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A Framework and Exploration of a Cybersecurity Education Escape Room

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ABSTRACT

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This thesis presents a review of educational-escape-room literature followed by a design-oriented framework (the Snyder Escape Room Framework or SERF) and demonstrates the potential efficacy of escape-rooms in cybersecurity education. Several authors have proposed frameworks and guidelines for game and educational design regarding escape rooms. This work coalesces some of those ideas into a more substantial and comprehensive framework (SERF) that designers can use when developing educational escape rooms. The Snyder Escape Room Framework provides heuristics for goals and objectives, players, activities, context, trajectory design, and evaluation.

Additionally, this work describes and analyzes the novel prototyped BYU GCC escape room experience and delves into some of what was successful and what could be improved. The first sessions of the experience were observed and documented, and an expert review was performed. Participants did not gain much confidence in learning new technology; however, they did increase their confidence in using new technology through the experience. Participants did indeed learn from the experience, however, participants focused more on team-related concepts gained from the experience rather than the cybersecurity concepts introduced through the escape-room activities. Based on overwhelming positive responses, participants seemed to enjoy performing the experience.

The BYU experience is evaluated against the Snyder Framework as an example of how to use the framework while designing or as a tool for evaluating. Using this framework systemizes and catalogues design choices and implications on the room and provides an informed approach for refinement. Applying the Snyder Escape Room Framework to the BYU experience provides further insight beyond just an expert review, and the BYU experience is a novel example to use with SERF. SERF gives a vocabulary and set of heuristics that help designers zero in on important design decisions. Using the framework provides a well-defined set of attributes for discussing the BYU experience and helps clarify what went well with the room and what could be improved upon. This is especially helpful when iterating on room design.

The nature of Snyder Framework and this work is that it is multidisciplinary and touches a wide array of related fields and topics. Of note, are the implications of this work on educational games. The SERF can be used as a resource when designing similar experiences while the analysis of the BYU experience based on the SERF provides an example of how the framework can be used for evaluation and iteration.

Keywords: snyder, escape room, design framework, cybersecurity, education, serf, gcc

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1 INTRODUCTION

1.1 Nature of Problem

Much of cybersecurity training consists of classroom learning sprinkled with labs. Cybersecurity in the real world remains far different from classroom education. But far worse is the lack of available professionals in cybersecurity: “There were 200,000 cybersecurity job vacancies in 2016. Researchers forecast that by 2019 there will be a global deficiency of 1.5 million cybersecurity professionals” and some researchers also indicate “that the cyber personnel deficiency will exceed 3 million by 2021. A Ponemon Institute's research project surveyed 504 participants in which 70% of the respondents indicated a scarcity in cybersecurity talent while a 2015 ISACA study involving 3,439 participants from 129 countries revealed that 90% reported cybersecurity personnel scarcities as a national-level issue” (Nobles and Burrell n.d.). To address the dearth of cybersecurity specialists, cybersecurity education and recruitment must be improved.

Some attempts at educational improvements have been made: capture-the-flag events, red team vs blue team, and competitions (Eagle 2013). Other improvements in education have seen some success such as educational simulations and alternate reality games. Escape-the-room games have also been increasing in popularity but have not been used in education yet. No one has mixed cybersecurity-training with escape-the-room games.

Considering the lack of cybersecurity practitioners in the field, more cybersecurity students are still needed (Nobles and Burrell n.d.). Giving would-be cybersecurity practitioners a taste of the field through a hands-on escape-the-room type experience could be the experience they need to get them excited and interested in cybersecurity topics.

This is an opportunity. If executed correctly, escape-room games could potentially be an effective tool in cybersecurity education and in cybersecurity recruitment.

Ultimately, without increasing the number of cybersecurity specialists and their capabilities and skill sets, attackers will always be ahead - they will continue to have free reign of our cybersystems and could potentially undermine the entire underlying structure that we as a modern society have come to rely on. Addressing cybersecurity education in unique ways – such as through escape rooms – is a positive first-step in adding more and better trained cybersecurity specialists to the field to address this growing threat.

1.2 Purpose of Research

The purpose of this research is to investigate cybersecurity education experiences in an escape-the-room environment – particularly with those recently introduced to cybersecurity, such as middle-school and high-school students.

1.3 Key Terms

Escape-room or escape-the-room: game type where players are placed in a "locked" room and their goal is to solve puzzles and clues to escape.

Gamerunner: person aiding or facilitating the game experience.

Cybersecurity: computer field that defends computers and computing infrastructure from attacks and intrusions.

1.4 Research Objectives and Questions

This research has the following objectives and corresponding research questions:

Research Objective 1: Examine current literature and model the design space of educational escape rooms. Create the Snyder Escape Room Framework (SERF) for the design and evaluation of educational escape rooms.

Research Question 1a: What are the components of the design space of educational escape rooms? How are they related?

Research Question 1b: What were some of the design choices of the BYU IT escape room?

Research Objective 2: Observe and evaluate several educational escape-the-room sessions occurring at the BYU IT escape room. Distribute a written survey to the participants before and after regarding prior cybersecurity familiarity and impact of the experience.

Research Question 2a: How are players affected by the experience?

Research Question 2b: Do players find the experience fun or engaging? Do they feel they learned something? Would they continue with cybersecurity in the future?

Research Question 2c: What aspects of the experience do players enjoy most? Least?

Research Objective 3: Using a thematic-analysis approach, evaluate the BYU IT escape room and determine what was most effective in engaging and educating students with cybersecurity. Compare with the Snyder Framework.

Research Question 3a: Which elements of the experience were most/least valuable for learning?

Research Question 3b: What could be improved for future experiences?

1.5 Scope

The scope of this research is generally exploratory in nature. Little has been researched on escape-room games in education. This research is meant to be a starting point for more in-depth research. It examines the current literature on escape-room games and education and presents a prototype room as an example.

The review of the room is meant to be more of an overview rather than a granular study of the experience and the activities involved. While multiple sessions were observed, the sessions were not compared as part of an experiment.

Overall, this research is meant to examine the literature, develop a design-oriented framework (SERF), and demonstrate the potential efficacy of escape-rooms in cybersecurity education – particularly of an introductory nature.

1.6 Outline

This thesis is outlined as follows:

- Introduction
- Literature Review and Proposed Framework
- Methodology
- Findings
- Discussion

2 REVIEW OF LITERATURE

Current literature was examined, and the design space of educational escape rooms was determined. Focusing on game mechanics and learning outcomes, the design space and design choices were scrutinized. Similar and related work was reviewed for an understanding of common and best practices. The design choices of the escape room at BYU are explored in the discussion chapter. This chapter also presents a novel framework that identifies the key components of educational escape-rooms and their relationship to one another.

2.1 Introduction

Researchers have looked into cybersecurity education through games with varying success. Denning et al. took a novel approach to cybersecurity education through reskinning a Steve Jackson card game. The goal of the game and research was to "increase people's awareness of computer security needs and challenges" and "show that the information technology community and its professions are open to people of diverse backgrounds" (Denning et al. 2013).

While this game was more introductory in nature, Denning made some insightful points on why choosing a game for cybersecurity education was a good idea in the first place:

> If designed well, we argue that games can be an appropriate tool for seeding a large audience of people with a modest amount of security information. Briefly:

- Games can be fun, which gets people engaged.
- Games can give you permission to explore ideas and ask questions.
- Games are intended to have intrinsic entertainment value, which gets people to pick them up and use them on their own time (Denning et al. 2013).

Also "physical games can create social environments, which can foster interaction and discussion of ideas encountered." And "because physical games can create interaction between players, they are suitable for use in social gatherings" (Denning et al. 2013). These insights on games in general can be applied to escape-the-room games as well. Escape-the-room games by their nature are highly social and interactive and provide many opportunities for participants to discuss the game and the concepts being conveyed through the game.

But what is an escape-the-room game? Scott Nicholson defines escape rooms as "live-action team-based games where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal (usually escaping from the room) in a limited amount of time" (Nicholson 2015). Players initially search for all the clues and puzzles, and then attempt to figure out how they are all related. Often the solutions to puzzles will lead to other clues and puzzles. Usually, a gamemaster is also present to offer hints or explaining puzzles if the group has questions. Games can last 30 minutes to an hour, but generally should not be longer than that.

> Escape rooms require teamwork, communication, and delegation as well as critical thinking, attention to detail, and lateral thinking. They are accessible to a wide age range of players and do not favor any gender; in fact, the most successful teams are those that are made up of players with a variety of experiences, skills, background knowledge, and physical abilities. As they are live-action games taking place in the physical world, they create opportunities for players to engage directly with each other in the same way that tabletop games do; players eager to look at something other than a glowing screen are flocking to games in the physical world for face-to-face engagement opportunities (Nicholson 2015).

Because escape rooms are so accessible, they make for a great platform for learning and assessment. In fact, escape rooms often draw from a wide variety of similar mediums as seen in Figure 2-1 below (Nicholson 2015).

Figure 2-1: Escape Rooms Share Attributes from Multiple Similar Mediums

"Inspiration [comes] from a variety of genres such as live-action role-playing, point-and-click adventure games, puzzle hunts, interactive theater, and haunted houses that created the spark in someone's head to create an escape room" (Nicholson 2015). Being rooted in multiple backgrounds allows escape rooms to be flexible and have a wide variety of puzzles and themes. Designers with a mind toward education can present and incorporate multiple topics within a single game. Coupled with a wide audience, escape rooms make for an ideal educational platform.

Nicholson explains,

> Live-action games, such as escape games and simulations, are ideal for in-person classrooms, as they can be developed to require little technology and can take advantage of the shared physical space in which classrooms are set. Unlike screen-based games, live-action games bring the players in face-to-face contact with each other and immerses them directly into the game world, which is the physical world the players inhabit."

He goes on highlighting the teamwork aspect of escape games:

> Escape games are cooperative games, so the players work together to win or lose as a team. Having a shared environment in which players are working together on a game designed around specific learning outcomes sets the groundwork for active learning and social constructivism. The team of players takes the prompts and artifacts and brings them to life by engaging with them and with each other to explore a narrative-driven challenge.

Additionally:

> Escape games are based on solving puzzles and accomplishing tasks. Unlike many screen-based games that are based around hand-eye coordination or board games that are based on strategy and luck, escape games are built around using the mind to solve challenges. They are a natural match to the learning environment of the classroom and the types of activities that students already do, and can result in more engaging educational games than shooting asteroids that match the answer to a math problem or answering trivia questions from cards.

2.2 Escape Room Framework

A few frameworks have been created to address designing escape rooms and using them as educational platforms. Two will be expanded upon here as part of a proposed educational escape room design framework: Clarke's EscapED framework and Nicholson's Ask Why framework. Ideas from these frameworks and other authors are combined and extended to create the Snyder Escape Room Framework (hereafter referred to as SERF or Snyder Framework).

EscapeED provides some excellent skeletal structure. Clarke proposes six stages in developing an escape room: "participants, objectives, theme, puzzles, equipment, and

evaluation" (Clarke et al. 2014) – each stage waterfalling into the other. However, each stage influences the others and should be designed with that in mind. This would help designers have a more iterative and complete design process. Objectives should also come before participants as the designer's goals and objectives will help select the appropriate players as well as have better organization and structure from the beginning. Furthermore, while the EscapED Framework covers many important escape-room concepts, further research demonstrates that this framework can be extended with additional design concepts and heuristics as explained below.

I propose reordering and regrouping the structure into the following:

- Goals and Objectives
- Players
- Activities
- Context
- Trajectory Design
- Evaluation

2.3 Goals and Objectives

Escape games can easily turn into complicated and convoluted bodies of content and puzzles. Having a clear room goal helps to mitigate this confusion and helps the designer stay focused. Before the designing anything, a clear goal should be established. Designers should consider the following questions when establishing a goal:

1. What is the overall purpose of the room? How will the designer know when the room is successful?

2. What are the learning outcomes or assessments this room is going to support? How many is sufficient without overloading participants?

A clear goal helps the designer evaluate the room and will be crucial later in this framework.

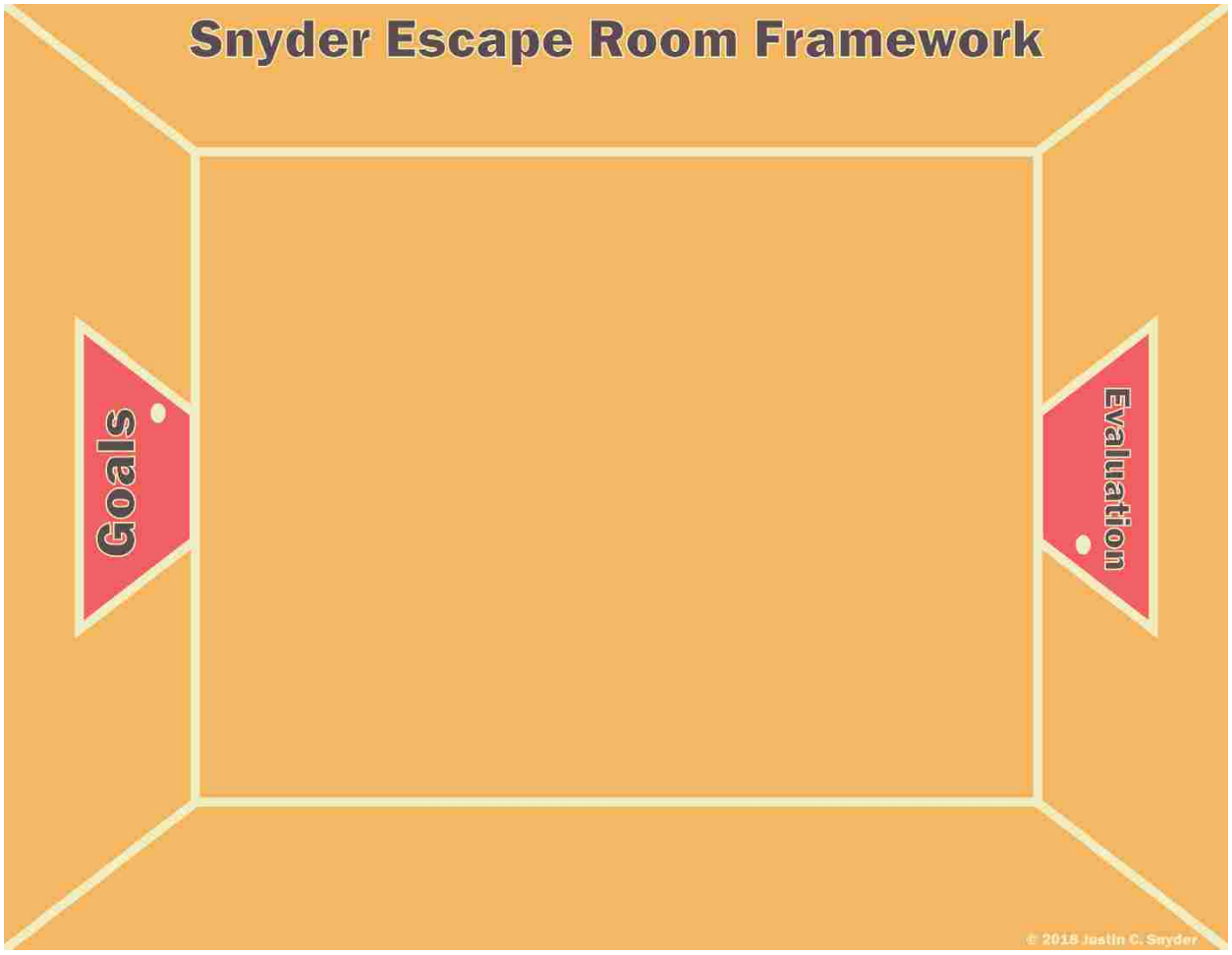

Figure 2-2: Goals and Objectives Provide Clear Direction for Evaluation

"Once the goal is established, the challenge is to break down what you want to accomplish into smaller, more specific tasks that will combine to accomplish the goal" (Wilson and Ogden 2008). These are the designer's objectives. Objectives are the milestones that help the designer reach the goal of the room. "Good objectives are specific and clearly defined. They are written and measurable…They should also be realistic and attainable" (Wilson and Ogden 2008). Objectives help the designer break the goal down into manageable tasks. These objectives can then be used as a benchmark to measure success. This will be discussed further in the evaluation section.

Clarke recommends creating learning objectives as well:

> Learning objectives are required to create a meaningful educational game. These objectives can be worked into the theme, its puzzles and its mode to help structure the learning plan. Creating tangible learning objectives allows evaluation of players learning experience, learning achievements and can be iteratively re-designed (Clarke et al. 2014).

2.4 Players

A well-designed room will be tailored to a certain type of player or certain types of players. Once a room's goals and objectives are determined, a designer should nail down who the game is specifically for. A good designer will create player types to cater to – akin to the practice of creating personas when developing or advertising products ("Personas" n.d.). Designers should understand their players intimately. Player considerations include:

- Demographics
- The player's self-interests

- The player's relationship with the room and learning objectives
- The player's relationship with other players

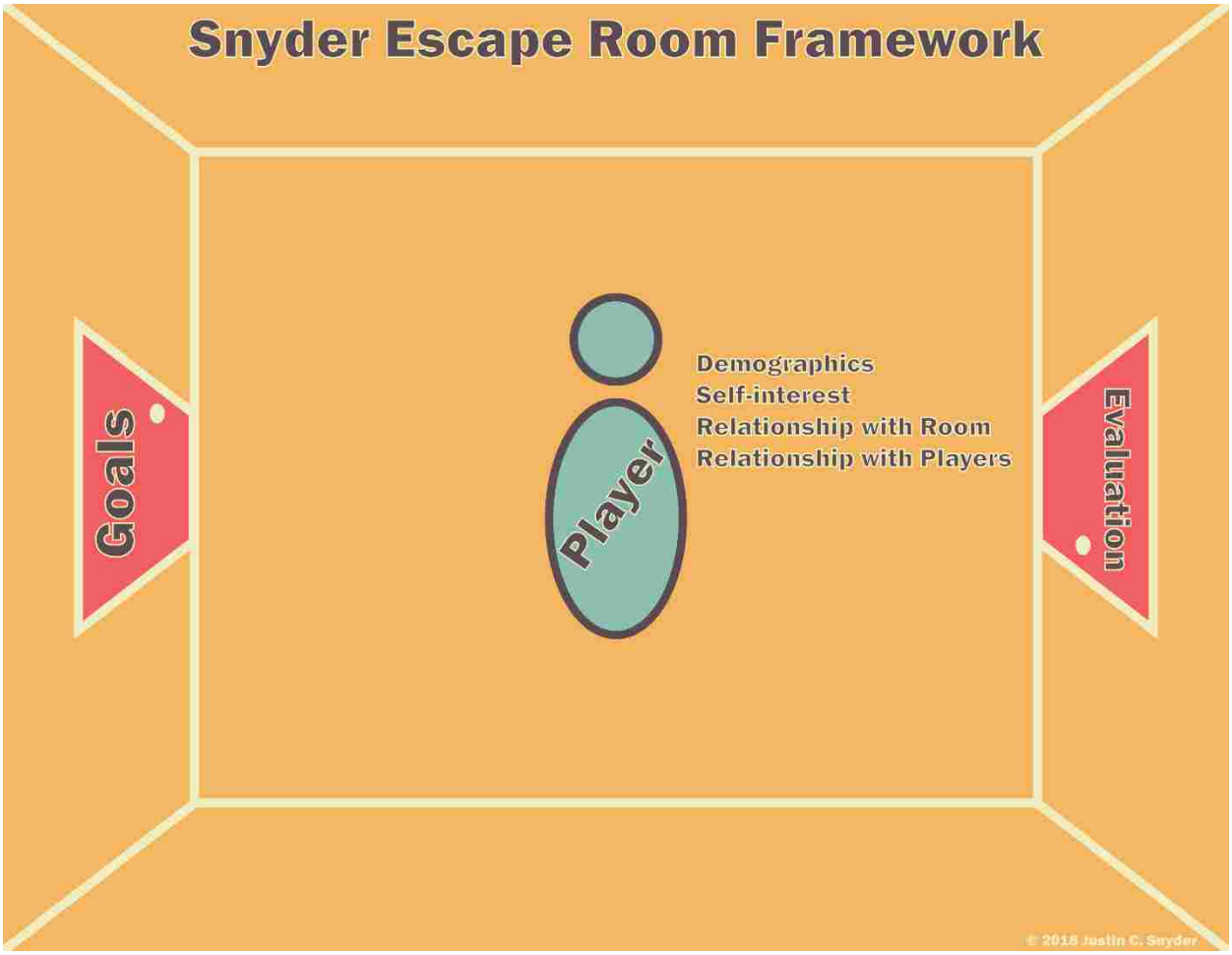

Figure 2-3: Well-Designed Rooms Center on the Player

2.4.1 Demographics

We know that all individuals are each unique, but when creating something meant to be enjoyed by vast numbers of people, we have to consider ways that groups of people are the same. We call these groups *demographics*, or sometimes *market segments*. There is no "official" means of establishing these groups – different professions have different reasons for grouping them differently. For game

> designers, the two most significant demographic variables are age and gender. We all play differently as we get older, and males and females play differently than one another at all ages (Schell 2008).

Different players have different needs. Clarke also advocates establishing user types: a "user needs assessment is [to be] carried out to determine player demographic and educational needs" (Clarke et al. 2014). Good designers should research their players as much as needed for the room goal. As suggested by Schell, designers should know their player type's age and gender, but also may need to know more things such as the player type's geographic location, socioeconomic status, common interests, existing educational level or even what roles they take on in life (i.e. student, brother, sister, daughter, son, employee, etc.). The more the designer can know about the potential player, the better the designer can design for the player.

