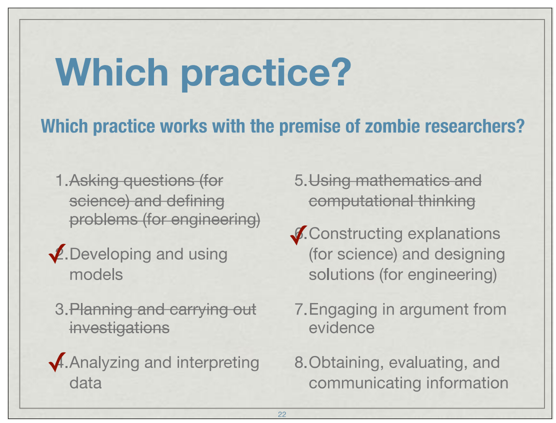
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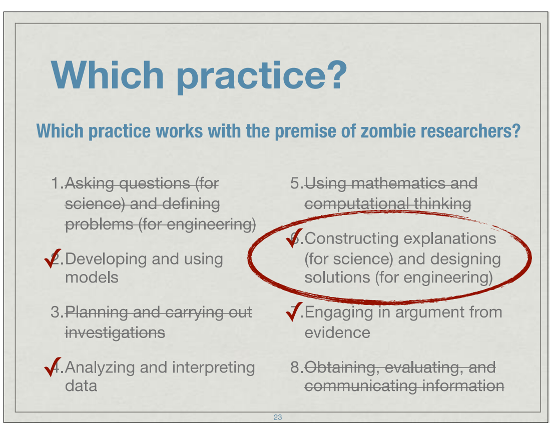
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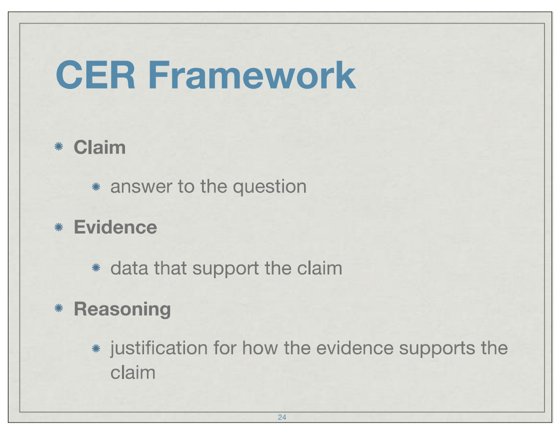
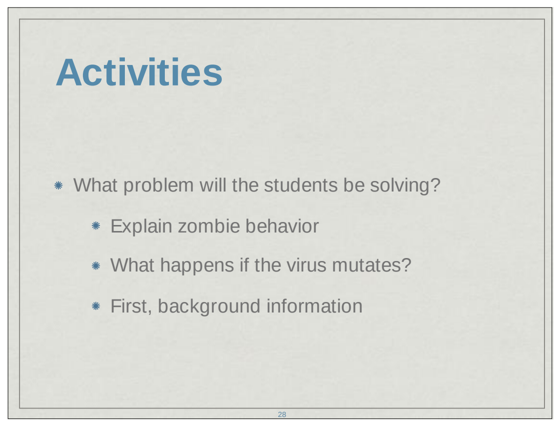
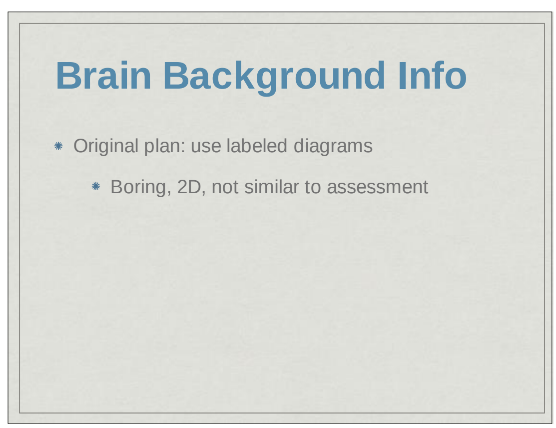

CER Framework
Claim
answer to the question
Evidence
data that support the claim
Reasoning
justification for how the evidence supports the claim
24


QUESTIONS SO FAR?

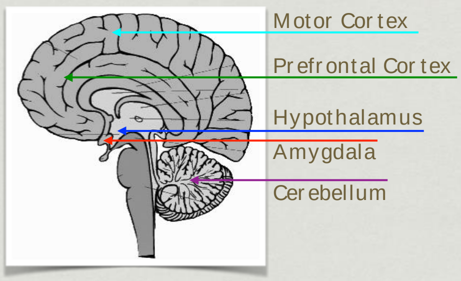

DESIGNING THE PROGRAM


Activities
What problem will the students be solving?
Explain zombie behavior
What happens if the virus mutates?
First, background information


ACTIVITY 1
BACKGROUND INFORMATION ABOUT BRAINS


Brain Background Info
Original plan: use labeled diagrams
Boring, 2D, not similar to assessment

Labeled Diagram



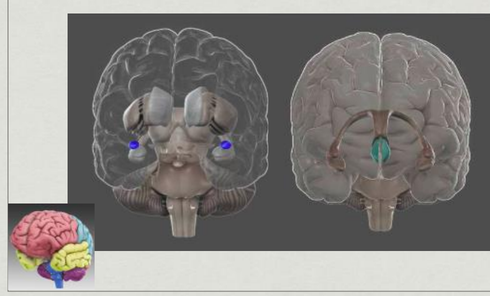
Brain Background Info

- Original plan: use labeled diagrams
  - Boring, 2D, not similar to assessment
- New plan: go with something digital
  - Exciting, 3D, digital natives, group work
- 3D Brain by Cold Spring Harbor
  - 3D model and highlighted parts
  - Info is understandable

3D Brain App

- Really nice 3D representation

3D Brain App



3D Brain App

- Really nice 3D representation
- Too much information

3D Brain App

3D Brain App

3D Brain App

- Really nice 3D representation
- Too much information
- How do I focus student attention on what they need to know?
  - Worksheet!
  - Short answer questions about 5 key parts of the brain
  - but…

3D Brain App

- I learned 3 key things in my pilot studies with the worksheet:
  1. Students are bad at bullet points
  2. They weren't retaining info
  3. It was too much writing

3D Brain App

- What to do instead?
- I talked with classmates and coworkers
- Brittany suggested a matching activity and I said, that's perfect!
  - Gives them more autonomy
  - Easier for group work
  - Simple to look back at for info later

Let's review some key functions of the brain!

