# Linear Algebra, Secret Agencies, and Zombies: Applications to Enhance Learning and Creativity


**Carolyn Otto**

**Abstract** This article will discuss activities and assignments created for a linear algebra course that aim to excite students about learning the course content. The linear algebra course taught at the University of Wisconsin-Eau Claire covers linear algebra, its applications, and serves as the introduction to proofs course. Students often become overwhelmed with all the content and proof techniques in this course. This leads to them not enjoying, nor engaging in, what they are learning and they become discouraged with the material. Throughout the semester, interactive projects are introduced which cover applications of the course content. These activities center around the idea that the students have been recruited to work with the "Zombie Containment Task Force" under the supervision of Agent Frank Larson. Throughout the semester, students must complete several missions to uncover secrets about the workings of the task force, discover knowledge about zombies, and reveal double agents. At the end of the semester, students use clues given throughout the semester to make a final decision which informs them of their future in this fictional world. This article will give the outline of five interconnected projects that are used in the course as well as discuss the implementation of these missions.

## 1 Project Based Learning

To give a full picture of how I use projects in my course, first I present a background of the linear algebra course at my institution. I will follow the introduction with a discussion of how I incorporate these projects into my teaching approach.

C. Otto (✉)
University of Wisconsin-Eau Claire, Eau Claire, WI, USA
e-mail: ottoa@uwec.edu



S. D'Agostino et al. (eds.), *A Celebration of the EDGE Program's Impact on the Mathematics Community and Beyond*, Association for Women in Mathematics Series 18, https://doi.org/10.1007/978-3-030-19486-4_15

### *1.1 Linear Algebra at the University of Wisconsin-Eau Claire*

The linear algebra course taught at the University of Wisconsin-Eau Claire (UWEC) is a four credit-hour course taken by most mathematics/physics majors during their sophomore or junior years. Each semester, there are typically 35–50 enrolled for the course, which could be split between two sections. The course covers the typical linear algebra curriculum, including matrix algebra, systems of linear equations, vector spaces, linear transformations, eigenvalues, and applications of these concepts. The course also covers methods of proof and is treated as the "introduction to proof writing" course for our math majors. New to the curriculum is an overview of student-faculty research and the related opportunities for students.

This course is also used in the department's assessment of the mathematics major with a liberal arts emphasis. Specifically, the course assesses the following two program outcomes:

- Students will be able to write mathematical proofs.
- Students will be able to work independently and collaboratively on mathematical problems.

I have taught this course six times at UWEC. The first time I was in charge of the course, it was only three credit-hours and applications of the material were optional content. The previously stated course description demonstrates how this one semester course is quite dense with content. Within the last several years, our department (with university approval) has increased the number of credits to four in order to add in the applications to the topical outline. The additional credit allows for more time with the application content. Even with the fourth credit, the core content, the proof techniques, the applications, and projects still push the limits on material for a four credit-hour course.

Since the addition of the fourth credit-hour, I have taught our linear algebra course five times. I began by covering a selection of applications from the course textbook [5] by lecturing and assigning problems from those sections. While I did cover all the required material, I found myself not giving the applications the full treatment they deserved in favor of more time with the proof techniques and proof writing.

This is where zombies enter the story. As I taught the course more, I started to incorporate writing projects in my linear algebra sections to get students interested in the material and to engage their creativity. These projects have evolved over time and now focus on covering some of the application sections of the course while creating an ongoing narrative of the students' involvement in a secret government agency, "Zombie Containment Task Force." The specifics of the narrative and projects can be found in Sect. 2.

## 1.2 Rationales for the Zombie Projects

Sharing my excitement for math is one of the reasons I love being an educator. However, it sometimes takes more than just my excitement to get the students engaged with the material. I create a fun and interesting experience for my linear algebra students by developing creative zombie projects to motivate them to learn and apply the material.

Over the course of my career, I have attended several panels and talks on the incorporation of writing projects into the classroom. Specifically, I attended a Project NExT Session on incorporating writing projects into undergraduate research courses. The speaker mentioned several ways to incorporate projects, how to create effective rubrics, and gave reference to their book [3], which I used to model my rubrics. For more information on Project NExT, please visit the website www.maa.org/programs-and-communities/professional-development/project-next. The idea of incorporating writing projects really appealed to me for this linear algebra course at UWEC, especially considering the two outcomes that this course assesses. While these projects focus on applications and assessment of the second outcome in Sect. 1.1, I have found that more practice writing mathematics helps students to become comfortable writing proofs, which also helps with the first listed outcome in Sect. 1.1. A mathematics focused paper has a different style than a mathematical proof, but it has been my experience that when students are comfortable communicating math in the first form, they have an easier time effectively explaining why a mathematical statement is true. From there we work on transforming their explanation into a proof.

Throughout my course, I give five writing projects to the students (see Sect. 2) with the fourth project, an escape room, as an optional project. I decided to use a zombie theme for these projects. This is for several reasons. First, I love zombies and Halloween, so it is fun for me to write projects involving them. Second, when I first started writing these projects, TV shows, books, and movies such as *Zombieland*, *iZombie*, *World War Z*, and the *Walking Dead* (to name just a few) were popular in the mainstream media. I cannot forget to mention that Colin Adams wrote and published *Zombies & Calculus* [1]. It is worth mentioning that this book and these projects are completely independent and were created without the knowledge of each other[1]. Third, sci-fi topics lead to a little wiggle room when it comes to storytelling and solutions. For example, if I find that 4.58 zombies survive, I don't need to round up. Having 0.58 of a zombie could make sense. Another example my students see is blood flow in the brain changing directions after the injection of a chemical. Again, this scenario could happen in this world.