2.4.2 Player Motivations

Good designers should know what motivates their players. Demographics influence player self-interests. For instance, Schell details that different ages have different roles and goals they are attempting to achieve. This effects how that age demographic will approach play such as when children aged 7-9 years "start making their own decisions about what kinds of toys and games they like and dislike, no longer just accepting whatever their parents choose for them", or teens whose job "is to start getting ready for adulthood" (Schell 2008). He then goes on to describe some general differences between boys and girls and what they are interested in getting out of play. He gives five major attributes for each gender. Boys enjoy mastery, competition, destruction, spatial puzzles, and trial and error. Girls enjoy emotion, real world, nurturing, dialog and verbal puzzles, and learning by example (Schell 2008). Schell makes an important note that these are extremely generalized, and further categories and interests could be enumerated for

each gender. However, these lists are included to help designers start thinking about what interests their players have.

At a more fundamental level,

> ultimately, the motivation for every human action can be traced back to some kind of pleasure seeking. It is a tricky business, though, for there are many kinds of pleasures in the world, and no one seeks only one kind. But it is certainly true that people have their pleasure preferences. Game designer Marc LeBlanc has proposed a list of eight pleasures that he considers the primary 'game pleasures,'

namely sensation, fantasy, narrative, challenge, fellowship, discovery, expression, and submission (Schell 2008). Schell continues with Bartle's taxonomy of player types: achievers, explorers, socializers, and killers. Each of these player types finds delight in their namesake – achievers enjoy achieving, etc. Schell adds that killers are probably a mix of the pleasures of competition and destruction. Finally, he follows up with more pleasures in his own list: anticipation, delight in another's misfortune, gift giving, humor, possibility, pride in an accomplishment, purification, surprise, thrill, triumph over adversity, and wonder. Again, this is not meant to be an exhaustive list, but more of a jumping off point for room designers to consider when researching their players. A good room will leverage its player's motivations and pleasures.

2.4.3 Player Relationship with the Room

Designers need to also account for their players' relationship with the room being designed. For most players it will likely be their first time through the room, however, a player's familiarity with the room will strongly affect the player's experience. Some players may have never encountered an escape room before. Others may have never had any experience with the theme, narrative, or puzzle type. Still others may have never had any experience relating to the

learning objectives of the room. A good designer will compensate for this lack of familiarity. Conversely, having some idea of what the player already knows or has already experienced will greatly help in room design. If designers know their players have some familiarity with aspects of the room, they can use that to their advantage – potentially speeding up the room learning curve or puzzle design. Catering to players who may replay a room can be particularly challenging since unchanging puzzles are easy once a solution is known.

2.4.4 Coop Considerations

If more than one player at a time is experiencing an escape room, the designer has an opportunity to create competitive or cooperative play. This social dynamic of escape rooms adds another layer to room design and can be a great way to introduce learning experiences related to teamwork and other positive social interaction.

> Escape games are cooperative games, so the players work together to win or lose as a team. Having a shared environment in which players are working together on a game designed around specific learning outcomes sets the groundwork for active learning and social constructivism. The team of players takes the prompts and artifacts and brings them to life by engaging with them and with each other to explore a narrative-driven challenge (Nicholson 2018).

Players' relationships with each other can strongly influence the experience. Designers should consider what types of interpersonal relationships their players will have with one another vis-à-vis this observation of escape rooms:

> Players and groups come into the escape room with an existing set of social roles and structure. For example, some people were used to being social leaders in a group because of workplace or family dynamics and hierarchy (e.g., a manager of a workgroup, a parent of a family). These dynamics sometimes dissolved in the escape room and new ones emerged based around one's experience with puzzle solving tasks. If players are not expecting a shift in social status and it occurs, social conflicts may arise (Pan, Lo, and Neustaedter 2017).

For example, will the room experience be catering to families? Then the room should work with parent-child relationships and a wide variety of ages. Perhaps the room experience will cater to a group of friends or coworkers. Room design should consider those types of relationships. Frequently, escape rooms will put several groups of strangers through an experience. Designers should be prepared to work with these relationships ways that are comfortable and best for their players. Often escape room experiences can foster fellowship as players learn to work together better to solve problems. Fellowship is one pleasure highly prevalent in escape room games. Collaboration is discussed below.

2.5 Activities

An escape room experience is made up of many smaller experiences. Nicholson refers to them as challenges and suggests that there are three types:

- Searching, where the players are looking for something physically hidden in the space. Most searching tasks have an unknown end state, so the players are continually searching in the room.
- Puzzles, where the players are attempting to discover [or develop] an answer that is hidden within a game-based space.
- Tasks, where the players are given a set of resources and an end goal, and have to determine and execute the best process to reach that goal (Nicholson 2016).

Nicholson further explains, "A challenge can have aspects of all three tasks; for example, the players may have to locate things in the room, assemble them into a tool, and then use that tool to carry out a physical task" (Nicholson 2016).

For the Snyder Framework, these smaller experiences will be called activities. Borrowing from Nicholson, these activities are made up of smaller units called tasks. Escape rooms can draw from a number of tasks, but have come to be known by a few core tasks:

- Sense-making
- Searching
- Collaborating
- Puzzle-solving

Traditional escape rooms use combinations of these tasks repeatedly, and often layered, to create activities that shape the room's unique escape experience.

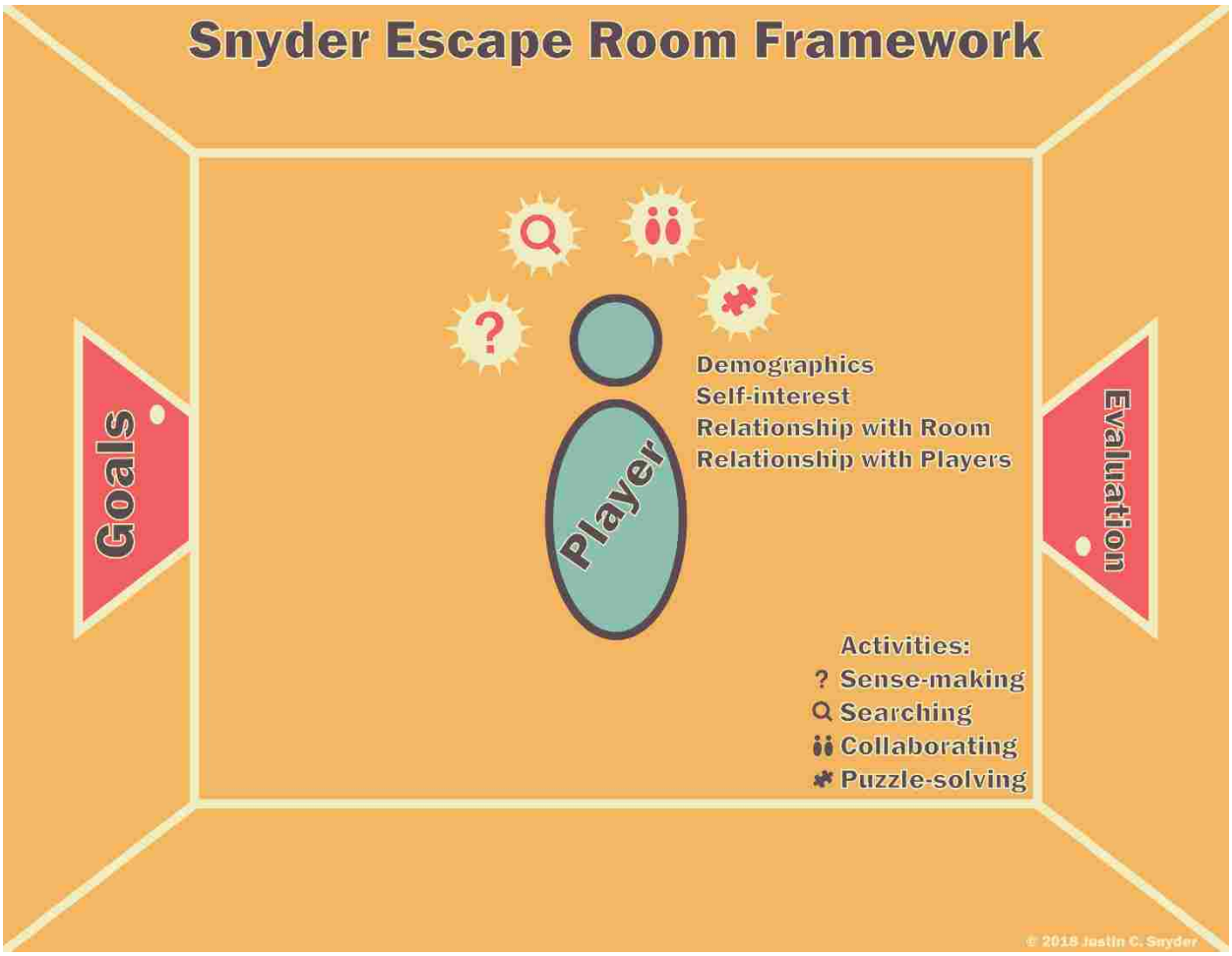

Figure 2-4: Escape Rooms Have Activities

2.5.1 Sense-Making

Sense-making is taking time to think about and come to conclusions about an environment, object, or activity.

> Sensemaking, as in to make sense, suggests an active processing of information to achieve understanding (as opposed to the achievement of some state of the world), and this is sense in which we mean it here: Sensemaking involves not only finding information but also requires learning about new domains, solving ill-structured problems, acquiring situation awareness, and participating in social exchanges of knowledge. In particular, the term encompasses the entire gamut of behavior surrounding collecting and organizing information for deeper understanding (Pirolli and Russell 2011).

Often it also involves making connections between different and sometimes disparate things. Consider when players first walk into the room. The players immediately engage in sense-making and start solving the problem of where to start – looking for the dominant strategy that will help advance the room the quickest. As they take in the room they find themselves in, they begin to make judgements and conclusions about what to do next – one of the other core tasks of searching, collaborating, or puzzle-solving. Each of these tasks then leads to further sense-making, and so on. Sense-making is a critical problem-solving activity that advances the players through the room – and is an activity that players will come back to again and again as they begin to see the connections between puzzles within the room.

2.5.2 Searching

Searching tasks involve finding an object or a clue that advances the player. Searching taps into the pleasures of discovery and surprise. Likely, searching will lead to further sense-making or a puzzle. Searching is relatively straightforward, but some skill is required in determining what is relevant to the search and what will advance the player in the room. Searching shares qualities with what Shan-Ju Chang defines as browsing:

> Browsing [or searching], in essence, is an examination of unknown items of potential interest by scanning or moving through an information [or game] space in order to judge the utility of the items [or game objects and mechanics], to learn about something of interest in the item, or to satisfy curiosity about something. Browsing [or searching is often associated with the vagueness of information objects sought in order to make a value judgment. The nature of browsing [or searching] is fundamentally evaluative and inclusive. At the micro-level, the nature of a browser's [or searcher's] goal and specificity of object sought are the two most important factors influencing the way people browse (Chang 2005).

Chang provides a multidimensional framework for browsing which again translates well to searching tasks. He defines four aspects of browsing (or searching): scanning, resource, goal, and object (Chang 2005). Each of these aspects can be further broken down.

Within an escape-room context, a player when scanning can be looking for, identifying, selecting, or examining. The resource would be the room itself including all objects and mechanics. The player's goal could be to locate, evaluate, keep up, learn, satisfy curiosity, or be entertained. Finally, the object a player is searching for could be a specific item, common items, a defined location, or general searching (Chang 2005). Designers can use this list to mix and match searching tasks.

Searching tasks need to be appropriate to the demographic of the player. Too little searching tasks and the designer risks the room being too straightforward or simplistic – and the sense of discovery is lost. Too many searching tasks create a room that is more of an egg hunt and can potentially bottleneck players that cannot find all the hidden clues. Designers should also tailor the difficulty of finding clues to their players. Finding something that is cleverly hidden can be quite a joy for players, but quite frustrating if never found.

2.5.3 Collaborating

Most rooms are designed to be played by more than one player. Add cooperative players to a room and collaboration becomes possible. Collaboration can happen at any point, but good designers will create places for collaboration to more naturally occur. According to Schell, "Collaborating and succeeding as a team is a special pleasure that can create lasting social bonds" and "games provide a very socially safe way to explore how the people around us behave in stressful situations – this is a secret reason we like to play games together" (Schell 2008). Schell recommends designers ask these questions:

- Cooperation requires communications. Do my players have enough opportunity to communicate? How could communication be enhanced?
- Are my players friends already, or are they strangers? If they are strangers, can I help them break the ice?
- Is there synergy (2 + 2 = 5) or antergy (2 + 2 = 3) when the players work together? Why?
- Do all the players have the same role, or do they have special jobs?
- Cooperation is greatly enhanced when there is no way an individual can do a task alone. Does my game have tasks like that?
- Tasks that force communication inspire cooperation. Do any of my tasks force communication? (Schell 2008).

As Nicholson has mentioned, escape rooms are known for fostering teamwork and creating interpersonal experiences for players – the medium lends itself well to this type of behavior. A well-designed room takes advantage of these attributes. According to Clarke, "Interactive live-action games can aid development of soft skills such as communication and leadership" (Clarke et al. 2014). She recommends designers "develop problem solving challenges to make the game experience interesting to players. A range of challenges will appeal to different learner types". This additional layer should be kept in mind as a room is designed.

Additionally:

> Escape rooms provide people with opportunities to practice their collaboration skills where they are able to perform various nuanced collaborative acts. Team members move between loosely and tightly coupled group work and can practice methods to smoothly do so; they can practice gathering situational and workspace awareness; they can practice their communication skills; and, they can practice the development of a shared mental model. The time pressure of the room tends to cause people to 'not hold back'; thus, it brings out somewhat of a more 'authentic' form of a person in a short manner of time. That is, one can see how another reacts and collaborates when under time pressure and a potentially increased amount of stress as a result. This could certainly be advantageous as a means to learn about others and develop team skills in a short amount of time (Pan, Lo, and Neustaedter 2017).

Consider adding spaces that encourage collaboration such as meta-puzzles that require other puzzles and clues around the room to complete. As players discover new clues and parts of puzzles, they will be brought together to communicate and collaborate to solve the room.

2.5.4 Puzzle-Solving

Escape rooms usually rely heavily on puzzles, but what is a puzzle? Schell gives this definition: "A puzzle is a game with a dominant strategy" (Schell 2008). Part of the fun becomes discovering that dominant strategy. While doing so, players engage in quite a bit of sense-making – in fact, puzzles could be described as a specific type of sense-making or problem-solving task. However, a discussion on puzzles is warranted due to their extensive use in escape rooms.

Good puzzles will take advantage of what Mihaly Csikszentmihalyi calls flow. Flow is characterized as being

> totally immersed in what you're doing, fully concentrating, and unaware of yourself. The activity you're performing is challenging and engrossing, stretching your skills and expertise. When in flow, people report feeling strong and efficacious, at the peak of their abilities, alert, in control, and completely

> unselfconscious. They do the activity for the sheer sake of doing it (Lyubomirsky 2008).

Human beings love being in a state of flow. According to Lyubomirsky, the mental state of flow is pleasurable and fulfilling – enjoyment that is lasting and reinforcing. Flow states are also intrinsically rewarding.

> The key to creating flow is to establish a balance between skills and challenges…if the challenges of the situation overwhelm your skill or expertise, you will feel anxious or frustrated. On the other hand, if the activity is not challenging enough, you will become bored. Flow is a way of describing an experience that falls in just the right space between boredom and anxiety (Lyubomirsky 2008).

Schell offers ten puzzle principles that encapsulate the idea of flow within the realm of puzzle design (Schell 2008):

1. Make the goal easily understood
2. Make it easy to get started
3. Give a sense of progress
4. Give a sense of solvability
5. Increase difficulty gradually
6. Parallelism lets the player rest
7. Pyramid structure extends interest
8. Hints extend interest
9. Give the answer
10. Perceptual shifts are a double-edged sword

The first four principles help the player feel in control – the player understands what is required with the sense of progress giving the player feedback along the way. The next three principles tap into the push-pull aspect of flow, keeping the player engaged and interested. Finally, the last three are related to the pleasure of puzzle-solving. Schell makes the point that players delight in seeing the answer or experiencing the change in perception that puzzles give – though designers need to be careful because if the player does not experience that perception change, then the player gets nothing out of it and becomes frustrated. Designers would do well to follow these principles when creating and playtesting puzzles.

Also, puzzles do not have to be solely within the intellectual domain. Many good puzzles also involve some aspect of physicality. Some escape rooms have puzzles such as traversing a laser maze or avoiding a chained zombie while working through the room. This creates another layer of puzzle solving and leverages the physical medium. Additionally, not all puzzles are as discrete as what typically comes to mind such as the widely available brain-teaser puzzles or even jigsaw puzzles. Puzzles can be found not only dispersed about an escape room, but also as part of the room in various ways.

Puzzles can facilitate learning in ways that other activities do not. “The puzzle-based learning approach aims to encourage students to think about how to frame and solve problems” (Falkner, Sooriamurthi, and Michalewicz 2010). Furthermore,

> The ultimate goal of puzzle-based learning is to lay a foundation for students to be effective problem solvers in the real world. At the highest level, problem solving in the real world calls into play three categories of skills: dealing with the vagaries of uncertain and changing conditions; harnessing domain specific knowledge and methods; and critical thinking and applying general problem- solving strategies (Falkner, Sooriamurthi, and Michalewicz 2010).

Falkner et al. explain that educational puzzles that support problem-solving skills and creative thinking should have the following attributes:

1. Independence: The puzzles are not specifically tied to a single problem-solving domain.
2. Generality: Educational puzzles should explain some universal mathematical problem-solving principles.
3. Simplicity: Educational puzzles should be easy to state and easy to remember.
4. Eureka factor: Educational puzzles should initially frustrate the problem solver, but with the promise of resolution. A puzzle should be interesting because its result is not immediately intuitive. Eventually a Eureka! moment is reached…when the correct path to solving the puzzle is recognized.
5. Entertainment factor: Educational puzzles should be entertaining and engaging. Entertainment is often a side-effect of simplicity, frustration, the Eureka factor, and an interesting setting (Falkner, Sooriamurthi, and Michalewicz 2010).

Notice the similarities with Schell on points three through five. Good *educational* puzzle design stems from good puzzle design.

2.5.5 Creating Learning-Based Activities

The above tools provide the structure for activities. Each activity can be designed around a learning outcome. In fact, each sense-making task is a learning opportunity – either teaching a player how to play (often referred to as onboarding) or teaching a player how to learn (also known as educational scaffolding).

> Scaffolding techniques are often needed to help students succeed in their learning and to achieve the expected learning outcomes. Scaffolding techniques are processes, such as coaching through prompts, templates and guides, tools or strategies that teachers implement in order to support a student, that thoroughly guide students towards the successful completion of a learning activity (Melero, Hernández-Leo, and Blat 2011).

Each activity should include onboarding and scaffolding according to player needs.

Activities are a particularly good space to learn and practice skills in a safe environment. Following the principles of flow and puzzles as outlined above, designers help players get into the state of flow as they learn and practice the skills these activities are based on. Designers can then add similar learning-based activities throughout the room for repetition and reinforcement of concepts and ideas – creating parallelism.

Because activities are the primary way of fulfilling room goals, designers should create them first. This ensures that no learning objectives will be left out or shoehorned in at the last minute. It can be fun to start with a theme or narrative, but designers will often find that it is easier to create the context around activities rather than vice versa. A designer's

> sole responsibility is to know what the game is about and to ensure that the game teaches that thing. That one thing, the theme, the core, the heart of the game, might require many systems or it might require a few. But *no system should be in the game that does not contribute towards that lesson.* It is the cynosure of all the systems; it is the moral of the story; it is the point (Koster 2014).

2.6 Context

Context gives meaning to the activities that the players do. Context helps tie everything together into a cohesive experience and fills the space between activities. Context provides the framing needed to support activities. Context includes things such as theme and narrative – but also includes things such as the physical and game environments. The theme and narrative are placed on the walls of the SERF demonstrating that this is what players see and interact with as they enter and work through the room. The physical and game environments are depicted as being on the floor as this is the space players work within – they are constrained by these environments (see Figure 2-5). Context gives life and character to an escape room.