Match each structure of the brain to its function

Brain structure	Function
Prefrontal Cortex	Controls coordination, balance, and posture; damage to it causes loss of coordination and inability to walk
Cerebellum	Critical for initiation of movement; associated with some coordination
Hypothalamus	Damage to this part of the brain leads to aggression and irritability
Amygdala	Regulates functions necessary for survival including: hunger, thirst, and sleep
Primary Motor Cortex	Planning, reasoning, and judgement; personality and emotion

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NOW THAT WE HAVE SOME BACKGROUND…

ACTIVITY 2

WHY DO ZOMBIES BEHAVE THE WAY THEY DO?

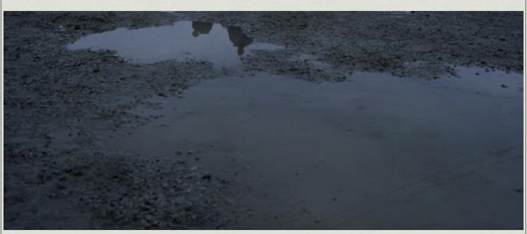
Zombie Behavior

- **Why is zombie behavior different than human behavior?**
- Students are given basic info at the beginning:
  - There's been a zombie outbreak
  - It's caused by a virus
  - The virus damages the brain
  - The virus is mutating
- Now they have a basic understanding of the brain
- What else do they need to know to answer this question?

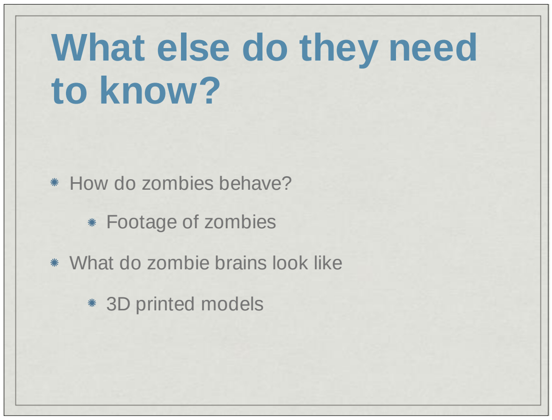
What else do they need to know?

- How do zombies behave?
  - Footage of zombies

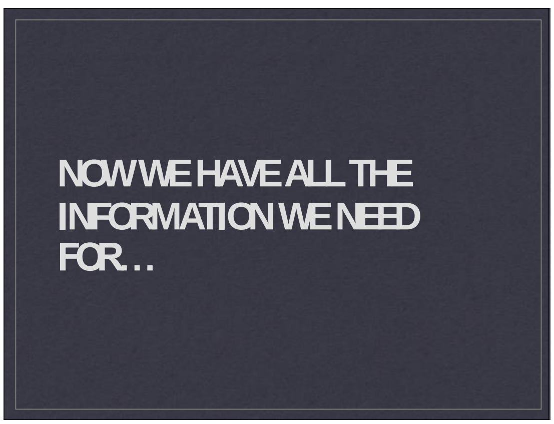
Zombie Behavior



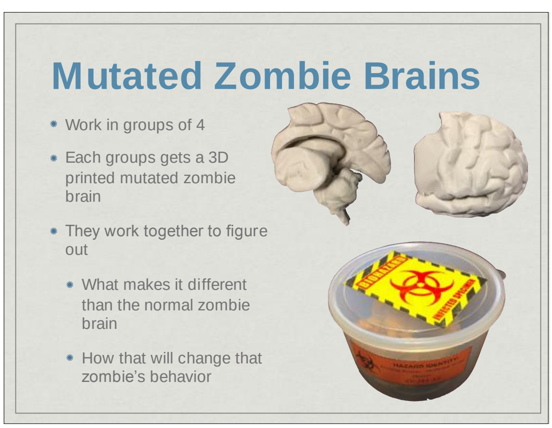
Zombie Behavior

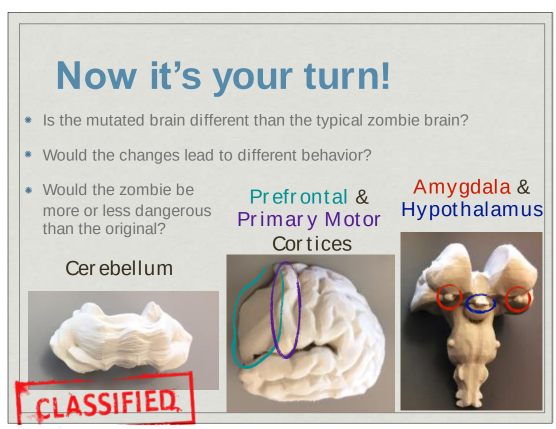

What else do they need to know?
How do zombies behave?
Footage of zombies
What do zombie brains look like
3D printed models