I also give these projects a zombie theme in order to help motivate the students. When I share my enthusiasm for this fictional world, I demonstrate to my students that I care about the material and am excited to share it with them. The time I

[1] How awesome is it to have multiple, creative math and zombie products?

spend developing and testing these projects is evident to the students and seeing my dedication motivates them to learn the material [4]. The idea of telling stories is also a great motivator to retain the information, "organizing a lesson plan like a story is an effective way to help students comprehend and remember" [7]. My projects are unique in regard to the storytelling. It is the aim that students will remember the projects, math, and their experiences with them more than just working problems from the book. For more ideas to incorporate projects with more realistic applications, please see [2].

The primary focus of these projects is the communication of the solutions by the students. I write the problems in a way that requires students to identify what the problems are asking and determine the best method to solve them. I am interested to see if they can explain the solution and what it means in a document written to a person that does not know all the linear algebra details. When I first explain this to the class, I receive comments such as "I thought I was taking a math class not an English class," or "If I wanted to write I would have been an English major." This usually leads to a discussion on why it is important to communicate effectively, especially when working with mathematics. I emphasize the following points:

- an application of linear algebra in the "real world" will not be phrased as "solve this equation,"
- employers need to be able to follow the logic of the solutions,
- many individuals outside of our linear algebra class may not understand math jargon and it is important to know how to communicate ideas effectively, and
- writing down a solution with words helps to communicate the thought process for yourself and the reader.

In addition to the points above, I also discuss collaboration skills at the beginning of the semester, even though students are not in larger groups until the fourth and fifth project. I take the time to explain the importance of working with others. Specifically, I try to foreshadow work scenarios where they will be collaborating with all different types of people and skill levels.

In the next section, I will detail the projects that I give for my course. This article is just an overview of these projects. If you are looking for more specific details, you can contact zombiecontainmenttaskforce@gmail.com and Agent Frank Larson will supply you with more details and materials.

## 2 The Projects: Missions from the Zombie Containment Task Force

This section provides details about each project/mission: the story, linear algebra component, assignment, the assessment, and other details. In addition, I will provide the general setup of the world of the "Zombie Containment Task Force." It is important to note that in my courses I use wide variety of materials and software

in the management and logistics of these projects. If one is interested in creating similar projects, these items are not all necessary and can be altered to fit an instructor's needs.

On the first day of the course, students receive a letter from the mysterious Agent Frank Larson, see Fig. 1. They have been recruited to work for the "Zombie Containment Task Force (ZCTF)." They are informed that throughout the semester they will receive missions that require knowledge of linear algebra to successfully complete.

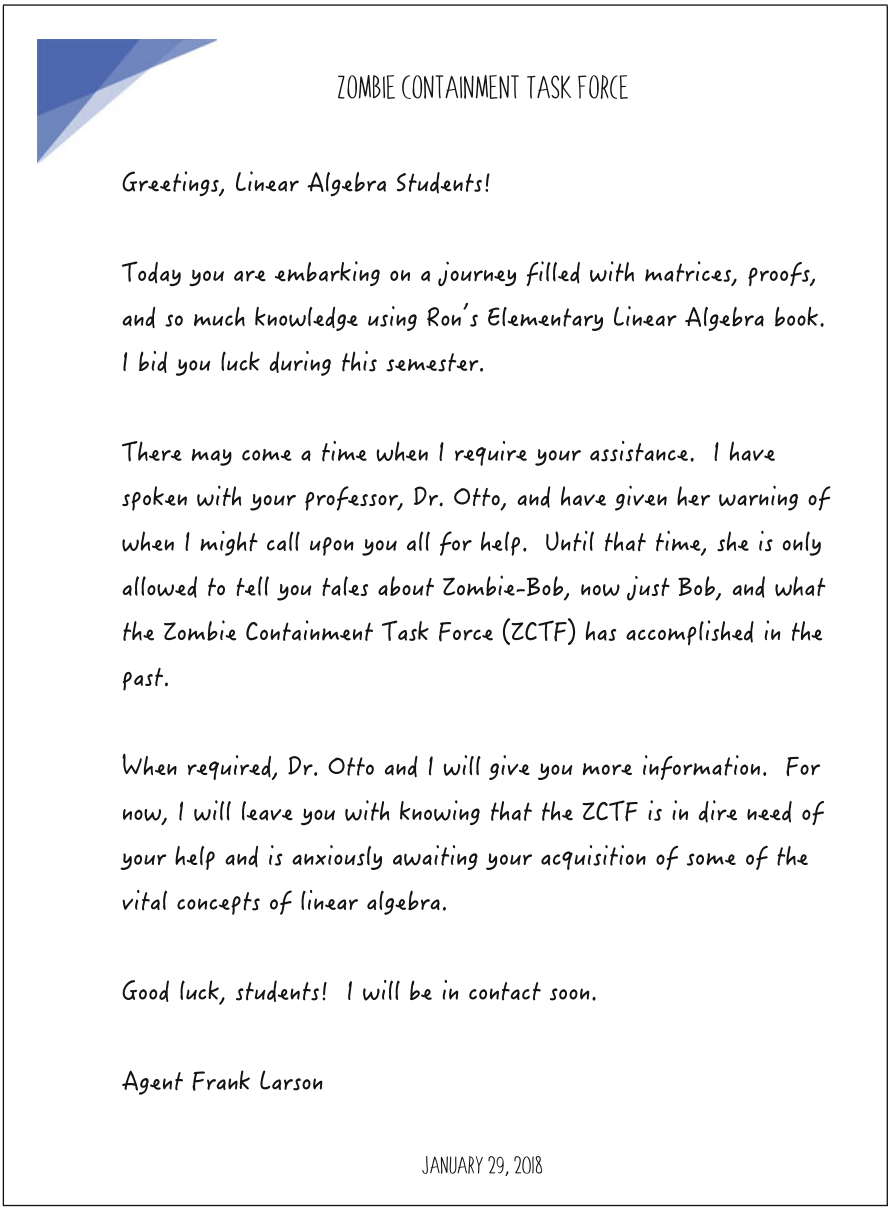
## *2.1 Project One: Zombie Classification*

*Mission* The ZCTF computer system has crashed! Information about zombie specimens has been lost, only the paper copies remain. Students are given one of the six medical files for a zombie specimen. In each of these files is general information about a zombie, a photo, an image of "observed blood flow analysis," and information about experimentation that Dr. William had previously performed on the zombie. Using the information supplied, you are to classify your zombie as a crawler, shambler, walker, runner, or thriller by finding the blood flow at the indicator site. The letter written by Agent Frank Larson can be found in Fig. 2.