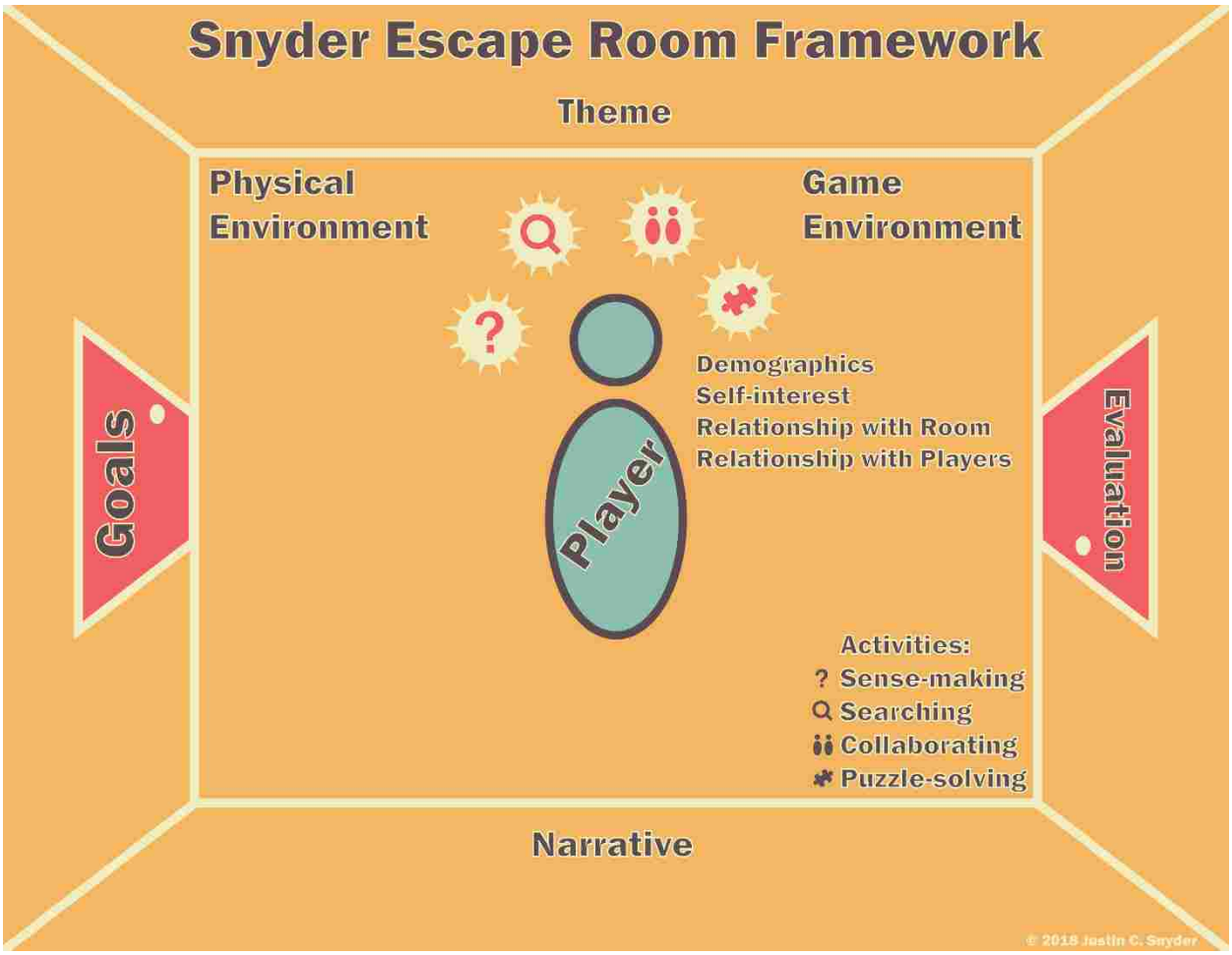

Figure 2-5: Filling the Room with Context Supports the Activities

2.6.1 Theme

A theme is akin to a setting where and when the room takes place and includes recurring elements to help reinforce that concept. Many escape rooms have a central theme that weaves the activities and context together. A good theme unifies the room's look and feel, but a great theme gives the room a beating heart and can help touch and shape tasks and activities.

Nicholson breaks up the idea of a theme into three parts:

- Genre – the overall category of the general experience of the room. The genre is one of the few things marketed about the room, and guides players as to what overall experience they are going to have (e.g. horror, heist, detective, exploration).
- Setting – the physical place where the game is set. This may or may not be marketed with the genre. The physical set for the game helps the player engage with the setting (e.g. a laboratory, a dungeon, someone's office, a museum).
- World – the external world in which the game is set. This may include a timeframe, a physical location, a historical event, or a fictional place (e.g. the 1920's, during the Cold War, in an alien-infected space station) (Nicholson 2016).

Genre, setting, and world all contribute to the room's theme. Simple themed rooms could include a detective-themed room or a future-themed room, but more complex themes could be a Sherlock Holmes room or a lunar colony room. Specificity and attention to detail assist in creating a more immersive experience: "What games do best will almost certainly center around their ability to give concrete shape to our memories and imaginings of the storyworld, creating an immersive environment we can wander through and interact with" (Jenkins 2003). Also, including a narrative often helps to reinforce a theme and give further meaning to room activities.

2.6.2 Narrative

Narrative or storytelling can provide impetus for the various activities in an escape room, but often it will be introduced and discovered in bits and pieces. Narrative within an escape room is like narrative within other types of transmedia narratives and games – sometimes that means a cutscene, but in most cases the narrative is embedded into the game environment itself. Jenkins explains, "Environmental storytelling creates the preconditions for an immersive narrative

experience in at least one of four ways: spatial stories can evoke pre-existing narrative associations; they can provide a staging ground where narrative events are enacted; they may embed narrative information within their mise-en-scene; or they provide resources for emergent narratives" (Jenkins 2003). Escape rooms are an opportunity to tap into all four ways. Jenkins explains:

> In each of these cases, choices about the design and organization of game spaces have narratological consequences. In the case of evoked narratives, spatial design can either enhance our sense of immersion within a familiar world or communicate a fresh perspective on that story through the altering of established details. In the case of enacted narratives, the story itself may be structured around the character's movement through space and the features of the environment may retard or accelerate that plot trajectory. In the case of embedded narratives, the game space becomes a memory palace whose contents must be deciphered as the player tries to reconstruct the plot and in the case of emergent narratives, game spaces are designed to be rich with narrative potential, enabling the story-constructing activity of players. In each case, it makes sense to think of game designers less as storytellers than as narrative architects (Jenkins 2003).

Escape rooms allow players to physically interact with the narrative – and to even be present within the narrative. A good narrative embedded within the game adds significantly to the immersivity of the player.

2.6.3 Physical Environment

The physical environment is the platform for theme and narrative, and it is this raw material combined with the catalyst of activities that brings forth player experience. The physical environment includes things such as set pieces and props as well as actors, technology used, etc. It is the stage where the player experience will take place. "Game designers don't simply tell stories; they design worlds and sculpt spaces" (Jenkins 2003).

Like the theme and narrative, the room's physical environment supports (or detracts) from the activities and overall learning outcomes. It can sustain and encourage flow or pull a

player right from it. “Part of the art of game design comes in finding artful ways of embedding narrative information into the environment without destroying its immersiveness and without giving the player a sensation of being drug around by the neck” (Jenkins 2003). Each prop, set piece, actor, technology, moderation technique, etc. is an opportunity to encourage immersivity; one piece out of place can be jarring for the player. That piece becomes a distraction and can take them right out of flow.

However, some limitations to immersivity need to be made, such as allowing players to use the bathroom or to leave the room in an emergency. Other limitations may include compensating for a lack of technology or budget. But a good designer will try to limit these moments and keep players in flow as much as possible.

2.6.4 Game Environment

While the physical environment focuses on the tangibles, the game environment consists of the intangibles: artificial constraints, the definition of the play space, and other mechanics that define how the game is played. “Every game takes place in some kind of **space**. This space is the “magic circle” of gameplay. It defines the various places that can exist in a game, and how those places are related to one another” (Schell 2008). This space is constrained by rules: “Rules are the most fundamental of all game mechanics. A game is not just defined by its rules, a game *is* its rules” (Schell 2008).

A good example prevalent in escape rooms is the countdown timer. It usually constrains the room experience to 45 minutes to an hour creating a sense of urgency for players. Combined with a leaderboard, it provides a reason for a group to band together as a team to compete against other participants on the leaderboard.

Like the physical environment, the game environment can contribute or detract from a player experience, and must be planned with as much care as the physical environment.

2.7 Trajectory Design

How should a user experience such as escape rooms be designed? Benford et al. examined underlying concepts in interactive user experiences. Benford selected examples that demonstrate "key challenges for designing engaging user experiences that draw together multiple technologies, interfaces, physical artifacts and people into complex structures that extend across space and time" (Benford et al. 2009). Escape rooms fit well within these types of user experiences. Benford's answer was "trajectories". According to Benford,

> the essential unifying characteristic of [their] four user experiences is that they take their participants on journeys. While these journeys may pass through different places, times, roles and interfaces as we discuss below, they maintain an overall sense of coherence; of being part of a connected whole. These journeys are steered by the participants, but are also shaped by narratives that are embedded into spatial, temporal and performative structures.

Also, "each participant follows their own trajectory, which may be shaped and steered, and may cross those of others. Trajectories appear to be continuous, extending backwards in time to reveal a coherent history of experience, and forward in time to suggest anticipated routes and possible future actions" (Benford et al. 2009). This is particularly the case for escape-the-room games. Multiple trajectories – both for individuals and groups – are inherent in escape room games.

But what makes a trajectory? Benford posits "the structure of interactive user experiences consists of four key facets that then combine together: space, time, roles and interfaces." And

> a trajectory describes a journey through a user experience, emphasizing its overall continuity and coherence. Trajectories pass through different hybrid structures.

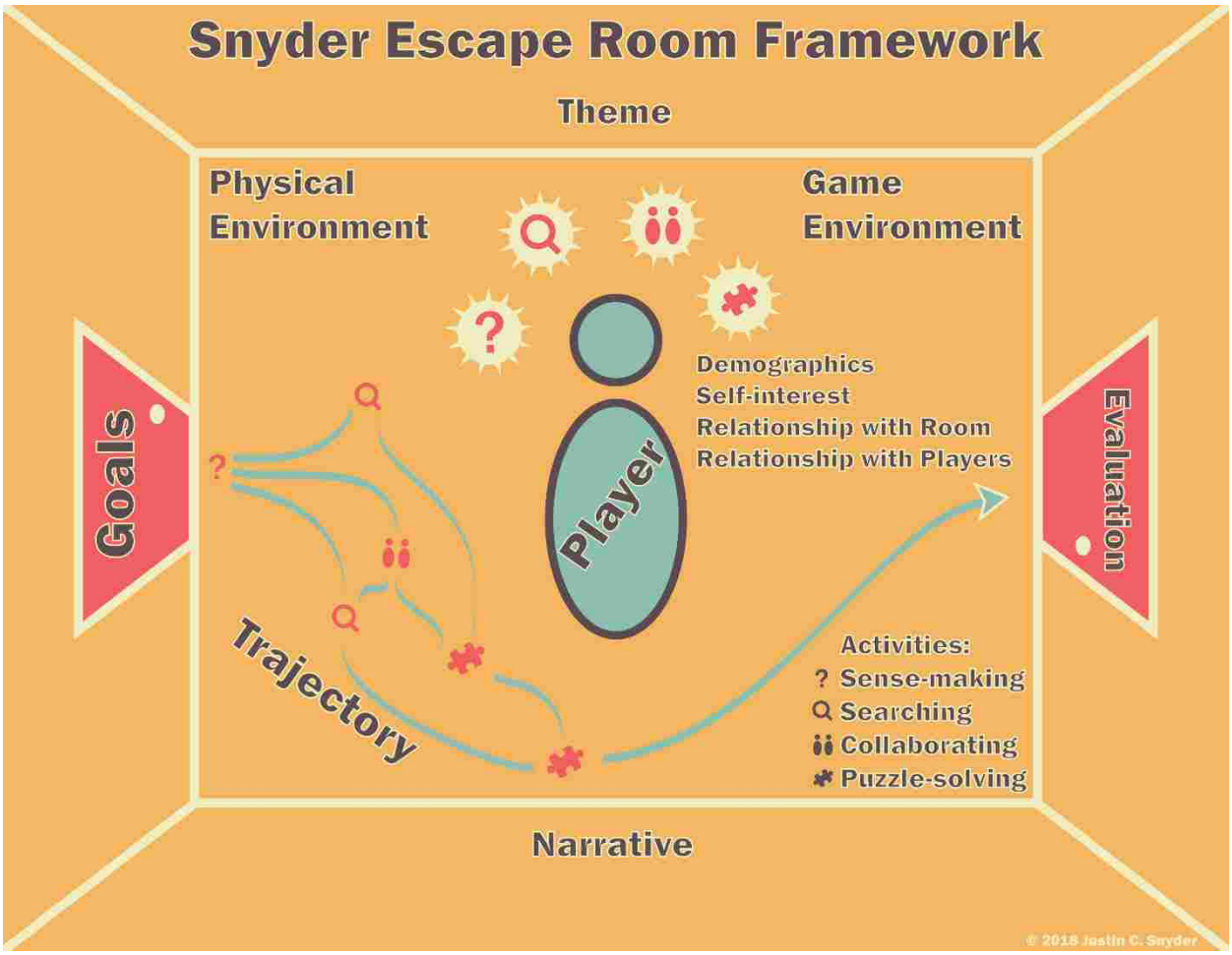

Figure 2-6: Players Can Select Different Trajectories in a Well-Designed Room

- Multiple physical and virtual spaces may be adjacent, connected and overlaid to create a hybrid space that provides the stage for the experience.
- Hybrid time combines story time, plot time, schedule time, interaction time and perceived time to shape the overall timing of events.
- Hybrid roles define how different individuals engage, including the public roles of participant and spectator (audience and bystander) and the professional roles of actor, operator and orchestrator.
- Hybrid ecologies assemble different interfaces in an environment to enable interaction and collaboration" (Benford et al. 2009).

Care also needs to be taken to provide immersion and suspend disbelief:

While trajectories through an experience are ideally continuous, maintaining continuity can raise significant challenges in practice. There are critical moments

> in an experience at which users must cross between spaces, rub up against schedules, take on new roles, or engage with interfaces, which need to be carefully designed if continuity and therefore coherence is to be maintained. We capture this in the idea that there are key transitions in each trajectory, moments at which, for whatever reason, continuity is at risk. Experience designers need to be aware of these moments and have at hand strategies for dealing with them (Benford et al. 2009).

"Interactive experiences enable each participant to define their own trajectory, making individual choices and following personal routes. However, this is not an entirely free choice. Artists carefully define one or more ideal routes through the hybrid structures of each experience as part of its overall narrative" (Benford et al. 2009). Essentially, the designer provides the trajectory architecture: a set of many possible trajectories through the activities. Players then explore this architecture and select which trajectories to take while advancing through the room (see Figure 2-6). Again, this is especially true for escape rooms. Within these trajectories, concepts can be introduced and taught – or skills and learning can be assessed. A trajectory becomes a medium for education.

But ultimately, "the purpose of cultural user experiences" – and escape-the-room games – "is not to reach a destination, solve a problem, or complete a task, but rather to enjoy an engaging journey" (Benford et al. 2009).

2.8 Evaluation

When clear goals and objectives are established for a room, evaluation becomes a simple task of measuring the room against these goals and objectives. Designers can ask themselves several questions:

- Did the room meet these goals, objectives, and learning outcomes?
- What aspects of the room contributed to fulfilling the room goals, objectives, and learning outcomes?
- What aspects of the room detracted from the room goals, objectives, and learning outcomes?
- How can the room be improved to meet these goals, objectives, and learning outcomes?

These questions should be iterated on with several playtests to be effective. Each playtest will bring to light different issues that need to be addressed.

Scott Nicholson introduced a framework to more fully prune escape rooms: "Ask Why". "The concept of "Ask Why" is simple – a designer should look at each element of the player experience of an escape room and ask "Why is this here?" Each puzzle, task, and item in the escape room should be there for a reason that is consistent with the overall concepts behind the design of the room" (Nicholson 2016). Anything else should be cut. If part of the room does not contribute to those goals, objectives, or learning outcomes, it should be changed so that it does or be removed. Every room experience is necessarily limited by time and space. Often, the difference between a good room and a great room is how effectively the designers used that time and space.

3 METHODOLOGY

3.1 Approach

The BYU IT escape experience provided an opportunity to use the Snyder Framework for evaluation. Below is a summary of the methodology used for observing and analyzing the BYU IT escape experience.

In this study, students are put in a "locked" room and are presented with a series of cybersecurity-related puzzles that help them escape or "solve" the room. The room, provided by the BYU Cybersecurity Research Lab (CSRL), is created to look and feel like a spaceship bridge, and consists of several stations. Each of these stations grants control of a part of the "ship," and is staffed by a participant. Before the experience, moderators go into the room posed as the ship's engineering crew. They explain how the ship's systems work and teach the participants what they will be doing during their mission. This entire setup is driven largely by the spaceship bridge simulator Artemis; however, it has been modified to create a custom experience that puts a focus on the cybersecurity topics covered at BYU Girls Cybersecurity Camp (GCC) such as understanding and using log files, python scripting, incidence response, and others.

Six groups of teenage girls were observed as they worked through the room. Notes were taken on general observations during and after the experience and debriefing. Additional notes were gathered from reviewing the video footage of each of the sessions. Participants completed a

survey before and after the experience for further gathering of trends and generalizable insights. A thematic-analysis approach (Braun and Clarke 2006) was used to analyze the data from the notes and survey questions to identify the aspects of the experience that were most compelling, what did not work as well, and evidence was captured on the impact the experience had on the participants.

Finally, a heuristic review of the overall room experience was performed. “In a heuristic review, an expert takes a set of heuristics (rules of thumb) and compares the heuristics to the interface in question” (Lazar, Feng, and Hochheiser 2010). The design of the room was evaluated using the SERF model as a guide and reviewed through common game and interface design principles. The room experience was evaluated on what during the experience went well and what could be improved upon based on participant feedback as well as what was learned concerning the design space. Additionally, the effectiveness of learning and practicing cybersecurity topics within the experience was examined, including how well the experience seemed to lend itself to learning generally.

3.2 Recruitment

The BYU escape room was put together in conjunction with the BYU GCC and received IRB approval. As this was a first pass prototype, girls that attended the camp were the participants recruited for the escape-room experience. This was an ideal group. GCC attendees ranged in age from approximately 13 to 17 years of age with little to no previous exposure to cybersecurity topics – but attendees were more likely to be interested in cybersecurity than their peers as participation in the camp was voluntary. Attendees or their guardians signed them up for the camp. All attendees participated in the escape room. Additionally, the escape room featured

challenges related to what the girls learned in their classes at GCC, so it was a natural fit to have them as participants.

3.3 Survey Design

Survey questions were created to assess the participants before and after the escape-room experience. Two surveys were administered: a pre-survey and a post-survey. Both surveys included name and age. Participant names were asked of them to link their before and after surveys. Age was asked to determine a participant age breakdown.

The pre-survey focused on participants' perceived technical ability and prior knowledge of cybersecurity topics, sentiments toward classes taught at GCC, and previous escape-room experience or simulation experience.

The post-survey focused on participants' perceived technical ability, sentiments toward the escape-room experience, perceived learning, and sentiments toward cybersecurity.

The surveys featured many open-ended questions. Answers with similar ideas and sentiments were grouped together for analysis. Two questions were asked on both surveys and paired t-tests were conducted to measure significant differences between the pre-survey and post-survey responses.

Following the survey, participants had a short debriefing (around ten minutes) with the gamerunners.

3.4 Observation

Each of the six sessions during the BYU GCC were observed by this author. Observation began before the session and included the mission briefing, mission training, room experience,

and mission debriefing. Observation concluded once the last survey was collected. The observer was with the participants during the briefing and debriefing but was in the control booth (outside the players' view) for the training and experience. Notes were made related to design, participant experience, technical difficulties, and the overall experience. Additionally, video was collected from three camera locations: front, back, and the tube.

3.5 Analysis

Several themes were pulled from the data of the surveys and observations using a thematic-analysis approach. This includes:

3. Becoming familiarized with the data
4. Generating initial codes
5. Searching for themes
6. Reviewing themes
7. Defining and naming themes
8. Producing a report (Braun and Clarke 2006)

Braun stresses that this process is not linear, but recursive "where movement is back and forth as needed, throughout the phases" (Braun and Clarke 2006). The data and potential themes from the surveys and observations were reviewed multiple times until suitable themes were found and defined.

The determined themes centered on what worked well in the experience, what did not work well, and the impact of the experience on the participants. The author used open coding to categorize participant responses.

These themes were then compared with the concepts outlined in the design space. Thoughtful consideration was given to what worked and what did not. Design choices were then examined in detail and possible changes proposed.

4 FINDINGS FROM THE BYU IT GCC EXPERIENCE

As stated in the methodology chapter, a pre- and post-survey were administered to the participants of the BYU IT GCC experience. Participants were also observed as they completed the experience. Below are insights from the surveys followed by an expert review of the experience.

4.1 Demographics

GCC 2016 was comprised wholly of adolescent females. Six groups of approximately eight participants each experienced the simulation for a total of 44 participants.

Participants ranged in age from 13 to 17 with most participants being 13, 15, or 16. The final group included three participants that had experienced the simulation before and one participant was a college student who taught classes during GCC. The college student's responses did not contribute to these findings and are omitted. Participants were roughly evenly distributed across groups by age (see Table 4-1).

Table 4-1: Age Distribution Across Groups

Age	6/27/16 2:20-2:30		6/28/16 2:40-2:45		6/28/16 4:15		6/29/16 11:00-12:00		6/29/16 1:15-2:15		6/29/16 3:30		Total
12 or under	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0
13	7.69%	1	23.08%	3	23.08%	3	7.69%	1	15.38%	2	23.08%	3	13
14	33.33%	2	0.00%	0	0.00%	0	33.33%	2	33.33%	2	0.00%	0	6
15	16.67%	2	8.33%	1	16.67%	2	25.00%	3	25.00%	3	0.00%	0	12
16	8.33%	1	33.33%	4	16.67%	2	8.33%	1	8.33%	1	25.00%	3	12
17	50.00%	2	0.00%	0	25.00%	1	25.00%	1	0.00%	0	0.00%	0	4
18	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0
19	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	100.00%	1	1
20 or over	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0

4.2 Survey Data Collected Prior to the Simulation Experience

4.2.1 Technical Ability and Prior Knowledge

Most participants indicated that they felt confident in learning new technology (see Figure 4-1). Thirty-eight (86%) participants agreed or strongly agreed with the statement: “I feel confident in my ability to learn new technologies” and none disagreed.

