TEAM PROJECT REPORT

Secure Software Development

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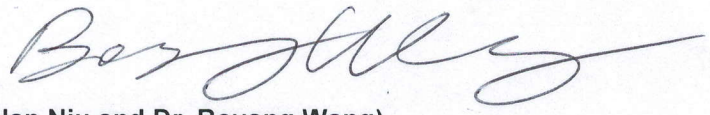

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***Abstract* - Web applications are expected to maintain a balance of security and usability. Massive amounts of data are collected and stored by web applications, increasing the need to be proactive in finding vulnerabilities in the software. The large scale of modern websites makes protecting against all kinds of attacks difficult. Cross-site scripting attacks impact both the safety and usability of a website and are among the most common forms of attack. Finding a solution for discovering cross-site scripting vulnerabilities opens the door to explore solutions for more and different types of attacks. In this study, we extrapolate human intuition to develop an algorithm for finding vulnerabilities in web applications. Eight additional vulnerabilities were discovered on a long-lived health records management web application using the heuristics developed in the study.**

Index Terms - algorithm, cross-site scripting, heuristics, modeling, web security, vulnerability detection.

I. Introduction

Security in web applications has three factors, sometimes known as the CIA triad. These include confidentiality; the relative safety of information from being accessed by unintended users, integrity; the accuracy of the information provided, and availability; the ability for the right person to access the information. Unfortunately, when developing web applications all three components cannot be satisfied at the optimal level simultaneously. One must be compromised to a certain extent.

The rise of online banking represents a prime example of the multi-faceted nature of web application security. Banks are responsible for incredibly sensitive information, and some have turned to a two-factor authentication process to maintain confidentiality and integrity. Users, in these cases, must retrieve an authorization code via email or text before private information can be altered. Although this example preserves the confidentiality and integrity aspects of the CIA triad, the user's access to his or her services is delayed. In addition, compare to single-factor authentication involves more steps, there is higher possibility of occurrences of unexpected errors which further harm the web application's usability. This minor inconvenience illustrates the necessity of a caveat in order to maintain web security.

Availability is often the easiest to sacrifice, as security testing on large-scale web applications like online banking is particularly challenging. With the multitude of website functions and variety of user perspectives, an application of this size usually requires different teams of software developers working on different components. These are ultimately integrated into a single application. While individual pieces of the web application may work independently, there is an uncertainty in regards to how these sub-parts function when integrated. Bugs and other issues may remain unknown until deployment. Detecting vulnerabilities that may develop upon integration is difficult and costly [1]. Testing for vulnerabilities on large-scale web applications is usually done in individual units as a result.

The lack of access to multiple aspects of the web application simultaneously in tandem with the ever-changing catalog of features makes the use of an automated test tool complex. This study relied on a locally hosted sandbox server that provided access to all functions and perspectives of a model website. In addition to eight vulnerabilities uncovered manually with the heuristics, another contribution of this paper is an algorithm derived from the heuristics that can be applied to automatically find security vulnerabilities in (large-scale) web applications. This study is an early stage of the project focused on identifying and defining heuristics that can be used to find these vulnerabilities on this model website. Ideally, the tool created will be able to generalize to security-critical websites.

The researchers review related work on cross-site scripting and vulnerability detection in Section II. The context of the study is described in Section III, and Sections IV and V address results and discussion respectively. This paper concludes with limitations and future work in Section VI.

II. Background and Related Work

There are multiple pathways users can take to navigate a web application. While there may be a plethora of links to follow from any given web page, different paths are taken based on users' needs or goals. Some pathways are taken more than others. Humans can intuitively understand why certain links are chosen, but modeling the same decision making for a computer is more complicated. Computers lack the capability to weigh options the same way humans do. Statistical models, and more specifically Markov chains [2], have been used to model pathways more often taken by users of web applications. These models capture human decision making in an objective way based on gathered usage data. When some links are pursued more than others, they can be given more weight in the model. Figure I shows an example of a messaging tool which is adapted from the previous study by Kallepalli and Tian [2]. In this example,

cycles represent functions/sub-functions and arrows indicate pathways. The size of each cycle shows the weight of the arrow that points to it. According to Fig. I, users are more likely to select “Compose Message” than “Outbox” from the Messaging home screen, and thus the former is weighted more.

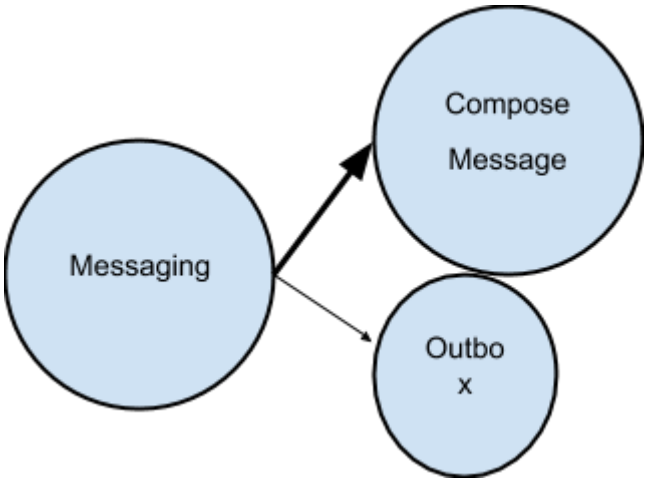

Fig. I

MODEL OF A SIMPLE DECISION PATHWAY

This methodology was adapted in this study to the process of discovering vulnerabilities in web applications. Understanding how humans interact and understand a given web application offers insight into finding where vulnerabilities may be expressed. Emphasis in this project was placed on the process of documenting and displaying the human rationale that factored into successful and failing injections of cross-site scripting (XSS) attacks.

XSS is a vulnerability found in 4.44% [3] of web applications that allow users to manipulate the content that is displayed for other users. Recently, many renowned websites, such as Twitter and Google+ have fallen victim to these attacks [4]. According to National Vulnerability Database [4], XSS is the most frequently reported vulnerability in 2018. Injection of such a malevolent code can lead to session take-over by another user, altering of information by the attacker, and data theft, among other inconveniences. Imperfections in software development that allows this type of attack is prevalent resulting in XSS attacks to be possible whenever a web application allows users to send or submit information without validation or very specific requirements for responses.

Five XSS attacks were chosen to be tested from Open Web Application Security Project’s (OWASP) cheat sheet of XSS attacks [5]. Use of this cheat sheet made it easier to attempt multiple attacks before giving up on an injection site, see Table I. If one of the scripts was successful, the remaining scripts on the cheat sheet were not attempted, as the vulnerability was already revealed.

NUM	SCRIPT
1.	<SCRIPT>alert(“XSS”)</SCRIPT>
2.	</TITLE><SCRIPT>alert(“XSS”)</SCRIPT>
3.	<IMG SRC=/
4.	onerror=”javascript:alert(‘XSS’);”> <isindex x="javascript:"
5.	onmouseover="alert(XSS)"> <img src=x onerror="&#0000106&#0000097&#0000118 &#0000097&#0000115&#0000099&#000011 4&#0000105&#0000112&#0000116&#00000 58&#0000097&#0000108&#0000101&#0000 114&#0000116&#0000040&#0000039&#000 0088&#0000083&#0000083&#0000039&#00 00041">

TABLE I

XSS SCRIPTING ATTACKS

III. GOALS AND OBJECTIVES

This study is an early stage of the project focused on identifying and defining heuristics that can be used to find these vulnerabilities on this model website. Ideally, the tool created will be able to generalize to real-world websites.

IV. RESEARCH STUDY DETAILS

To generate rationales for discovering XSS vulnerabilities, this study used iTrust’s website. iTrust is a health information manage web application that allows users to log in to various model users of the website, see Fig. II. Users can sign in as patients, healthcare providers, and administrators to access every side of the system. We deploy the iTrust on the Ohio Cyber Range at the University of Cincinnati (OCR@UC), a sandbox system that isolates the untested system from the live systems. This is especially useful for research into cross-site scripting as it allows for the success of attacks to be verified without harming others.

The iTrust system was used in this study to generate human pathways for exploring potential vulnerabilities in the software. Attempts to inject XSS attacks were cataloged and supported with rationale by the researchers. The individual rationales of the researchers were combined to establish heuristics for finding XSS vulnerabilities in the application. The goal of this study is to use these heuristics based on human decision making to inform the creation of an algorithm for finding XSS vulnerabilities in web applications.

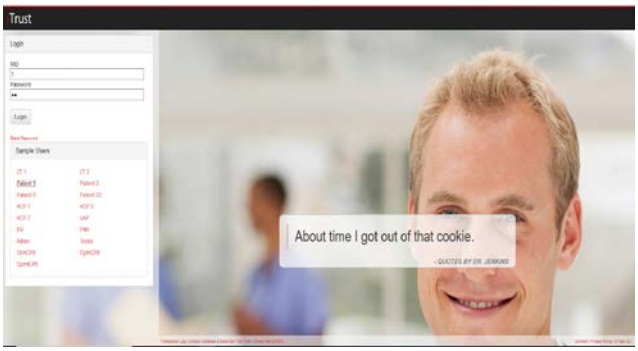

Fig. II

ITRUST WEB APPLICATION EMPLOYED BY RESEARCHERS

Each phase of the research was carried out with specific objectives in mind. The objective for Phase One was for the researchers to become familiar with all of the functions of the iTrust website and to inject XSS attacks in any vulnerable areas found. The focus at this stage of the research was not on documentation, but rather on building an understanding of the website. Phase One was unique in that researchers explored separately for a total of 16.5 hours per person and at no time discussed their successes or failures.

Each researcher was able to identify a vulnerability in the 'Request an Appointment' function patients have access to. XSS attacks could be injected into the comment section since it lacks a character restriction. For this attack to display, users had to login as the healthcare provider to whom the request was sent. Rather than an innocuous comment about the appointment, the healthcare provider is displayed an XSS attack that depends on the script used.

Phase Two, similarly to Phase One, was done independently as researchers documented their rationales and designed a generalized algorithm that could potentially assist others with discovering vulnerabilities on the iTrust website. A major insight offered by the 'Request an Appointment' vulnerability was that logging into iTrust as a different user to try to get the information to display is a good first step[1,2].

Failure served a very important role in the crafting of rationales. Notable among the failures was the messaging function of the iTrust website, see Fig. III. There were several pathways that led to a patient being able to compose a message where XSS attacks could potentially be injected. However, both the subject line and body of the 'compose message' function were restricted to alphanumeric characters, preventing the injection of malicious code. This effectively terminated further exploration down the Messaging pathway. When this failed, it was apparent that other functions of the Messaging tool were likely to fail as well. No further exploration was done in this area and progress could be made elsewhere.

XSS vector bug injection failure along the messaging pathway was additionally informative as it encouraged one of the researchers to pursue the 'Review Expert' function. Unlike the 'Message' function, users could leave a review of their assigned health care provider without any character or formatting restrictions. One of the vulnerabilities discovered on the 'Add' review page was the 'Describe Your Experience' text box. When injected here, other patients attempting to view that specific health care provider's patient reviews will suffer the attack.

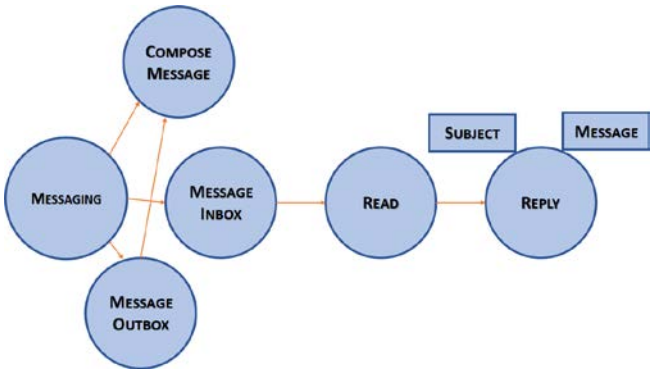

Fig. III

MODEL OF THE FULL MESSAGING PATHWAY

In the third phase of the study, independent work was synthesized. Researchers shared their rationales, discovered vulnerabilities, and generalized algorithm for XSS vulnerability detection on iTrust. Similarities and differences in thought processes were discussed in an effort to generate standard operational insights. These insights helped form a collaborative design for an algorithm that could detect each of the eight unique vulnerabilities discovered.

[1] https://drive.google.com/drive/u/0/folders/1Q_KDfQPOGzWqO7CdRYdQPtu3_xiTEkn9

[2] https://drive.google.com/drive/u/0/folders/1Q_KDfQPOGzWqO7CdRYdQPtu3_xiTEkn9

V. RESEARCH RESULTS

Researchers were able to successfully inject XSS vector bugs along eight vulnerable areas of the iTrust web application[3]. Most of the vulnerabilities were discovered from the Patient's side of the website. Malicious script could be injected when 'Requesting an Appointment' in the comment text box and the HCP would suffer the attack when viewing 'Appointment Requests'. The 'Expert's Review' function had two vulnerabilities - at the subject line and body- and any user attempting to view that specific HCP Reviews would suffer the attack. Researchers were successful in injecting the XSS attack as a part of the patient's email located under the editing demographics' function, thus causing the HCP to suffer the attack when attempting to retrieve the 'Group Report'.

The remaining vulnerabilities were discovered on the HCP and Administrator user accounts. XSS attacks could be injected when uploading a patient file, however the attack is instantaneous and other users are not on the receiving end. As an Administrator the malicious script could be injected when making changes to 'HCP Specialty' and shows under 'Expert Reviews' search, while injecting the attack when altering the 'Manage Ward' function shows its effect immediately, see Table II.

[3] https://docs.google.com/document/d/1EdtzuNSRnqt5rRENh7LYc7MgLe1po7gYNyb46CTkhaM/edit

USER	INJECTION SITE	DISPLAY PAGE
Patient	Request an Appointment	View Appointment Request from HCP
Patient	Expert Review - Subject	HCP Reviews
Patient	Expert Review - Body	HCP Reviews
Patient	Email	Group Report from HCP
Patient	Records Release	Displays Immediately
HCP	Upload Patient File	Displays Immediately
Admin	HCP Specialty	Experts Reviews from Patient
Admin	Manage Ward - Add	Displays Immediately

TABLE II: DISCOVERED VULNERABILITIES

Discovery made up a significant portion of the study. Lack of experience with the software led to beneficial insights, but also slowed down the pace of progress during Phase One. On average, it took two hours to find a new vulnerability. To combat this in future research, broad, human language algorithms were created. These were guidelines for finding vulnerabilities in terms humans would understand. Each researcher generated his or her own algorithm before combining them into a singular process.

First, users should build a catalog of vulnerable website functions. The user should focus on becoming familiar with the website as they search for those that allow text entry. Where applicable, XSS strings should be inserted, being careful to note where they think the code will display. Text boxes that are limited by alphanumeric characters are eliminated from further consideration to save time. The next step is finding pages that could potentially display data entered by the user. Using iTrust permits users to log into multiple sides of the system, meaning there are several different ways to view data. Each should be explored by the patient, healthcare provider, and administrator perspective.

VI. CONCLUSION

Security of web applications is a constantly evolving issue. With hundreds of millions of websites around the world, patching every distinct vulnerability is unlikely. Computer algorithms struggle to both accurately and quickly discover vulnerabilities in web applications. This study contributes heuristics useful for finding vulnerabilities in an effective and efficient way.

The work in this study was done on a singular and fairly mature website, so generalizability is lacking. The web application's maturity also means that it has been tested numerous times by engineers whose previously discovered vulnerabilities have been addressed. Thus, vulnerabilities become more difficult to discover.

Security of web applications is a constantly evolving issue. With hundreds of millions of websites around the world, patching every distinct vulnerability is unlikely. Computer algorithms struggle to both accurately and quickly discover vulnerabilities in web applications. This study contributes heuristics useful for finding vulnerabilities.

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The time dedicated to vulnerability discovery and the number of researchers taking on the role of 'white hacker', although impactful, is not confirmation that the list of discovered vulnerabilities is exhaustive. Furthermore, if there are, in fact, other vulnerabilities on the iTrust web application, their inclusion in this research might better inform the coding process for the automated tool that will be generalized and used to detect vulnerabilities on other web applications.

More importantly, the approaches used extrapolate to many other websites, as these heuristics effectively model the discovery of cross-site scripting vulnerabilities.

VII. Recommendations

Future work includes using human intuition harvested from this study to inform other work focused on vulnerability detection. Perhaps our work can facilitate vulnerability detection more swiftly with room to build upon it. There is a necessity to code the algorithm so that vulnerabilities are discovered much more quickly and entirely on the iTrust web application and ultimately generalized to detect vulnerabilities on other websites.