*Linear Algebra Component* The blood flow image given in the file gives the fixed and variable blood flow rates of certain veins/arteries in the zombie brain. An example of one of these images can be seen in Fig. 3. Students set up a system of linear equations to solve the system representing this network. The solution they find includes a free variable. The experimentation data given instructs what students should do with that free variable.

*Assignment* This is an individual assignment. Each student sets up and solves a system of equations based on the information in their file. After they solve the system of equations, they are supplied with one more piece of information: Dr. William was conducting experiments and was able to find one more blood flow value. Using the data, they are instructed to classify their zombie and write a letter to Agent Larson in response to his inquiry that includes the explanation of the solution and the method of solving the problem. This letter is to be typed and submitted to the class's Dropbox folder.

*Assessment* When the students receive their file folder of information, they are also supplied with a detailed rubric for the assignment. Since this is their first mission/writing assignment, I offer to read a rough draft of their response letter. I specifically require that when they solve the system of equations, they obtain a free variable. Then using Dr. William's experimentation notes, the students can find a value for this variable. I want to demonstrate the convenience of solving the system in general. I make this a specific rubric item, mention it in class, and point it out in the drafts supplied to me as most students will skip this step.



ZOMBIE CONTAINMENT TASK FORCE

Greetings, Linear Algebra Students!

Today you are embarking on a journey filled with matrices, proofs, and so much knowledge using Ron's Elementary Linear Algebra book. I bid you luck during this semester.

There may come a time when I require your assistance. I have spoken with your professor, Dr. Otto, and have given her warning of when I might call upon you all for help. Until that time, she is only allowed to tell you tales about Zombie-Bob, now just Bob, and what the Zombie Containment Task Force (ZCTF) has accomplished in the past.

When required, Dr. Otto and I will give you more information. For now, I will leave you with knowing that the ZCTF is in dire need of your help and is anxiously awaiting your acquisition of some of the vital concepts of linear algebra.

Good luck, students! I will be in contact soon.

Agent Frank Larson

JANUARY 29, 2018

**Fig. 1** Introductory letter from Agent Frank Larson which is given to the students on the first day of class. The character of Zombie-Bob, or Z-Bob, is important to the story as he is a character that was turned into a zombie and then took the cure to become human again

ZOMBIE CONTAINMENT TASK FORCE

Greetings, Linear Algebra Student:

My name is Agent Frank Larson and I oversee the Zombie Containment Task Force (ZCTF). Information about the ZCFT is strictly "need to know." I have been in contact with Dr. Otto and she assures me that your linear algebra skills are at the level needed to be of use to the ZCTF. To be frank (no pun intended), I am not as confident. However, we are in dire need of some help and I, for some reason, trust Dr. Otto.

At the beginning of January one of our computer systems was compromised and we lost a large amount of data collected from some of our incapacitated zombie specimens. Luckily, some hard copies of the original examinations of the subjects were discovered. Some of that data is now in your hands. Unfortunately, the analysis of the data was lost...this is where the ZCTF needs your help.

Data collected about blood flow in the specimen's brain while they were alive can determine the classification of the zombie. I have listed the classifications with information given to me from Dr. William. Before you ask, NO, we cannot just have them run around to classify them. The brains have been harvested and the bodies burned.

| Classification | Blood Flow Rates in milliliters per minute at indicator site |
|---|---|
| Crawler | 0-100 |
| Shambler | 101-250 |
| Walker | 251-450 |
| Runner | 451-650 |
| Thriller | 650 and up |

The indicator site is the vein leaving site B away from site A. Dr. William injected a fluid into the zombie's brain while they were "alive" and observed that some of the other blood flows were dependent on the alteration of one specific site's flow.

We have lost all the classifications of our specimens because of the computer situation. You will find all other relevant information in Dr. William's notes. I do not have time to go into more details. I have left all other instructions with Dr. Otto. I anticipate the proper classification of your zombie with justification by February 19.

Do not fail in this task.