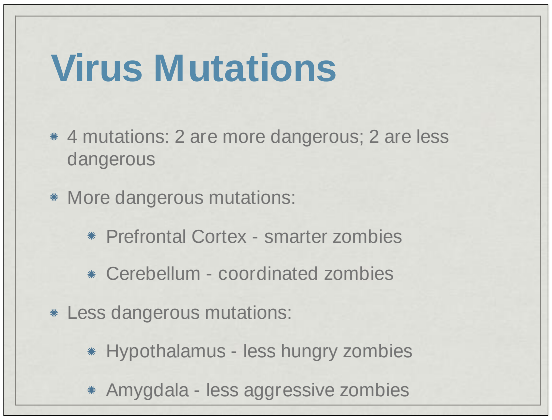

Zombie vs Healthy BRAAAAINS

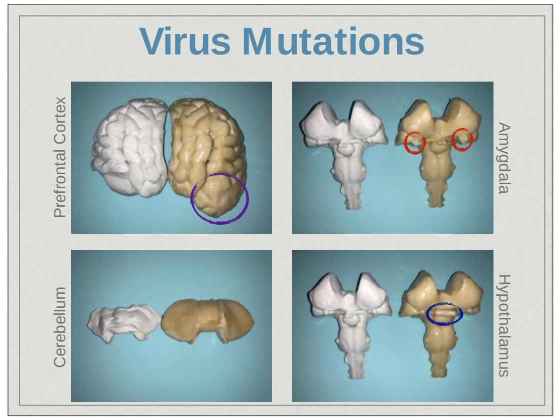

NOW WE HAVE ALL THE INFORMATION WE NEED FOR…


ACTIVITY 3
MUTATED ZOMBIE BRAINS

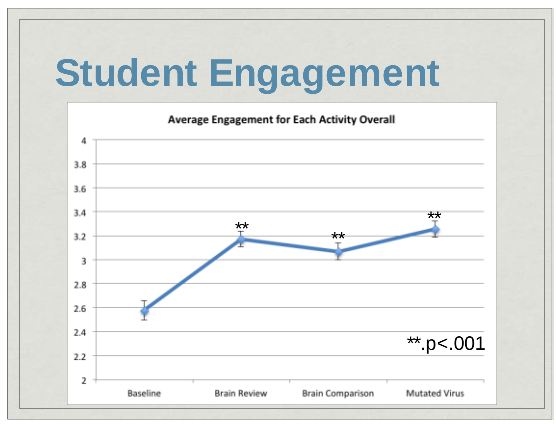

Mutated Zombie Brains
Work in groups of 4
Each groups gets a 3D printed mutated zombie brain
They work together to figure out
What makes it different than the normal zombie brain
How that will change that zombie's behavior


Now it's your turn!
Is the mutated brain different than the typical zombie brain?
Would the changes lead to different behavior?
Would the zombie be more or less dangerous than the original?
Cerebellum
Prefrontal & Primary Motor Cortices
Amygdala & Hypothalamus
CLASSIFIED


Virus Mutations
4 mutations: 2 are more dangerous; 2 are less dangerous
More dangerous mutations:
Prefrontal Cortex - smarter zombies
Cerebellum - coordinated zombies
Less dangerous mutations:
Hypothalamus - less hungry zombies
Amygdala - less aggressive zombies


Virus Mutations
Prefrontal Cortex
Amygdala
Cerebellum
Hypothalamus


THOSE SOUND LIKE FUN ACTIVITIES
BUT ARE THE STUDENTS ENGAGED?


Student Engagement
Average Engagement for Each Activity Overall
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
**
**
**
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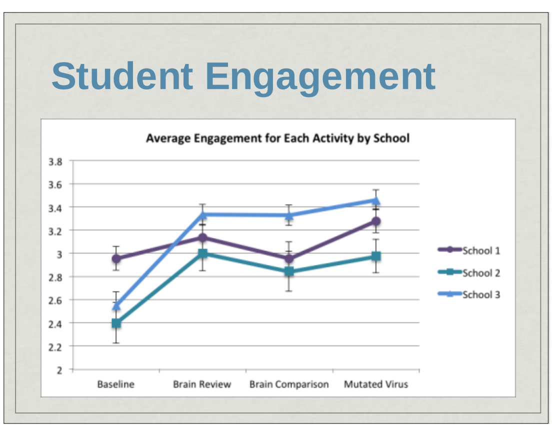
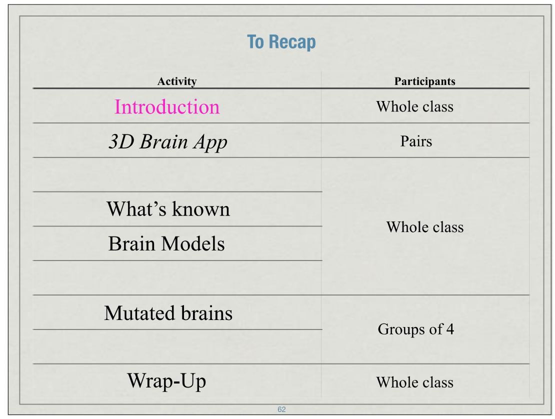
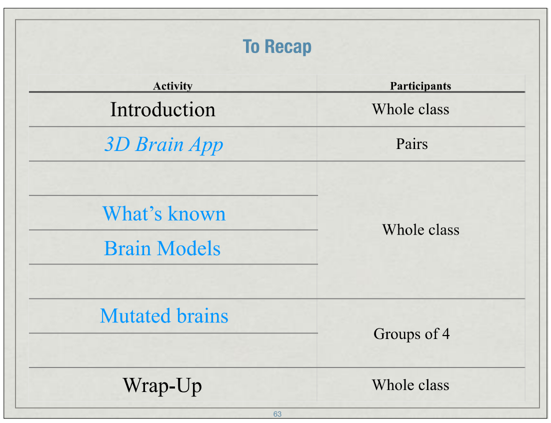
Baseline
Brain Review
Brain Comparison
Mutated Virus


Student Engagement
Average Engagement for Each Activity by School
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
School 1
School 2
School 3
Baseline
Brain Review
Brain Comparison
Mutated Virus


SUGGESTIONS?
OTHER QUESTIONS?


TO RECAP…


To Recap
Activity
Participants
Introduction
Whole class
3D Brain App
Pairs
What's known
Brain Models
Whole class
Mutated brains
Groups of 4
Wrap-Up
Whole class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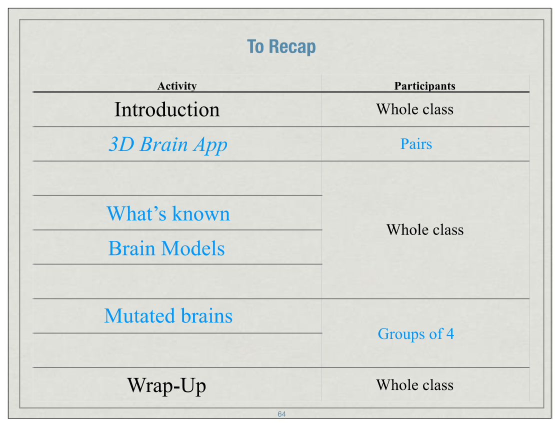
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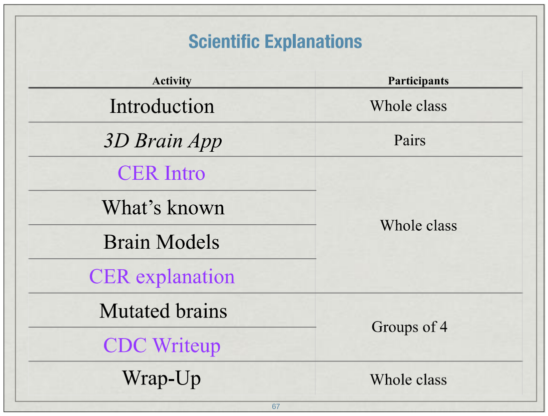
Whole class


SO FAR SO GOOD
BUT WAIT A MINUTE, WAIT A MINUTE….