VIII Acknowledgment

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Research Experience for Teachers Program

University of Cincinnati

IX. BIBLIOGRAPHY

[1] Godefroid, P., Klarlund, N., and Sen, K. (2005). DART: Directed automated random testing. ACM SIGPLAN Notices, 40(6), 213-223.

[2] Kallepalli, C., and Tian, J. (2001). Measuring and modeling usage and reliability for statistical web testing. IEEE Transactions on Software Engineering, 27(11), 1023-1036.

[3] SiteLock, “SiteLock 2019 Web Security Report”, https://www.sitelock.com/cybersecurity-trends-2019

[4] National Vulnerability Database, “Common weakness enumeration (CWE) over time”, https://nvd.nist.gov/general/visualizations/vulnerability-visualizations/cwe-over-time

[5] OWASP, “Top ten most critical web application security risks”, https://www.owasp.org/index.php/Category:OWASP Top Ten Project

X. AUTHOR INFORMATION

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XI. Appendix I: Nomenclature Used

Web application: A web application is a computer program that utilizes web browsers and web technology to perform tasks over the Internet. It is a unique hostname (a name which can be resolved, using a name server, into an IP address).

Function: actions/ services that a user has access to.

Unit: A unit is the smallest testable part of any software. It usually has one or a few inputs and usually a single output.

Pathway: Pathway Pages are considered the navigation, how to get to the page that I want; the destination page.

XSS: Also known as Cross-site Scripting, is a type of computer security vulnerability typically found in web applications.

Node: The point at which pathways intersect or branch.

Confidentiality: The relative safety of information from being accessed by unintended users.

Integrity: The accuracy of the information provided on a web application.

Availability: The ability for the right person to access the information on a web application.

XII. Appendix II: Research Schedule

Monday - June 17th 1:00pm - 5:00pm	Tuesday - June 18th 9:00am - 10:00am 2:45pm - 5:00pm	Wednesday - June 19th 3:00pm - 5:00pm	Thursday - June 20th 9:00am - 12:00pm 2:45pm - 5:00pm	Friday - June 21st 2:00pm - 5:00pm
Monday - June 24th 1:00pm - 5:00pm	Tuesday - June 25th 9:00am - 12:00pm 1:00pm - 5:00 pm	Wednesday - June 26th 3:45pm - 5:00pm	Thursday - June 27th 1:15pm - 5:00pm	Friday - June 28th 1:00pm - 5:00pm
Monday - July 1st 10:10am - 12:00pm 1:00pm - 5:00pm	Tuesday - July 2nd 9:00am-12:00pm 2:45pm - 5:00pm	Wednesday - July 3rd 1:00pm - 5:00pm	Thursday - July 4th Holiday Break (Research team did not meet on this day)	Friday - July 5th Holiday Break (Research team did not meet on this day)
Monday - July 8th 1:00pm - 5:00pm	Tuesday - July 9th 1:00pm - 5:00pm	Wednesday - July 10th 3:15pm - 5:00pm	Thursday - July 11th 1:00 - 5:00pm	Friday - July 12th 1:00 - 5:00pm

*Final two weeks of the RET Program were dedicated to completing the following during research lab hours (Writing Research Paper and Research Summary Report, creating and improving Team PowerPoint, and Recording Team Research Video)

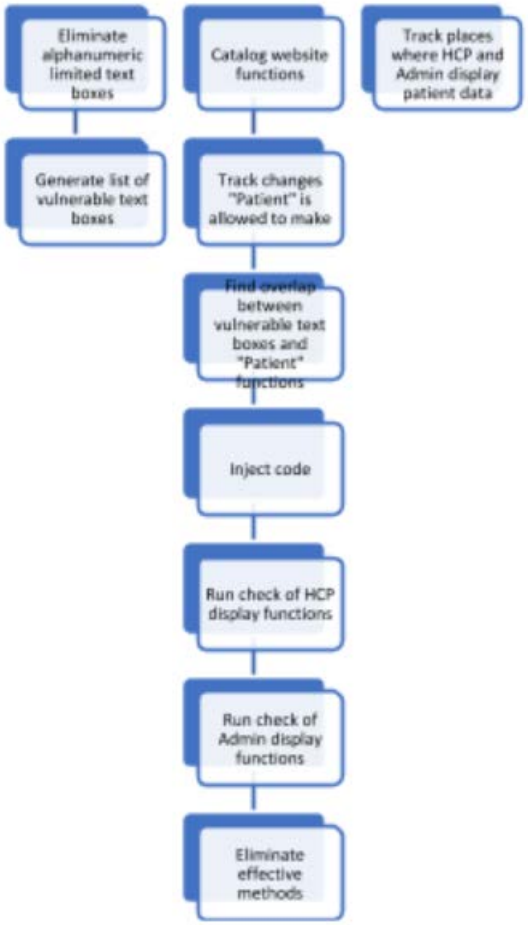
XIII. Appendix III: Individual Researchers' Algorithms and Rationales

Researcher 1:

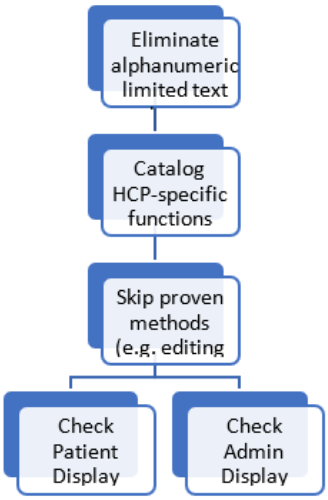
1. *Catalog website functions*
    a. Eliminate alphanumeric limited text boxes

    b. Which pages have entry boxes?
    c. Which pages display data?
2. *Progress through patient – HCP – Admin functions*

Patient



HCP



Researcher 2:

Step 1: Look for input boxes from the patient log in. I soon learned that these input boxes cannot be drop down boxes (inputs are pre-written and cannot be altered).

Step 2: So now I need to look for input boxes that allow type ins. I need to be able to control the characters in my response as the XSS attack vectors have specifically ordered special characters.

Step 3: Type XSS vector bug in the comment box.

Step 4: Check to see if bug was effective from the HCP log in.

Step 5: If bug's effectiveness is visible from HCP perspective, go to Step 6. If bug is NOT visibly effective from HCP perspective, try accessing node from another patient's login.

Step 6: If XSS vector bug was successful in the comment box, inject it in the title/ subject line (usually located above the comment box.

Step 7: Repeat Step 4

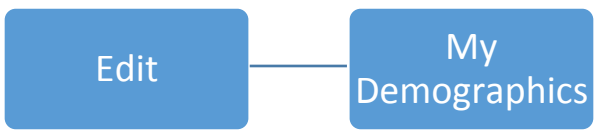
Step 8: Repeat Step 5.

Step 9: If a vector injection is successful, try to inject vector into mirroring nodes from other user accounts (ex. HCP).

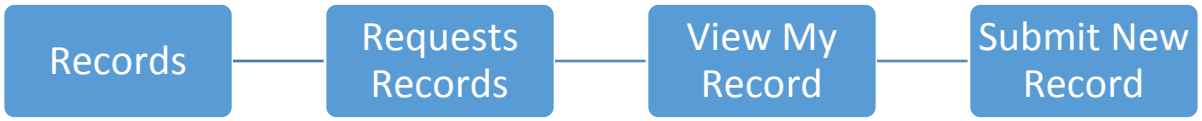
Step 10: Repeat entire process on another mode that meets criteria.

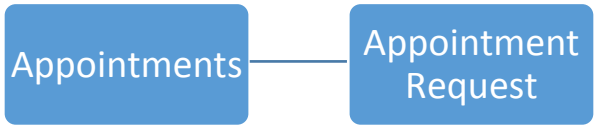
*Finally, search for possible nodes from HCP log in that do not have a mirrored function on patient's log in (ex.

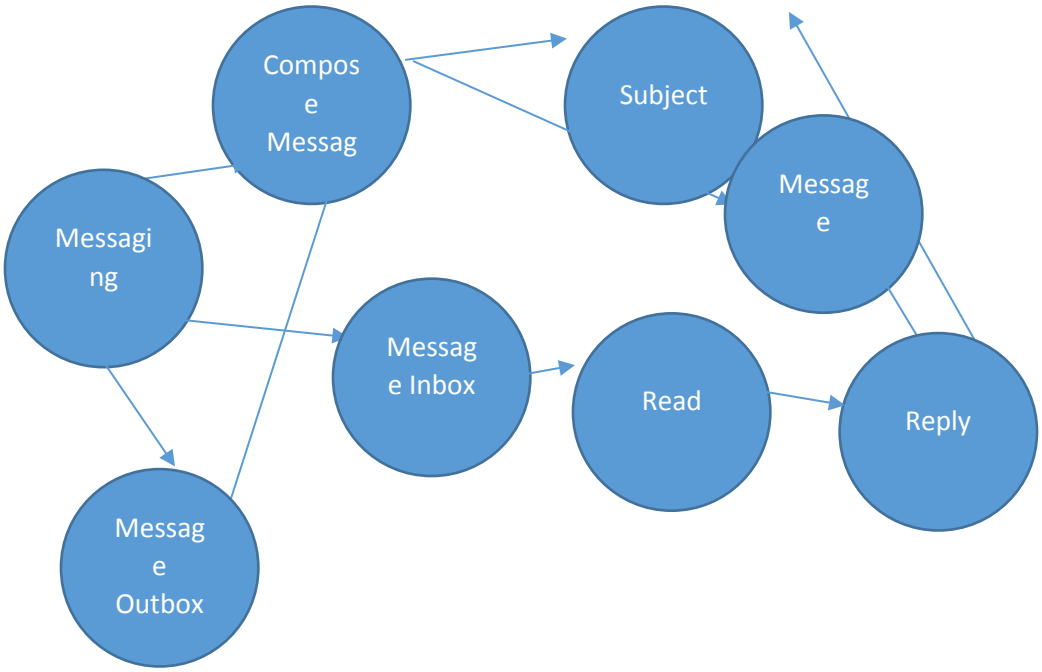
Below is a mapping of my algorithm applications.

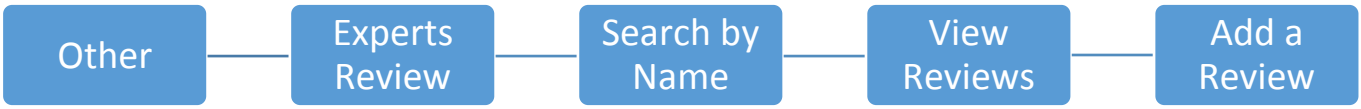


Having tried injecting the vector along these two initial paths, I thought, "When Wentao was able to successfully inject the vector bug from the 'Appointment Request' node it worked. What's different about that node verses the ones that I've chosen to begin testing first? One of the differences that came to mind almost immediately was that the 'Appointment Request' node allows for information to be sent/shared away from the patient's side of ITRUST. I then began looking for such nodes in ITRUST. I tried the following paths;









Having exhausted all of my ideas from the patient's perspective and contemplating where I had to check from the HCP's log in, I wondered if just as I was able to successfully inject along those pathways, perhaps I could also inject the same node, but from the HCP and admin's log ins.

The 'Review' node was not mirrored from as a HCP (I learned this earlier).

I tried injecting from the 'Appointment' node since I had success there earlier from the patient's log in. Unfortunately, this did not work.

I ultimately decided to click on the 'Add' node, then the 'Upload Patient File' thinking that injecting at this specific node would be vulnerable. I tried to save the document with the vector bug as the name, but that did not meet Microsoft Word's criteria for a document's name. In speaking with Wentao and learning about his and Dr. Niu's discoveries, I learned that they too saw this as a possible vulnerable node, but were successful because the typed the XSS vector bug in the actual document as text and then saved it with a different name.

XIV. Appendix IV: Consolidated List of Vulnerabilities

1. Patient -> Request an appointment
    a. Shows under “appointment requests” from HCP
2. Patient -> Expert’s Review - Subject Line
    a. Displays with HCP Reviews
3. Patient -> Expert’s Review - Body
    a. Displays with HCP Reviews
4. Patient email
    a. Shows under “group report” from HCP
5. Admin changes HCP Specialty
    a. Shows under “Expert Reviews” search
6. Admin -> Manage Ward
    a. Shows immediately
7. HCP -> Upload patient file
8. Patient -> Records Release Request
    a. Shows immediately

XV. Appendix V: Operational Insights with Standardized Algorithms to be Coded

Operational Insights

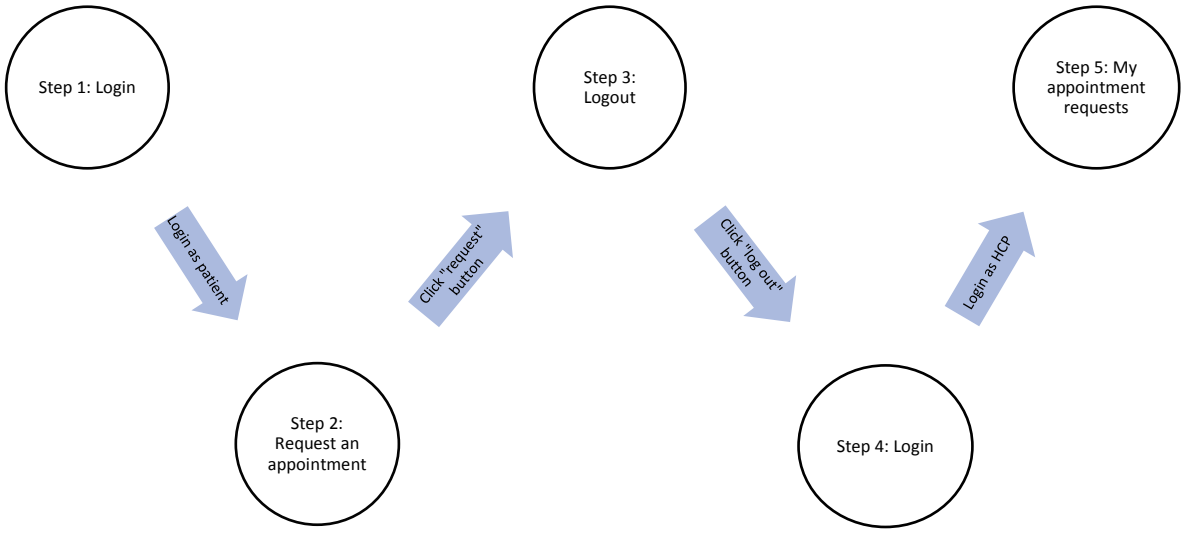
1. Vulnerability could be revealed by injecting attack at one function and checking the related functions.
2. Vulnerability could be revealed by checking communication channels between different users/roles.

Vulnerability 1:

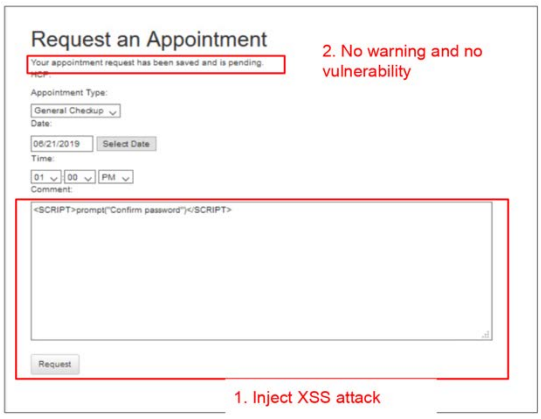
Description:

Patient can inject cross-site scripting attack into comment when she requests a new appointment. Health care personnel who receives this appoint request will suffer the attack.

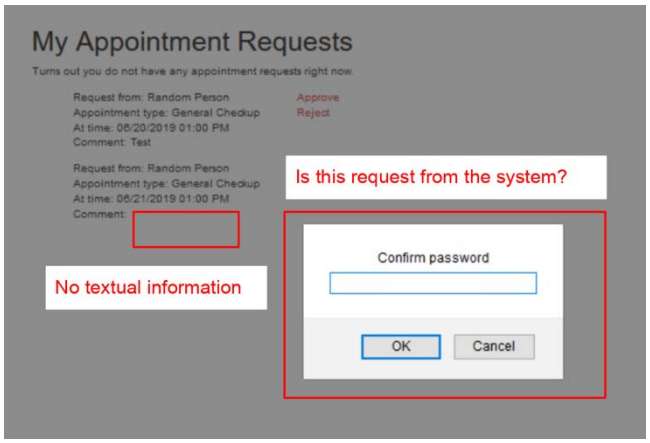
Test path(s):



Step 1: Login as a patient and go to request an appointment page;
Step 2: Inject XSS attack (<SCRIPT>prompt("confirm password")</SCRIPT>) in "Comment" and submit the request by clicking "Request" button;



Step 3: Logout patient;
Step 4: Login as a health care personnel;
Step 5: Go to my appointment requests. A pop-up window will reveal the vulnerability.