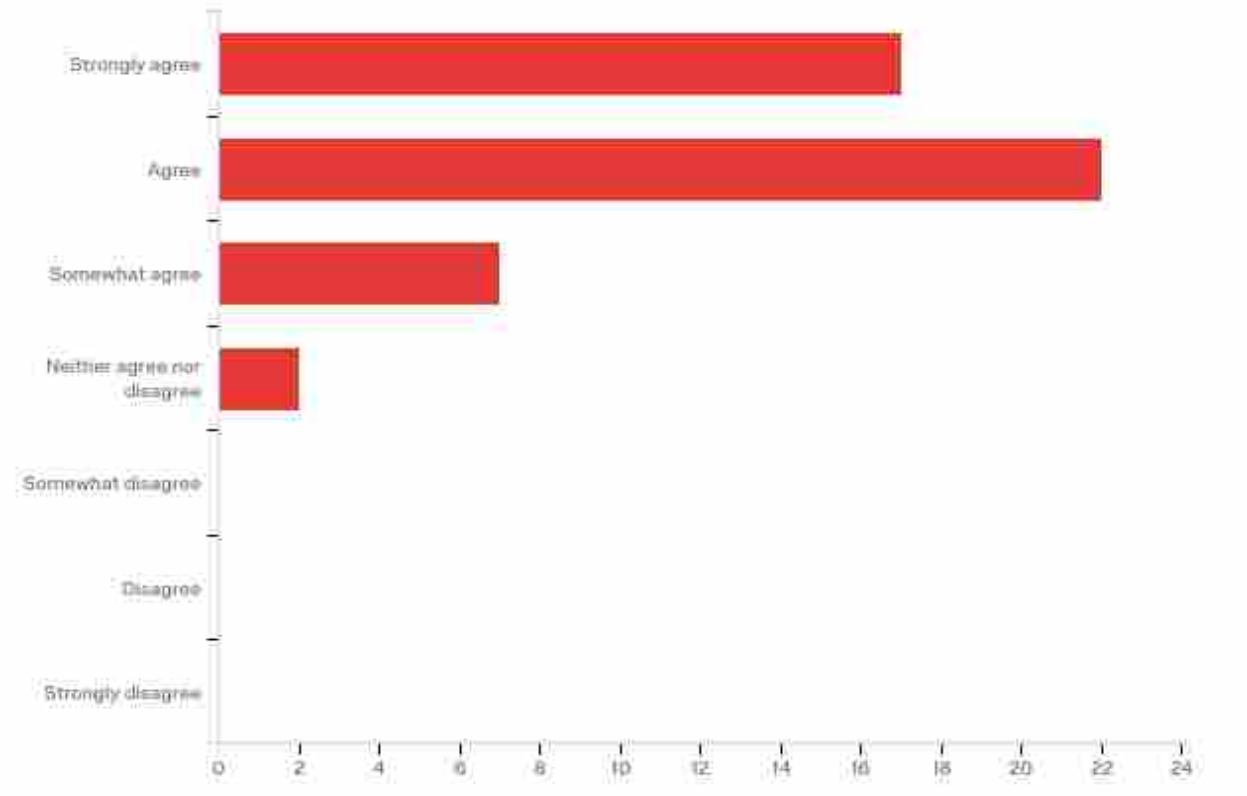

Figure 4-1: Participant Response to Feeling Confident Learning New Technology

Participants indicated that they were slightly less confident (but still quite confident) in using new technologies (see Figure 4-2). Thirty-one (70%) participants agreed or strongly agreed with the statement: "I feel confident in my ability to use new technologies." Fifteen (34%) somewhat agreed with the statement. Only one disagreed.

When asked, "Which topics covered in the classes were you already familiar with?" participants designated a broad range of topic familiarity (see Figure 4-3). Responses were coded by category. Nearly half of the participants (21 of 44 or 48%) indicated they had prior coding or programming experience; eight (18%) specifically mentioned Python. Seven (16%) participants indicated they had received some internet safety training, and about 10% indicated some

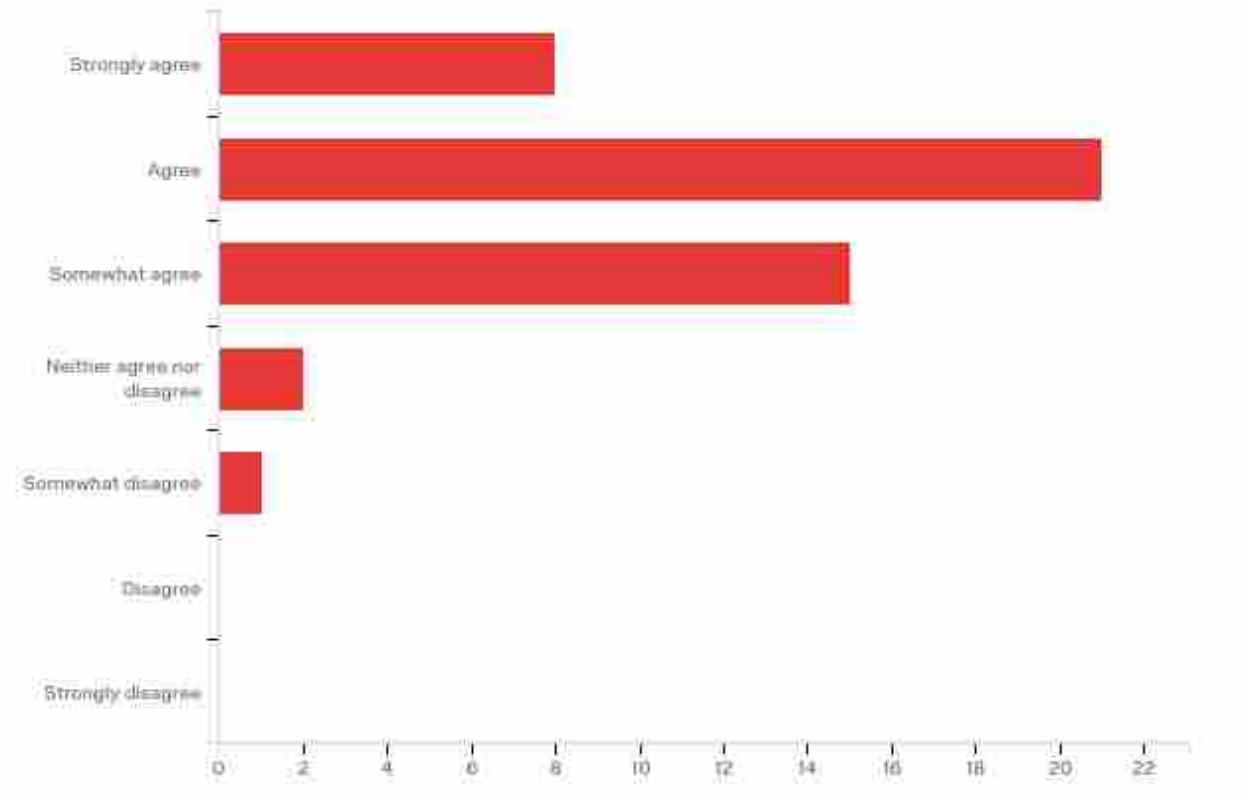

Figure 4-2: Participant Response to Feeling Confident Using New Technology

experience with circuits, terminal usage, or Linux. This suggests that many of the activities tied to the camp and escape room were new to participants.

4.2.2 Previous Escape Room or Simulation Experience

Most participants (29 of 44 or 65%) had never played or experienced an escape room or simulation experience before (see Figure 4-4).

Half of the participants that had participated in an escape room or simulation experience did so locally (see Figure 4-5).

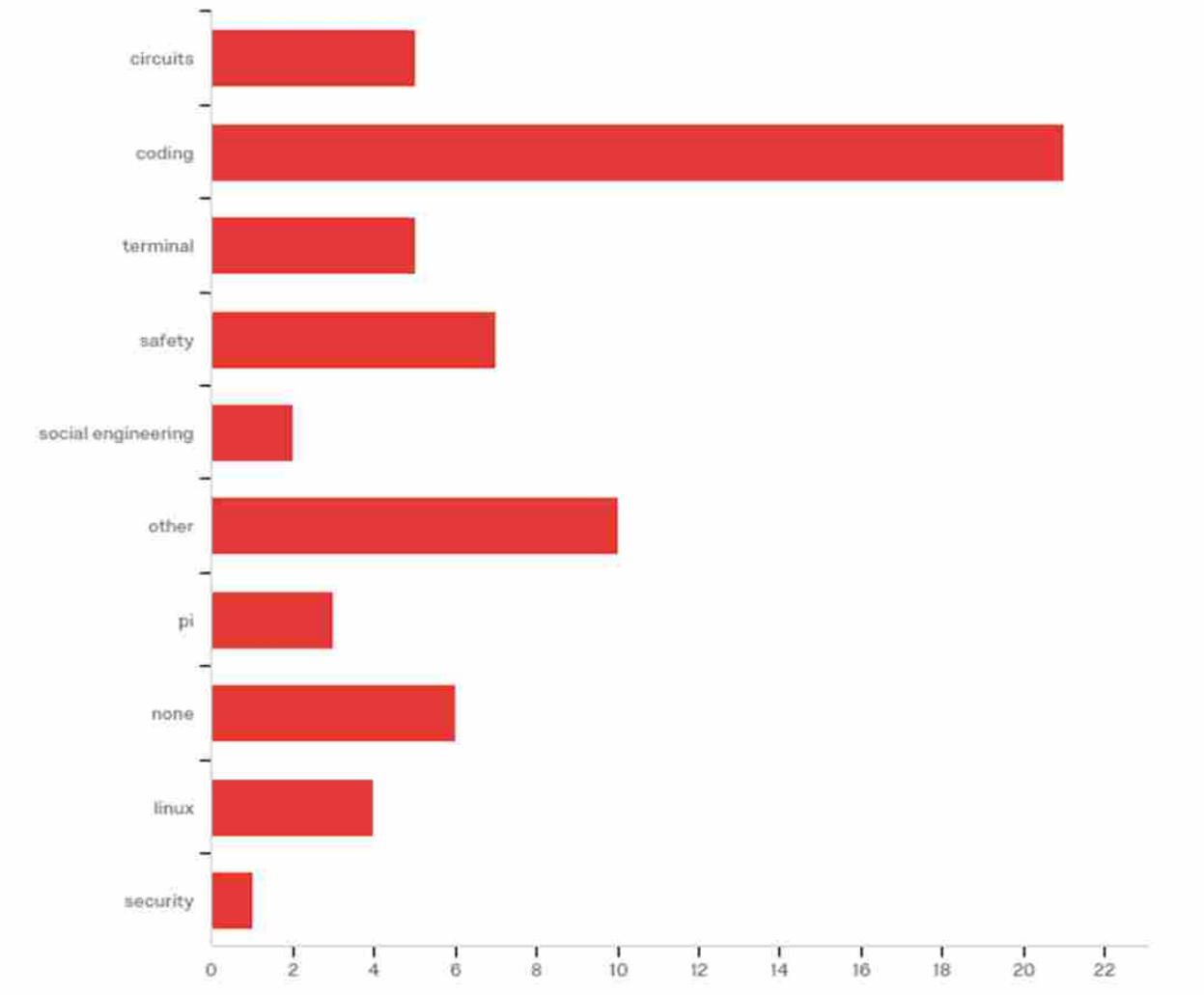

Figure 4-3: Topics Participants Were Familiar with Before GCC

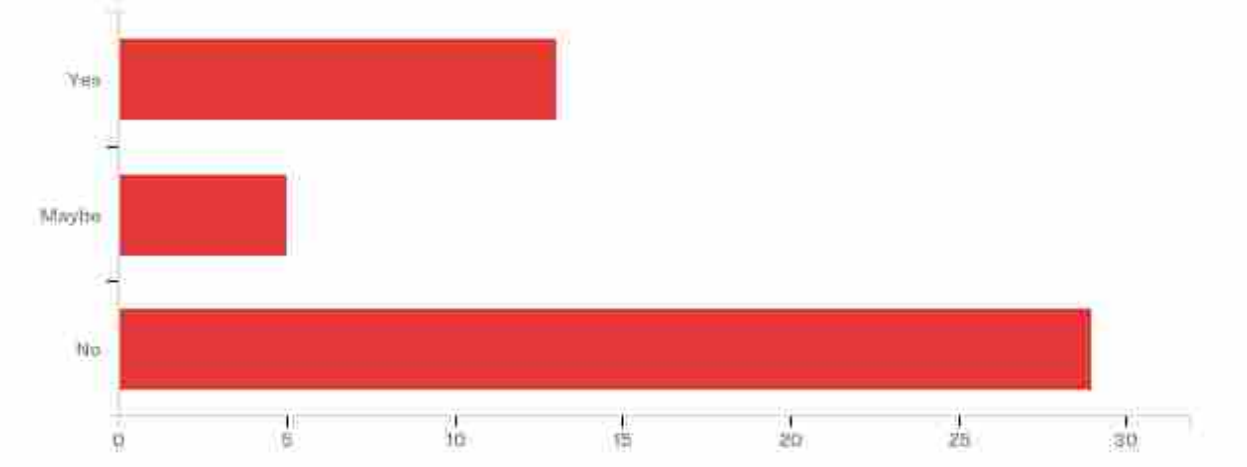

Figure 4-4: Participant Response to Participating in a Previous Escape-Room Experience

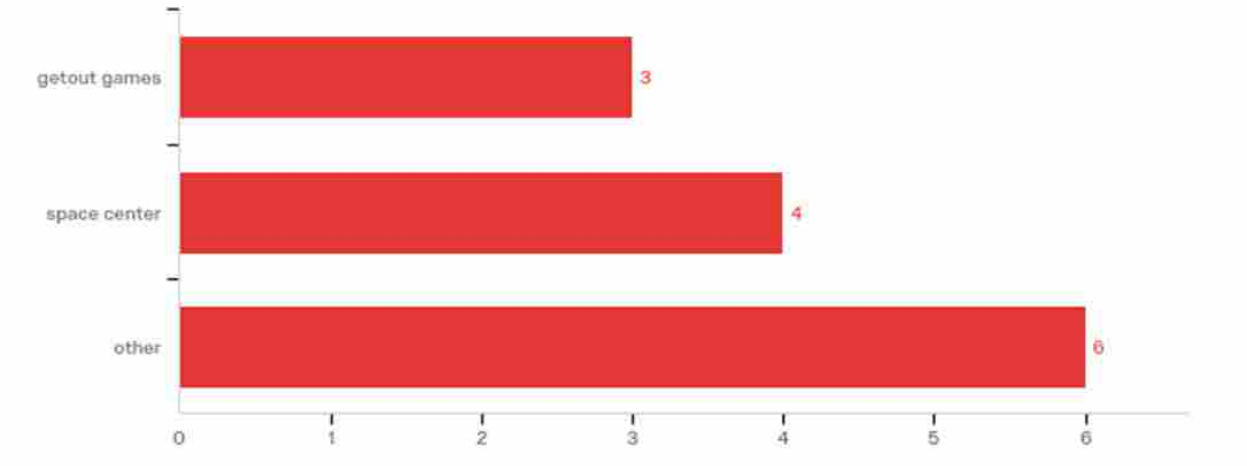

Figure 4-5: Participant Response to Where They Had Participated in an Escape Room

4.3 Survey Data Collected After the Simulation Experience

4.3.1 Technical Ability

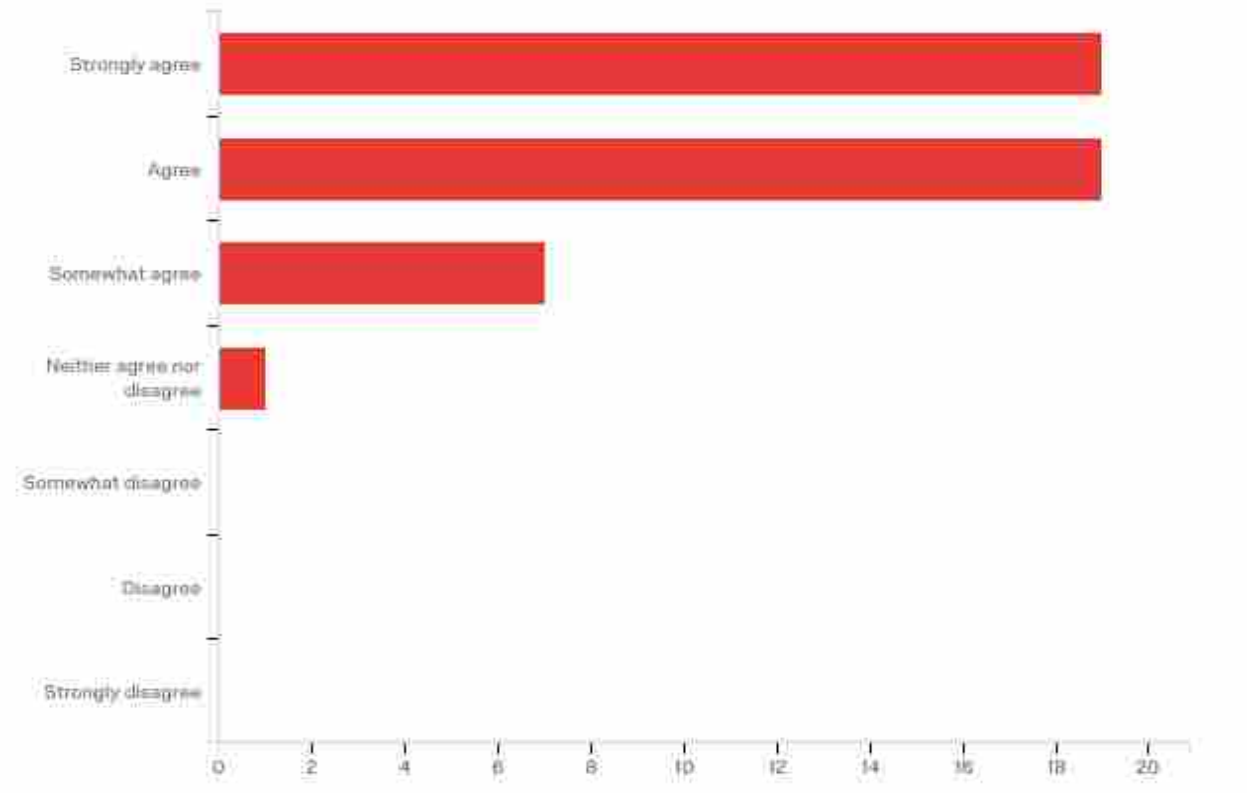

Figure 4-6: Participant Response to Feeling Confident Learning New Technology

After the experience, most participants still felt comfortable with new technologies. Thirty-eight (86%) participants agreed or strongly agreed with the statement, "I feel confident in my ability to learn new technologies." Seven (16%) more participants somewhat agreed (see Figure 4-6).

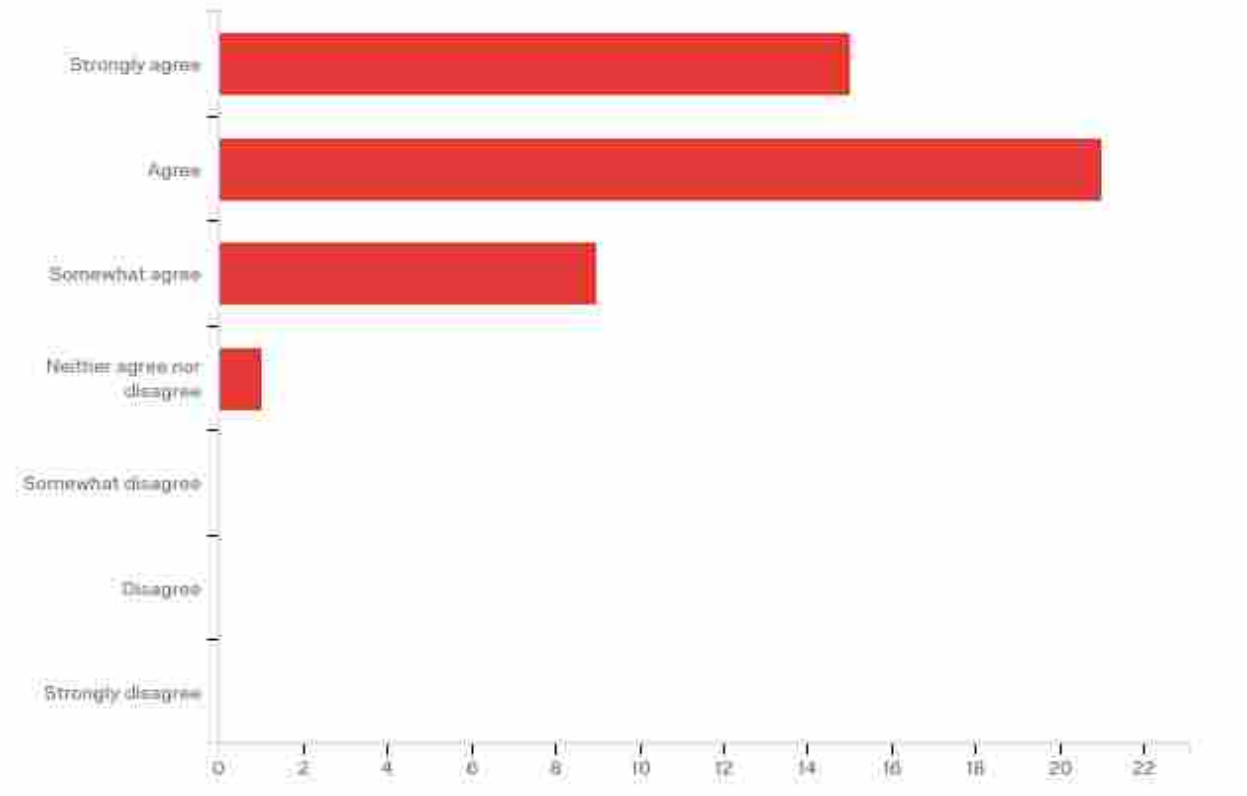

Figure 4-7: Participant Response to Feeling Confident Using New Technology

Thirty-six (82%) agreed or strongly agreed that they felt confident in their ability to use new technologies. Nine (20%) somewhat agreed (see Figure 4-7).