DIDN'T I SAY I WAS
TARGETING EXPLANATIONS?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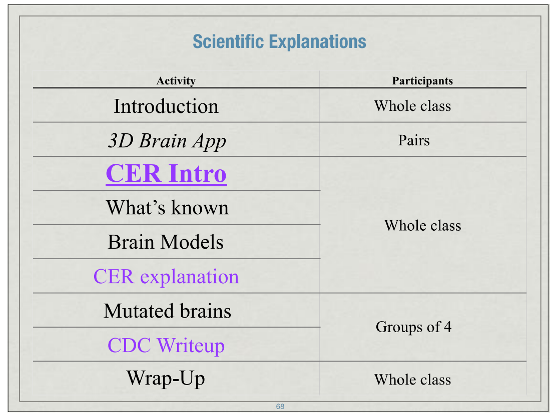
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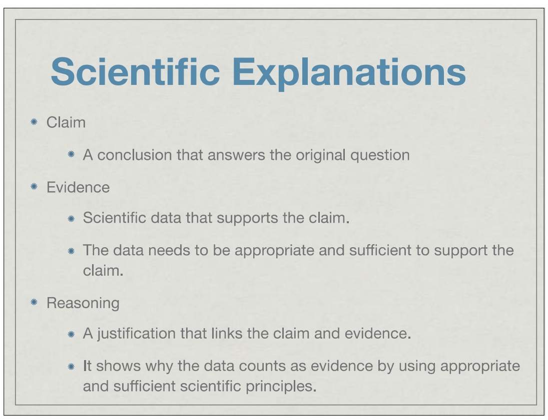
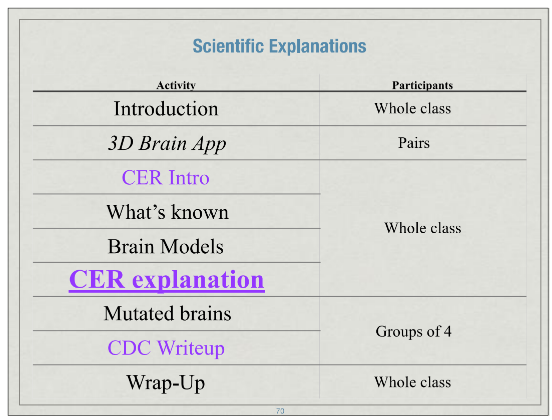

Scientific Explanations
Claim
A conclusion that answers the original question
Evidence
Scientific data that supports the claim.
The data needs to be appropriate and sufficient to support the claim.
Reasoning
A justification that links the claim and evidence.
It shows why the data counts as evidence by using appropriate and sufficient scientific principles.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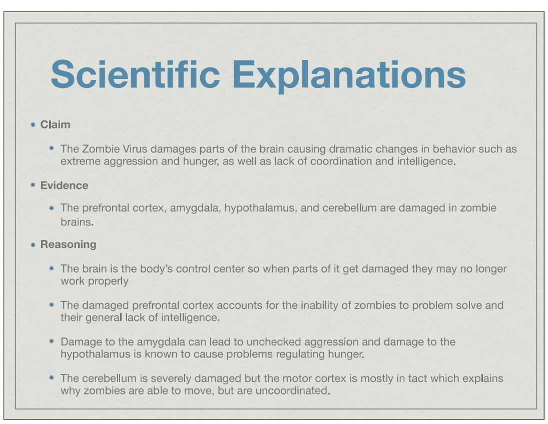
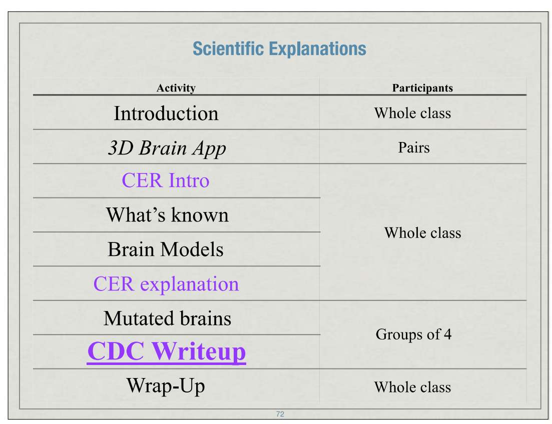

Scientific Explanations
Claim
The Zombie Virus damages parts of the brain causing dramatic changes in behavior such as extreme aggression and hunger, as well as lack of coordination and intelligence.
Evidence
The prefrontal cortex, amygdala, hypothalamus, and cerebellum are damaged in zombie brains.
Reasoning
The brain is the body's control center so when parts of it get damaged they may no longer work properly
The damaged prefrontal cortex accounts for the inability of zombies to problem solve and their general lack of intelligence.
Damage to the amygdala can lead to unchecked aggression and damage to the hypothalamus is known to cause problems regulating hunger.
The cerebellum is severely damaged but the motor cortex is mostly in tact which explains why zombies are able to move, but are uncoordinated.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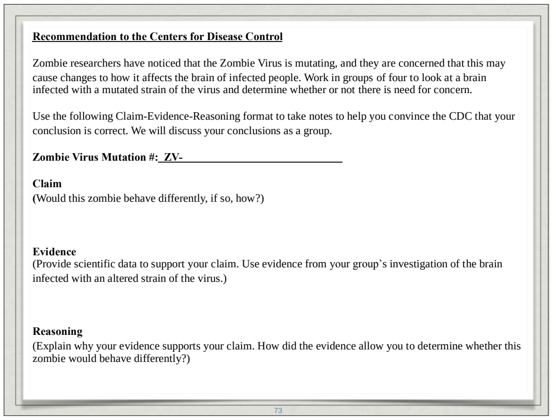

Recommendation to the Centers for Disease Control

Zombie researchers have noticed that the Zombie Virus is mutating, and they are concerned that this may cause changes to how it affects the brain of infected people. Work in groups of four to look at a brain infected with a mutated strain of the virus and determine whether or not there is need for concern.