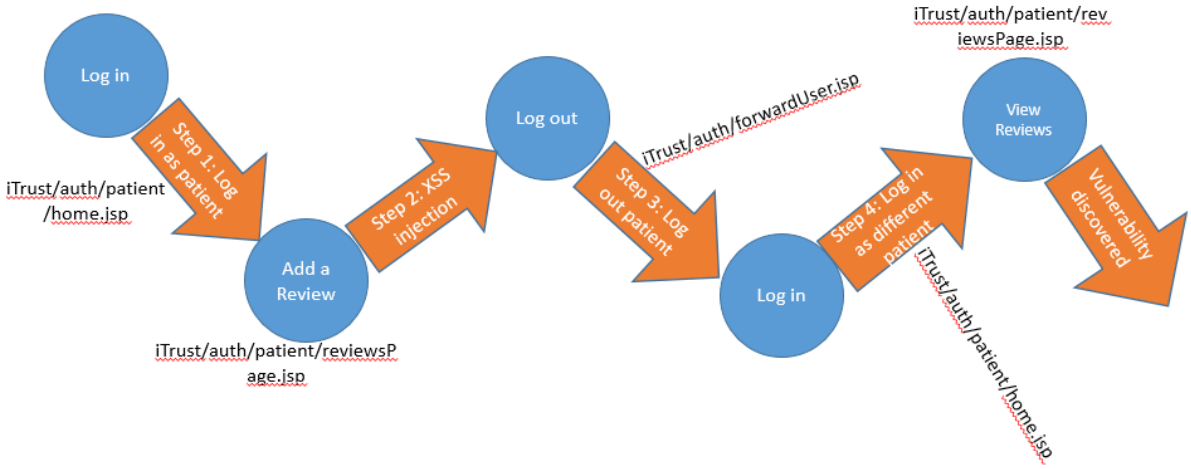


Vulnerability 2:

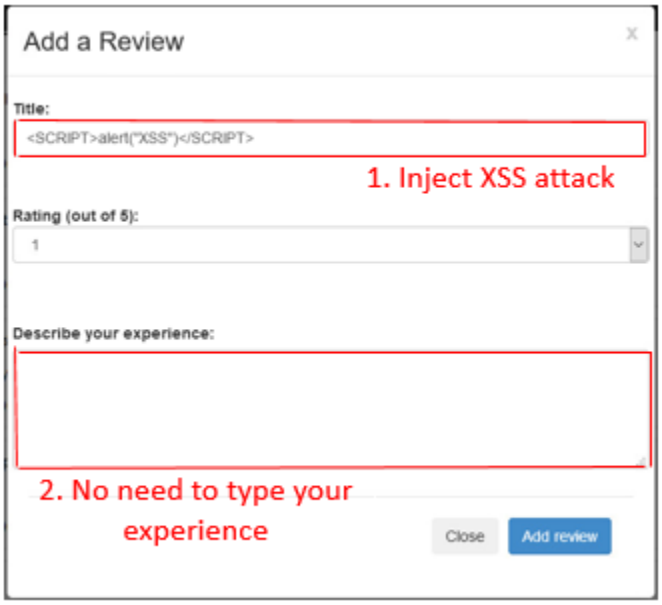
Description:

Patient can inject cross-site scripting attack into subject line when leaving an expert's review.
Other patients attempting to view that specific health care provider's patient reviews will suffer the attack.

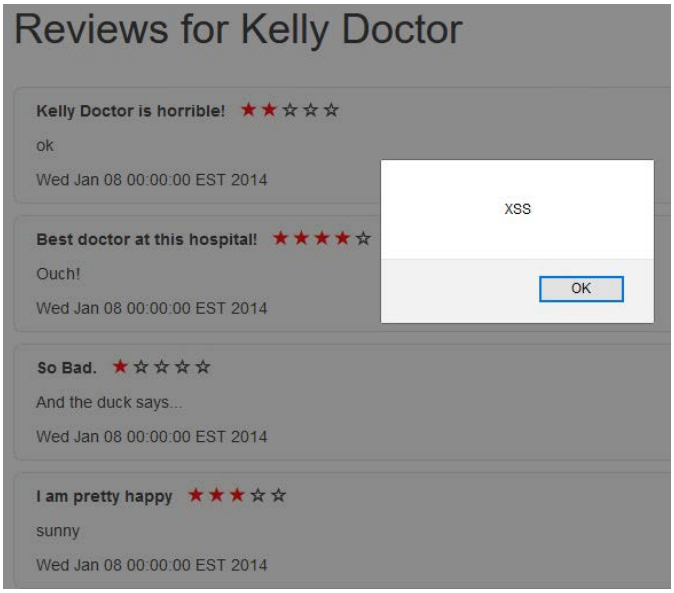
Test path(s):



Step 1: Login as a patient and go to add a review page;
Step 2: Inject XSS attack (<SCRIPT>alert("XSS")</SCRIPT>) in "Title" and submit the review by clicking "Add review" button;



Step 3: Logout patient;
Step 4: Login as another/different patient;
Step 5: Go to view the reviews of that specific expert. A pop-up window will reveal the vulnerability.

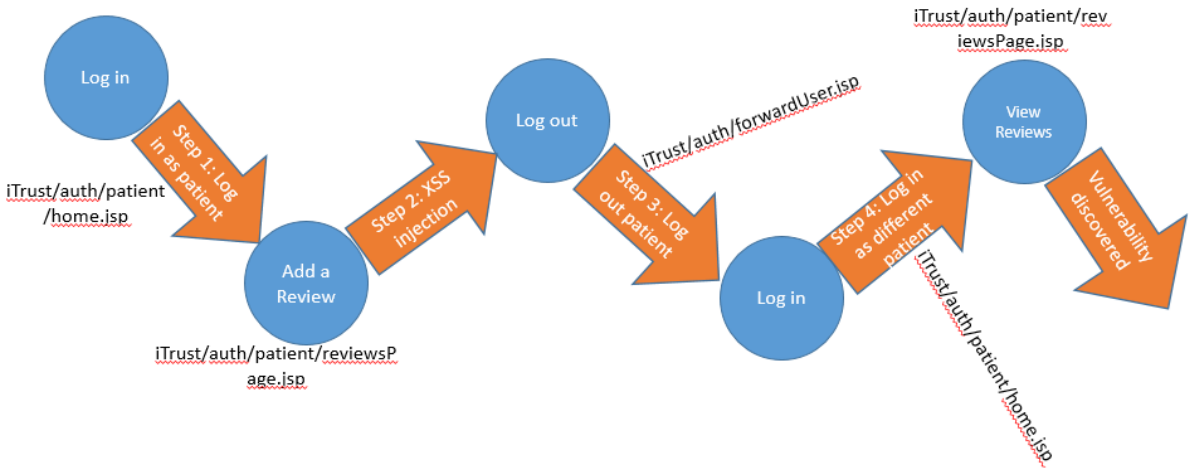


Vulnerability 3:

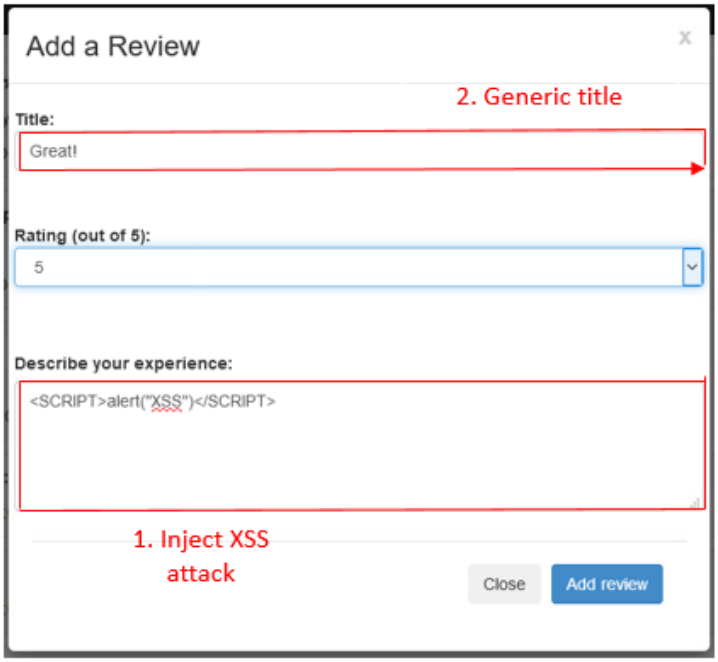
Description:

Patient can inject cross-site scripting attack into the 'Describe your experience' text box when leaving an expert's review.
Other patients attempting to view that specific health care provider's patient reviews will suffer the attack.

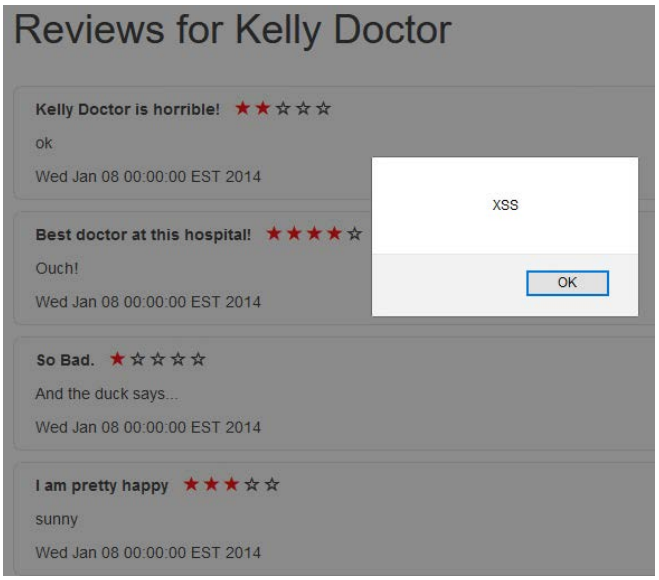
Test path(s):



Step 1: Login as a patient and go to add a review page;
Step 2: Inject XSS attack (<SCRIPT>alert("XSS")</SCRIPT>) in 'Describe your experience' text box and submit the review by clicking "Add review" button;



Step 3: Logout patient;
Step 4: Login as another/different patient;
Step 5: Go to view the reviews of that specific expert. A pop-up window will reveal the vulnerability.

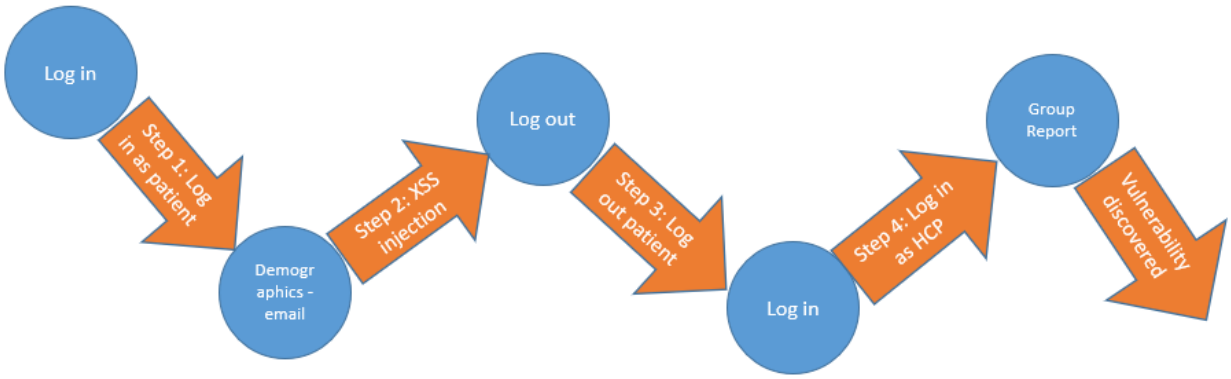


Vulnerability 4:

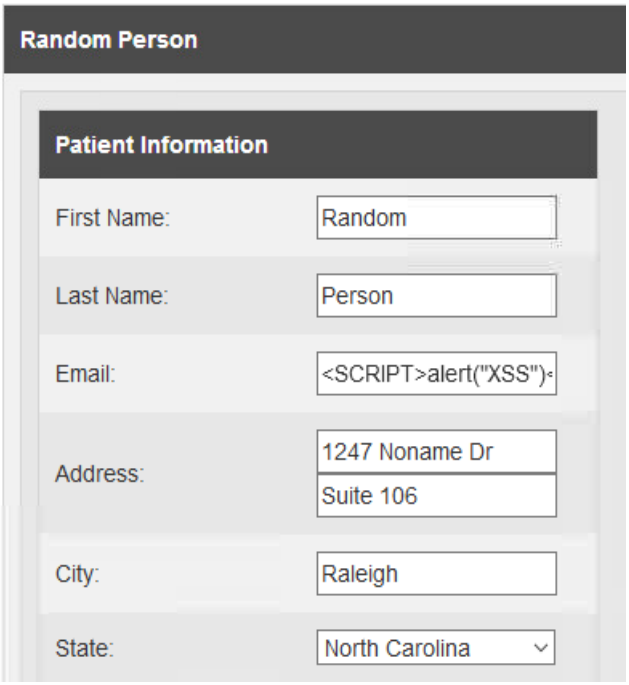
Description:

Patient email can be edited to include cross-site scripting attack.
The attack displays when HCP look up “group report” for patient information

Test path(s):

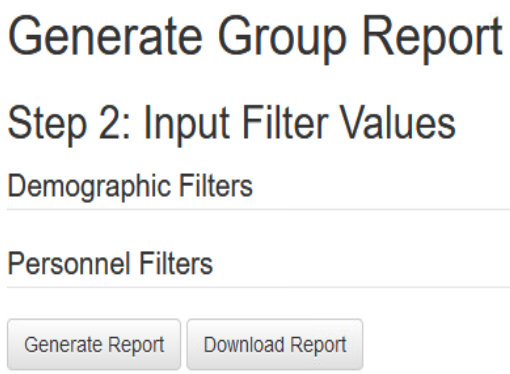


Step 1: Login as a patient and select “Edit Demographics”
/iTrust/auth/patient/home.jsp --->
/iTrust/auth/patient/editMyDemographics.jsp
Step 2: Inject cross site scripting attack into “email” text box
(<SCRIPT>alert(“XSS”)</SCRIPT>@gmail.com)

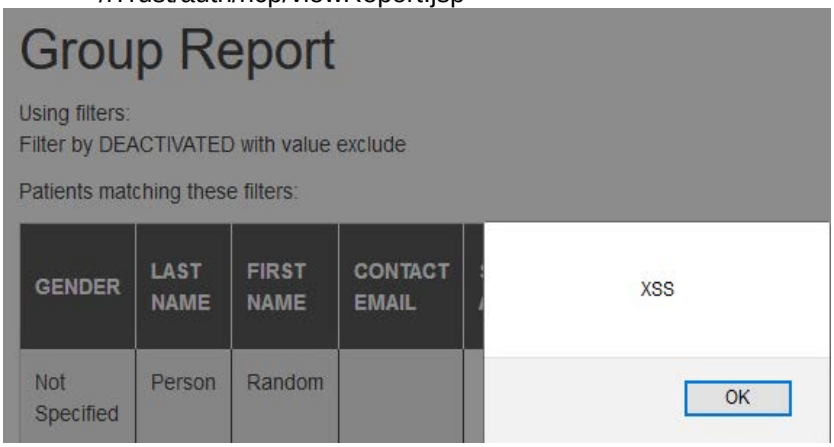


Step 3: Log out of patient and into HCP
/iTrust/auth/forwardUser.jsp -->
/iTrust/auth/hcp/home.jsp

Step 4: Select Group Report. Do not apply any filters
/iTrust/auth/hcp/groupReport.jsp



Step 5: Attack displays as report loads
/iTrust/auth/hcp/viewReport.jsp



Vulnerability 5:

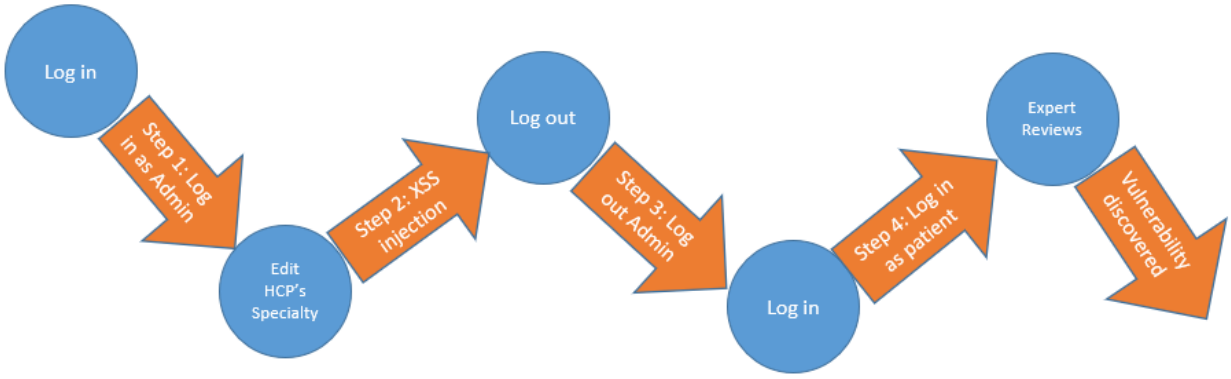
Description:

Admin can inject cross-site scripting attack into the 'specialty' box when adding a ward to a hospital. The attack displays when patients search for experts

Test path(s):

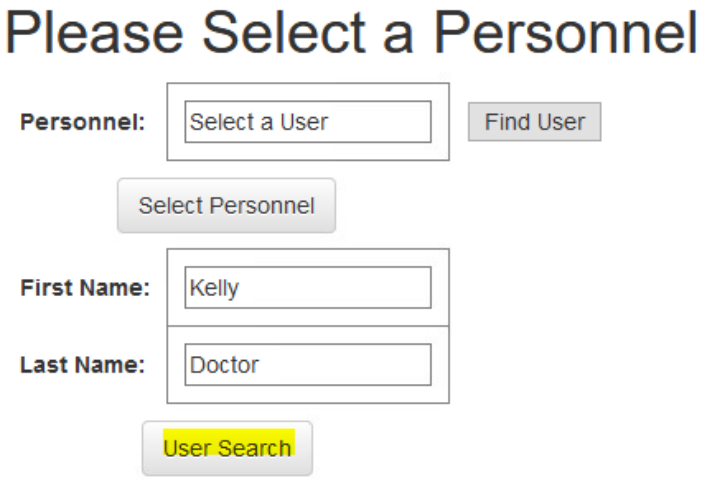
Step 1: Login as Admin and select "Edit Personnel"

/iTrust/auth/admin/home.jsp ---> /iTrust/auth/getPersonnelID.jsp?forward=staff/editPersonnel.jsp



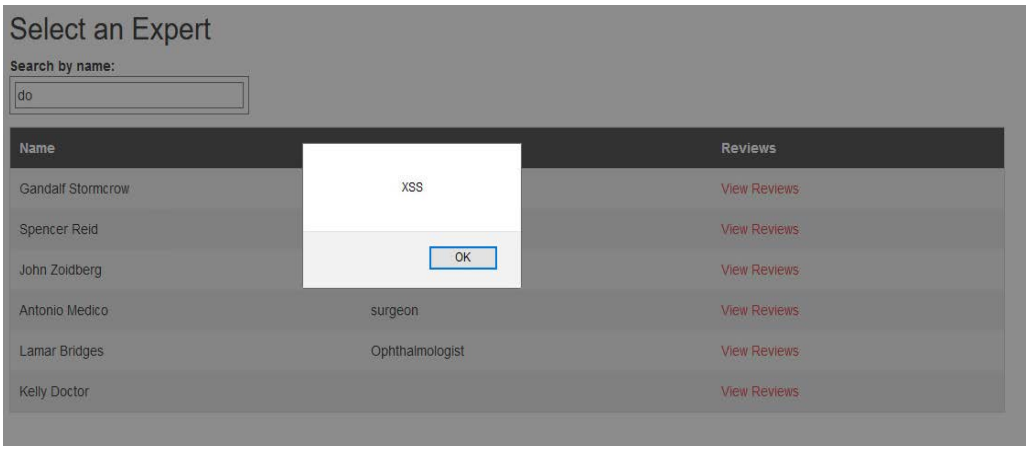
Step 2: Search for and select a HCP

→ /iTrust/auth/staff/editPersonnel.jsp



Step 3: Edit HCP's "specialty" to include cross-site scripting attack (<SCRIPT>alert("alert")</SCRIPT>) and submit by clicking "Edit Personnel Record."

Step 4: Log out of Admin,
Step 5: Log in as a patient and select “Expert’s Reviews”
/iTrust/auth/patient/home.jsp →
/iTrust/auth/patient/expertNameSearch.jsp
Step 6: Begin searching for HCP with corrupted specialty



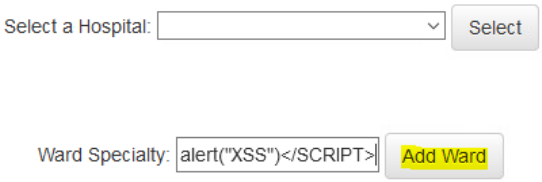
Vulnerability 6:

Description:

Admin can inject cross-site scripting attack into the ‘name’ box when adding a ward to a hospital. The attack displays immediately and for anyone who logs in to view wards

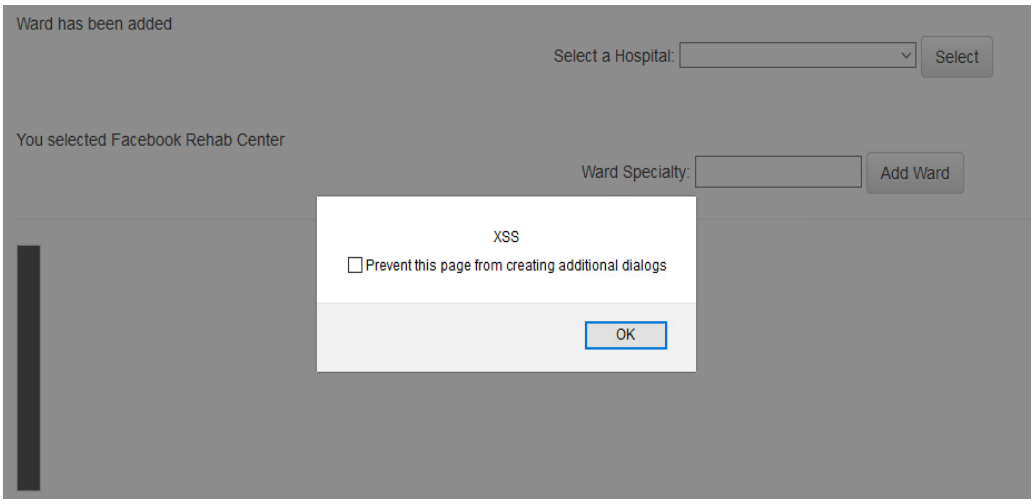
Test path(s):

Step 1: Login as Admin and select “Manage Wards”
/iTrust/auth/admin/home.jsp ---> /iTrust/auth/admin/manageWards.jsp
Step 2: Select a hospital (Facebook Rehab Center)
Step 3: Inject XSS attack (<SCRIPT>alert(“alert”)</SCRIPT>) in “Ward Specialty” and submit the request by clicking “Add Ward” button.

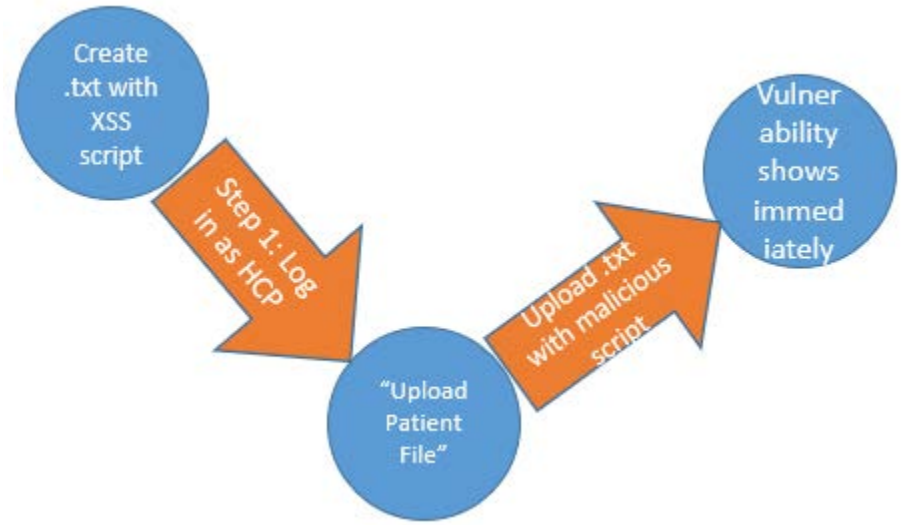


Step 4: The attack displays immediately

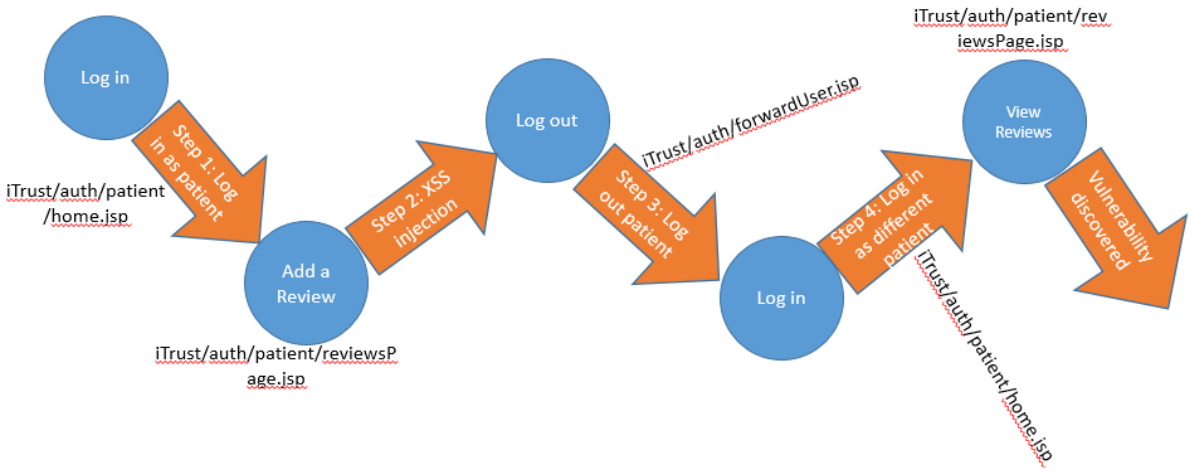
And one more time when submitting for the first time.



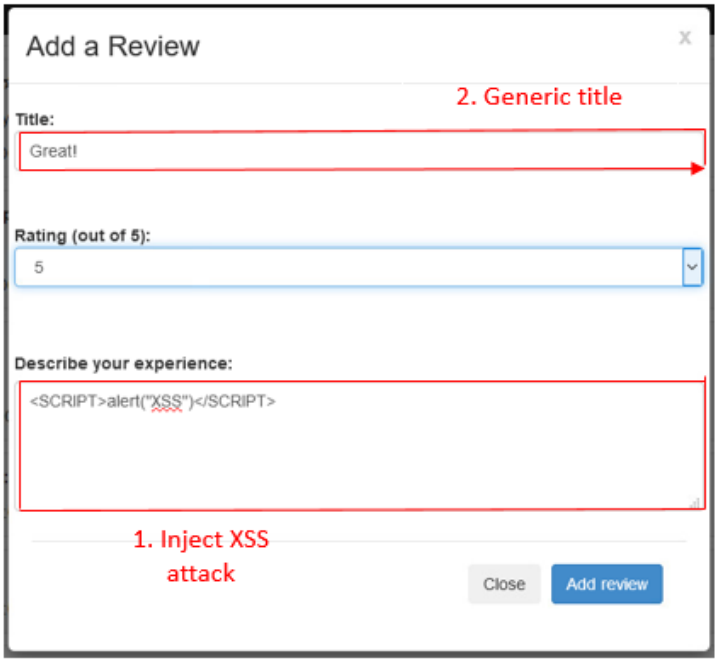
Vulnerability 7:
Description:
HCP can upload a text file with a malicious script in the “upload patient file” function. The HCP will see the attack immediately.
Test Path(s):
Step 1: Create a .txt file with XSS attack (<SCRIPT>alert(“XSS”)</SCRIPT>)
Step 2: Login as HCP and navigate to “upload patient file”
Step 3: Upload file with XSS attack
Step 4: Vulnerability displays immediately.



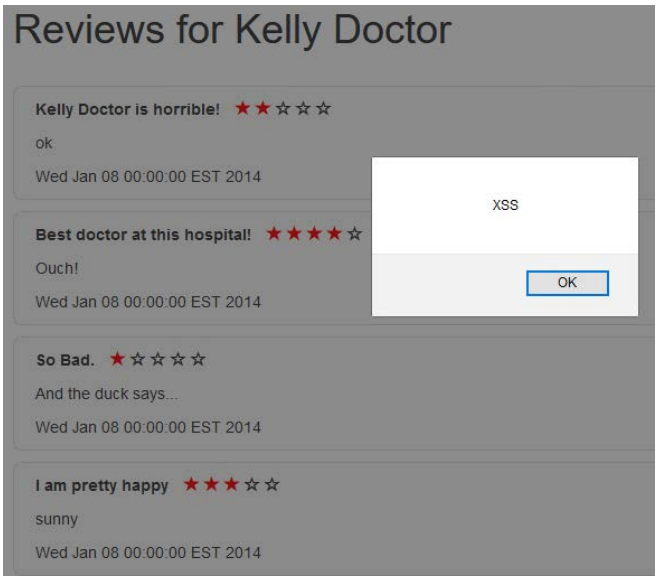
Vulnerability 8:
Description:
Patient can inject cross-site scripting attack into the ‘Describe your experience’ text box when leaving an expert’s review.
Other patients attempting to view that specific health care provider’s patient reviews will suffer the attack.
Test path(s):



Step 1: Login as a patient and go to add a review page;
Step 2: Inject XSS attack (<SCRIPT>alert("XSS")</SCRIPT>) in 'Describe your experience' text box and submit the review by clicking "Add review" button;



Step 3: Logout patient;
Step 4: Login as another/different patient;
Step 5: Go to view the reviews of that specific expert. A pop-up window will reveal the vulnerability.


Reviews for Kelly Doctor
Kelly Doctor is horrible! ★★☆☆☆
ok
Wed Jan 08 00:00:00 EST 2014
Best doctor at this hospital! ★★★★☆
Ouch!
Wed Jan 08 00:00:00 EST 2014
So Bad. ★☆☆☆☆
And the duck says...
Wed Jan 08 00:00:00 EST 2014
I am pretty happy ★★★☆☆
sunny
Wed Jan 08 00:00:00 EST 2014
XSS
OK

XVI. APPENDIX VI: UNIT PLANS AND ACTIVITIES

Name: Eli Rolfes	**Contact Info:** eli.rolfes@covington.kyschools.us	**Date:** 7/26/2019

Unit Number and Title: Unit 6 – Comparing Functions

Grade Level:	11
Subject Area:	Algebra II

Total Estimated Duration of Entire Unit:	11 Days

Part 1: Designing the Unit

1. **Unit Academic Standards (**Identify which standards: NGSS, OLS and/or CCSS. Cut and paste from NGSS, OLS and/or CCSS and be sure to include letter and/or number identifiers.**):**

KY.HS.F.1 Understand properties and key features of functions and the different ways functions can be represented.

KY.HS.F.4 Graph functions expressed symbolically and show key features of the graph, with and without using technology (computer, graphing calculator).

KY.HS.F.6 Write a function that describes a relationship between two quantities.

KY.HS.F.11 Distinguish between situations that can be modeled with linear functions and with exponential functions.

KY.HS.F.12 Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table)

KY.HS.F.13 Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.

2. **Unit Summary**

The Big Idea (including global relevance): There has been a zombie outbreak on the eastern half of the United States. Student teams are responsible for developing a plan to cure the epidemic using their knowledge of functions. Information on how the CDC and WHO handle crises will factor into student decision making.

- Students will use functions to determine potential solutions for an epidemic.

The (anticipated) Essential Questions: List 3 or more questions your students are likely to generate on their own. (Highlight in yellow the one selected to define the Challenge):

- How can functions be used to make informed decisions?
- How does technology help us handle complex problems?
- How should we respond to epidemics?

3. Unit Context

Justification for Selection of Content– Check all that apply:

- ☐ Students previously scored poorly on standardized tests, end-of term test or any other test given in the school or district on this content.
- ☐ Misconceptions regarding this content are prevalent.
- ☐ Content is suited well for teaching via CBL and EDP pedagogies.
- ☐ The selected content follows the pacing guide for when this content is scheduled to be taught during the school year. (Unit 1 covers atomic structure because it is taught in October when I should be conducting my first unit.)
- ☐ Other reason(s)

_____

_____

The Hook: (Describe in a few sentences how you will use a "hook" to introduce the Big Idea in a compelling way that draws students into the topic.)