4.3.2 Sentiments Toward the Experience

Participant responses were coded into categories for the following three questions.

Participants were asked, "What did you enjoy most about the experience?" Nine (20%) said they enjoyed participating as a team and practicing teamwork the most. One representative comment was, "I enjoyed working with my team to get things done." Eight (18%) remarked on the atmosphere of the experience as what they enjoyed most. One participant responded that what she liked most was "the atmosphere! The chairs were really cool as well as the computers!

The engineer computers were my favorite!" Six (14%) participants said they enjoyed everything, and five (11%) said it was fun (see Figure 4-8).

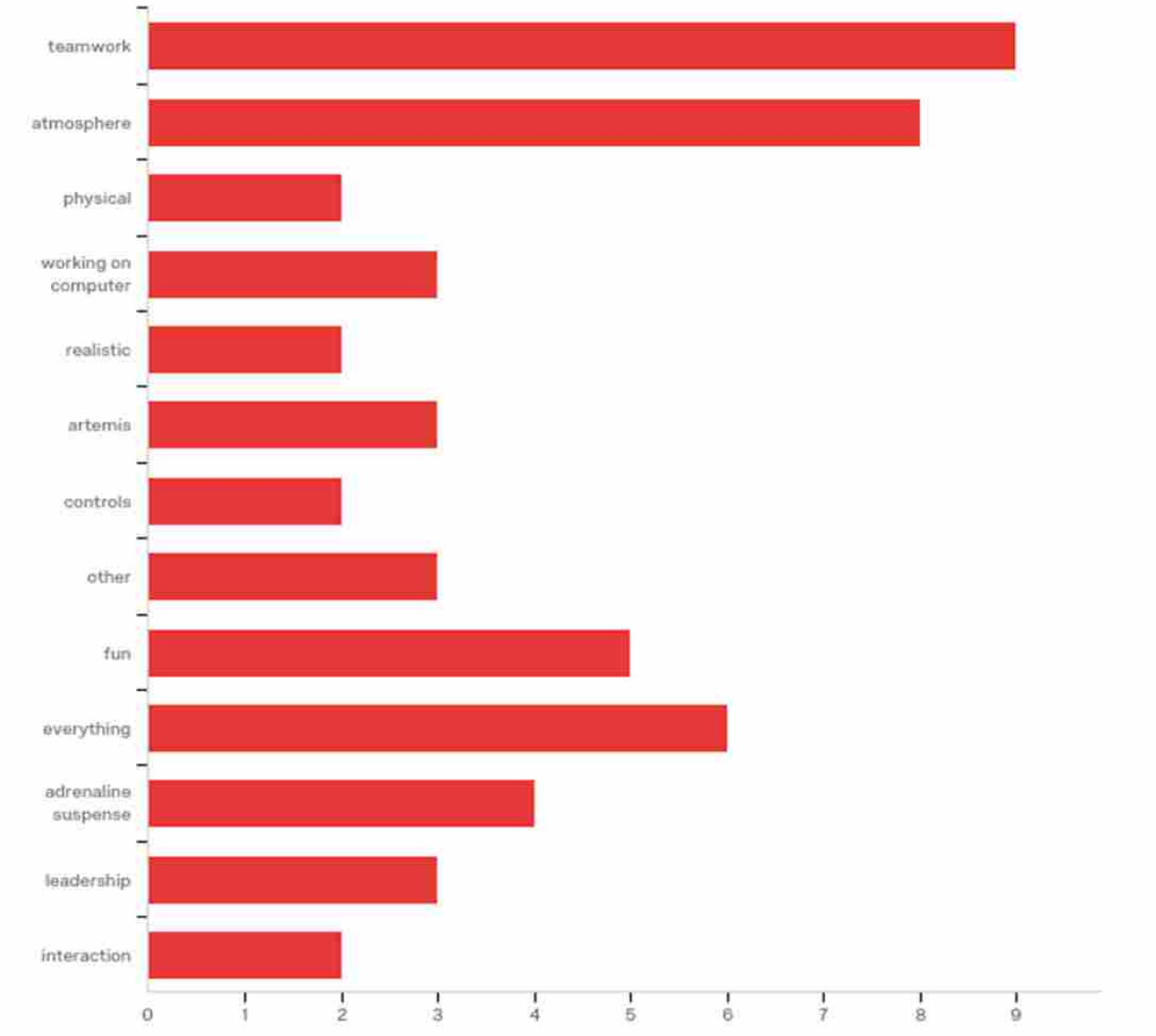

Figure 4-8: Participant Response to What Was Most Enjoyable About the Experience

When participants were asked what they enjoyed least about the experience, eight (18%) responded that poor teamwork was what they liked least. A few comments were: "My team

didn't talk to me ☹" and "It was hard to listen to the captain when she wouldn't make decisions." Another mentioned that she "didn't know what [she] was supposed to do for unity." Seven (16%) participants felt that there was too much pressure put on them during the experience. One said that she thought that "the sense of pressure overwhelmed [her]" while another simply put "Panic." Six (14%) said the experience was difficult or confusing – and expressed that they did not like not knowing what they were doing, and another six (14%) indicated they did not like the technical difficulties that arose. They were distracting and "made it more difficult to complete the mission" (see Figure 4-9).

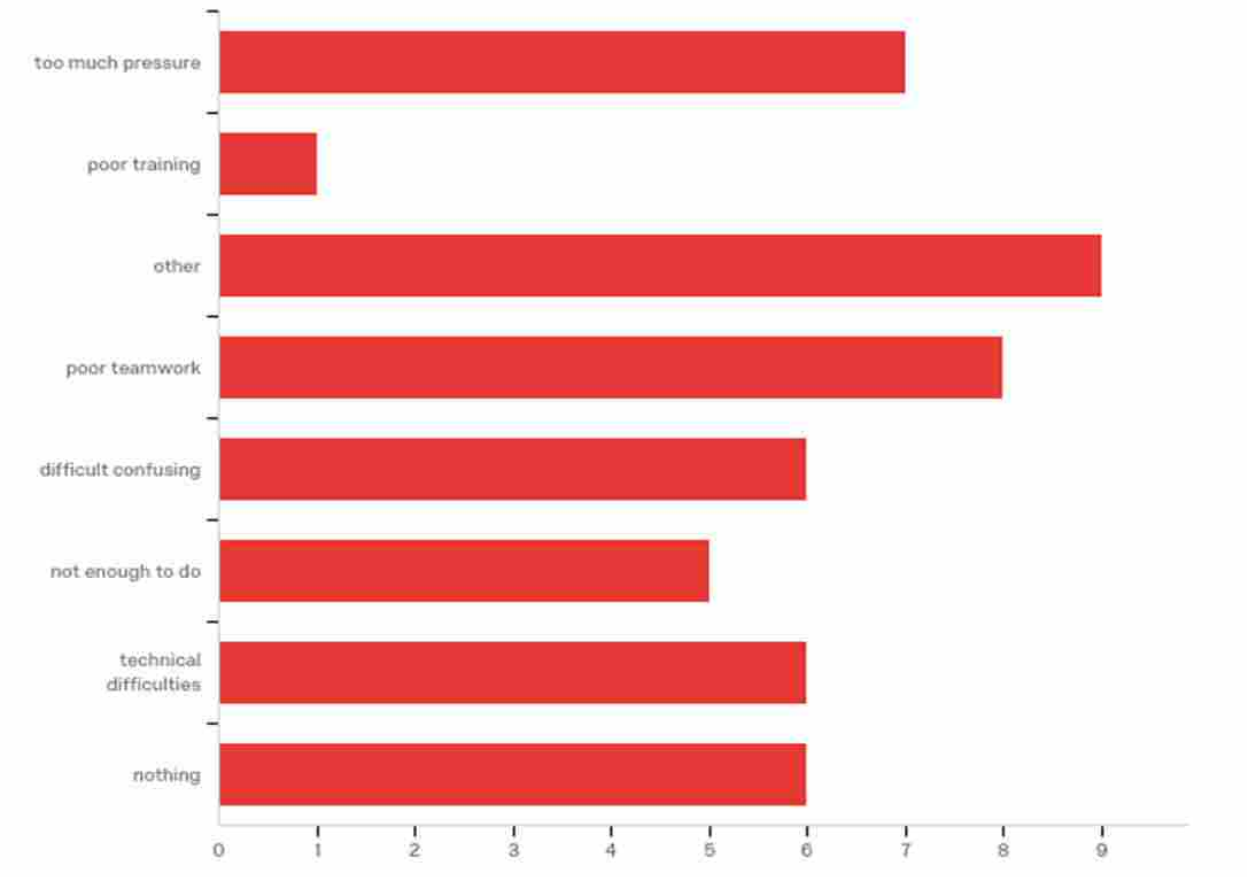

Figure 4-9: Participant Response to What Was Least Enjoyable About the Experience

When asked what one thing would improve the experience, 10 (23%) participants pointed to better training. One participant wanted “a little more help in training” while another wanted “more practice with the positions [or roles].” Five (11%) suggested that more content or more time would improve the experience. They wanted “more attacks” and “more energy ships.” Five (11%) other participants wanted less technical difficulties or “less malfunctions.” Four (9%) participants said that they would have liked more to do: One girl wanted “more issues to solve so we had things to do.” Others made similar comments. Four (9%) others wanted a better crew in some way (see Figure 4-10).

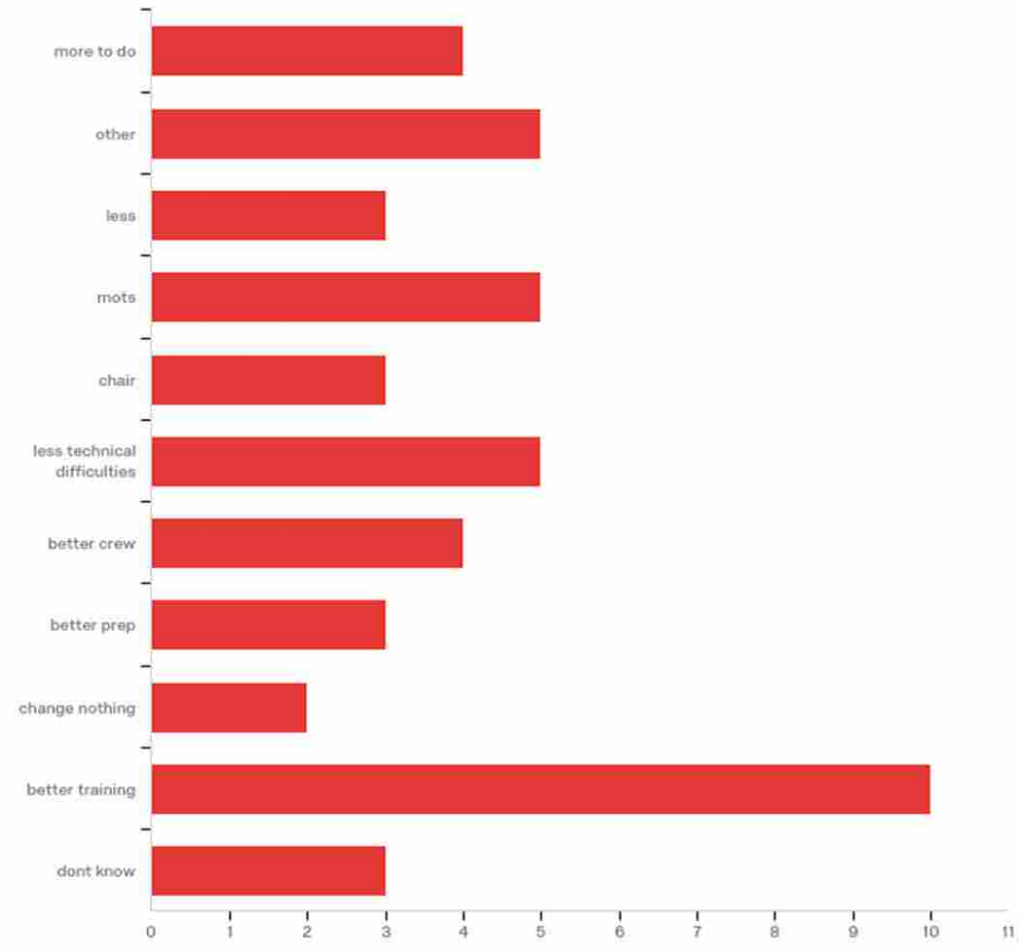

Figure 4-10: Participant Response to What Would Make the Experience Better

When asked if the escape room experience was fun, 41 (93%) participants agreed or strongly agreed (see Figure 4-11).

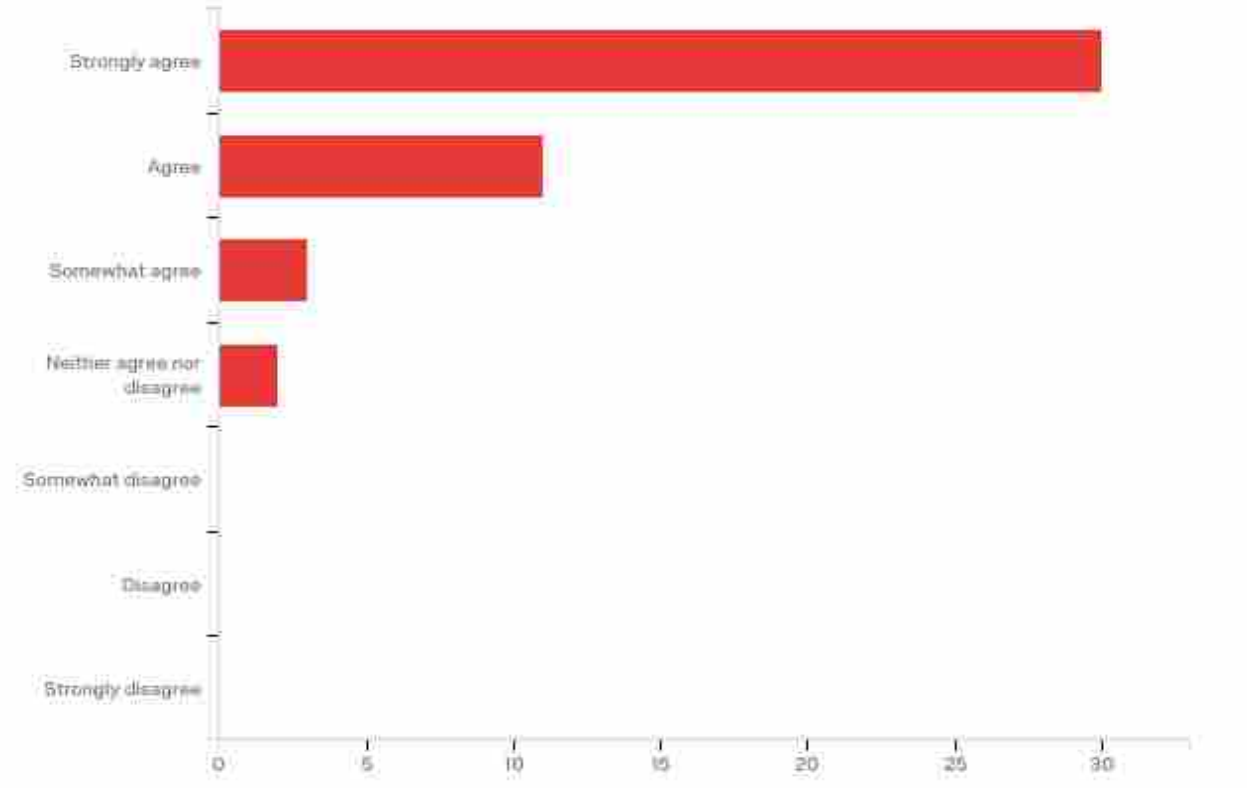

Figure 4-11: Participant Response to Feeling the Experience Was Fun

Forty-one (93%) participants also agreed or strongly agreed that the escape room experience was engaging (see Figure 4-12).

Forty-two (95%) participants were extremely likely or moderately likely to recommend the experience to a friend (see Figure 4-13).

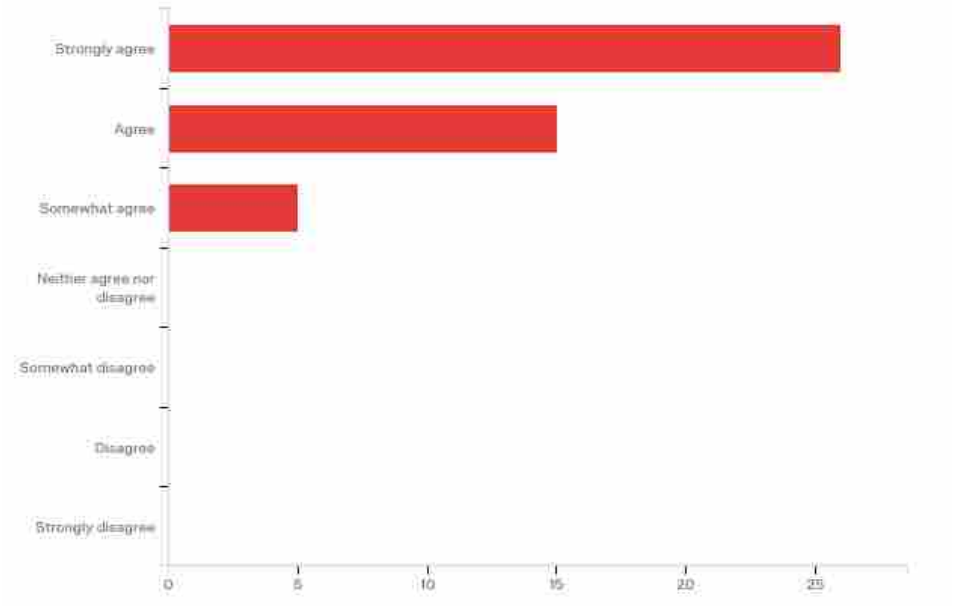

Figure 4-12: Participant Response to Feeling the Experience Was Engaging

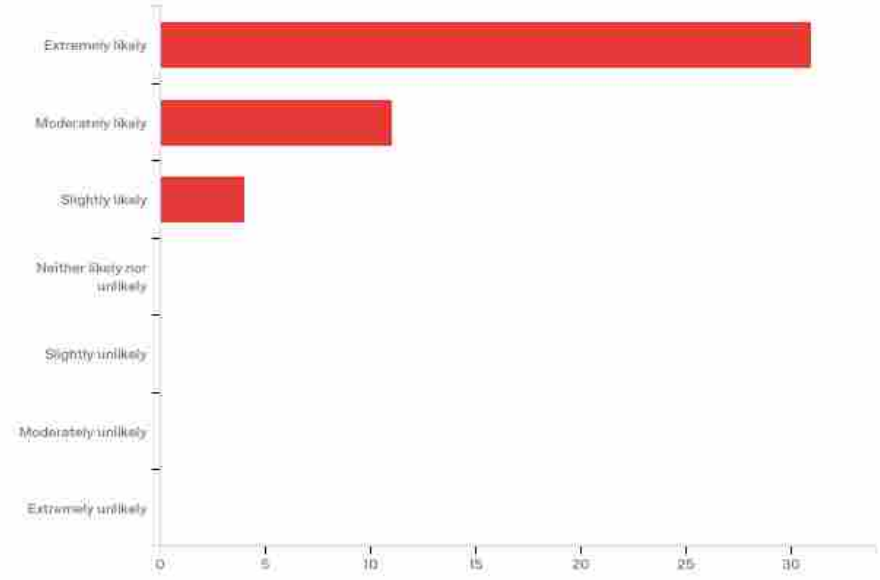

Figure 4-13: Response to Likelihood of Recommending the Experience to a Friend

When asked if they would participate in a similar experience with a different subject matter, 42 (95%) participants said yes, and 16 (36%) said it would be fun. Responses were coded into categories (see Figure 4-14). One participant said, “Yes, this experience is so engaging and hands on that it could be helpful when learning other things.” Several had similar responses.