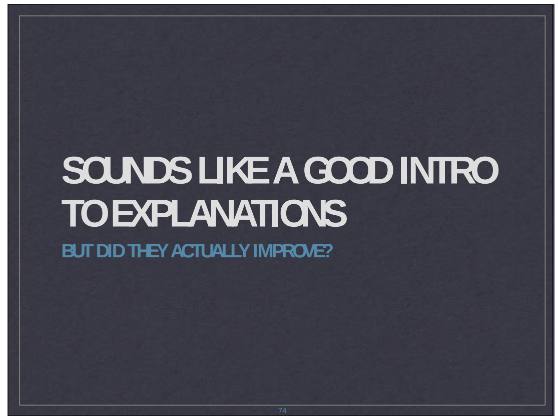
Use the following Claim-Evidence-Reasoning format to take notes to help you convince the CDC that your conclusion is correct. We will discuss your conclusions as a group.

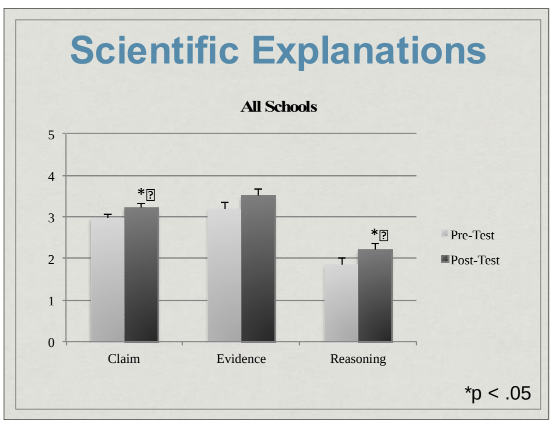
Zombie Virus Mutation #: ZV-____________________

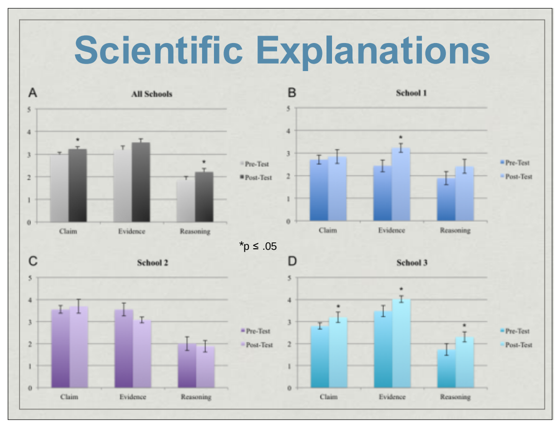
Claim
(Would this zombie behave differently, if so, how?)

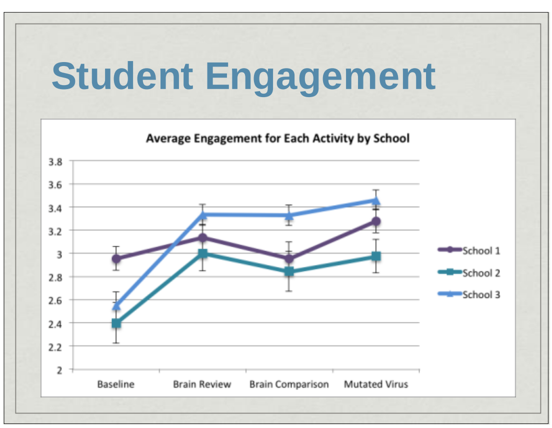
Evidence
(Provide scientific data to support your claim. Use evidence from your group's investigation of the brain infected with an altered strain of the virus.)

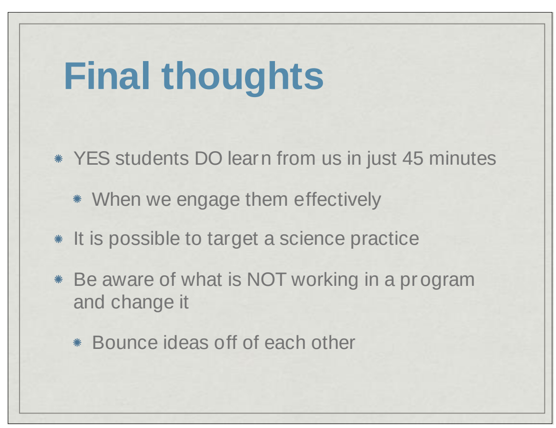
Reasoning
(Explain why your evidence supports your claim. How did the evidence allow you to determine whether this zombie would behave differently?)



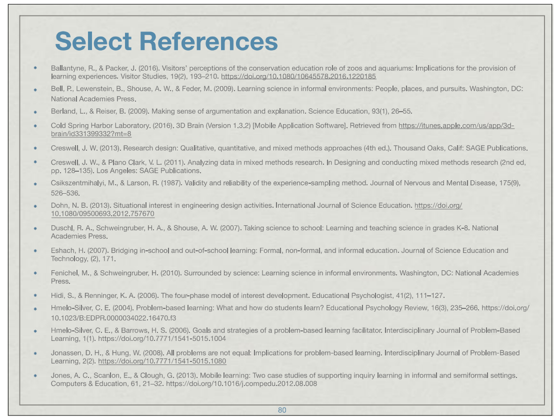









THANK YOU!
QUESTIONS?
79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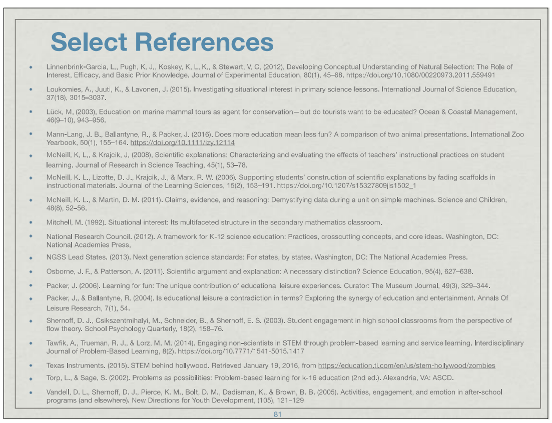
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Linnenbrink-Garcia, L., Pugh, K. J., Koskey, K. L. K., & Stewart, V. C. (2012). Developing Conceptual Understanding of Natural Selection: The Role of Interest, Efficacy, and Basic Prior Knowledge. Journal of Experimental Education, 80(1), 45–68. https://doi.org/10.1080/00220973.2011.559491
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Chapter 5: Implications and Reflections

In creating this portfolio format dissertation, I was able to examine a problem of practice that is relevant to my daily practices as a Sr. STEM Educator at Liberty Science Center in a way that was practical and useful, while also allowing me to share what I have learned with a wider audience than just my immediate coworkers and the students we teach. This problem of practice is how to create a 45-minute, one-time traveling science program that engages and excites students with science learning while also meeting the needs of schools by being aligned with the NGSS. I examined the use of the premise of a zombie outbreak to engage students with the practice of constructing scientific explanations. The iterative design process of creating *BYtZ* as well as the data yielded by the final analysis gave results that were interesting to researchers as well as practitioners. Therefore, each component of the portfolio serves a different purpose in terms of audience and intended outcomes from the students who participated in *BYtZ*, to my colleagues at LSC who learned from my PD seminar, to the readers of my article who can all benefit from what I have learned from my research.