The Hook will be watching a clip from "I am Legend" leading into a discussion of how students would respond to an apocalypse. The connection to the CBL unit will be a discussion of vaccinations and various medical outbreaks.

https://www.youtube.com/watch?v=sFNPNT_4Qww

The Challenge and Constraints:

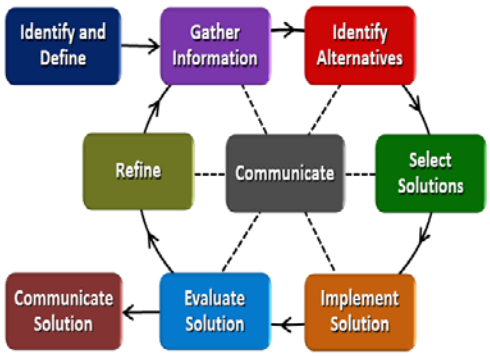
☐ Product **or** ☐ Process (Check one)

Description of Challenge (Either Product or Process is clearly explained below):	List the Constraints Applied
Students will use their knowledge of functions to determine the best path to cure all cities. **Students will present this information as if it were a presentation to the CDC.**	**1. No city can drop below 5,000 humans** **2. 7-day time limit.** **3. There is a limited number of days to work on the project**

Teacher's Anticipated Guiding Questions (that apply to the Challenge and may change with student input.):

- **How have the CDC and WHO responded to outbreaks?**
- **Which strains are most dangerous? -> Discussion of functions**
  - **What kind of growth does this function have?**
  - **Which function has a higher growth rate right now?**
- **What cities are a higher priority?**
  - **Which will reach the population limit sooner?**
-

4. EDP: Use the diagram below to help you complete this section.



How will students test or implement the solution? What is the evidence that the solution worked? Describe how the iterative process from the EDP applies to your Challenge.

Students will attempt multiple paths to determine if their solutions cure each city. Obvious answers don't generate a viable a solution, so refinement is necessary.

How will students present or defend the solution? Describe if any formal training or resource guides will be provided to the students for best practices (e.g., poster, flyer, video, advertisement, etc.) used to present work.

Students will give a group presentation for their chosen solution. Prior presentations and practice time will be provided. Training for Google Sheets and Google Sites will be provided in this unit. Teams will also create a website justifying their pathway and respond to additional prompts.

What academic content is being taught through this Challenge?

Functions (Linear, Polynomial, Exponential)

- **Analyzing graphs, comparing data, function notation**

Assessment and EDP:
Using the diagram above, identify any places in the EDP where assessments should take place, as it applies to your Challenge. Describe below what kinds of assessment are most appropriate.

What EDP Processes are ideal for conducting an Assessment? (List ones that apply.)	List the type of Assessment (Rubric, Diagram, Checklist, Model, Q/A etc.) Check box to indicate whether it is formative or summative.

Gather Information	Checklist_____ ☐ formative ☐summative
Identify Alternatives	Diagram/ Model_____ ☐ formative ☐ summative
Communicate Solution	Website Rubric_____ ☐ formative ☐ summative
Communicate Solution	Presentation Rubric_____ ☐ formative ☐ summative

Check below which characteristic(s) of this Challenge will be incorporated in its implementation using EDP. (Check all that apply.)

- ☐ Has clear constraints that limit the solutions
- ☐ Will produce more than one possible solution that works
- ☐ Includes the ability to refine or optimize solutions
- ☐ Assesses science or math content
- ☐ Includes Math applications
- ☐ Involves use of graphs
- ☐ Requires analysis of data
- ☐ Includes student led communication of findings

5. ACS (Real world applications; career connections; societal impact):

Place an X on the continuum to indicate where this Challenge belongs in the context of real world applications:

Abstract or Loosely Applies to the Real World |----------x----------| **Strongly Applies to the Real World**

Provide a brief rationale for where you placed the X**:**_**While there is a connection to the treatment of epidemics, this isn't something that students use or see every day.**

What activities in this Unit apply to real world context? **Evaluation of data, spreadsheet skills, responding to emergencies, effective planning**

Place an X on the continuum to indicate where this Challenge belongs in the context of societal impact:

Shows Little or No Societal Impact |----------x-|----------| **Strongly Shows Societal Impact**

Provide a brief rationale for where you placed the X**:** _**Students will be informed of the necessity of vaccination for managing health crises, but we aren't doing any tangible work toward that goal**

What activities in this Unit apply to societal impact? **Students will do their own ACS research in Activity #2**

Careers: What careers will you introduce (and how) to the students that are related to the Challenge? (Examples: career research assignment, guest speakers, fieldtrips, Skype with a professional, etc.)

Career research assignment

Public Health Careers

- Epidemiologist
- OSHA Specialist
- Public Health Nurse
- Emergency Management Specialist
- Microbiologist

College Majors

- Public Health
- Biology
- Biostatistics
- Psychology
- Medical Sciences

6. Misconceptions:

7. Unit Lessons and Activities: (Provide a tentative timeline with a breakdown for Lessons 1 and 2. Provide the Lesson #'s and Activity #'s for when the Challenge Based Learning (CBL) and Engineering Design Process (EDP) are embedded in the unit.)

Assignment	Assignment Description	Days
Lesson 1		
Assignment #10 Comparing Functions	Analyze background data and answer Guided Questions. (Gather Information)	120 min
Presentation Prep #1	Complete independent background research, including careers and filling in missing data. (Gather Information)	110 min
Lesson 2		
Presentation Prep #2	Begin work on a solution based on the data collected about the zombie outbreak. (Identify Alternatives)	55 min
Work Day	Refine and document solution processes.	120 min
Communication of Ideas		
Google Site Tutorial	Create a website template to use for the culmination of the unit project.	55 min
Work Days	Work on Google Slides and rehearse presentation as a team.	110 min
Presentation	Deliver 15 minute presentations on the solution implementation and justification. (Communicate Solution)	120 min
Website Work Days	Address follow-up questions and finalize content for the website. (Refine)	110 min
Website Submission	Make final adjustments to website and submit a final draft. (Communicate Solution)	55 min
Evaluation & Review	Evaluate and discuss feedback; critique websites of other teams.	120 min

8. Keywords:

epidemiology, data analysis, functions, growth and decay

9. Additional Resources:

This will be updated with links to a Google Drive with the data sheet and activity forms.

10. Pre-Unit and Post-Unit Assessment Instruments:

Pre unit assessments are Unit Assessment for each type of function covered.

Post unit assessment is the presentation and Google Site rubrics attached below.

11. Poster	**12. Video (Link here.)**

If you are a math teacher, check the boxes below that apply:

Ohio's Learning Standards for Math (OLS) or Common Core State Standards -- Mathematics (CCSS)	
Standards for Mathematical Practice (Check all that apply)	
☐ Make sense of problems and persevere in solving them	☐ Use appropriate tools strategically
☐ Reason abstractly and quantitatively	☐ Attend to precision
☐ Construct viable arguments and critique the reasoning of others	☐ Look for and make use of structure
☐ Model with mathematics	☐ Look for and express regularity in repeated reasoning

Presentation Rubric

	Below Standard	Approaching Standard	At Standard	Above Standard
Explanation of Ideas and Information	Does not present information, arguments, ideas, or findings clearly, concisely, and logically; argument	Presents information, arguments, and supporting evidence in a way that is not always clear, concise,	Presents information, arguments, ideas, or findings clearly, concisely, and logically; audience	

	lacks supporting evidence; audience cannot follow the line of reasoning Selects information, develops ideas and use a style inappropriate to the purpose, task, and audience (may be too much or too little information, or the wrong approach) Does not address alternative or opposing perspectives	and logical; line of reasoning is sometimes hard to follow Attempts to select information, develop ideas and use a style appropriate to the purpose task and audience but does not fully succeed Attempts to address alternative or opposing perspectives, but not clearly or completely	can easily follow the line of reasoning Selects information, develops ideas and use a style appropriate to the purpose, task, and audience Clearly and completely addresses alternative or opposing perspectives	
Organization	Does not meet the requirements for what should be included in the presentation Does not have an introduction and/or conclusion Uses time poorly; the whole presentation, or a part of it, is too short or too long	Meets most requirements for what should be included in the presentation Has an introduction and conclusion, but they are not clear or interesting Generally times presentation well, but may spend too much or too little time on a topic, a/v aid, or idea	Meets all requirements for what should be included in the presentation Has a clear and interesting introduction and conclusion Organizes time well; no part of the presentation is too short or too long	
Eyes and Body	Does not look at audience; reads notes or slides Does not use gestures or movements Lacks poise and confidence (fidgets, slouches, appears nervous) Wears clothing inappropriate for the occasion	Makes infrequent eye contact, reads notes or slides most of the time Uses a few gestures or movements, but they do not look natural Shows some poise and confidence (only a little fidgeting or nervous movement) Makes some attempt to wear clothing appropriate for the occasion	Keeps eye contact with the audience most of the time; only glances at notes or slides Uses natural gestures and movements Looks poised and confident Wears clothing appropriate for the occasion	

Voice	Mumbles or speaks too quickly or slowly Speaks too softly to be understood Frequently uses filler words Does not adapt speech for the context and task	Speaks clearly most of the time Speaks loudly enough for the audience to hear most of the time, but may speak in a monotone Occasionally uses filler words Attempts to adapt speech for the context and task but is unsuccessful or inconsistent	Speaks clearly; not too quickly or slowly Speaks loudly enough for everyone to hear; changes tone and pace to maintain interest Rarely uses filler words Adapts speech for the context and task, demonstrating command of formal English when appropriate	

Google Site Rubric

	Below Standard	Approaching Standard	At Standard	Above Standard
Explanation of Ideas and Information	Does not present information, arguments, ideas, or findings clearly, concisely, and logically; argument lacks supporting evidence Selects information, develops ideas and use a style inappropriate to the purpose, task, and audience Fails to connect ideas to underlying mathematical reasoning	Presents information, arguments, and supporting evidence in a way that is not always clear, concise, and logical; line of reasoning is sometimes hard to follow Attempts to select information, develop ideas and use a style appropriate to the purpose task and audience but does not fully succeed Uses mathematical language to communicate ideas inconsistently	Presents information, arguments, ideas, or findings clearly, concisely, and logically; audience can easily follow the line of reasoning Selects information, develops ideas and use a style appropriate to the purpose, task, and audience Connects ideas to underlying mathematical reasoning	
Organization	Does not meet the requirements for what should be included on the site	Meets most requirements for what should be included on the site	Meets all requirements for what should be included on the site	

	Has an ineffective or unclear layout; uses inappropriate media Some linked resources (Docs, Sheets, Slides) are inaccessible	Has a mostly clear layout, but lacks consistency or engaging media All linked resources (Docs, Sheets, Slides) are accessible	Has a clear and interesting layout; uses appropriate and engaging media All linked resources (Docs, Sheets, Slides) are accessible	
Writing Mechanics	Has frequent grammatical or spelling errors Has inappropriate language	Has a few grammatical or spelling errors, but they do not detract from the content Has appropriate language	Has proper grammar and spelling throughout Has appropriate language	
Post-Presentation Analysis	Apparent that little consideration was put into follow-up responses Analysis fails to add anything new to the presentation content Does not address alternative or opposing perspectives Incomplete feedback	Follow-up questions are addressed but lack depth Analysis is largely based on the presentation content and adds little that is new Attempts to address alternative or opposing perspectives, but not clearly or completely Incomplete feedback	Considerable thought is put into follow-up responses Analysis goes beyond what was addressed in the presentation Clearly and completely addresses alternative or opposing perspectives All team members contribute feedback	

Name: Eli Rolfes	**Contact Info:** eli.rolfes@covington.kyschools.us	**Date:** 7/26/2019

Lesson Title: Comparing Functions	**Unit #: 6**	**Lesson #: 1**	**Activity #: 1**
Activity Title: Guided Question Discovery			

Estimated Lesson Duration:	**120 Minutes**
Estimated Activity Duration:	**120 Minutes**

Setting:	**Holmes High School**

Activity Objectives:

1. Students will discuss background data on the zombie outbreak
2. Students will be able to complete Guided Questions as a team to get a better understanding of the outbreak
3. Students will begin to analyze linear and exponential functions representing the zombie strains

Activity Guiding Questions:

1. Which cities should we focus on first?
2. Which strains are most dangerous (what kind of functions are they?)

Ohio's Learning Standards for Math (OLS) and/or Common Core State Standards -- Mathematics (CCSS)	
Standards for Mathematical Practice (Check all that apply)	
☐ Make sense of problems and persevere in solving them	☐ Use appropriate tools strategically
☐ Reason abstractly and quantitatively	☐ Attend to precision
☐ Construct viable arguments and critique the reasoning of others	☐ Look for and make use of structure
☐ Model with mathematics	☐ Look for and express regularity in repeated reasoning

Unit Academic Standards (NGSS, OLS and/or CCSS):

Kentucky Standards
KY.HS.N.4 Use units in context as a way to understand problems and to guide the solution of multi-step problems; **KY.HS.N.5** Define appropriate units in context for the purpose of descriptive modeling. **KY.HS.N.6** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
KY.HS.F.1 Understand properties and key features of functions and the different ways functions can be represented.
KY.HS.F.4 Graph functions expressed symbolically and show key features of the graph, with and without using technology (computer, graphing calculator).
KY.HS.F.6 Write a function that describes a relationship between two quantities.
KY.HS.F.7 Use arithmetic and geometric sequences to model situations and scenarios.
KY.HS.F.11 Distinguish between situations that can be modeled with linear functions and with exponential functions.

KY.HS.F.12 Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table)
KY.HS.F.13 Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.
KY.HS.F.14 Interpret the parameters in a linear or exponential function in terms of a context.

Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)

All resources are included in the Unit Plan.

Teacher Advance Preparation:

Baseline data for student mastery of functions should already be collected from previous unit assessments. These data should inform the rigor involved. The included spreadsheet can be adapted to include more or less information depending on student needs.

Activity Procedures:

1. Introduction of background data (spreadsheet, assignment description)
2. Student led discussion of background data
3. Teams begin to answer guided questions and analyze functions

Formative Assessments:

Completion of Guided Questions

Summative Assessments:

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners. Refer to Activity Template for details.

Students are grouped in mixed-ability teams and have guided questions to slowly increase the intensity of the math expected from them.

Reflection: Reflect upon the successes and shortcomings of the lesson.

Name: Eli Rolfes	**Contact Info:** eli.rolfes@covington.kyschools.us	**Date:** 7/26/2019

Lesson Title: Presentation Prep #1	**Unit #: 6**	**Lesson #: 1**	**Activity #: 2**
Activity Title: Career Research			

Estimated Lesson Duration:	**110 minutes**
Estimated Activity Duration:	**55 minutes**

Setting:	**Holmes High School**

Activity Objectives:

- Students will be able to identify and describe careers in public health
- Students will identify ways they can impact public health

- Students will explore and describe programs related to public health at local universities

Activity Guiding Questions:

1. What is the CDC? What do they do?
2. What kinds of careers deal with epidemics?
3. How does one get into these fields?
4. What experience is needed to work in public health?

Ohio's Learning Standards for Math (OLS) and/or Common Core State Standards -- Mathematics (CCSS)	
Standards for Mathematical Practice (Check all that apply)	
☐ Make sense of problems and persevere in solving them	☐ Use appropriate tools strategically
☐ Reason abstractly and quantitatively	☐ Attend to precision
☐ Construct viable arguments and critique the reasoning of others	☐ Look for and make use of structure
☐ Model with mathematics	☐ Look for and express regularity in repeated reasoning

Unit Academic Standards (NGSS, OLS and/or CCSS):

This assignment is not aligned to CCSS Algebra 2 standards.

Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)

All materials and handouts are included in the Unit Plan.

Teacher Advance Preparation:

Teachers should have a rough ideas of areas students should search for careers in public health. If there's interest, college majors/schools that offer degrees in public health can be explored as well.

Activity Procedures:

1. Students conduct independent and self-guided research on careers in public health
2. Students complete the attached guided questions
3. Teams discuss discoveries amongst themselves

Formative Assessments: Link the items in the Activities that will be used as formative assessments.

Formative assessment comes from the completion of the task

Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.
Refer to Activity Template for details.

Teachers can change functions and alter the amount of information given depending on student needs.

Reflection: Reflect upon the successes and shortcomings of the lesson.

Name: Eli Rolfes	**Contact Info:** eli.rolfes@covington.kyschools.us	**Date:** 7/26/2019

Lesson Title: Presentation Prep #1	**Unit #: 6**	**Lesson #: 2**	**Activity #: 1**
Activity Title: Path Planning / Identify Functions			

Estimated Lesson Duration:	**110 minutes**

Estimated Activity Duration:	55 minutes

Setting:	Holmes High School

Activity Objectives:

- Students will be able to plot baseline efficient pathways
- Students will be able to complete the data table and rank cities by time remaining
- Students will be able to identify functions for each of the strains of zombies

Activity Guiding Questions:

1. If there wasn't a zombie outbreak, what routes would you take?
2. Which cities are seeing the highest growth of zombies?
3. Which strains are in which cities?
4. Which cities have similar growths?