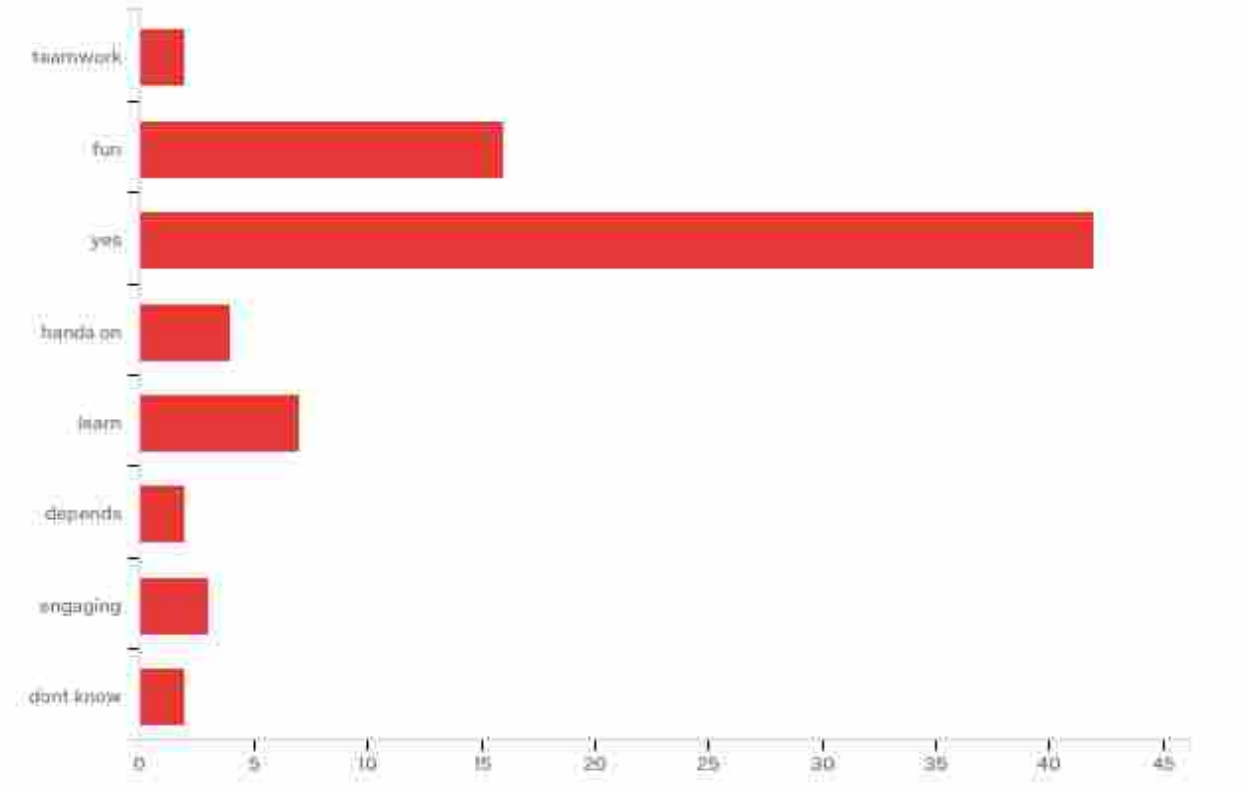

Figure 4-14: Response to Participating in a Similar Experience with Different Subject Matter

4.3.3 Participants’ Learning from Experience

Participants self-reported that they learned from the escape room experience. Fourteen participants had responses that focused on teamwork-related learning, 10 (23%) participants focused their responses on learning under pressure such as staying calm and not panicking, nine

(20%) participants focused their responses on communication-related learning such as listening to the captain and listening and communicating with others, and five (11%) participants focused on following directions (see Figure 4-15). Interestingly, the majority of learning content was not on the cybersecurity puzzles themselves, but on the collaborative experiences surrounding them.

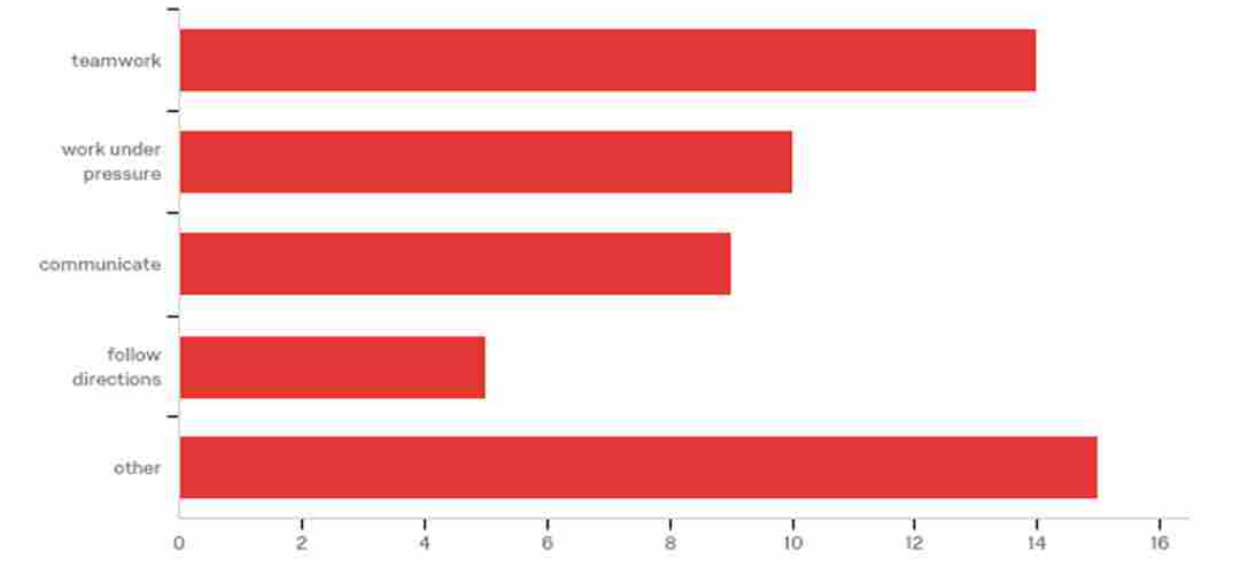

Figure 4-15: Participant Response to What They Learned in the Experience

Twenty-four (55%) participants agreed or strongly agreed that the escape room experience helped them learn the concepts taught in classes. Sixteen (36%) somewhat agreed, and five (11%) neither agreed nor disagreed (see Figure 4-16). Participants likely responded this way for several reasons. While the cybersecurity activities had to be completed before advancing the experience, not every participant was able to contribute (only a few could operate the computer that two of the activities were on). Also, many groups struggled to complete the activities and needed multiple hints to succeed. These issues are discussed further in the expert review section below as well as in the following chapter.

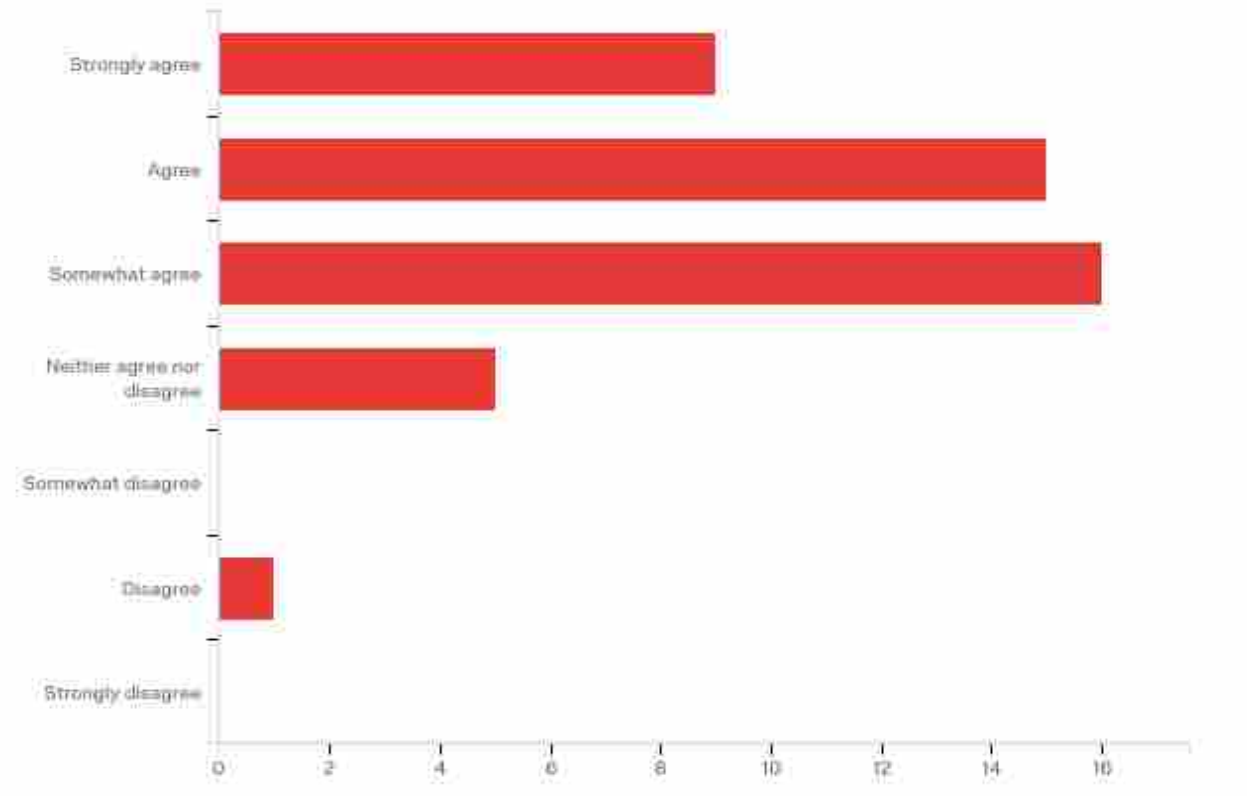

Figure 4-16: Participant Response to the Experience Helping to Learn Concepts from Class

4.3.4 Impact on Sentiments Toward Cybersecurity

The participants find cybersecurity cool, interesting, and fun. Five (11%) even said they are planning on going into the field (see Figure 4-17). One 13-year-old said, "I think cyber security is really cool, and it would be fun to do." Another agreed: "I really like it and want to go into a profession that has something to do with it."

Thirty-seven (84%) participants said they were extremely likely or moderately likely to continue with cybersecurity education (see Figure 4-18).

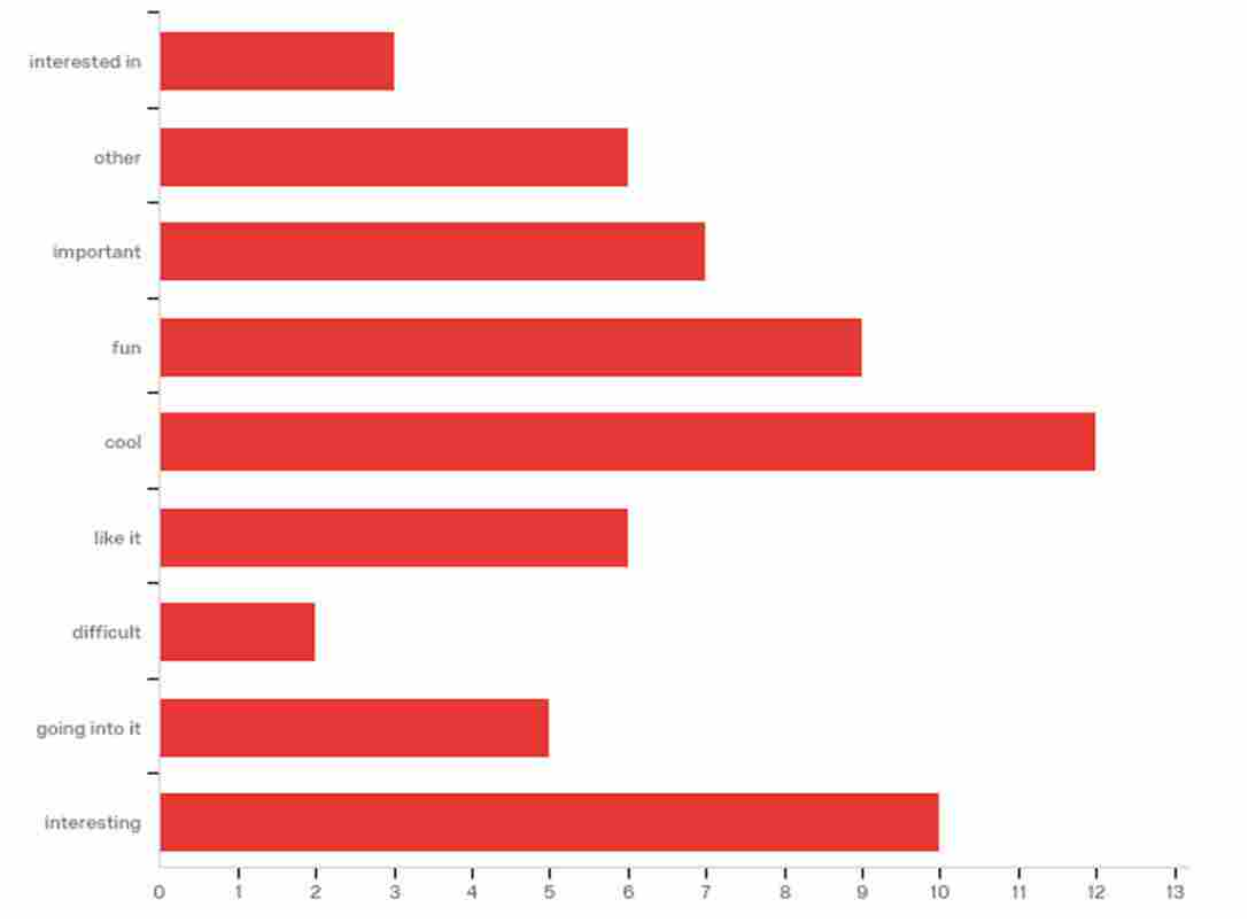

Figure 4-17: Participant Feelings Toward Cybersecurity

When asked why they would or would not continue in cybersecurity education, 12 (27%) participants said they liked it, nine (20%) said it was interesting, and eight (18%) were considering it as a career. One participant said, "it is fun, and I want to learn more about computers" and another stated, "I think that it would be a good career for me." Another eight (18%) decided cybersecurity was not for them (see Figure 4-19). Many of these participants had already found an area of study they wished to pursue more than cybersecurity: "Although I like the field, I have already considered the medical field – I also think I could help more people

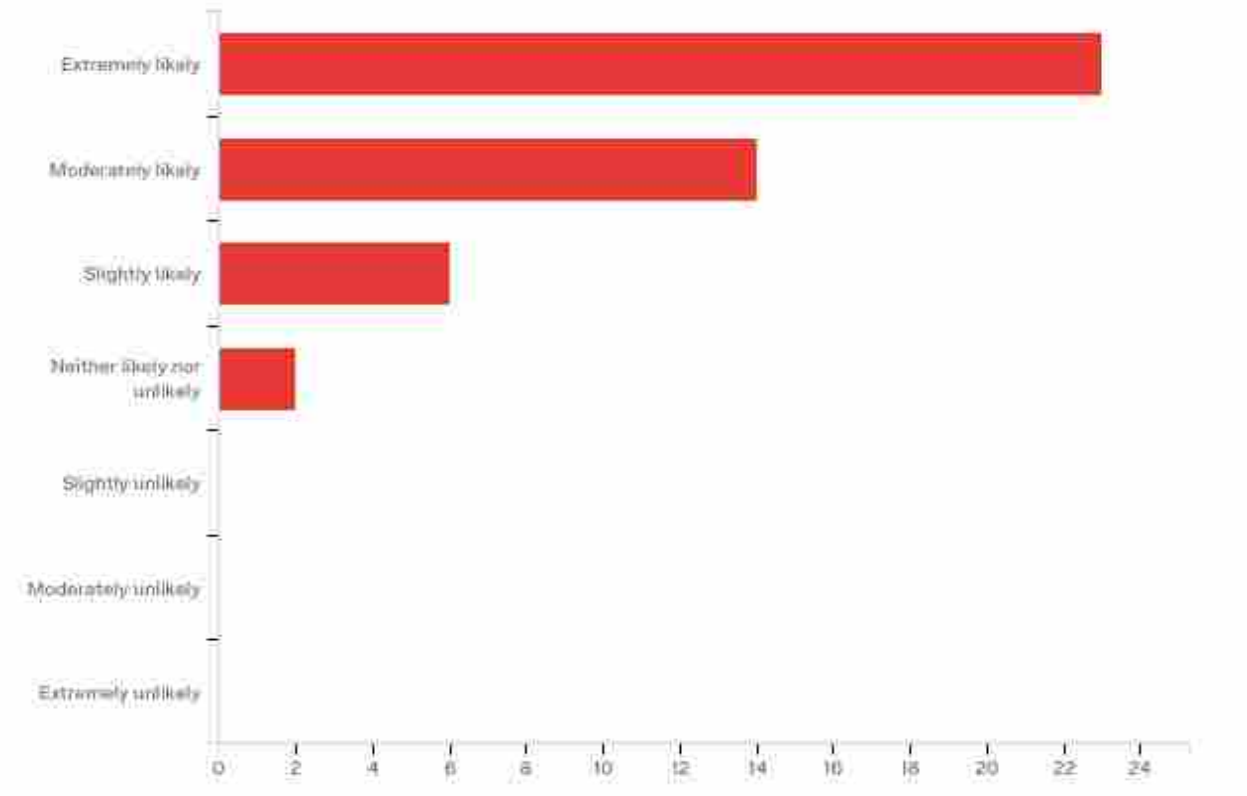

Figure 4-18: How Likely Participants Felt They Would Continue Cybersecurity Education

with something like that. Cybersecurity is my second career field but it's still less likely to happen," said one participant.

4.4 Themes from Survey Data

4.4.1 Technical Ability

Participants' perceived confidence in their technical ability differed between before and after the experience. A two-tailed paired t-test was completed to compare participants' responses.

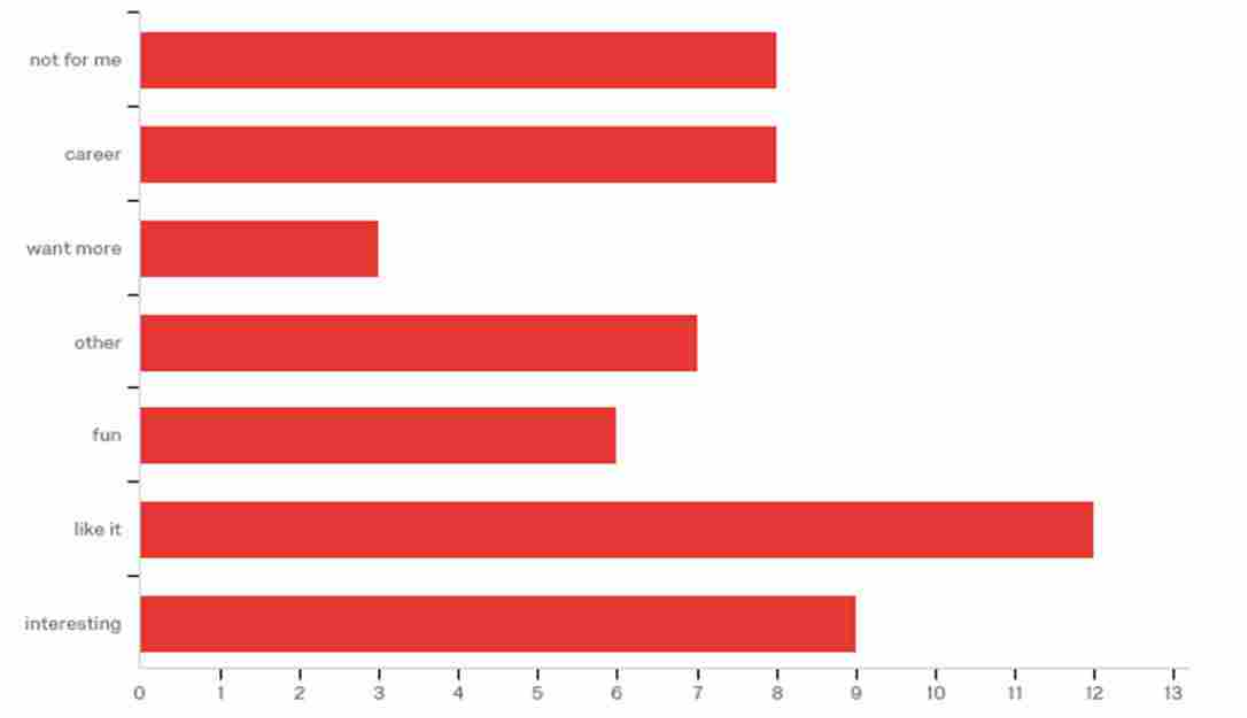

Figure 4-19: Why Participants Would or Would Not Continue Cybersecurity Education

When indicating how much they agreed or disagreed with the statement "I feel confident in my ability to learn new technologies," several participants seemed to lose a bit of confidence from before to after the experience. Those that agreed or strongly agreed with the statement were slightly lower than before. Those that somewhat agreed with the statement saw a slight uptick. This question did not show a statistically significant difference between the pre-survey and the post-survey ($p=0.3517$; $df=43$), though the mean went up .09 points.

However, participants' confidence in using new technologies seemed to improve. When asked how much they agreed or disagreed with "I feel confident in my ability to use new technologies," those that strongly agreed went from eight (18%) participants before the experience to 15 (34%) after. Those that somewhat agreed dropped from 15 (34%) to nine (20%). A few of the participants that somewhat disagreed or neither agreed nor disagreed moved

into the more affirmative categories. This question showed a significant difference (p=0.0021, df=43). Overall, the post-survey score minus the pre-survey score was 0.39 suggesting that participants did feel more confident in their ability to use new technology after the experience.