General Implications

My research findings indicate three major findings. The first is that an interesting premise such as a zombie outbreak combined with hands-on activities and group work leads to high levels of student engagement and that their interest is maintained at the high level throughout a 45-minute traveling science program. Second, that it is possible for students to make improvements in their construction of scientific explanations after participating in a traveling science program. And finally, that higher levels of engagement lead to increased learning.

These findings indicate that it is indeed possible to design a program that simultaneously meets the needs of an informal science institution and of the schools they travel to. In other words, it is possible to design a program that engages and excites students with science through the use of an interesting premise and engaging activities. At the same time, the students are able to progress in their ability to perform a science and engineering practice. While this study only examined the premise of a zombie outbreak to engage students with constructing scientific explanations, it is reasonable to assume that similar results would be seen with other interesting scenarios and activities relevant to another scientific practice, though additional research would be needed to support this conclusion.

The findings from this research demonstrate that though traveling science programs are short, one-time offerings, they can have a meaningful impact on student learning. This is an important piece of information to have about these programs as it becomes harder for schools to secure field trips that require bussing and are looking for “field trips” to come to them. This is important information for both the schools and the museum to have because it helps demonstrate the success of our programs to the schools, as well as the importance of the iterative design process and a well thought out program for achieving those goals. Overall the data also support the idea that engagement is a critical part of learning.

Reflection on Portfolio

The program design component of my dissertation portfolio embodies the design element of this Design of Learning Environments dissertation, and I learned a lot from this process. Designing this program and bringing it on the road for pilot testing really made me understand the importance of the iterative design process. I will admit that I thought the program would go off without a hitch because I had come up with a good idea. What I discovered was that while students were enjoying some components of the program, others did not go over as well. One of the main things that I discovered was that I had included too much writing and this was not engaging to the students. It also largely prevented me from collecting useful post-test explanations because the students did not want to write anymore. I learned my biggest lesson about what kinds of worksheets to include in a program from the first worksheet I created to help direct students' attention to the parts of the brain relevant to zombies when they were using the iPad app. This worksheet consisted of a series of short answer questions. I was expecting the students to bullet point their answers quickly and move on. This was not the case, they were writing down every piece of information from the *3D Brains* app that they could squeeze onto the paper. And therefore they were largely not retaining the information, nor was it easy for them to look back at the sheet as a quick reference later in the program. I tried adapting by modeling and going through two or three of the brain structures with them, but this took away from their autonomy and group work, and therefore detracted from the PBL scenario. So instead my coworker helped me come up with the idea to have the students complete a matching activity, which gave the students the information they needed, while giving them the autonomy to work in pairs to ensure correct matching of each brain structure to its function. I think it is useful to have worksheets for students to use during a program, however, it is important to be deliberate about what kinds of worksheets you use to maintain student engagement. In my experience, worksheets that call students' attention to the key information while minimizing the amount of writing are the most successful. There were also many aspects of the program that worked well from the first iteration, the way they were explained or presented may have been tweaked slightly as I went through the program, but overall they have not changed.

Most of the activities that worked well from the first iteration were the components that I included purposefully to engage the students. The premise of the zombie outbreak has been very engaging to students whether or not they are already fans of the genre, so the use of a fantasy scenario was successful (Bergin, 1999; Lepper & Cordova, 1992; Parker & Lepper, 1992). More than just the fantasy scenario, having a problem to solve and questions to answer within that context also kept the students engaged, and gave me something to continuously tie back to as the students learned each new piece of information (Hmelo-Silver, 2004; Jonassen & Hung, 2008; Torp & Sage, 2002). The hands on components, whether it was the activity with the iPads or the mutated brains, also seemed to have the highest level of engagement and student interest. I believe part of this was these activities allowed the students to work in pairs or small groups and have some autonomy to make the decisions and get the information for themselves (Dresner & Gill, 1994; Gibson & Chase, 2002; Rotgans & Schmidt, 2011; Torp & Sage, 2002). Finally the inclusion of the CER framework was crucial for scaffolding the practice of scientific explanation construction (McNeill & Berland, 2017; McNeill & Martin, 2011). Altogether, I found that there were some design principles that seem to work very well for short, one-time, semi-formal learning experiences, many of them similar to PBL:

1. **Fantasy context or storyline.** It is not necessary to use the premise of a zombie outbreak, however, setting the program in some kind of storyline, possibly with a fantastical twist, is a really great way to make it fun and exciting for the students, and to get them invested right away.
2. **Problem to solve or questions to answer.** Providing a problem to solve or a question to answer helps keep the students invested and understand why they need to collect different pieces of information throughout the program.
3. **Hands-on activities.** Whether the students have their hands on a piece of technology, a scientific too, or a model, give them the chance to get their hands on

what they are learning and keep them busy with something other than just a worksheet.

4. **Group work.** Give the students the chance to work things out on their own. Allowing them to argue and discuss in pairs or groups is an important part of the learning process as they work things out together.
5. **Explicitly scaffold scientific practices.** The goal for short, one-time, semi-formal programs is not to for the students to walk away experts, but to give them experience with the topic and / or practice. Therefore, when designing a program to target a scientific practice, it's ok to give the students explicit scaffolds that guide them through the process step by step.

They don't cover everything, and not every topic is the same or as readily adaptable, but I believe these five design principles are a good place to start when designing a short, one-time, semi-formal learning experience. Designing *BYtZ* and learning from that process has also made me think about our other programs and whether there might be ways to improve them further. Perhaps some of our programs could benefit from the addition of a PowerPoint presentation, or the addition of a worksheet to focus students on the important details. More ambitiously, perhaps some of our programs could be reworked to follow a storyline and give the students a problem to solve over the course of the program. I look forward to reworking old programs and developing new ones to make them engaging and exciting for the learners.