Ohio's Learning Standards for Math (OLS) and/or Common Core State Standards -- Mathematics (CCSS)	
Standards for Mathematical Practice (Check all that apply)	
☒ Make sense of problems and persevere in solving them	☒ Use appropriate tools strategically
☒ Reason abstractly and quantitatively	☒ Attend to precision
☒ Construct viable arguments and critique the reasoning of others	☒ Look for and make use of structure
☒ Model with mathematics	☒ Look for and express regularity in repeated reasoning

Unit Academic Standards (NGSS, OLS and/or CCSS):

Kentucky Standards
KY.HS.N.4 Use units in context as a way to understand problems and to guide the solution of multi-step problems; **KY.HS.N.5** Define appropriate units in context for the purpose of descriptive modeling. **KY.HS.N.6** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
KY.HS.F.1 Understand properties and key features of functions and the different ways functions can be represented.
KY.HS.F.4 Graph functions expressed symbolically and show key features of the graph, with and without using technology (computer, graphing calculator).
KY.HS.F.6 Write a function that describes a relationship between two quantities.
KY.HS.F.7 Use arithmetic and geometric sequences to model situations and scenarios.
KY.HS.F.11 Distinguish between situations that can be modeled with linear functions and with exponential functions.
KY.HS.F.12 Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table)
KY.HS.F.13 Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.
KY.HS.F.14 Interpret the parameters in a linear or exponential function in terms of a context.

Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)

All materials and handouts are included in the Unit Plan.

Teacher Advance Preparation:

Teachers should have removed most data from the City Data spreadsheet so that students have to work logically to uncover functions and strains

Activity Procedures:

1. Students work independently on the tasks assigned to their role in the worksheet
2. Students combine results and help one another as tasks are completed
3. Class discussion of progress made in each team
4. Team members provide feedback to each other

Formative Assessments: Link the items in the Activities that will be used as formative assessments.

Formative assessment comes from the completion of the task

Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.
Refer to Activity Template for details.

Teachers can change functions and alter the amount of information given depending on student needs.

Reflection: Reflect upon the successes and shortcomings of the lesson.

Name: Eli Rolfes	**Contact Info:** eli.rolfes@covington.kyschools.us	**Date:** 7/26/2019

Lesson Title: Final Presentation	**Unit #: 6**	**Lesson #: 2**	**Activity #: 2**
Activity Title: Zombie Outbreak Presentation			

Estimated Lesson Duration:	**120 Minutes**
Estimated Activity Duration:	**120 Minutes**

Setting:	**Holmes High School**

Activity Objectives:

1. Students will be able to present their solutions

Activity Guiding Questions:

- What does your cure look like?
- How did you use functions to determine a path to cure the outbreak?
- How did we select our solution?
- How quickly did we eradicate each strain (and all strains)?
- How does this apply to the real world?

Ohio's Learning Standards for Math (OLS) and/or Common Core State Standards -- Mathematics (CCSS)	
Standards for Mathematical Practice (Check all that apply)	
☒ Make sense of problems and persevere in solving them	☒ Use appropriate tools strategically
☒ Reason abstractly and quantitatively	☒ Attend to precision
☒ Construct viable arguments and critique the reasoning of others	☒ Look for and make use of structure

☒ Model with mathematics	☒ Look for and express regularity in repeated reasoning

Unit Academic Standards (NGSS, OLS and/or CCSS):

Kentucky Standards
KY.HS.N.4 Use units in context as a way to understand problems and to guide the solution of multi-step problems; **KY.HS.N.5** Define appropriate units in context for the purpose of descriptive modeling. **KY.HS.N.6** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
KY.HS.F.1 Understand properties and key features of functions and the different ways functions can be represented.
KY.HS.F.4 Graph functions expressed symbolically and show key features of the graph, with and without using technology (computer, graphing calculator).
KY.HS.F.6 Write a function that describes a relationship between two quantities.
KY.HS.F.7 Use arithmetic and geometric sequences to model situations and scenarios.
KY.HS.F.11 Distinguish between situations that can be modeled with linear functions and with exponential functions.
KY.HS.F.12 Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table)
KY.HS.F.13 Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.
KY.HS.F.14 Interpret the parameters in a linear or exponential function in terms of a context.

Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)

Presentation Rubric

	Below Standard	Approaching Standard	At Standard	Above Standard
Explanation of Ideas and Information	Does not present information, arguments, ideas, or findings clearly, concisely, and logically; argument lacks supporting evidence; audience cannot follow the line of reasoning Selects information, develops ideas and use a style inappropriate to the purpose, task, and audience (may be too much or too little information, or the wrong approach) Does not address alternative or opposing perspectives	Presents information, arguments, and supporting evidence in a way that is not always clear, concise, and logical; line of reasoning is sometimes hard to follow Attempts to select information, develop ideas and use a style appropriate to the purpose task and audience but does not fully succeed Attempts to address alternative or opposing perspectives, but not clearly or completely	Presents information, arguments, ideas, or findings clearly, concisely, and logically; audience can easily follow the line of reasoning Selects information, develops ideas and use a style appropriate to the purpose, task, and audience Clearly and completely addresses alternative or opposing perspectives	
Organization	Does not meet the requirements for what should be included in the presentation Does not have an introduction and/or conclusion	Meets most requirements for what should be included in the presentation Has an introduction and conclusion, but they are not clear or interesting	Meets all requirements for what should be included in the presentation Has a clear and interesting introduction and conclusion	

	Uses time poorly; the whole presentation, or a part of it, is too short or too long	Generally times presentation well, but may spend too much or too little time on a topic, a/v aid, or idea	Organizes time well; no part of the presentation is too short or too long	
Eyes and Body	Does not look at audience; reads notes or slides Does not use gestures or movements Lacks poise and confidence (fidgets, slouches, appears nervous) Wears clothing inappropriate for the occasion	Makes infrequent eye contact, reads notes or slides most of the time Uses a few gestures or movements, but they do not look natural Shows some poise and confidence (only a little fidgeting or nervous movement) Makes some attempt to wear clothing appropriate for the occasion	Keeps eye contact with the audience most of the time; only glances at notes or slides Uses natural gestures and movements Looks poised and confident Wears clothing appropriate for the occasion	
Voice	Mumbles or speaks too quickly or slowly Speaks too softly to be understood Frequently uses filler words Does not adapt speech for the context and task	Speaks clearly most of the time Speaks loudly enough for the audience to hear most of the time, but may speak in a monotone Occasionally uses filler words Attempts to adapt speech for the context	Speaks clearly; not too quickly or slowly Speaks loudly enough for everyone to hear; changes tone and pace to maintain interest Rarely uses filler words Adapts speech for the context and task,	

		and task but is unsuccessful or inconsistent	demonstrating command of formal English when appropriate	

Teacher Advance Preparation:

Teachers can invite administrators and other teachers to spectate and grade. Students should be given rubrics to grade themselves before they present and grade others as they present.

Activity Procedures:

Teams have 15 minutes to present and justify their solutions and implementation.

Formative Assessments:

None.

Summative Assessments:

This presentation is graded by the rubric above.

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.
Refer to Activity Template for details.

Students are grouped in mixed-ability teams

Reflection: Reflect upon the successes and shortcomings of the lesson.

CEEMS is supported by the National Science Foundation, grant #1102990.

Name: Elsheika Thompson	**Contact Info:** elsheika.thompson@beechwood.kyschools.us	**Date:** 20th June 2019

Unit Number and Title: #1: Linear Piecewise-defined Functions with Application

Grade Level:	9th
Subject Area:	Algebra 1

Total Estimated Duration of Entire Unit:	2 weeks

Part 1: Designing the Unit

4. Unit Academic Standards (Identify which standards: NGSS, OLS and/or CCSS. Cut and paste from NGSS, OLS and/or CCSS and be sure to include letter and/or number identifiers.**):**

- KY.HS.F.1 Understand properties and key features of functions and the different ways functions can be represented.
- KY.HS.F.4 Graph functions expressed symbolically and show key features of the graph, with and without using technology (computer, graphing calculator).
- KY.HS.F.6 Write a function that describes a relationship between two quantities.

Mathematical Practices

- MP.1. Make sense of problems and persevere in solving them.
- MP.2. Reason abstractly and quantitatively.
- MP.3. Construct viable arguments and critique the reasoning of others.
- MP.4. Model with mathematics.
- MP.6. Attend to precision.
- MP.7. Look for and make use of structure.

5. Unit Summary

The Big Idea: Linear Piecewise-defined Functions – modeling truss bridges using popsicle sticks.

Algebra is everywhere and can be used to interpret information and make informed decisions.

The (anticipated) Essential Questions (to help frame the problem):

- What is the connection between truss bridges and linear functions?

- What features of a truss bridge makes it safe?
- What are five types of bridges?
- Why are bridges important?

6. Unit Context

Justification for Selection of Content– Check all that apply:

☐ Students previously scored poorly on standardized tests, end-of term test or any other test given in the school or district on this content.

✔ Misconceptions regarding this content are prevalent.

✔ Content is suited well for teaching via CBL and EDP pedagogies.

☐ The selected content follows the pacing guide for when this content is scheduled to be taught during the school year. (Unit 1 covers atomic structure because it is taught in October when I should be conducting my first unit.)

☐ Other reason(s)

_____

_____

The Hook: (Describe in a few sentences how you will use a "hook" to introduce the Big Idea in a compelling way that draws students into the topic.)

The Hook for this unit has multiple parts and is intended to introduce the Big Idea and maintain a high level of student interest throughout. The Hook as a whole will help to bring local and global awareness, connect the problem to societal impacts, as well as encourage students to think of possible solutions. The series of Hook components are as follows;

- Students will brainstorm what they know about bridges (types, materials used, shapes, reasons used, memorable bridges that they have driven or ridden on, etc.)
- Glass Window Bridge Video #1: Introduction of the Glass Window Bridge with short video displaying high waves from the Atlantic Ocean side. This video will also include its dimensions and location.
- Whole group discussion on, "How might the closure or destruction of The Glass Window Bridge or other bridges effect the people living nearby?"
- Glass Window Bridge Video #2: I will record and share a video with students about 'The Glass Window Bridge' (news clips about the bridge will be included). It is a bridge on the island of Eleuthera (where I grew up) that connects the southern and northern parts of the island. What's interesting is that the island of Eleuthera separates the Atlantic Ocean from the shallow waters of the sea and this is directly below the bridge. When a hurricane hits (which is almost yearly), the rough ocean waves reaches the bridge and quickly eats away at the asphalt which is what the bridge is mostly made of. For weeks settlers of the island are prohibited from traveling across the bridge. This means students are unable to attend school, and families are separated until it is repaired. This bridge could be better engineered in a way that makes it more secure and possibly not as easily damaged.

- Students will research career fields associated with bridge building.
- Small groups will brainstorm Math concepts that might be considered during bridge building.

The Challenge and Constraints:

✔ Product **or** ☐ Process (Check one)

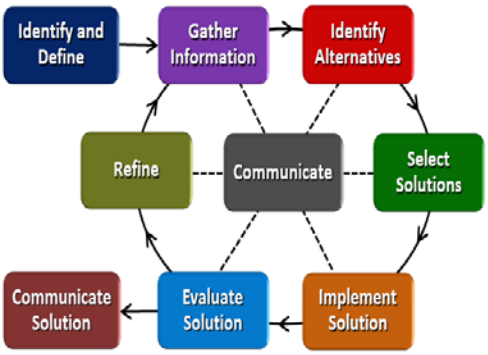
Description of Challenge (Either Product or Process is clearly explained below):	List the Constraints Applied
Proposal: The Island of Eleuthera has received funding from the Ministry of Public works for improvements to the Glass Window Bridge. Use the Engineering Design Process to design, build, and refine a secure model truss bridge using 100 popsicle sticks. Upon completion, members of other groups will identify the weakest area of another group's model bridge. The identified weakest area of the bridge will be tested to see if it can support 5 gram increments of weight in an effort to identify its capacity.	Piecewise-defined functions from three different regions of the bridge should be written. Piecewise might consist of two OR three pieces with domain. Glue should only be applied at the nodes of the bridge. Popsicle sticks should only overlap at the nodes (ex. to connect legs of the triangular parts of the bridge design). Only two days to design, build and refine the model truss bridge.

Teacher's Anticipated Guiding Questions (that apply to the Challenge and may change with student input.):

- What is a truss bridge?
- Why are truss bridges important?
- What are some types of truss bridges and how are the types similar and different?
- What features of a truss bridge make it safe/ secure?
- What materials can we use to model a truss bridge?

- What Math concepts can be applied when designing a truss bridge (think back as early as second grade and as recent as this school year)?

4. EDP: Use the diagram below to help you complete this section.



How will students test or implement the solution? What is the evidence that the solution worked? Describe how the iterative process from the EDP applies to your Challenge.

As students design the trusses for their bridge, they will be encouraged to test its individual strength and continue to do so as trusses and other bridge components are added on to their design. This 'test as I build' process will also indicate which parts of the bridge need to be redesigned before the entire model is assembled. Students will be able to test the strength of their bridge (in essence its security) by balancing their truss bridge (leveling on top of two desks spaced a part) and then adding weight to the area of the bridge that their group deems as the weakest, checking to see if it can support the 5 gram increment weights and if refinement of their design in needed. Once each group's model truss bridge is built and small groups have presented their model along with structural and mathematical details, each truss bridge will be tested. The bridge(s) with the highest weight capacity (at the areas considered 'weakest' by other groups) will receive a 'certificate of security' for their bridge.

How will students present or defend the solution? Describe if any formal training or resource guides will be provided to the students for best practices (e.g., poster, flyer, video, advertisement, etc.) used to present work.

Upon completion of their model truss bridge, students will create an advertisement in which they share a rationale for their design (which includes an example of a two or three piece linear piecewise-defined function in their design, bridge specifications, and any other physical attributes that make their bridge unique), the career background of their designing and building team, and any other selling point for why their bridge design should be chosen by the Ministry of Public Works.

Throughout the academic year, students will have multiple opportunities to present and receive feedback from the teacher and their peers. Algebra 1 students have all taken one year of 'Seminar' class in which they learn 21st century skills and have multiple opportunities to showcase these to community partnering companies.

What academic content is being taught through this Challenge?

Students are learning and applying the following extension of linear function concepts;

- Identify features of a linear function.
- Writing and graphing linear functions
- Understand and identifying domain and range of a function
- Understand what a piecewise-defined function is.
- Writing and graphing linear piecewise-defined functions

Assessment and EDP:
Using the diagram above, identify any places in the EDP where assessments should take place, as it applies to your Challenge. Describe below what kinds of assessment are most appropriate.

What EDP Processes are ideal for conducting an Assessment? (List ones that apply.)	List the type of Assessment (Rubric, Diagram, Checklist, Model, Q/A etc.) Check box to indicate whether it is formative or summative.
pre-assessment post assessment part 1 Post assessment part 2	Q/A X formative ☐ summative Student-created advertisement (rubric to assess) ☐ formative X summative Q/A X formative ☐ summative

Check below which characteristic(s) of this Challenge will be incorporated in its implementation using EDP. (Check all that apply.)

- X Has clear constraints that limit the solutions
- ☐ Will produce than one possible solution that works
- X Includes the ability to refine or optimize solutions
- X Assesses science or math content
- X Includes Math applications
- X Involves use of graphs
- ☐ Requires analysis of data
- X Includes student led communication of findings

5. ACS (Real world applications; career connections; societal impact):

Place an X on the continuum to indicate where this Challenge belongs in the context of real world applications:

Abstract or Loosely Applies to the Real World |----------|----------X----- **Strongly Applies to the Real World**

Provide a brief rationale for where you placed the X**:**

This challenge strongly applies to the real world as students are connecting and using math concepts learned to design, build, and refine (problem solve to improve) a model truss bridge as a solution to a bridge that is not secure and has tremendous impact on the lives of people who live nearby.

What activities in this Unit apply to real world context?

Lesson One Activities One and Two, and Lesson Two Activity Two all apply to real world context.

Lesson One Activity One helps students to learn about the engineering design process and to apply it as they build a tall, but secure tower using fifty index cards and twelve inches of scotch tape.

Lesson One Activity Two focuses on students learning about the careers associated with bridge building as well as formulating the Big Idea and Essential Questions of the unit. They learn about important features of bridges, and then importance they serve, and finally they are able to attend a presentation by a local engineering professor and ask questions related to the field.

Lesson Two Activity Two focuses predominantly on the Challenge at which time students will have the opportunity to use everything that they have learned about bridges, related careers, and linear piecewise-defined functions to build a secure model truss bridge and then present their model.