Participants did not gain much confidence in learning new technology. This is likely due to being trained on unfamiliar systems very quickly. However, they likely found that they could use these unfamiliar systems during the experience, thus increasing their confidence in using new technology.

4.4.2 Did Participants Feel They Increased in Learning

Participants felt the experience did help them learn concepts covered in class. Twenty-four (55%) participants agreed or strongly agreed with the statement "The escape room experience helped me learn concepts taught in classes." However, 21 (48%) somewhat agreed or neither agreed nor disagreed with the statement.

Yet when asked what they learned, participants' statements centered on teamwork, working under pressure, communication, and following directions. While classes did not focus on these areas, participants did seem to gain useful experience with them. When asked, 14 (32%) participants mentioned teamwork, 10 (23%) mentioned working under pressure, nine (20%) mentioned communication, and five (11%) mentioned following directions.

Participants did indeed seem to be learning from the experience but were not necessarily learning the same concepts as taught in the classes. Participants focused more on team-related concepts gained from the experience.

4.4.3 Participants Found the Experience Enjoyable

Forty-one participants agreed or strongly agreed that the experience was fun. Forty-one (93%) also agreed that the experience was engaging. Forty-two (95%) participants agreed they would participate in a similar experience for a different subject. Forty-two (95%) participants also agreed they would recommend this experience to a friend. Based on these overwhelming positive responses, participants seemed to enjoy performing the experience.

4.5 Observational Notes

4.5.1 Participant Reactions

As noted before, participants enjoyed the created atmosphere. Upon entering the room, they were elated. Several even danced out of excitement. This excitement carried through the instructions given by the engineers.

The instructions were extensive, and while participants listened intently, learning the Artemis system in 15 minutes was likely overwhelming. Because some stations were more difficult to explain, some participants had to wait for their team members to finish training.

Some parts were frustrating for participants and staff – both would get frustrated when participants could not solve the cybersecurity challenges quickly and correctly. The added pressure of a time limit served to magnify the frustration as well.

Also, because the sessions had more participants than consoles, some participants would not always have something to do. While several would tackle the bigger challenges, others would get bored. Additionally, many activities did not involve all roles. This meant that some participants would have to wait on others to complete an activity before resuming their role.

The Artemis parts of the experience seemed to be the most compelling for participants – likely because they were the most stimulating and immersive parts of the experience.

Overall, however, participants enjoyed the escape-room experience and found it quite fun and engaging. Interestingly, age disparity did not seem to affect the experience much.

4.5.2 Expert Review

Overall, the GCC escape room experience is a compelling one. This author observed that participants enjoyed the many consoles, the varied objectives, and the unique storyline. Care was put into the ambience creating a spaceship feel and enhancing the suspension of belief. What follows is a chronological review of the experience.

Before each session, participants were briefed by a member of the room staff just outside the room. Participants were given some background to the story, the setting, and rules of engagement. This was usually performed in character by a gamerunner as an "engineer" (though a few times it was out of character as gamerunners became fatigued later in the day). Crew roles were explained, and each participant was given a role that they would fill once they entered the room. Assigning the roles beforehand kept excitement and interest up, but also gave each participant clear goals and expectations for their experience. Roles were picked by participants based on what they thought would be most interesting to them. For those that did not pick, gamerunners assigned remaining roles. The roles remained the same as the roles in Artemis: Captain, helm (pilot), tactical (weapons), engineering, science, and communications. A further role of technician was added to accommodate additional players. The technician was generally a "floater" player that would help where needed. Most of these briefings were fun and upbeat and contributed to participant excitement. Participants would excitedly talk about their upcoming

roles and what could be next. However, a few of the session briefings only focused on the necessary rules and did not contribute to the overall experience. For a good experience session to session, consistency is key.

Once inside, participants were wowed by the look, sound, and design of the room. Awe was expressed by many when entering. Of note was the fog machine. A good bit of fog was always pumped out in the doorway before participants entered. Speakers pumped out a strong engine hum. These design choices added to the spaceship atmosphere and helped transport participants into the game world. Adding to this were the runner lights situated around the room. Not only were these lights decorative, but they also served to alert crew to the current threat level. Controlled from the captain's chair, the lights could be changed from white to green to yellow to red. Ideally this would aid the captain in getting the attention of the crew. In addition to the engine hum, the speakers were used to convey alarms and alerts as well as let the gamerunners communicate with the crew. The front of the room included a large screen that allowed all participants to see what the ship was doing and what was around the ship. Also, the chairs, consoles, and keyboards all looked amazing and fit right in with the spaceship theme. Additional lighting was added around the side console and back console for convenience without detracting from the ambience. Altogether, the room looked and felt the part (see Figures 4-20 through 4-23).

On the back wall was a window installed with one-sided glass. Fortunately, participants had difficulty seeing through the glass because on the other side was the control booth. Most of the time, this did not detract from the experience. However, because the experience room was darkened (to allow for better viewing of the front screen), staff faces could be seen from the light reflecting off their screens (some participants noted this). Also, a TV was installed on the booth's

Figure 4-20: Front Screen and Some of the Consoles of the Escape Room

Figure 4-21: Rear of the Escape Room

side wall and could be seen from the experience room. To fix this, a black curtain was installed. This alleviated the problem somewhat, but it did make it more difficult to observe the participants. At times, staff could not determine what exactly participants were doing or looking at.

Inside the control booth, multiple computers were set up to run the Artemis system and other parts of the custom experience. Five monitors and two TVs helped to show the various Artemis screens, camera feeds of the room, the additional engineering console computer screen, and the captain's chair console screen. This level of detail was quite helpful to gamerunners in administering the room.

Figure 4-22: Control Booth of the Escape Room

When participants were all in the room, staff (called engineers for immersion) told participants which station was which. Because participants were assigned their roles beforehand, they could quickly take their stations. Signs or placards identifying stations would have been a simple addition that would have potentially enhanced the ambience while simplifying getting into the room.

Once participants were at their appointed stations, an engineer (gamerunner) in character went to each console and explained to each participant what their role entailed in detail. This explanation included walking participants through their Artemis consoles, discussing what the role's various duties included and how they integrated with the rest of the crew's duties, and answering participant questions. The experience had more roles than gamerunners so some engineers had to explain multiple roles. This ship training took approximately 12-15 minutes for every session. It was a lot for participants to take in. They had to learn their station duties, the Artemis system and how each station works together, and understand their roles sufficiently to be prepared for additional activities outside of Artemis. Unfortunately, the Artemis system adds quite a bit of complexity, necessitating the extensive training. A simple training mission would probably help here, however, it could also significantly add to the time the room takes to complete. An alternative would be to pare down the functionality of the Artemis consoles and make them primarily mission specific – though that would limit player options. In short, more user testing and iterating would help fine tune this training experience.

When the staff felt the participants were sufficiently trained, they would "beam off" the ship (or leave the room and go into the control room). TSN Command, their command headquarters for the simulation, would then assign the crew their mission over the "loudspeaker" (just the actual speakers, but in an immersive way). Participants would be left to themselves to

Figure 4-23: Side View of the Escape Room

fulfill their assigned mission. The cameras (and sometimes window) allowed staff to view participants, however, when the door to the control booth was closed, the participants became difficult to hear. Microphones were originally planned for the room, which would have aided staff immensely. A clever workaround to this problem was to give the captain a walkie-talkie. This allowed the captain to talk directly to the control booth when difficulties would arise. This walkie-talkie was a direct link to TSN Command. Because staff could not hear the participants, they had to communicate through their captain to TSN Command for hints. Additionally, staff used the onboard computer (a monotone voice over the speakers) to give unsolicited hints. This is an excellent way to provide help to participants while maintaining immersion, and a particularly good workaround to missing microphones.

As part of their mission, the crew were instructed to transport a scientist to another part of the sector for research purposes. This "scientist" turns out to be a saboteur who attempts to incapacitate the ship and crew. She also is a member of the staff. Having her observe participants for much of their experience gave further insight to staff at how well participants were doing and what they struggled with. Just having her aboard the ship helped bridge that auditory gap between the participants and staff.

At this point, the participants could get a feel for the Artemis system as a crew. Artemis provides a large three-dimensional game space for players to explore. It can include random events and structures as well as potential hazards for players to navigate. This randomness helps to make each playthrough unique – it helped make each session unique even though participants were provided with the same custom mission. The variety Artemis provides makes it quite replayable. The refined game mechanics that Artemis provides induce engagement. One such mechanic requires the crew to manage their energy. Energy is collected while energy consumption remains lower than production, but energy is necessary for every system to run on the ship (though different systems have varying energy needs).

Each member of the crew must be attentive and alert, and more importantly a team player, for the crew to succeed. Artemis makes for excellent collaborative gameplay due to the various interdependent roles. This focus on collaboration and teamwork is likely why many participants felt the experience helped them learned how to work better as a team. However, these same strengths that make Artemis compelling and fulfilling to play on its own potentially detracted from the overall room experience when other activities were introduced.

Dealing with an oxygen failure, power failure, and social engineering were some of these activities. Each of these added cybersecurity concepts to the room experience. Oxygen and

power challenges required using the additional engineering Linux-based console under the engineering desk. The oxygen failure required participants to troubleshoot a missing file. The saboteur had deleted the python file that controlled the oxygen system, and the crew needed to find the missing file and copy it into the appropriate folder to restore the system – all while under pressure as they only had minutes to left to survive without oxygen. While this is a relatively simple activity and one that participants had learned about in classes, it proved to be tricky when the time-limit pressure was added. All groups had difficulty with this activity and required multiple hints and assists. One group even managed to break the Linux filesystem much to the frustration of staff. Testing this activity a few times would have likely helped staff determine that it should have been simpler or required more hints to be solved in a timely fashion.

The power failure required the crew to check the log files to determine that the python file that controlled the power system had been altered. Then they needed to set the while loop in the file to true to restore the power. This challenge had less pressure though the participants still needed to watch the overall mission timer. Like the oxygen challenge, this challenge required many hints for the groups to solve it. The first group even had the assistance of an engineer from the warp gate crew. Again, testing the challenge beforehand would have likely helped this challenge.

The final cybersecurity challenge was detecting the social engineering by the saboteur scientist. While on the ship, she surreptitiously spent time on the engineering console, went in the tube (where a locked box was hidden), and generally did suspicious things. Only a couple groups caught on and discovered the hidden box. This challenge was executed the best by staff. Because it was not required to advance the narrative, staff did not give any hints about the scientist or the box making the discovery more exciting for participants. Also, participants had to

be paying attention to the scientist to catch her – just like actual social engineering. The saboteur also made for an interesting plot twist when she was revealed to be such.

The cybersecurity challenges were good example prototypes of potential challenges for a cybersecurity-focused escape room. The oxygen and power challenges would have benefited with further user testing to fine tune the clarity and difficulty of the puzzle, but overall participants seemed to enjoy solving them. The social engineering challenge seemed to provide the highest satisfaction for participants, however. Many talked about the saboteur and things related to her role such as catching her do suspicious things or finding her hidden cache.

Also, the cybersecurity challenges were integrated well into the custom Artemis mission. Both the oxygen and power failures required the crew to stop and address these challenges. Completion of these challenges was required for advancement. The social engineering challenge, while not required, fit well into the narrative.

Because these challenges and the Artemis system were both so involved, it was a lot for participants to focus on. Generally, when groups were focused on one, they neglected the other. For example, when the oxygen and power systems were down, several groups just let the ship drift – even into sector walls (the edge of the game) or into hazards. And when attempting to complete an Artemis task, they would ignore the cybersecurity activities. The Artemis experience seemed to overshadow the cybersecurity activities – for both the participants and staff. While a major part of the mission, the cybersecurity activities did not feel central to it. They functioned more as obstacles to experiencing all that Artemis had to offer. Making cybersecurity activities the primary activities of the room would fix this.

The narrative ended with a bang. Participants learned that the scientist was a saboteur – and she had commandeered a ship to destroy them. This was the most exciting part of the experience as the crew had to work together using the Artemis system to outmaneuver and target an enemy ship. Ending with this was smart. Participants would finish with an exciting win (though one group did get blown up).

This fulfillment carried over into the debriefing. Participants were excited to talk about what they had learned from the experience – and what their favorite parts were. The debriefing helped to pull them back and transition out of the game space gracefully as well.

5 DISCUSSION AND CONCLUSIONS

5.1 Applying the Framework to the BYU Experience

The BYU experience provides an opportunity to walk through the Snyder Framework (see Figure 5-1) and demonstrate how aspects of the SERF were applied or could have been applied. Each part of the framework is important, so the following sections will review the BYU experience in light of each piece of the framework:

- Goals and Objectives
- Players
- Activities
- Context
- Trajectory
- Evaluation

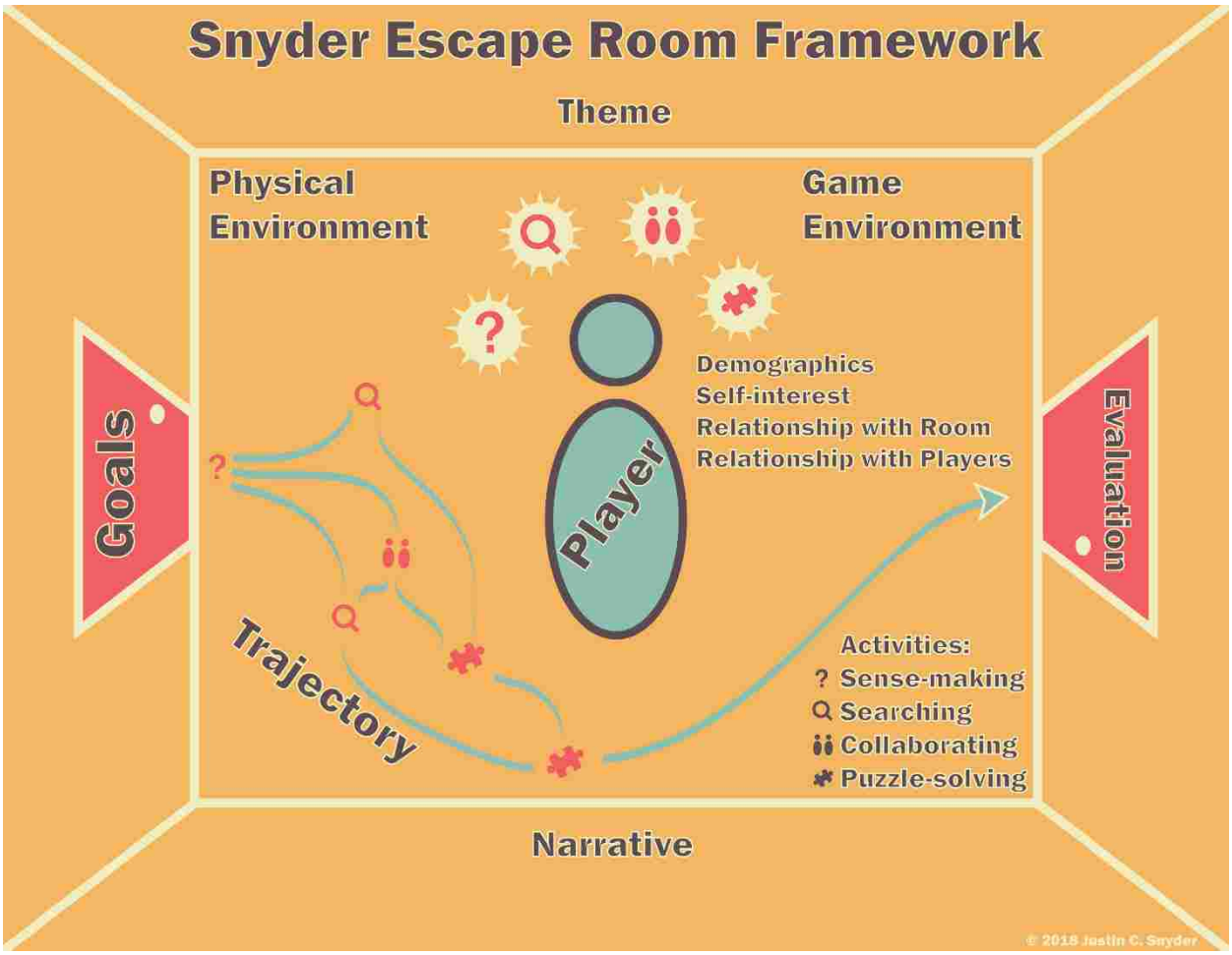

Figure 5-1: Snyder Escape Room Framework

5.1.1 Goals and Objectives

Clear goals should be established first. Designers should ask questions such as:

- What is the overall purpose of the room? How is success defined?
- What are the learning objectives for this room?

Goals should be specific and measurable – especially if the room is to be evaluated and improved upon. The BYU experience had several goals:

- Create an educational escape room prototype that incorporates cybersecurity learning outcomes
- Give players a more contextualized environment to practice the skills learned in class
- Encourage interest in cybersecurity among teenage girls
- Provide a fun and novel experience for the GCC participants

While these goals are admirable, they lack specificity and were largely implicit. Based on observation, the BYU designers each had a different idea of the room and what learning outcomes should be included and did not have a clear vision to rally around. Creating a more cohesive vision with explicit goals would help.

Several designers were tasked with coming up with room activities with cybersecurity learning outcomes. These activities were incorporated into a custom script and Artemis mission. This worked well enough, however, specific goals would have led to specific objectives and would have helped the design team focus on integrating the learning outcomes throughout the experience. Also, specific and explicit goals and objectives would have helped with organization and time management of the project. Future design iterations on the experience will help with specificity.

5.1.2 Players

Understanding the players that will be participating is key in setting up a good room. This includes understanding the player's:

- Demographics
- Self-interests
- Relationship with the room
- Relationship with other players

BYU designers did an excellent job picking a demographic to cater to. Participants were girls between the ages of 12 and 18 who had some interest in cybersecurity and who lived locally. This is a clear demographic to cater to which makes it easier when designing activities and puzzles.

Noted ways the BYU designers catered to these girls' self-interests included context-related aspects of the room such as the ambience and narrative as well as through the activities – especially the social engineering activity. The room was tailored to feel like participants entered a spaceship. The lights and sounds all contributed to the futuristic feel making the experience feel more immersive and invoking some sense of awe. The narrative was also decidedly compelling, and the participants loved talking about their part in it. BYU designers tapped into a few pleasures, notably: awe and wonder, realism, identity (with the roles), narrative, sensation, thrill, and surprise – especially within the social engineering activity.

Most of the girls had never experienced an escape room or experience like the BYU experience – and had little relationship with the room or its concepts. This made the BYU experience quite novel. However, none had experience with Artemis requiring the lengthy Artemis tutorial at the beginning of each session. For future sessions, BYU designers could either simplify the Artemis portion of the experience or provide Artemis training as part of a class during GCC. Participants did have some experience with cybersecurity activities through

the classes at GCC. The designers intended this to be of help with the activities, but more often than not participants struggled significantly and needed multiple hints and help as noted in the next section. Future GCC classes could offer more practice related to the activities in the escape room.

Regarding player relationships with one another, participants engaged with the experience with other members of their peer group. Participants had already had several GCC classes and activities together, and some knew each other from school or other activities. This was good for the overall experience as players did not have to do a great deal of getting accustomed to one another. Other than older participants handling themselves a bit better in socially straining conditions, age discrepancy did not seem to impact the experience.

5.1.3 Activities

Activities are where learning outcomes can really shine. They can include several tasks:

- Sense-making
- Searching
- Collaborating
- Puzzle-solving

The room used for the BYU experience was simple enough to make sense of. It was comprised of several consoles that each performed a different function. In addition, was a front screen that acted as a main screen and window into Artemis, another console under the engineering console for two of the cybersecurity activities, and a tunnel underneath the communications console for a hidden cache related to the saboteur.

However, Artemis took a lot of time for participants to wrap their heads around – even with training. The BYU experience relied heavily on Artemis. Artemis has some excellent in-game activities, but this paper focuses primarily on the activities created by the BYU designers.

When faced with the cybersecurity challenges, participants could not readily understand what they needed to do – or even where to do it (which for two of the activities was the Linux console under the engineering console). The expert review in this paper goes into further detail, but in future sessions BYU designers should do more in assisting the participants more naturally such as decorating the console so that it stands out more as a game object and leaving other visual cues related to the tasks the participants need to do.

That said, searching was not used prevalently in this experience. Finding the Linux console (though not very hard) could be counted as a searching task – even though it is mentioned in the Artemis training. Searching was employed by the teams that recognized that the saboteur used the tunnel. Two teams (out of six) found the hidden case. Teams engaged in digital searching as well – finding the appropriate files for the cybersecurity activities. While these searching tasks were adequate for the BYU experience, traditional escape rooms employ searching much more liberally.

Regarding collaboration, the BYU experience was planned to have multiple participants engaged in cooperative play. Artemis is designed accordingly. Participants worked together with their peers. They noted that teamwork was a big component of their experience and that they learned quite a lot from it. The BYU experience also required high levels of communication and collaboration between players. Participants stressed that following directions and listening to orders from the captain would have helped them with the experience. Because of this high level of communication and collaboration, some players became frustrated with other players that

struggled with following directions or acting as a team. Playtesting would likely have helped determine some of these team-related issues earlier on. Additionally, only two or three participants could work on the two Linux-based cybersecurity activities at a time – and only one operator. As the experience required these activities to be completed to advance, many of the other participants had nothing to do but frantically wait (as they were time-based as well). Concurrent activities would remedy this.