Agent Frank Larson

FEBRUARY 7, 2018

**Fig. 2** Agent Larson's instruction letter for the first mission

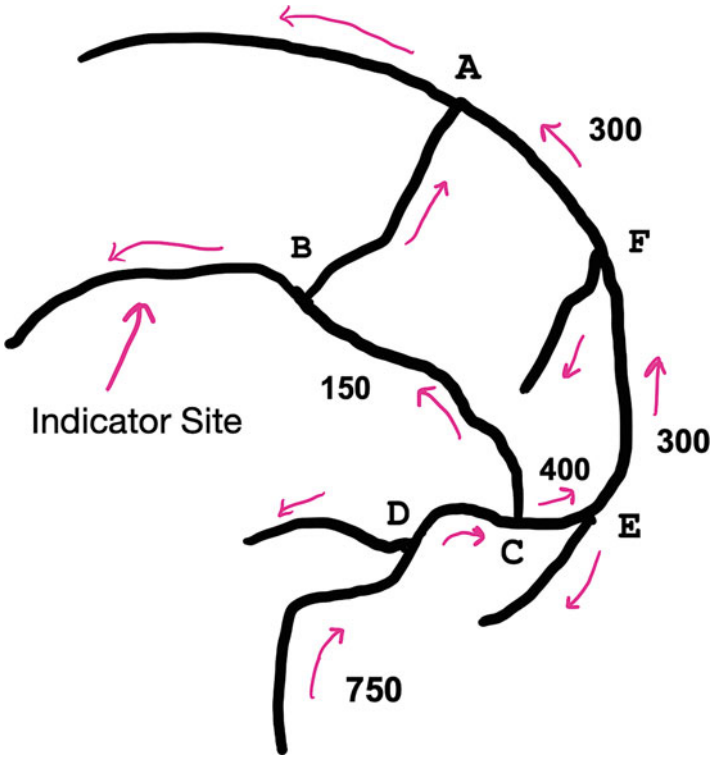



**Fig. 3** Example of a brain scan of a zombie showing the blood flows used in the first mission. The letters indicate junction sites, while the numbers indicate the rate of the blood in milliliters per minute

*Debriefing* I make comments on the letter and supply additional comments on a copy of the rubric the students receive. In addition, students are supplied with the classifications of all six zombies, the capture sites of these zombies, and some identifying feature: a dragon brand or a black umbrella tattoo. This piece of information is a clue for the students which they will use later to make a choice about what happens to their character. These six zombies are used throughout the projects.

*Fun Extras* To deliver this assignment, I assemble file folders with the information. Each folder has the information sheets stapled in them to resemble a medical file. Students from previous semesters agree to have their photo taken and turned into a zombie and these photos are paper clipped to the file. Lastly, I create a label for the ZCTF that matches their security clearance.

## 2.2 Project Two: Code Breaking

*Mission* After completion of the first mission, Agent Frank Larson decides to grant the students a new security clearance! With continuing problems of the main computer systems, employees of the ZCTF have been communicating through coded messages. Two mysterious messages are discovered by Agent Larson's personal assistant Reginald. Students receive one of the two envelopes, each of which contain a set of encrypted messages. Using a set of potential decoding matrices, students must decipher the messages and report back to Agent Larson.

*Linear Algebra Component* Each message was encoded using one of the several $n \times n$ invertible matrices, known as coding matrices. The messages were partitioned into uncoded row matrices, then multiplied by the coding matrices to obtain coded row matrices. Potential coding matrices are provided to the students from Agent Larson. Students must determine which inverse matrices will used to decode the message and submit the message to Agent Larson.

*Assignment* This is an individual or partner assignment, students can choose. Each envelope of information includes a coded message broken up into three parts and a collection of five matrices. Students are informed that three of the matrices were used to encrypt the message, one for each part of the message. They need to determine which matrix decodes which part and then decode the message. The description of the mission, detailed instructions on how to decode the message, computations of the decryption, and a conclusion all of which must be typed into a Maple template. Maple is a mathematics algebraic software that serves as a computational environment which students are able to use on any school computer and is the software we use most in class. If trying to adapt this project to one's own needs, the calculations could easily be done on their calculators or in Wolfram Alpha.

*Assessment* When the students receive their envelopes of information, they are supplied with a detailed rubric for the assignment, see Fig. 4. For this project, I specifically require that they use a Maple template which I supply to them. They are given one class period to work on this project. The classroom in which I teach this course is our department's computer lab so there are an ample number of computers. At UWEC, students are also able to use a virtual lab which allows them to access the Maple software even if they are not on campus. Since the ZCTF lost all their computer files, students need to supply instructions on how to decode the message using Maple. Thus, their Maple worksheet must be able to run and include all relevant computations and instructions.

*Debriefing* I run all the Maple code to make sure the students' computations work without bugs. I make comments in the Maple code as well as on the rubric. Since there are two different messages, students are given the answers to both when I hand back the assignment. Their Maple code is returned by email so they are able to look at all the comments in the Maple software. The messages set up the main mystery

INSTRUCTIONS FROM DR. OTTO AND AGENT LARSON

The purpose of this project is to apply the method of code-breaker to "real-life" situations. You are to decipher the code given to you using the techniques from Section 2.5. It is expect that you will provide Agent Larson a Maple Worksheet the includes the explanation of the solutions and method of decoding the message.

- You may work by yourself or with a partner. (1-2 people groups!)
- Dr. Otto has provided a Maple Worksheet template on D2L that you should use to write up your assignment. Make sure you use it, but of course, feel free to make it your own.
- This list will be used as a guide to grade your assignment and will be returned to you with comments.
- Put your Maple Worksheet in the Dropbox Folder on D2L labeled "Codes" by Wednesday, February 28 by the beginning of class.

Please feel free to use these checklists as a guide for yourself while writing this assignment.

MATH 324 PROJECT CHECKLIST: MAPLE WORKSHEET

Does this Maple Project:

1. clearly (re)state the problem to be solved?
2. state the answer in a complete sentence which stands on its own?
3. provide a paragraph which explains how the problem was approached?
4. aim its explanations at the appropriate audience?
5. explain how the data is derived, or where it can be found?
6. give acknowledgement where it is due?

In this Project,

1. did the writers use Maple? and the template that was given? follow the instructions in the template?
2. did the writers follow the instructions on the template?
3. are the spelling, grammar, and punctuation correct?
4. are the mathematics correct? include the correct amount of work? too little?
5. did the writers solve the question that was originally asked?