Place an X on the continuum to indicate where this Challenge belongs in the context of societal impact:

Shows Little or No Societal Impact **|----------|----------X-------| Strongly Shows Societal Impact**

Provide a brief rationale for where you placed the X**:**

Bridges are an integral part of our society as they facilitate travel. The connection between two pieces of land made possible by bridges allows us to commute to work and school. Visiting friends and family is easier and businesses rely on bridges. When a bridge is being repaired or is shut down traffic flows for alternate routes are often impacted negatively.

What activities in this Unit apply to societal impact?

Lesson One Activity Two specifically applies to societal impact as students brainstorm and discuss the impact of bridge closures

Careers: What careers will you introduce (and how) to the students that are related to the Challenge? (Examples: career research assignment, guest speakers, fieldtrips, Skype with a professional, etc.)

During Activity Two, students will complete a career research assignment to learn about all of the careers associated with bridge building. Perhaps the result is that they understand that multiple careers often collaborate in an effort to successfully execute a plan and/or create a product (similarly to the coming together of their different skill sets when building their model truss bridge in Activity Four).

Also, during Lesson One Activity Two, the engineering field will be of focus as a software engineering professor from the University of Cincinnati has agreed to talk with my students as well as answer their questions. The hope is that their interaction and conversation with a stem-related professional will further spark their interest in stem-related fields.

Dr. Nan Niu, a software engineering professor at the University of Cincinnati has agreed to speak to students about security in software development and how this translates to security in physical structures, etc.

6. Misconceptions:

When learning about linear piecewise-defined functions students can sometimes have difficulty differentiating between graph features such as domain and range. Another assumption is that all pieces of a linear piecewise-defined function are connected forming a continuous complex graph. Understanding that the domain and range play an important role in this is key. There is also sometimes a misconception about the slope ratio being a horizontal change over vertical change.

7. Unit Lessons and Activities: (Provide a tentative timeline with a breakdown for Lessons 1 and 2. Provide the Lesson #'s and Activity #'s for when the Challenge Based Learning (CBL) and Engineering Design Process (EDP) are embedded in the unit.)

Lesson 1 activities: During Lesson One Activity One students participate in a team activity to introduce them to the Engineering Design Process (EDP), help encourage the mindset of multiple solutions and refining, and collaboration when creating a product. The EDP is explored through designing and building a secure model tower using fifty index cards and twelve inches of scotch tape. By the end of this activity students will be able to identify parts of the Engineering Design Process. Lesson 1 activities (four days total): During Lesson One Activity One students participate in a team activity to introduce them to the Engineering Design Process (EDP), help encourage the mindset of multiple solutions and refining, and collaboration when creating a product. The EDP is explored through designing and building a secure model tower using fifty index cards and twelve inches of scotch tape. By the end of this activity students will be able to identify parts of the Engineering Design Process.

Students participate in a 'Foldable Pieces and Pieces to Continue' activity during Lesson One Activity Two which allows them to independently graph linear functions and then together, using a given domain for each function, create a three-piece linear piecewise-defined function. The second part of this activity requires students to independently write the function along with the domain for their assigned piece of a given three-piece linear piecewise-defined function and then collaborate in an effort to omit a piece of the piecewise and replace it with another function accompanied by the domain with the goal of constructing a continuous complex graph. Students' understanding of the domain feature as well as continuous versus discrete graphs are put to the test, however collaboration is key.

Lesson 2 activities (five days total): Lesson Two Activity One presents the opportunity for students to 'Explore Bridges' through means of research coupled with brainstorming activities. The objectives of this lesson are as follows; to identify at minimum four types of bridges, and then compare and contrast the different types of bridges found. Real world connections and societal impacts are addressed as students identify careers associated with bridge designing and building, and discuss the importance of bridges in communities and how their closure impacts the lives of those living and working in that area.

Lesson Two Activity Two mainly focuses on the unit 'Challenge' which is presented as a proposal from 'The Ministry of Public Works' to bridge engineering companies to submit their designs and other details that would help to make The Glass Window Bridge safe for local residents and visitors. Students will create a secure model truss bridge using one hundred popsicle sticks and will enlist technology and Algebra 1 concepts to better visualize their complete design and strengthen their bridge respectively.

8. Keywords:

- linear functions, piecewise-defined functions, domain, range, slope truss, truss bridge, nodes.

9. Additional Resources:

Lesson One Activity One fifty index cards (per small group of three students) and twelve inches of scotch tape (per small group of three students) for building secure model tower, beanie baby for testing the model tower.

Lesson One Activity One

- Unit Pre-test https://drive.google.com/open?id=1zntrTKE8kn0iVeESaymM85w45TtEYdBC
- Rubric for oral presentation of secure tower https://drive.google.com/open?id=1HjgWP8Mrhqa_JXNzfFLSZqP2yHLj9dmq
- Engineering Design Process pre and post assessment. https://drive.google.com/open?id=17Mf1cp71-M932maepxG5Z7MfPO9rF4LH
- Template for recording group's response to guiding questions. https://drive.google.com/open?id=1LVJAzy6en3g8Dfv2qAMtkQtA7L4v9LEZ

Lesson One Activity Two:

- Guiding Questions Response Recording Sheet Template. https://drive.google.com/open?id=1juNFQjrI-h0uowxaPXA_GBKY6nBkxRMe
- 'Foldable Pieces' activity sheet. https://drive.google.com/open?id=1k1-ro1TWPccd18FtW8FYnPTyG2bGBrdi
- 'Pieces to Continue' Activity sheet. https://drive.google.com/open?id=1NmV53dAjjAZTNOSYkjoWijd6YLcrMiGv

Lesson Two Activity One:

- Guiding Questions Response Recording Sheet Template. https://drive.google.com/open?id=1jeIftVPBm1g73i1Z-QI0F2oagGg7sHQO
- Bridge Personality Profile https://drive.google.com/open?id=1XYMjPlBa9yWoKC1tTg3_r_SeRSIbYD-B
- Types of Bridges Sheet (for collecting information through research) https://drive.google.com/open?id=1lWg94JkS1GlpYoN_YvsPQ6PQHQBD_kW9

- Bridge Matching Sheet (used as pre and post- assessment for this activity) https://drive.google.com/open?id=1leXzSokKfU1ydyq7AcJu9LB9W7Uyzj2-
- **Video #1 (12 Most Amazing Bridges Ever Built) :** https://www.youtube.com/watch?v=hz6ghvVbKpY
- **Video #2 (Doha Sharq Crossing):** https://www.youtube.com/watch?v=GImCUoYTOGI

Lesson Two Activity Two:

- brainstorming sheet https://drive.google.com/open?id=1O9KjMlhLVgqtmQS-li54t-Sr3UsTJIIg
- Glass Window Bridge Personal Reflection Video https://drive.google.com/open?id=1BiTYiOmgzuaMMKp1d7ScHerb6XNbTA28
- Glass Window Bridge Introductory Video https://www.cnn.com/travel/article/eleuthera-bahamas-glass-window-bridge/index.html
- 'Certificate of Safety' (to present to group(s) with the most secure model truss bridge)
- Desmos Graphing Calculator: https://www.desmos.com/calculator
- Post-Unit Test https://drive.google.com/open?id=1zntrTKE8kn0iVeESaymM85w45TtEYdBC

10. Pre-Unit and Post-Unit Assessment Instruments:

Lesson One Activity One Engineering Design Process pre and post assessment.

Pre-unit assessment on 'Linear Piecewise-defined Functions' to be administer prior to the unit.

Bridge Advertisement Rubric attached to be used as a post-unit assessment as students present their company's bridge design.

Post-unit assessment on 'Linear Piecewise-defined Functions' to be administer post unit implementation.

In this section put a link to your pre-assessment/post assessment.

11. Poster	**12. Video (Link here.)**

If you are a science teacher, check the boxes below that apply:

Next Generation Science Standards (NGSS)	
Science and Engineering Practices (Check all that apply)	**Crosscutting Concepts (Check all that apply)**
X Asking questions (for science) and defining problems (for engineering)	☐ Patterns
☐ Developing and using models	☐ Cause and effect
☐ Planning and carrying out investigations	☐ Scale, proportion, and quantity

☐ Analyzing and interpreting data	☐ Systems and system models
X Using mathematics and computational thinking	☐ Energy and matter: Flows, cycles, and conservation
☐ Constructing explanations (for science) and designing solutions (for engineering)	X Structure and function.
☐ Engaging in argument from evidence	☐ Stability and change.
☐ Obtaining, evaluating, and communicating information	

If you are a science teacher, check the boxes below that apply:

Ohio's Learning Standards for Science (OLS)
Expectations for Learning - Cognitive Demands (Check all that apply)
☐ Designing Technological/Engineering Solutions Using Science concepts **(T)**
☐ Demonstrating Science Knowledge **(D)**
☐ Interpreting and Communicating Science Concepts **(C)**
☐ Recalling Accurate Science **(R)**

If you are a math teacher, check the boxes below that apply:

Ohio's Learning Standards for Math (OLS) or Common Core State Standards -- Mathematics (CCSS)	
Standards for Mathematical Practice (Check all that apply)	
X Make sense of problems and persevere in solving them	X Use appropriate tools strategically
X Reason abstractly and quantitatively	☐ Attend to precision
☐ Construct viable arguments and critique the reasoning of others	☐ Look for and make use of structure
X Model with mathematics	X Look for and express regularity in repeated reasoning

Part 2: Post Implementation- Reflection on the Unit

Results: Evidence of Growth in Student Learning - After the Unit has been taught and the Post-Unit Assessment Instrument has been used to assess student growth in learning, the teacher must

analyze the data and determine whether or not student growth in learning occurred. Present all documents used to collect and organize Post- Unit evaluation data such as graphs or charts. Provide a written analysis in sentence or paragraph form which provides the evidence that student growth in learning took place. Please present results and, if applicable, student work (as a hyperlink) used as evidence after the Unit has been taught.

Please include:

- Any documents used to collect and organize post unit evaluation data. (charts, graphs and /or tables etc.)
- An analysis of data used to measure growth in student learning providing evidence that student learning occurred. (Sentence or paragraph form.)
- Other forms of assessment that demonstrate evidence of learning.
- Anecdotal information from student feedback.

Reflection: Reflections: Reflect upon the successes of teaching in this Unit in 5 or more sentences in the form of a narrative. Consider the following questions:

1) Why did you select this content for the Unit?
2) Was the purpose for selecting the Unit met? If yes, provide student learning related evidence. If not, provide possible reasons.
3) Did the students find a solution or solutions that resulted in concrete meaningful action for the Unit's Challenge? Hyperlink examples of student solutions as evidence.
4) What does the data indicate about growth in student learning?
5) What would you change if you re-taught this Unit?
6) Would you teach this Unit again? Why or why not?

Name: Elsheika Thompson	**Contact Info:** elsheika.thompson@beechwood.kyschools.us	**Date:** 6/20/2019

Lesson Title: Exploring the Engineering Design Process and Delving into the Pieces of Piecewise Functions	**Unit #:**1	**Lesson #:** 1	**Activity #:** 1
Activity Title: Introduction to the Engineering Design Process			

Estimated Lesson Duration:	Four to Five days
Estimated Activity Duration:	Three days

Setting:	Beechwood High School Classroom

Activity Objectives:

Students will be able to:

- Identify parts of the Engineering Design Process
- Apply the Engineering Design Process through designing and building a model tower.

Activity Guiding Questions:

- What are some strategies that could be implemented to make your tower safe?
- How can we check the safety of our model tower?
- When should we check the safety of our model tower?
- Is there a part of our tower that is strongest? How does this impact the strength of the tower?
- Is there a part of our tower that is weakest? How does this impact the strength of the tower?
- Could we refine our design to enhance the safety of the model tower?
- Which parts of the Engineering Design Process have we completing and how?

Next Generation Science Standards (NGSS)	
Science and Engineering Practices (Check all that apply)	**Crosscutting Concepts (Check all that apply)**
☐ Asking questions (for science) and defining problems (for engineering)	☐ Patterns
☒ Developing and using models	☐ Cause and effect
☒ Planning and carrying out investigations	☐ Scale, proportion, and quantity

☐ Analyzing and interpreting data	☐ Systems and system models
☐ Using mathematics and computational thinking	☐ Energy and matter: Flows, cycles, and conservation
☐ Constructing explanations (for science) and designing solutions (for engineering)	☒ Structure and function.
☐ Engaging in argument from evidence	☐ Stability and change.
☐ Obtaining, evaluating, and communicating information	

Ohio's Learning Standards for Science (OLS)
Expectations for Learning - Cognitive Demands (Check all that apply)
☐ Designing Technological/Engineering Solutions Using Science concepts **(T)**
☐ Demonstrating Science Knowledge **(D)**
☐ Interpreting and Communicating Science Concepts **(C)**
☐ Recalling Accurate Science **(R)**

Ohio's Learning Standards for Math (OLS) and/or Common Core State Standards -- Mathematics (CCSS)	
Standards for Mathematical Practice (Check all that apply)	
☒ Make sense of problems and persevere in solving them	☐ Use appropriate tools strategically
☐ Reason abstractly and quantitatively	☐ Attend to precision
☐ Construct viable arguments and critique the reasoning of others	☐ Look for and make use of structure
☒ Model with mathematics	☐ Look for and express regularity in repeated reasoning

Unit Academic Standards (NGSS, OLS and/or CCSS):

- KY.HS.F.1 Understand properties and key features of functions and the different ways functions can be represented.

- KY.HS.F.4 Graph functions expressed symbolically and show key features of the graph, with and without using technology (computer, graphing calculator).
- KY.HS.F.6 Write a function that describes a relationship between two quantities.

Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)

- Template for recording group's response to guiding questions https://drive.google.com/open?id=1LVJAzy6en3g8Dfv2qAMtkQtA7L4v9LEZ
- Index cards (50 per small group of three students)
- Scotch Tape
- A Beanie baby (for testing solutions – the secure model towers)
- Rubric for brief presentation of group's secure model tower. https://drive.google.com/open?id=1HjgWP8Mrhqa_JXNzfFLSZqP2yHLj9dmq

Teacher Advance Preparation:

- Separate index cards into groups of 50 (a set for each group)
- Cut scotch tape into twelve inch strips.

Activity Procedures:

- On day one, students will complete the pre-test for the engineering design process.
- Teacher will use direct instruction initially to teach students the Engineering Design Process.
- They will be given the challenge of designing and building the tallest secure model tower that can support the weight of a beanie baby for ten seconds.
- Having learned about the challenge, students will complete Guiding Questions sheet to record their discussion of the prompts.
- Small groups of three will begin to sketch their tower, annotating their drawings.
- On day two, groups will build their secure model tower being sure to test it. *Groups will be encouraged to take pictures of their model tower from different angles.
- Groups will outline and discuss how they will present their secure model tower.
- Day three will begin with presentations, each followed by feedback from their peers in regards to the presentation rubric components.
- We will conclude with misconceptions being addressed as well as students sharing other everyday problems for which the Engineering Design Process can be applied. Students will be administered the engineering design process post-test.

Formative Assessments: Link the items in the Activities that will be used as formative assessments.

Engineering Design Process pre-test
https://drive.google.com/open?id=1zntrTKE8kn0iVeESaymM85w45TtEYdBC

Engineering Design Process post-test
https://drive.google.com/open?id=1zntrTKE8kn0iVeESaymM85w45TtEYdBC

Rubric for oral presentation of tallest secure tower
https://drive.google.com/open?id=1LVJAzy6en3g8Dfv2qAMtkQtA7L4v9LEZ

Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.

Refer to Activity Template for details.

When presenting their tower, although meant to be an oral presentation, flexibility will be given to allow drawings of their model or process (for students who tell stories better through images, or the creation of a short video for groups that are more comfortable meeting the requirements through means of a video recorded in the hallway or adjoining room to the classroom.

Reflection: Reflect upon the successes and shortcomings of the lesson.

Name: Elsheika Thompson	**Contact Info:** elsheika.thompson@beechwood.kyschools.us	**Date:** 6/20/2019

Lesson Title: Exploring the Engineering Design Process and Delving into the Pieces of Piecewise Functions	**Unit #:**1	**Lesson #:** 1	**Activity #:** 2
Activity Title: Foldable Pieces and Pieces to Continue			

Estimated Lesson Duration:	Four to Five days
Estimated Activity Duration:	One to two day(s)

Setting:	Beechwood High School Classroom

Activity Objectives:

Students will be able to:

- To graph a three-piece linear piecewise-defined function
- Write a linear piecewise-defined function with two or more pieces
- To distinguish between discrete and continuous functions

Activity Guiding Questions:

- What is the difference between < and ≤?
- How do you differentiate between < and ≤ when graphing?
- What directions do you look when considering the domain of a graph?
- How can you tell that the pieces of a piecewise function form a continuous graph?
- What real world applications are a continuous function or series of lines essential?
- How might the concept of continuity with graphs be helpful in the real world?