Beyond just the curriculum of the program, I believe another key component of making a successful program is in how you teach it. Though I used multiple facilitation strategies, I thought that a good way to lead the students through the process of constructing explanations would be to use what the PBL literature calls reframing or revoicing and pushing for explanations (Hmelo-Silver & Barrows, 2006). When we were first going over the CER framework and I would ask the students to give me their answers, I would often not just take their answer and move on to another answer. Instead, I would push them to give me more information when needed, and then take what they said and repeat it but I would say “ok so your claim / evidence / reasoning would be…” This was especially true for the evidence and reasoning where the student would tell me, for example, “the cerebellum is shrunken” to which I would respond “ok good, what does that have to do with zombies?” and push them until I got the additional information that zombies are uncoordinated and the cerebellum controls coordination. Sometimes I would pull all of the information from one student, other times I would get it from multiple students if I needed to. Then I would reframe it to model an explanation. Similarly, during the group work, especially with the mutated zombie brains, I would go around the room with a typical zombie brain and have the students help me compare it to their mutated brain if they were struggling to find the differences and then get them to tell me how that would change the zombie’s behavior. If they didn’t all agree I would tell them to discuss it and I would come back to them to give them that chance to figure it out on their own. Overall, I think this mix of getting the students to come up with the answers on their own, but reframing it in the language of a scientific explanation contributed to students’ understanding of the process of constructing a scientific explanation.

The research article component of my portfolio includes many of the same elements as a traditional dissertation because it communicates my research findings in a scholarly fashion. Presenting my research in this format provides me with the opportunity to share my research with a broader audience who may find it interesting and benefit from it outside of the schools we visit and my colleagues who present the program. I am currently in the process of refining the journal article to meet the submission guidelines for the journal Science Education. I chose this journal because it covers all science education from formal to informal experiences. It is my hope that upon publication my research findings will be useful to researchers in both fields, as well as those who design and teach programs that, like traveling science programs, fall somewhere in between. While this research demonstrated that small learning gains are achievable in one-time, short (45-minute) programs and that students who are more engaged tend to show larger gains, there are still many questions to be answered. For example:

- Was it the zombie scenario or the hands-on activities that engaged students?
- Can similar learning gains be seen for other science and engineering practices?
- Are the results the same in communities of more varied socioeconomic status?

Future research in the field may help answer these and other questions and further enhance our understanding of the best way to design short, one-time programs like the TSPs offered by LSC.

In addition to the contribution I hope my work will make to the academic research community, I look forward to using what I have learned in my own professional work, and sharing it with my coworkers. Unfortunately, we rarely have as much time as we would like to design new programs. However, that doesn't mean that my coworkers and I cannot use what I have learned about the design process and bring that into designing new programs. In addition to training my coworkers how to teach *BYtZ* specifically, I hope to impart to them through the professional development (PD) component of this portfolio dissertation the importance of the iterative design process. I have received compliments from my colleagues about how well designed this program is, and I have thanked them and shared with them that it wasn’t easy and it didn't happen overnight. I attribute the success of this program to my research, collaboration and brainstorming with my coworkers and graduate school colleagues, pilot testing components of the program as well as the program in its entirety, and generally to the iterative design process. I look forward to sharing this idea with them in more detail with the professional development component of the dissertation. I also look forward to discussing the design principles and teaching principles that came out of this process.

It's a bit difficult to explain in the PD itself, but one thing I plan to do is when my coworkers are participating in the different program components, I will go around and work with them the same way I do with the students, including pushing them to tell me more and reframing when necessary or simply repeating what they told me with an emphasis on which part is the claim, the evidence, and the reasoning. After each activity I will also ask questions about what I was doing to help them see where I was using those reframing and revoicing techniques. I will follow this up with examples of the kinds of responses I am likely to get from the students as well and how I might reframe those. Additionally, I have included my research findings throughout the PD to demonstrate to them that what we do does make a difference. Qualitatively, most of my fellow STEM educators recognize this, but it will be nice to be able to share quantitatively that this is indeed true. We can and do engage students with our programs and they in turn can and do learn from them. It is also my intention to demonstrate a new way to think about what we focus on as our learning goals when designing new programs and demonstrate that we do not have to go only by the content. As I have demonstrated with *BYtZ*, while zombies are certainly not part of any curriculum, there is still a place for an exciting premise like a zombie outbreak in science education.

Overall this portfolio reflects my effort to make a positive change through research. The three components of my portfolio – the *BRAAAAINS: You & the Zombie* curriculum, scholarly research article, and professional development – target different stakeholders. The curriculum was designed to positively impact student learning. The research article will share my findings with the broader academic community. The PD will not only help my coworkers present their best possible version of *BYtZ*, it will also give them the opportunity to learn what I discovered with my research. Additionally, the PD will give my coworkers and I the opportunity to brainstorm additional potential improvement to *BYtZ* as well as possible new program ideas, and hopefully they will apply what they learned from me in the development of future programs. Each year we have more schools request our traveling science programs, so I believe studying the impact of these programs and ways to improve them is an important research area and one that I hope to continue to contribute to.

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Appendix A – Pre/Post-Test Explanation Assessment Question

Please answer the following question to the best of your ability:

Consider the data in the following table on four zombies, each of which has been infected with a different version of the zombie virus:

Patient Info			**Virus Form**	**Brain Structure**				
ID#	Sex	Age		**Cerebellum** (Balance)	**Amygdala** (Emotion)	**Hypothalamus** (Hunger Control)	**Frontal Lobe** (Intelligence)	**Motor Cortex** (Movement)
Z1	*M*	*32*	*Original virus*	*Damaged*	*Damaged*	*Damaged*	*Damaged*	*Normal*
CV1	F	27	Changed virus 1	Normal	Damaged	Damaged	Damaged	Damaged
CV2	F	38	Changed virus 2	Damaged	Normal	Damaged	Damaged	Normal
CV3	M	43	Changed virus 3	Normal	Damaged	Damaged	Normal	Normal

Write a **scientific explanation** that states whether any of the zombie virus's variants (changed virus forms) would result in a more dangerous zombie than the original form?
Make sure your scientific explanation includes a claim, evidence to support the claim, and reasoning why the evidence supports the claim.