Comments:

**Fig. 4** The rubric for the second mission

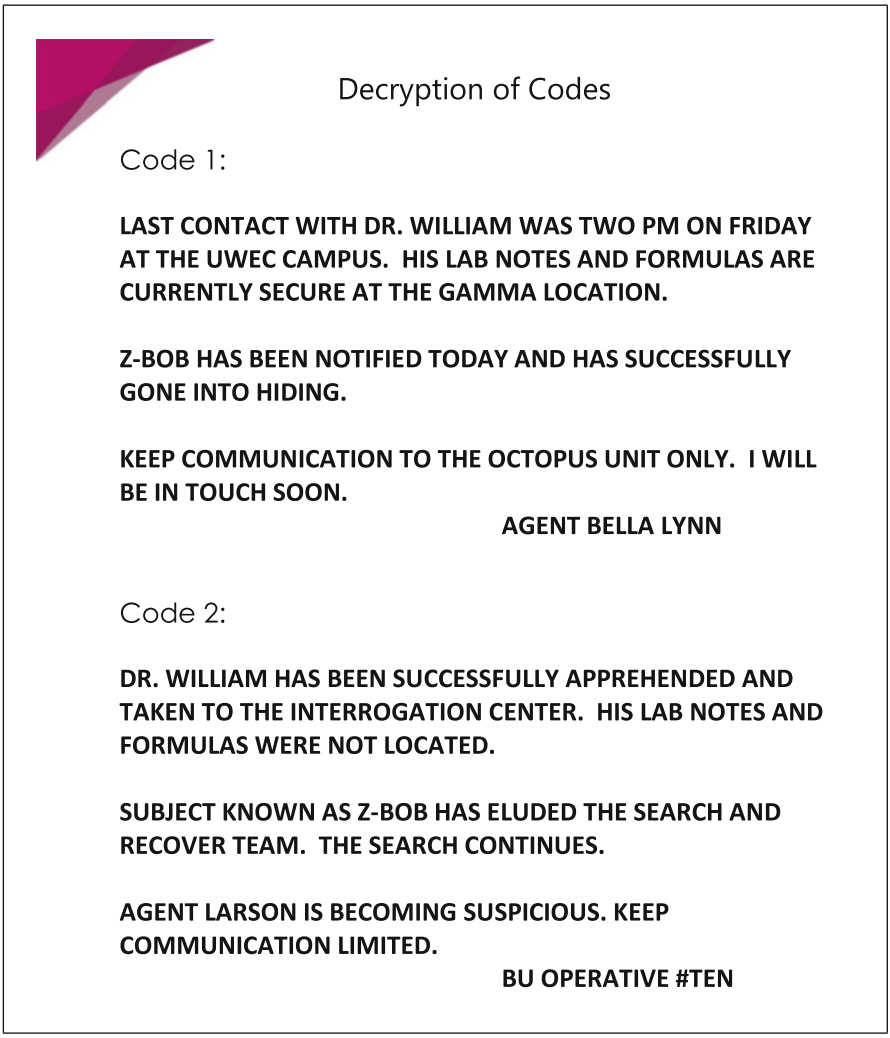



**Fig. 5** The deciphered messages from the second mission

for the course: "Who are the Black Umbrella Operatives?" In addition, we find that Dr. William has gone missing. Decoded messages can be found in the appendix section in Fig. 5.

*Fun Extras* Students meet a new character named Reginald, Agent Larson's personal assistant. I have a member of our math department come in and read a script for my class and hand out the mission to the students.

**Zombie Internal Body Temperature**

Dr. William was studying many aspects of the zombie virus. In particular, he was working with Hugo Pecos and Robert Lomax on the "Science of Zombism." While the ZCTF was able to debunk a lot of that "science," the thermal analysis seems to be correct. The typical zombie core temp is between 64 and 76 degrees Fahrenheit. Heat is released by the various parasites living in the zombie flesh. This means that the thermal image camera can detect zombies and is able to distinguish between the undead and living humans. The thermal cameras' rays can penetrate man-made structures as well. The rays condense into a tetrahedron shape and can detect heat in the whole figure.

**Gamma Location Information**

The Gamma Location is located at 333 Gibson Street and 205 S Barstow, Eau Claire, WI 54701. The height of the building/camera mount is 100ft. Some of more confidential documents are housed here. It is of the utmost importance that the Black Umbrella spies do not find out about this location!

This location is in plain sight and we work hard to keep the public unaware of its real purpose. You are able to purchase coffee, enjoy dinner, and book a room in the spacious hotel. These purchases directly go to the ZCTF. Shop and eat local!

**Fig. 6** Some information provided to the students that will be helpful in this mission. The science behind zombies included can be found at [6]

## *2.3 Project Three: Location Finding*

*Mission* Agent Frank Larson is quite impressed with the work of the students and increases their security clearance! He informs them that there have been whispers of something known as "Black Umbrella" and that the ZCTF has a secret facility in downtown Eau Claire known as the Gamma Location. Students receive a mini-file of information about sightings and capture locations of zombies as well as the location and specifications of the Gamma Location, see Fig. 6. Using this information and a map of Eau Claire, the main objective is to determine where the Black Umbrella's Interrogation Center is and try to locate Dr. William.

*Linear Algebra Component* In the information file, students are supplied with a map that includes the observation and capture sites of three zombies as well as the Gamma Location. There is also given a grid printed on a picture of transparency paper that fits over the map. Creating coordinates of all the points of interest, students are able use linear algebra, in particular determinants, to find the area between the zombie capture sites and to find the volume of the tetrahedron that a thermal camera can cover if on top of the Gamma Location. Students are informed that two of the zombies travel in a straight line (but do not know which two). This allows the students to find the points of intersection of the paths that these zombies are following and then can deduce possible locations for the Interrogation Center. In particular there will be three possible locations as there are three distinct combinations of pairs of zombies.

*Assignment* This is an individual assignment. Each student finds coordinates that represent all the relevant locations and construct matrices in which the determinants will provide the needed values. They are to write a letter to Agent Larson in response to his inquiry that includes the explanation of the solution and the method of solving the problem. This letter is to be typed and submitted to the class's Dropbox folder. For this mission, students are allowed to handwrite the supporting mathematics if they desire with the story justification that the ZCTF is in a rush to find Dr. William.