Next Generation Science Standards (NGSS)	
Science and Engineering Practices (Check all that apply)	**Crosscutting Concepts (Check all that apply)**
☒ Asking questions (for science) and defining problems (for engineering)	☐ Patterns
☒ Developing and using models	☒ Cause and effect
☐ Planning and carrying out investigations	☐ Scale, proportion, and quantity
☐ Analyzing and interpreting data	☐ Systems and system models

☒ Using mathematics and computational thinking	☐ Energy and matter: Flows, cycles, and conservation
☐ Constructing explanations (for science) and designing solutions (for engineering)	☒ Structure and function.
☐ Engaging in argument from evidence	☐ Stability and change.
☐ Obtaining, evaluating, and communicating information	

Ohio's Learning Standards for Science (OLS)
Expectations for Learning - Cognitive Demands (Check all that apply)
☐ Designing Technological/Engineering Solutions Using Science concepts **(T)**
☐ Demonstrating Science Knowledge **(D)**
☐ Interpreting and Communicating Science Concepts **(C)**
☐ Recalling Accurate Science **(R)**

Ohio's Learning Standards for Math (OLS) and/or Common Core State Standards -- Mathematics (CCSS)	
Standards for Mathematical Practice (Check all that apply)	
☒ Make sense of problems and persevere in solving them	☒ Use appropriate tools strategically
☒ Reason abstractly and quantitatively	☐ Attend to precision
☒ Construct viable arguments and critique the reasoning of others	☒ Look for and make use of structure
☒ Model with mathematics	☐ Look for and express regularity in repeated reasoning

Unit Academic Standards (NGSS, OLS and/or CCSS):

- KY.HS.F.1 Understand properties and key features of functions and the different ways functions can be represented.
- KY.HS.F.4 Graph functions expressed symbolically and show key features of the graph, with and without using technology (computer, graphing calculator).
- KY.HS.F.6 Write a function that describes a relationship between two quantities.

Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)

- 'Foldable Pieces' Activity https://drive.google.com/open?id=1k1-ro1TWPccd18FtW8FYnPTyG2bGBrdi
- 'Continuous Pieces' Activity https://drive.google.com/open?id=1NmV53dAjjAZTNOSYkjoWijd6YLcrMiGv
- Mini- grid sheets (three per small group for 'Foldable Piecewise' Activity) https://www.dadsworksheets.com/printables/coordinate-plane/name-coordinate-plane-four-problem-eighth-inch.html
- Scotch tape (a few pieces per small group of three students to join pieces of the piecewise function together and then the completed piecewise function onto the activity sheet).
- Color Pencils (three unique colors per small group).
- Guiding Questions Response Recording Sheet Template. https://drive.google.com/open?id=1juNFQjrI-h0uowxaPXA_GBKY6nBkxRMe

Teacher Advance Preparation:

- Cut out mini-grid sheets and organize three per small group.
- Organize color pencils into sets of three (a set of three for each group)
- Cut strips of scotch tape (about five pieces per group for 'Foldable Pieces' Activity

Activity Procedures:

- Linear Piecewise-defined Functions Pre-test will be administered on prior to the start of this activity or unit.
- Groups response to the activity guiding questions should be recorded

For Part One of this activity;

- Small groups of students will each be given three small grid sheets along with 'Foldable Piecewise' activity sheet, and four to six strips of scotch tape.
- Members of small group will assign roles for the 'Foldable Piecewise' activity and then individually graph the linear function that they have been assigned using a unique color coloring pencil to trace their individual linear graph.
- Once individual functions have been graphed, students will use the domain assigned to them to fold their function only revealing a specific piece of the function.
- Groups should tape the three pieces of functions to form one graph (ensuring that consecutive numbers on the x-axis are in order) and then draw their newly formed graph with three pieces on a single grid provided on the activity sheet.

- Groups should collaborate to answer remaining questions on the activity sheet and are encouraged to help another group member who might be struggling.

For Part Two of this activity;

- Small groups will be given a copy of the 'Continuous Pieces' activity sheet. Members are to investigate the three graphs of piecewise functions to determine which of the three graphs are continuous and which are discrete.
- For all three graphs, they must work together to write the piecewise function.
- For graphs they consider to be discrete they are to choose a piece to eliminate and then replace it with a new piece that now makes the graph continuous. This change is to be documents on the graph itself as well as written as a function with its domain in the table.
- Whole Group discourse about challenges in addition to tricks or insight that groups might want to share in regards to graphing and writing piecewise functions.

Formative Assessments: Link the items in the Activities that will be used as formative assessments.

- Linear piecewise-defined functions pre-test.

Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.

Refer to Activity Template for details.

For struggling students, the activity might be scaffolded with prompting questions. For instance; for the 'Continuous Pieces' activity they might be asked to visually show the triangular movement associated with finding the slope of a line or for each piece of the function two points may be identified to assist with slope finding (one of them possibly being the y-intercept). Part of each pieces that extend the function beyond the given domains might be drawn in with a different color in hopes that students may be able to write the slope-intercept form of the function.

Reflection: Reflect upon the successes and shortcomings of the lesson.

Name: Elsheika Thompson	**Contact Info:** elsheika.thompson@beechwood.kyschools.us	**Date:** 6/20/2019

Lesson Title: Exploring, Designing, and Building a Secure Bridge	**Unit #:**1	**Lesson #:** 2	**Activity #:** 1
Activity Title: Exploring Bridges			

Estimated Lesson Duration:	Five to six days
Estimated Activity Duration:	One to two days

Setting:	Beechwood High School Classroom

Activity Objectives:

Students will be able to:

- To identify at minimum four types of bridges
- Compare and contrast the different types of bridges
- Identify careers associated with bridge designing and building.
- Understand the importance of bridges in communities.
- Understand the societal impacts of bridge closures.

Activity Guiding Questions:

- Why are bridges important?
- What are some types of bridges and how are the types similar and/or different?
- What features of a bridge make it safe/ secure?
- What Math concepts can be applied when designing bridges (think back as early as second grade and as recent as this school year)?
- What careers are associated with bridge designing and building?

Next Generation Science Standards (NGSS)	
Science and Engineering Practices (Check all that apply)	**Crosscutting Concepts (Check all that apply)**
☒ Asking questions (for science) and defining problems (for engineering)	☒ Patterns
☐ Developing and using models	☐ Cause and effect
☒ Planning and carrying out investigations	☐ Scale, proportion, and quantity

☐ Analyzing and interpreting data	☐ Systems and system models
☒ Using mathematics and computational thinking	☐ Energy and matter: Flows, cycles, and conservation
☐ Constructing explanations (for science) and designing solutions (for engineering)	☐ Structure and function.
☒ Engaging in argument from evidence	☐ Stability and change.
☒ Obtaining, evaluating, and communicating information	

Ohio's Learning Standards for Science (OLS)
Expectations for Learning - Cognitive Demands (Check all that apply)
☐ Designing Technological/Engineering Solutions Using Science concepts **(T)**
☐ Demonstrating Science Knowledge **(D)**
☐ Interpreting and Communicating Science Concepts **(C)**
☐ Recalling Accurate Science **(R)**

Ohio's Learning Standards for Math (OLS) and/or Common Core State Standards -- Mathematics (CCSS)	
Standards for Mathematical Practice (Check all that apply)	
☐ Make sense of problems and persevere in solving them	☒ Use appropriate tools strategically
☐ Reason abstractly and quantitatively	☐ Attend to precision
☒ Construct viable arguments and critique the reasoning of others	☐ Look for and make use of structure
☒ Model with mathematics	☐ Look for and express regularity in repeated reasoning

Unit Academic Standards (NGSS, OLS and/or CCSS):

- KY.HS.F.1 Understand properties and key features of functions and the different ways functions can be represented.
- KY.HS.F.4 Graph functions expressed symbolically and show key features of the graph, with and without using technology (computer, graphing calculator).
- KY.HS.F.6 Write a function that describes a relationship between two quantities.

Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)

- Guiding Questions Response Recording Sheet Template. https://drive.google.com/open?id=1jeIftVPBm1g73i1Z-QI0F2oagGg7sHQO
- Bridge Personality Profile https://drive.google.com/open?id=1XYMjPlBa9yWoKC1tTg3_r_SeRSIbYD-B
- Types of Bridges Research Sheet https://drive.google.com/open?id=1lWg94JkS1GlpYoN_YvsPQ6PQHQBD_kW9
- Chromebooks for students to extend their knowledge of bridges through research.
- **Video #1 (12 Most Amazing Bridges Ever Built) : https://www.youtube.com/watch?v=hz6ghvVbKpY**
- **Video #2 (Doha Sharq Crossing): https://www.youtube.com/watch?v=GImCUoYTOGI**

Teacher Advance Preparation:

Activity Procedures:

- Bridge Matching pre-test to be completed.
- As the first of several hooks in this lesson meant to conjure up student's interest in the Challenge and keep it, video #1 should be viewed by students at the beginning of this lesson.
- Using their Chromebooks, students will complete Types of Bridges sheet so that the information gathered during their research is organized and can easily be referenced as they make similarities and differences between the different types of bridges. Students should be encouraged to share their findings with one another.
- Video #2 will be viewed, after which a few students will be encouraged to share any related thoughts aloud.
- Students will complete 'Brainstorming Activity' to address remaining lesson objectives.
- Each student will create a Bridge Personality Profile; identify a bridge that fits their personality best or one that they are particularly drawn to and briefly explain the reason for their choice in one or two sentences.
- Post-assessment administered

Formative Assessments: Link the items in the Activities that will be used as formative assessments.

- Bridge Matching Sheet to be used as a pre and post assessment. https://drive.google.com/open?id=1leXzSokKfU1ydyq7AcJu9LB9W7Uyzj2-

Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.

Refer to Activity Template for details.

- For students without internet access at home to further research carried out in the classroom, additional research time will be provided.

Reflection: Reflect upon the successes and shortcomings of the lesson.

Name: Elsheika Thompson	Contact Info: elsheika.thompson@beechwood.kyschools.us	Date: 6/20/2019

Lesson Title: Exploring, Designing, and Building a Secure Bridge	Unit #:1	Lesson #: 2	Activity #: 2
Activity Title: The Challenge			

Estimated Lesson Duration:	Five to six days
Estimated Activity Duration:	Four Days

Setting:	Beechwood High School Classroom and then outdoors (for spraying bridge model)

Activity Objectives:

Students will be able to:

- Collaborate with others to create a product
- Apply Algebra concepts to our everyday living
- Understand that a problem can have multiple solutions and/or multiple strategies for solving it.
- Effectively present a product or solution.

Content specific objectives:

Students will be able to:

- Identify features of a linear function.
- Writing and graphing linear functions
- Understand and identifying domain and range of a function
- Understand what a piecewise-defined function is.
- Writing and graphing linear piecewise-defined functions

Activity Guiding Questions:

- What is a truss bridge?
- Why are truss bridges important?
- What are some types of truss bridges and how are the types similar and different?
- What features of a truss bridge make it safe/ secure?
- What materials can we use to model a truss bridge?
- What Math concepts can be applied when designing a truss bridge (think back as early as second grade and as recent as this school year)?

Next Generation Science Standards (NGSS)

Science and Engineering Practices (Check all that apply)	Crosscutting Concepts (Check all that apply)
☒ Asking questions (for science) and defining problems (for engineering)	☐ Patterns
☒ Developing and using models	☐ Cause and effect
☐ Planning and carrying out investigations	☐ Scale, proportion, and quantity
☐ Analyzing and interpreting data	☐ Systems and system models
☒ Using mathematics and computational thinking	☐ Energy and matter: Flows, cycles, and conservation
☒ Constructing explanations (for science) and designing solutions (for engineering)	☒ Structure and function.
☐ Engaging in argument from evidence	☐ Stability and change.
☒ Obtaining, evaluating, and communicating information	

Ohio's Learning Standards for Science (OLS)
Expectations for Learning - Cognitive Demands (Check all that apply)
☐ Designing Technological/Engineering Solutions Using Science concepts **(T)**
☐ Demonstrating Science Knowledge **(D)**
☐ Interpreting and Communicating Science Concepts **(C)**
☐ Recalling Accurate Science **(R)**

Ohio's Learning Standards for Math (OLS) and/or Common Core State Standards -- Mathematics (CCSS)	
Standards for Mathematical Practice (Check all that apply)	
☒ Make sense of problems and persevere in solving them	☒ Use appropriate tools strategically
☒ Reason abstractly and quantitatively	☒ Attend to precision
☐ Construct viable arguments and critique the reasoning of others	☐ Look for and make use of structure
☒ Model with mathematics	☒ Look for and express regularity in repeated reasoning

Unit Academic Standards (NGSS, OLS and/or CCSS):

- KY.HS.F.1 Understand properties and key features of functions and the different ways functions can be represented.
- KY.HS.F.4 Graph functions expressed symbolically and show key features of the graph, with and without using technology (computer, graphing calculator).
- KY.HS.F.6 Write a function that describes a relationship between two quantities.

Materials: (Link Handouts, Power Points, Resources, Websites, Supplies)

- Glass Window Bridge Introductory Video https://www.cnn.com/travel/article/eleuthera-bahamas-glass-window-bridge/index.html
- Glass Window Bridge https://drive.google.com/open?id=1BiTYiOmgzuaMMKp1d7ScHerb6XNbTA28
- Brainstorming Sheet to develop Guiding Questions. https://drive.google.com/open?id=1O9KjMlhLVgqtmQS-li54t-Sr3UsTJIIg
- 100 Popsicle sticks per small group of three students
- Small hot glue guns
- Small glue sticks
- Krylon Spray in multiple colors (for spraying model bridges before presenting)
- Large grid sheet (for initial sketches of bridge)
- Chromebook
- Desmos Graphing Calculator (https://www.desmos.com/calculator)
- Gloves (for handling hot glue and for spraying model bridges)
- Flattened cardboard boxes (to rest models on to spray)
- Disposable plastic aprons

- Letter from The Ministry of Public Works about funding for The Glass Window Bridge repairs/ reconstruction. https://drive.google.com/open?id=1_zIsMsgdnzNHshHS_2BDGScgegCV8l85

Teacher Advance Preparation:

- Pre-heating glue sticks in glue guns
- Separating materials for each small group so that it is within the constraints of the challenge (popsicles sets of one hundred, one glue gun, several glue sticks, three pairs of disposable gloves, and three pairs of disposable aprons per small group).
- Flatten cardboard boxes for spraying

Activity Procedures:

Day 1:

- Introduction of the Glass Window Bridge Video #1 with short video displaying high waves from the Atlantic Ocean side. This video will also include its dimensions and location.
- Whole group discussion on, "How might the closure or destruction of The Glass Window Bridge or other bridges affect the people living nearby?"
- Share 'The Glass Window Bridge Video #2'
- Share letter from The Ministry of Public Works about funding for The Glass Window Bridge repairs/ reconstruction.
- Present the 'Challenge' along with constraints

Day 2:

- Revisit challenge and constraints.
- Have students develop 'Guiding Questions' through brainstorming
- Small groups will use large grid paper to make an annotated sketch of their truss bridge
- Small groups will use Desmos Graphing Calculator on their Chromebook to create a colored version of the bridge that will be built (This will serve as their 'Coming Soon' sign.

Day 3:

- Build model secure truss bridge, testing along the way to ensure its safety.
- Plan out bridge advertisement using rubric as a guideline

Day 4:

- Each small group will advertise their product.
- Each group will have the opportunity to identify the most vulnerable area on another groups bridge and then to determine the bridge's weight capacity, we will add weights in increments of 5 grams at the most vulnerable part.
- Presentation of 'Certificate of Security' awarding to group(s) with the most secure model truss bridge.

Formative Assessments: Link the items in the Activities that will be used as formative assessments.

Post-test for assessing understanding of linear piecewise-defined functions.
https://drive.google.com/open?id=1zntrTKE8kn0iVeESaymM85w45TtEYdBC

Summative Assessments: These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

Upon completion of their model truss bridge, students will create an advertisement in which they share a rationale for their design (which includes an example of a two or three piece linear piecewise-defined function in their design, bridge specifications, and any other physical attributes that make their bridge unique), the career background of their designing and building team, and any other selling point for why their bridge design should be chosen by the Ministry of Public Works. ***A rubric will be used by classmates to evaluate each advertisement.***
https://drive.google.com/open?id=1HjgWP8Mrhqa_JXNzfFLSZqP2yHLj9dmq

Differentiation: Describe how you modified parts of the Lesson to support the needs of different learners.

Refer to Activity Template for details.

For students without internet access at home to further research carried out in the classroom, additional research time will be provided.

Reflection: Reflect upon the successes and shortcomings of the lesson.