Appendix B – Specific Explanation Rubric for Pre/Post-Test Explanation Assessment

Claim		A conclusion that answers the original question.	
Level	**0**	Does not make a claim.	
	1	Makes an accurate or inaccurate claim that does not answer the question.	Ex: "virus is 1 is the same result as the unmutated virus" - A47. This is correct, but does not answer the question.
	2	Makes an inaccurate claim that answers the question.	Ex: “a possible result in a more dangerous zombie than the original can be CV1” - PA-07 “when the virus # goes up, they would be more dangerous” - PA - 08 “it depends on how you change the virus” - PA-18
	3	Makes an accurate but vague claim.	Ex: “It would result in a more dangerous zombie”
	4	Makes an accurate but incomplete claim. Probably focused on the difference between CV3 & Z1	Incomplete statement that includes that CV3 is more intelligent OR coordinated but does not include that CV3 would still be hungry or aggressive; Ex: "Zombie [CV3] would be more dangerous" or “CV3 would be more dangerous because...it would [be] more intelligent” - PA-01
	5	Makes an accurate but partially complete claim. Likely focused still on the differences between CV3 & Z1	States Zombie CV3 would be more dangerous because it would be more intelligent and coordinated but does not include that it would still be hungry and/or aggressive; “CV3 is more dangerous because its intelligence is normal and so is its movement” - PA-15
	6	Makes an accurate and nearly complete claim. Begins to incorporate what is the same about CV3 & Z1.	Zombie CV3 would be more dangerous because it is more intelligent and coordinated / moves normally. Also include either that it is more aggressive OR always hungry.
	7	Makes an accurate and complete claim. Addresses both the differences and similarities of CV3 & Z1	Zombie CV3 would be more dangerous because it would be more intelligent and more coordinated (or move normally) but would still be aggressive and hungry.

Evidence		Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.	
Level	**0**	Does not provide evidence.	
	1	Provides inappropriate evidence	Ex: age or gender; both zombies have "4 parts damaged" PA-07
	2	Provides vague evidence; may include some inappropriate evidence.	Ex: "some parts are damaged" or "it has 3 milds" "things are changed and they all act differently" - PA-19
	3	Provides appropriate, but insufficient evidence to support the claim; may also include inappropriate or vague evidence.	Provides only 1 of the following pieces of evidence: Normal cerebellum, frontal lobe, or motor cortex. May include age or gender. "It's also a male much stronger...the age shows that he has more physical abilities" - PA-27
	4	Provides appropriate, but insufficient evidence to support claim. May include some inappropriate evidence.	Provides 2 of the following pieces of evidence: Normal cerebellum, frontal lobe, or motor cortex. Does not include amygdala or hypothalamus. May include age or gender. "the cerebellum and motor cortex are normal which gives it human features" - PA-20
	5	Provides appropriate but insufficient evidence to support the claim.	Provides all 3 of the following pieces of evidence: Normal cerebellum, frontal lobe, and motor cortex in brain of CV3; does not include damaged amygdala or hypothalamus. "It has more things that are normal. Like it's motor cortex and frontal lobe and it's cerebellum" -PA-30
	6	Provides appropriate and nearly sufficient evidence to support the claim.	Includes 4 pieces of evidence: The cerebellum, motor cortex, and frontal lobe are normal, AND amygdala OR hypothalamus is damaged.
	7	Provides appropriate and sufficient evidence to support the claim AND incorporates all relevant data about the brain.	Includes all 5 pieces of evidence that make the zombie more dangerous. The cerebellum, motor cortex, and frontal lobe are normal BUT the amygdala and hypothalamus are still damaged.

Reasoning		A justification that links the claim and evidence. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.	
Level	**0**	Does not provide reasoning.	
	1	Provides reasoning that does not link evidence to claim or incorrect reasoning.	Ex: “as one of the males has 4 things damaged while the other has 2 things damaged” - PA-18 “because the emotions are as humans...” - PA-29 (this is incorrect because CV3 has a damaged amygdala) “the emotion are not [damaged] so it could get really angry” - PA-32
	2	Provides only vague reasoning moderately correct link to scientific principles.	Ex: "parts of the brain being less damaged make the zombie less dangerous" “He has all the things he needs to be able to attack and be more dangerous” - PA-27
	3	Repeats some of the evidence and begins linking to claim. Does not include general scientific principles.	Repeats that cerebellum, motor cortex, OR frontal lobe is normal and what effect that part has on behavior. Does not include information about aggression or hunger, or a generalization about the brain. Ex: “They are more intelligent and have more agility to move” - PA-37
	4	Repeats some evidence and links to claim. May include some scientific principles but not sufficient.	Repeats that fewer parts are damaged so the zombie would be more dangerous. OR provides an incomplete generalization about what causes zombie behavior. Ex: “since it is more intelligent it would be able to climb...come up with strategies...and since it can control its balance and movement it would be able to do [these] things” - C46
	5	Provides accurate reasoning that links all evidence to the claim; or includes appropriate scientific principles.	Repeats that fewer parts of the brain are damaged so the zombie would be more dangerous. AND provides an incomplete generalization about what causes zombie behavior. Ex:
	6	Provides accurate but incomplete reasoning that links evidence to claim. Includes appropriate but insufficient scientific principles.	Includes a complete generalization that damage to the brain changes behavior, and what parts of the brain are damaged cause different behavior changes. Since the cerebellum and motor cortex effect movement, less damage would make a more coordinated zombie. Since the prefrontal cortex is involved in intelligence, the zombie would be better at making decisions. Therefore, zombie CV3 would be more dangerous.
	7	Provides accurate and complete reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles.	Includes a complete generalization that damage to the brain changes behavior, and what parts of the brain are damaged cause different behavior changes. Since the cerebellum and motor cortex effect movement, less damage would make a more coordinated zombie. Since the prefrontal cortex is involved in intelligence, the zombie would be better at making decisions. Since the amygdala and hypothalamus are still damaged, the zombie would still be aggressive and always hungry. Therefore, zombie CV3 would be more dangerous.

Appendix C – Experience Sampling Method Survey

Survey Options for each ESM.

Note: A, B, C, and D correspond with the letters on the Promethean Clicker Pods used to collect the data.

		Not at all	Some what	Pretty much	Very much
1.	Was it interesting?	A	B	C	D
2.	Did you enjoy what you were doing?	A	B	C	D
3.	How hard were you concentrating?	A	B	C	D

Survey 1: Please take a moment to think about whatever you were doing right before you came into the classroom as you respond to each of the following questions.

Survey 2: Please take a moment to think about the iPads matching activity you were just doing as you respond to the following questions.

Survey 3: Please take a moment to think about the healthy human to zombie brain comparison activity we were just doing as you respond to the following questions.

Survey 4: Please take a moment to think about the mutated zombie brain comparison and explanation activity you were just doing as you respond to the following questions.