*Assessment* When the students receive their mini-file of information, they are also supplied with a detailed rubric for this assignment. At this point in the semester, students are accustomed to reading the rubrics and knowing what information to include. For this specific mission, students need to not only compute the quantities requested, but must construct a map illustrating why their solutions make sense and discuss any error that might occur.

*Debriefing* Just as with the first mission, I provide feedback on the letter and supply additional comments on a copy of the rubric the students receive. In addition, students are supplied with all the possible locations of the Interrogation Center with a note from Agent Larson. This note congratulates them on a job well done and now a more precise search for Dr. William will be conducted. A list of potential destinations are given to the students with a date on which the search teams will investigate.

*Fun Extras* My student grader (Agent Bella Lynn) and I had a ton of fun with the delivery of this mission. Before class starts, we tape envelopes to the bottom of their tables. Normally, I close the door to my classroom once class starts but on this day I leave it open. My grader throws in a paper airplane and I read the message inside to the class. The students are instructed to look under their tables to get the mission. They loved this little twist.

## *2.4 Optional Project Four: The Escape Room*

This is an optional project, optional in the sense that I choose whether or not the whole class will participate in this activity. I use factors as time and enthusiasm to decide if the class does this activity. It is meant to be a fun change of pace from the classroom and gives a narrative that advances our story. In the fall this activity usually occurs the day before Thanksgiving. I will give you the general outline of the project and some idea of the problems. Please contact Agent Frank Larson at the agency's email: zombiecontainmenttaskforce@gmail.com for a more thorough debriefing, if you are interested in the specific clues, puzzles, and problems.

*Mission* With a list of potential locations for the Interrogation Center, Agent Frank Larson is assembling the Octopus Unit (an elite squad in the ZCTF) to search for Dr. William. Students are given temporary clearance to join Agents Terry, Cory, and Rowan in the investigation of Acoustic Cafe. The objective is to recover Dr.

William, find information on Black Umbrella Operatives, and try to discover a mole in the agency. In preparation for the search, Agent Larson tells students to read about the applications of vector spaces in chapter 4 of their textbook [5]. At this point in the semester, students have already worked extensively with vector spaces and this section draws connections between their knowledge of vector spaces and applications to differential equations (which all had seen in the prerequisite course of Calculus II). Students prepare by reading over that chapter, working out problems. It is expected they come to class with a solid understanding of the material. In addition, Agent Larson randomly assigns groups of two or three students which will be the search teams. During the next class, students investigate and try to escape Acoustic Cafe. This cafe is a real location in Eau Claire that students often visit to get snacks, coffee, and work on homework. I supply pictures of the real location if students have never been there so all of the clues make sense.

There are three main tasks/puzzles for this escape room. For each task, groups are given a set of clues, which include edited photos, dials, file folders, and pieces of papers.

- Stopping the Pendulum: Students are locked in the cafe and pendulum blades are descending on them and the other patrons! To stop them students must give Agent Cory the relevant information.

  1. What is the differential equation that models the pendulum? (Can be found in the photographs and from the reading.)
  2. What is a solution set for the above differential equation? (A selection of possible solution sets are in a photo.)

  2b. Verify that the set gives solutions to the differential equation.

  3. Prove that the set is linearly independent using the Wronskian.

  Bonus: Why is this an application of vector spaces?

- Freeing the Barista: The barista is locked behind a glass counter and you see someone lying on the floor. There is a weird dial with an equation in two variables on it and flyers on a bulletin board. Agent Rowan says to perform a rotation of axes to eliminate the $xy$-term and then classify the conic section the equation represents.

  1. What is the angle of rotation?

  1b. Provide the work to verify the angle.

  2. What conic section is needed?

  2b. Provide the work showing the standard equation of the conic section.

  3. What symbol do students need to give to Agent Rowan to release the barista? (This is found on the dial, the trigonometric watch you're given, and information on the flyers.)

  Bonus: Why is this an application of vector spaces?

- Entering the Code: Dr. William is found lying behind the counter! Agent Terry gets the doctor and says they must leave. There is a keypad by the bathroom

door (true fact: Acoustic Cafe has a code to use the bathroom). The barista keeps shouting "PS 3321421" over and over. What could this mean?

1. What is the seven digit code to leave? Students have five attempts. For this question, there have been several clues on photos and paper to help figure it out. This is purely for fun and has no bearing on students' grades.

*Assessment* It is important to me that the students know that this project is mostly for fun and for them to get to know their new group members. The largest portion of the grade is participation points. For some group work/homework points, students are to answer Stopping the Pendulum 2b and 3 as well as Freeing the Barista 1b and 2b.

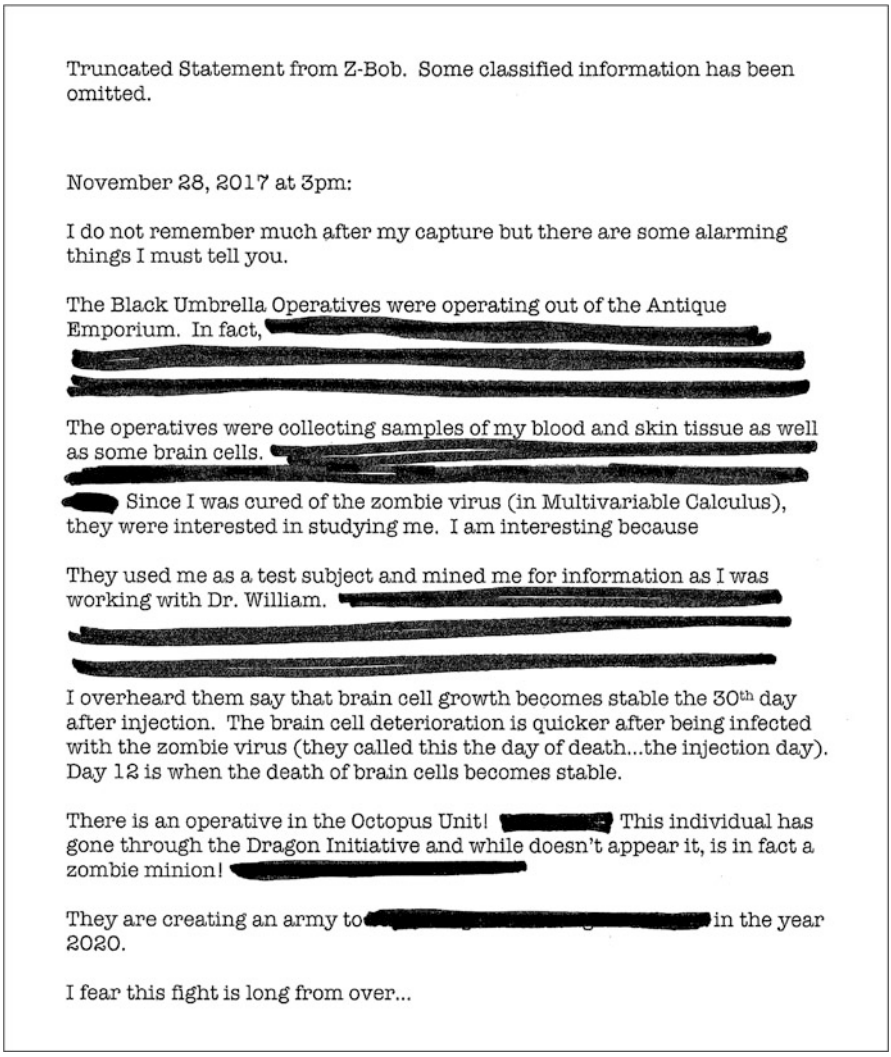
## *2.5 Project Five: Prediction Models*

If students did the escape room, they have all the information to start the final mission and will go to Mission B. If the escape room was not given in class, they go to Mission A.

*Mission A* With the completion of the previous mission, the Octopus Unit and Agent Bella Lynn create a list of potential locations for the Interrogation Center. It is still believed that Dr. William is being held there. This past Saturday, Agents Cory, Rowan, and Terry led the investigation of Acoustic Cafe, while the rest of the unit checked out the other locations. Dr. William was found at the cafe but remains unconscious. Agent Terry is keeping watch over him. The Octopus Unit found a collection of data sets at the Antique Emporium which belong to the Black Umbrella Organization. Students are to analyze the data to create six prediction models using the methods of least squares. Agent Larson supplies each group a flash drive of the found data, a statement from Z-Bob (see Fig. 7), instructions, peer assessment, and a rubric. Z-Bob is an important character introduced in my Calculus courses and has vital information about the zombie virus. He is highly sought after. Students do not need to have previous knowledge of Z-Bob for these projects.

*Mission B* After the debacle at Acoustic Cafe, Agent Larson has taken you off the Octopus Unit and back on office work duty. However he does congratulate the students on successfully finding Dr. William! The Octopus Unit searched the other locations and found a collection of data sets at the Antique Emporium which belong to the Black Umbrella Organization. Students are to analyze the data to create six prediction models using the methods of least squares. Agent Larson supplies each group a flash drive of the found data, a statement from Z-Bob, instructions, peer assessment, and a rubric.

*Linear Algebra Component* Each group is given a flash drive that has six collections of data. Students must use the method of least squares and create six quadratic



Truncated Statement from Z-Bob. Some classified information has been omitted.

November 28, 2017 at 3pm:

I do not remember much after my capture but there are some alarming things I must tell you.

The Black Umbrella Operatives were operating out of the Antique Emporium. In fact, [redacted]

The operatives were collecting samples of my blood and skin tissue as well as some brain cells. [redacted] Since I was cured of the zombie virus (in Multivariable Calculus), they were interested in studying me. I am interesting because

They used me as a test subject and mined me for information as I was working with Dr. William. [redacted]

I overheard them say that brain cell growth becomes stable the 30th day after injection. The brain cell deterioration is quicker after being infected with the zombie virus (they called this the day of death...the injection day). Day 12 is when the death of brain cells becomes stable.

There is an operative in the Octopus Unit! [redacted] This individual has gone through the Dragon Initiative and while doesn't appear it, is in fact a zombie minion! [redacted]

They are creating an army to [redacted] in the year 2020.

I fear this fight is long from over...

**Fig. 7** Z-Bob's statement

equations to predict values of zombie populations, brain cell regrowth (data can be seen in Fig. 8), and brain cell deterioration.

*Assignment* This is a group project and the groups are randomly generated. Each group must read the relevant material in the textbook. They also must write a letter in response with the answers as well as a written report on the solutions. Students are given two days in class to work on this letter and report. Also, as with the first mission, I offer to read a draft of these items. The projects must be returned on the flash drive.

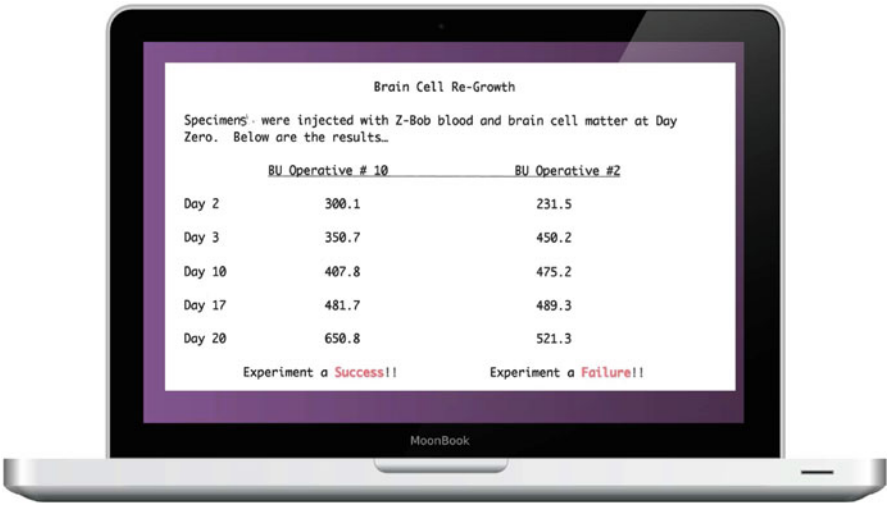



**Fig. 8** Data found on a computer at the Antique Emporium

*Assessment* When the students receive their flash drive of information, they are also supplied with a long, detailed rubric for the assignment and a peer review form. For this project, groups are required to do outside research on the topic of least squares and include references. They are also informed they must use this method, but in the report they must include why this method applies to this specific collection of data (this is the most commonly missed rubric item). Also, there is one model that seems incorrect. The students must explain this as well.

This project helps to assess the second outcome for this course: Students will be able to work independently and collaboratively on mathematical problems. Students must complete a peer evaluation on their group members. My observations and these evaluations will make up 20% of this project grade.

*Debriefing* As with the previous missions, I make comments on the letter and report and supply additional comments on a copy of the rubric the students received. Finally, students are given information about each of the Agents Terry, Cory, and Rowan. They each individually make a choice about who to give the prediction models and report. On the last day of class, I give them a final letter about what happened to them in this fictional world. See Fig. 9 for an example.

*Fun Extras* I inform the students of their fates by making them a name badge with a QR code on the back. They can scan the code to get their final outcome and to have a final memento from the course.

What Happened to You?

After turning in your official report to Dr. Otto, you decided to visit the ZCTF headquarters to try to get a look at Agent Frank Larson. However, you do not have the clearance to get past the lobby. On your way out of the building you spot Agent Rowan in the lobby. You remember that you asked Dr. Otto to give Rowan a copy of your final report.

As you head out of the building when you feel a tap on your shoulder. Rowan wants to chat with you and escorts you back into the ZCTF headquarters. For the next couple of hours Rowan informs you more about different departments in the task force. There are also a couple of side conversations about dogs, Agent Rowan loves dogs. It was when Rowan was with their dogs at the Eau Claire Dog Park, they encountered their first zombie (Z_42: Walker with Dragon Brand).

Agent Rowan tells you that the Octopus Unit is impressed with your work, along with Frank Larson. They also tell you that Dr. Otto is the main recruitment officer for ZCTF and she has been using her class for years to secretly recruit new initiates. You are offered a full-time position with the ZCTF and are told you would receive the elusive Opal Clearance and your choice of assignments. The ZCTF can provide excellent benefits, travel opportunities, and four weeks of paid vacation.

You gladly accept. Your first assignment is joining with Agent Bella Lynn and Agent Rowan to identify double agents in the agency. Specifically, you need to find who is BU Operative #10 and #13.

Your new security clearance does not allow you to speak of your mission to anyone. You live out the rest of your Math 324 days quite happy with your new job.

**Fig. 9** Example of what may have happened to you at the end of the projects

## 3 Steps Forward

These projects are living things in my courses; they are constantly evolving to be more effective as teaching tools. This involves changing the problems, adding more to the story, creating "mini" missions, and creating more thorough assessments for the projects themselves. I am currently working with the UWEC's Center of Teaching and Learning (CETL) to create an anonymous assessment survey for each of these projects that will be sent to current and previous students.

My absolute favorite thing about these zombie projects is the students' creativity with writing and storytelling. Students of course have the option of just answering the questions and writing a plain letter back to Agent Larson. However, most of the students really get involved in the world. I have had students create code names for themselves, new departments in the agency, puzzles for Agent Larson, and drawings/comics of the zombies. As such, it is my intention to get a small group of students, from math majors, to art majors, to English majors to write a course booklet about the ZCTF (or a brand new agency) that my calculus and linear algebra students would receive at the beginning of the semester. I have projects made for Calculus I, II, III, and Linear Algebra that would all be included in this volume.

**Acknowledgements** I would like to thank Cindy Albert from the UWEC's CETL office for all the useful teaching conversations and resources we have shared throughout the years that have helped create these projects. Also, I would like to thank the UWEC's Mathematics Department for giving me the flexibility in my courses to try these projects and the resources (office supplies, flash drives, etc.) that have helped make these projects a little extra special. Finally, I would like to thank and acknowledge Dr. Christopher Davis for all of his time listening to zombie lore and linear algebra ideas.

## References

1. Adams, C.: *Zombies and Calculus*. isbn=9781400852017. (2014). Princeton University Press.
2. Chang, Jen-Mei:*A practical approach to inquiry-based learning in linear algebra*. pp. 245–259. International Journal of Mathematical Education in Science and Technology. (2011). https://doi.org/10.1080/0020739X.2010.519795.
3. Crannell, A., LaRose, G., Ratliff, T., & Rykken, E.: *Writing Projects for Mathematics Courses: Crushed Clowns, Cars, and Coffee to Go*. pp. 9–96. Mathematical Association of America. (2004). https://doi.org/10.5948/9781614441137.002
4. Lang, James M: *Small Teaching: Everyday Lessons from the Science of Learning*. pp. 182–193. (2016). Jossey-Bass, Wiley Brand.
5. Larson, R. and Edwards, B.H. and Falvo, D.C: *Elementary Linear Algebra*. isbn=978061800508. (2003). Houghton Mifflin.
6. Lomax, R. and Pecos, H.: *The Science of Zombism*. Zombie Virus. (2018).https://fvza.org/zscience1.html.
7. Willingham, D. *Why don't students like school? A cognitive scientist answers questions about how the mind works and what it means for the classroom*. pp. 67–68. (2014). Jossey-Bass, San Francisco.