Concerning puzzle-solving, the cybersecurity activities performed poorly against the framework. Participants spent most of the time out of flow and anxious, frustrated, or overwhelmed (if they were working on it, otherwise they were bored). All three activities failed the first seven of Schell's puzzle principles. For each activity, the goal was difficult to understand, and it was hard to get started; there was no sense of solvability, no change in difficulty, no parallelism, and no pyramid structure. Because of this, many hints had to be liberally given – which did extend interest. With some teams, the gamerunners had to give the answer. However, the perceptual shifts did pay off. Participants enjoyed finally getting it, even if they had the answer given to them. Participants particularly enjoyed finding out about the saboteur and what happened regarding the social engineering activity. Playtesting and iterating on the puzzle design will likely help immensely with these cybersecurity activities.

5.1.4 Context

The context of an escape room includes:

- Theme
- Narrative

- Physical environment
- Game environment

The BYU designers nailed the theme of the room. When participants walked in they were struck with awe and excitement. Artemis contributed quite a bit to this, but so did the lights and sounds employed as participants entered the room as well as during the experience. Additionally, the cybersecurity activities fit well with the theme. The saboteur altered the ship's oxygen and engine systems and planted evidence against the crew – this is what participants were trying to fix during the experience.

Narrative was also used effectively. The custom mission designed on Artemis was compelling and participants enjoyed following the story. Even though the experience was largely linear, the story beats kept the excitement and interest up. Story elements were incorporated into the activities. The saboteur was doing suspicious things in the room with the participants for part of the experience. Participants had to discover the sabotage to the ship's systems and fix it before running out of oxygen or before they could power up the ship again. These aspects of immersivity brought the players into the story and really benefited the experience.

As touched upon earlier, the physical environment contributed significantly to the room experience. Lighting and sound was used to both dramatize the narrative as well as a way to communicate to the players what was happening. As stated in the expert review, the captain also had access to the lighting to get the crew's attention. Sound was used for alerts, but also for little things such as the engine running (or off when they had no power). The speakers and mics were also used to communicate with "stations" that were located around the game space and for computer messages (which were often used as hints). The consoles included space-age

keyboards and appropriate space-age chairs. Overall, however, there was little gameplay actually in the physical space. Escape rooms traditionally rely more upon the physical space for puzzles and activities. The cybersecurity activities had some elements of this, but it was largely the saboteur and the hidden cache that would fall under a traditional escape room. Having participants solve problems virtually adds a level of abstraction between the player and the activity. Adding more physical components to the activities should increase the immersivity.

The game environment largely consisted of the Artemis play space. The custom Artemis mission determined where the players needed to go (with their ship) and what they needed to do. Two of the cybersecurity activities lived primarily on the Linux computer under the engineering console. Because they were given full access to the Linux machine, some teams had trouble knowing where the game space ended. One team broke the Linux computer because they made a mistake with the filesystem and had to be advanced forward without completing the activity. The third cybersecurity activity had fuzzy game boundaries as well since it was a social engineering activity that involved a non-player character (NPC) actor. Making these game boundaries clearer or even restricting access to just the game space should help regarding the game environment.

5.1.5 Trajectory

Player trajectories are the selected routes that a player takes through the game space. They can vary widely player to player and experience to experience – provided the designers give players a space to choose.

Because the BYU experience was largely linear, player trajectories were quite limited. Trajectories were heavily influenced by the role chosen at the beginning of the experience with little option to deviate from the selected role. Again, this created bottlenecks at certain times

while select roles figured out what they needed to do to proceed. A better approach would be to create activities that incorporate multiple roles with multiple solutions. This will allow for a wider array of possible player trajectories – even within the constraints of roles. Additionally, more puzzles and challenges that could be worked on concurrently should also help immensely.

5.1.6 Evaluation

At its core, evaluation consists of reviewing the goals and objectives set for the room and measuring the room's performance against them. Questions that can help include:

- Did the room meet these goals, objectives, and learning outcomes?
- What aspects of the room contributed to fulfilling the room goals, objectives, and learning outcomes?
- What aspects of the room detracted from the room goals, objectives, and learning outcomes?
- How can the room be improved to meet these goals, objectives, and learning outcomes?

Iterating through multiple playtests and improving problems with each test helps designers determine and fix the most issues. Also, it is important to use Nicholson's Ask Why approach and cut what aspects of the room have little or no purpose in relation to the room goals.

As this was a prototype room, the BYU experience did little in the way of playtesting or evaluation before the GCC girls participated. Some tweaks were made group to group to help the game run a little smoother, but no major changes were made. Doing some amount of playtesting beforehand would have caught many of the bugs and difficulties that the players experienced.

Running the experience through Nicholson's Ask Why approach would have further refined it. Future sessions will benefit a great deal from applying these two concepts.

Overall participants enjoyed the BYU experience and found it entertaining and fun. Several participants expressed that they would like to pursue cybersecurity education further. However, the impact of the experience on participant interest in the field of cybersecurity is difficult to measure short-term.

5.2 Implications of This Thesis

5.2.1 Contributions

Several authors have proposed frameworks and guidelines for game and educational design regarding escape rooms. This work coalesces some of those ideas into a more substantial and comprehensive framework that designers can use when developing educational escape rooms.

This work also described and analyzed the novel prototyped BYU GCC escape room experience and delved into some of what was successful and what could be improved. The first sessions of the experience were observed and documented.

Then the BYU experience was evaluated against the Snyder Framework as an example of how to use the framework while designing or as a tool for evaluating. Using this framework systemized and catalogued design choices and implications on the room and provided an informed approach for refinement. Also, the BYU experience provided a novel example to use the Snyder Framework with.

Applying the Snyder Escape Room Framework to the BYU experience provided further insight beyond just the expert review. SERF gives a vocabulary and set of heuristics that help designers zero in on important design decisions. When reviewing the BYU experience, several things came to light. For example, using SERF strongly highlighted the importance of having specific goals and objectives before starting on room design – and how it can influence the rest of the experience. Several other examples follow.

SERF helps to understand why aspects of an escape room work or not. Participants enjoyed many aspects of the BYU experience. SERF helps explain why. As noted by player responses and the expert review, the room was a compelling space. SERF stresses an understanding of the player and what they like. The BYU experience tapped into some of these game pleasures that players like to see such as awe, realism, identity, and thrill. Players also enjoyed the room's theme and narrative – but they were particularly delighted with the look and feel of the physical space. SERF demonstrates that this interesting context is what helped players to get immersed in the game world.

But participants also struggled at times with the BYU experience. Many of these player issues became clear when examined using SERF. First, players did not have any familiarity with the Artemis system, a major component of the room. Analyzing the player relationship with the room helped to uncover that players may need more time to become familiar with the Artemis system before tacking other game elements. Players also had trouble with some of the puzzles. SERF looks at puzzle design and offers guidance on what good puzzles need to be successful. Again, while reviewing the BYU experience, it became apparent that many of the puzzles could be improved upon by more fully incorporating the principles of good puzzle design. While examining the context of the experience, it was discovered that improvements could be made to

better demarcate the game space. Also, it became clear that the physical space could have offered more elements for players to interact with. Finally, SERF covers trajectory architecture. The BYU experience was shown to be largely linear and adding further possible trajectories to the experience would likely give more for players to do concurrently.

Using the framework provided a well-defined set of attributes for discussing the BYU experience and helped to clarify what went well with the room and what could be improved upon. This is especially helpful when iterating on room design.

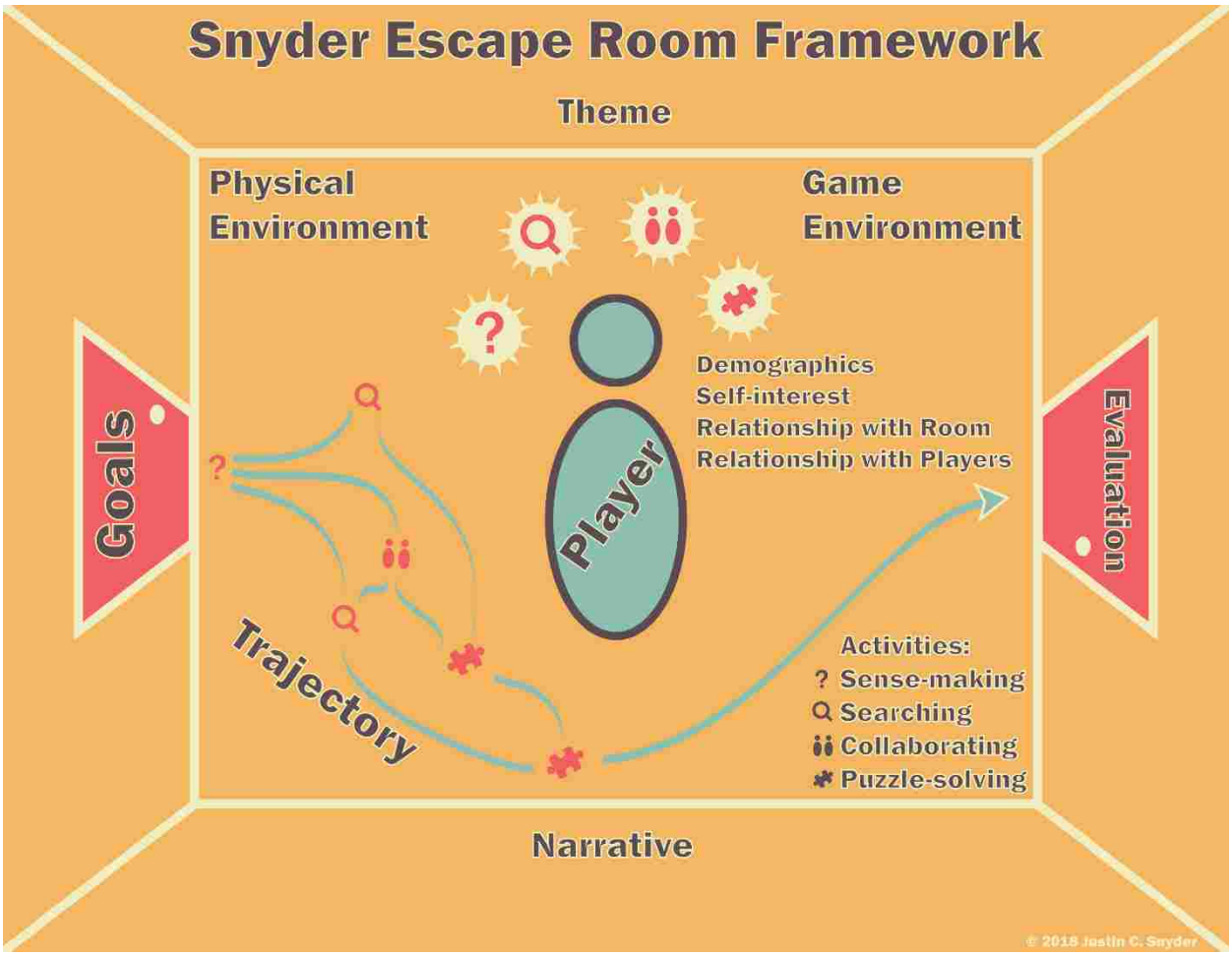

Figure 5-2: Snyder Escape Room Framework

The nature of Snyder Framework (see Figure 5-2) and this work is that it is multidisciplinary, and so touches a wide array of related fields and topics. Of note, are the implications of this work on educational games. The SERF can be used as a resource when designing similar experiences while the analysis of the BYU experience based on the SERF provides an example of how the framework can be used for evaluation and iteration. Also, this work explores further the concept of experiential learning and can be used as a guide for designing experiences beyond escape rooms as well, though further work will be needed to translate it for other experiential genres.

While most of this work has focused on developing escape rooms with learning outcomes, it can certainly be applied to entertainment-based rooms – or even broadened to other types of experiences. As Nicholson explained, escape rooms are related to a variety of other mediums including live-action role-playing, point-and-click adventures, puzzle and treasure hunts, interactive theater and haunted houses, adventure game shows and movies, etc (Nicholson 2015). This work can also be applied to these mediums – especially regarding education.

5.2.2 Limitations and Future Work

While the Snyder Framework incorporates a variety of sources, further research could be done to add to and further extend the framework. The SERF is meant to be comprehensive in covering escape room design, but each part of the framework can be a source of research in and of itself. Further work within these framework elements would also influence how each of these elements interact within a room, which would be another source of future work.

Also, the framework was only used to evaluate one experience, the BYU experience. Further iterations could be made with the framework based on further use. Applying the

framework to more experiences will bring to light further work that can be done. Making changes to the BYU experience based on the evaluation followed by testing and iterating to see if the room increased in effectiveness would also provide direct evidence of the usefulness of the analysis.

Regarding the BYU experience, it was a prototype room that can be further iterated and playtested on. It had three strong learning outcomes that could each be refined and added upon, but with some rework there is also space for additional learning outcomes in the room. Depending on the length and vigorousness of the activity, several more cybersecurity learning outcomes could be added. Also, the room was limited in scope to only the 44 teenage girls that went through the cybersecurity camp. The room would benefit from the refinement of additional playtesting within this group, but further work could be done by broadening this demographic or further changing it. This could allow for other puzzle and activity development based on other cybersecurity learning outcomes as well. Also, this room experience could be modified to have learning outcomes in other fields instead of or alongside the cybersecurity learning outcomes.

5.2.1 Concluding Statements

Education through escape room games shows promise. This work has brought together the tools that designers need to push forward in the space and make a difference in the lives of their participants. With this framework, designers have a clear path to designing exceptional learning escape-room experiences. Researchers and designers also have a way to evaluate existing educational escape rooms. But players win the most. Successful educational escape-room games help create the learning experiences that players need – and they get to have more fun in the process.

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APPENDIX A.

SURVEY QUESTIONS AND DATA

A.1

Pre-Experience Survey

All GCC Pre-exp

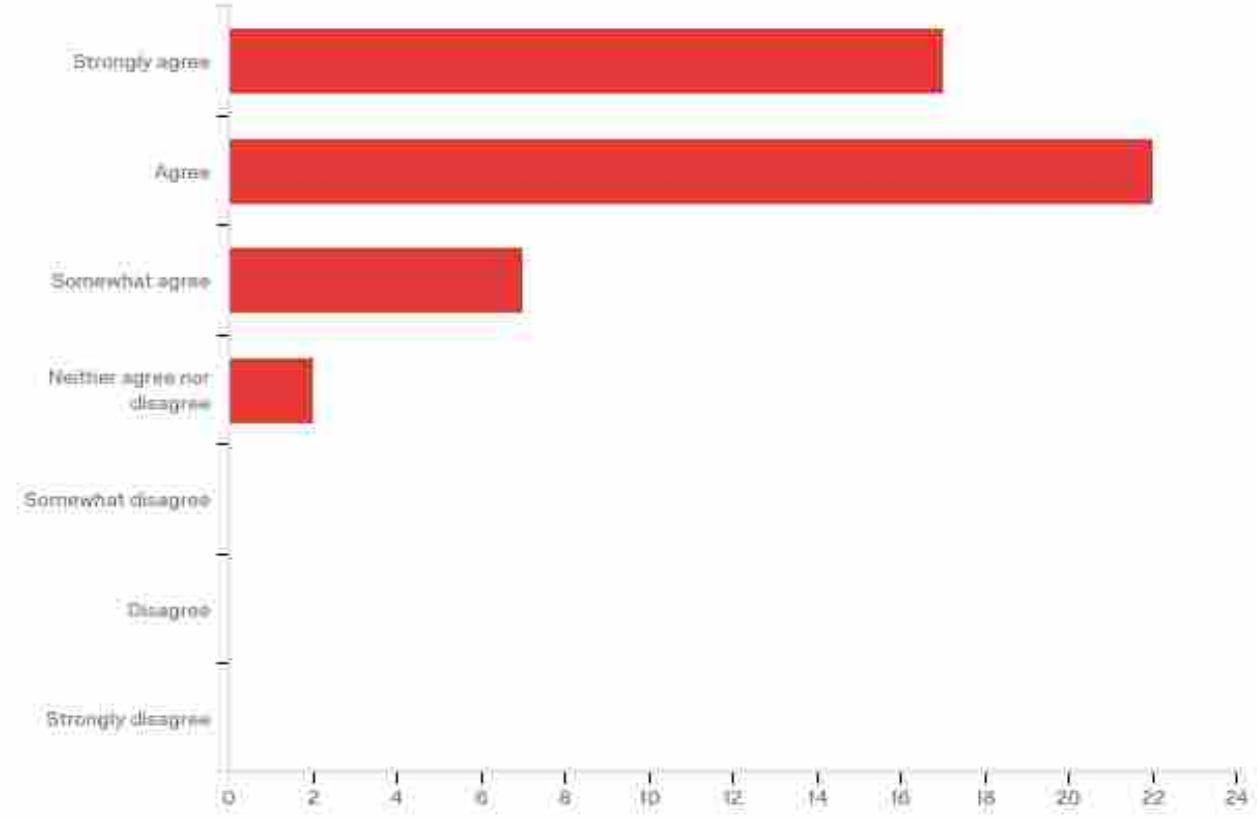
Pre-experience

Q3 - Age

#	Answer	%	Count
1	under 12	0.00%	0
2	12	0.00%	0
3	13	27.08%	13
4	14	12.50%	6
5	15	25.00%	12
6	16	25.00%	12
7	17	8.33%	4
8	18	0.00%	0
9	19	2.08%	1
10	20	0.00%	0
11	21	0.00%	0

12	22	0.00%	0
13	23	0.00%	0
14	24	0.00%	0
15	over 24	0.00%	0
	Total	100%	48

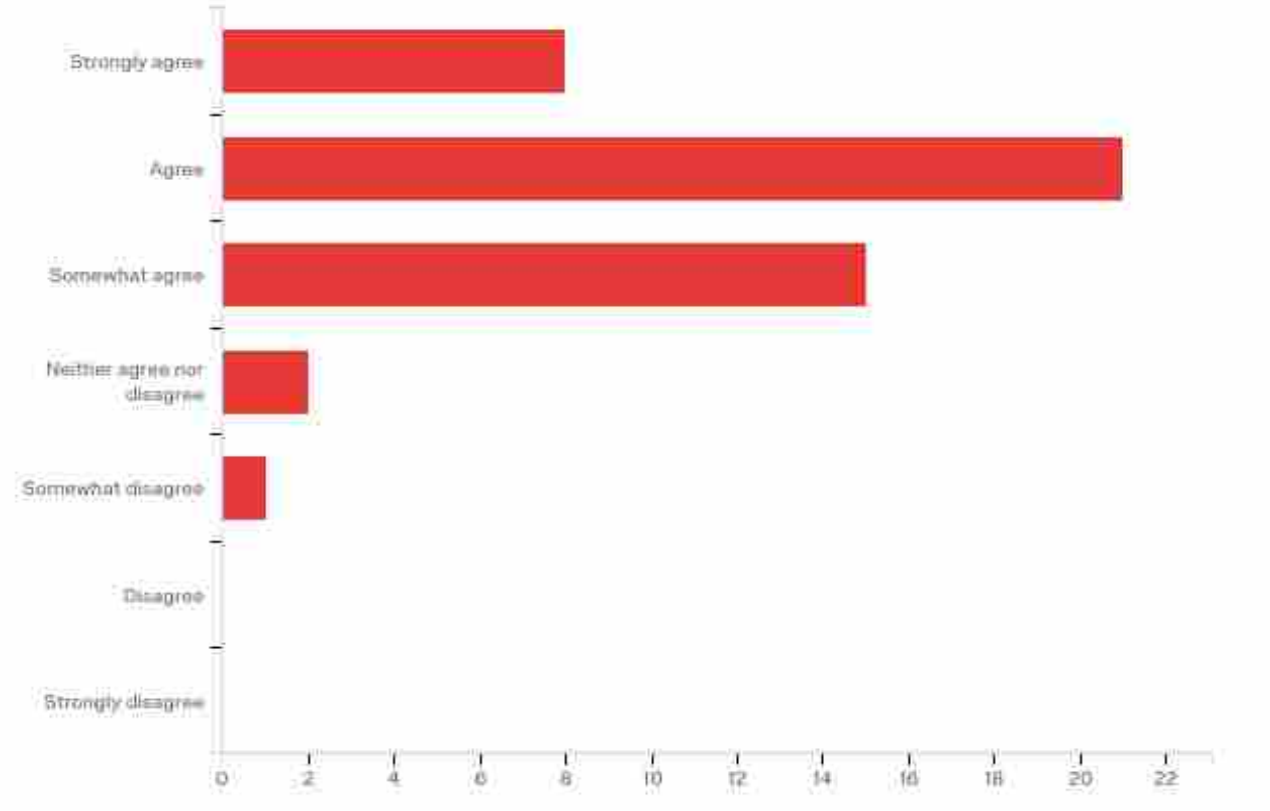
Q2 - Indicate how much you agree with or disagree with the following statement: "I feel confident in my ability to learn new technologies".



#	Answer	%	Count
1	Strongly agree	35.42%	17
2	Agree	45.83%	22
3	Somewhat agree	14.58%	7
4	Neither agree nor disagree	4.17%	2

5	Somewhat disagree	0.00%	0
6	Disagree	0.00%	0
7	Strongly disagree	0.00%	0
	Total	100%	48

Q5 - Indicate how much you agree with or disagree with the following statement: "I feel confident in my ability to use new technologies".



#	Answer	%	Count
1	Strongly agree	17.02%	8
2	Agree	44.68%	21
3	Somewhat agree	31.91%	15
4	Neither agree nor disagree	4.26%	2

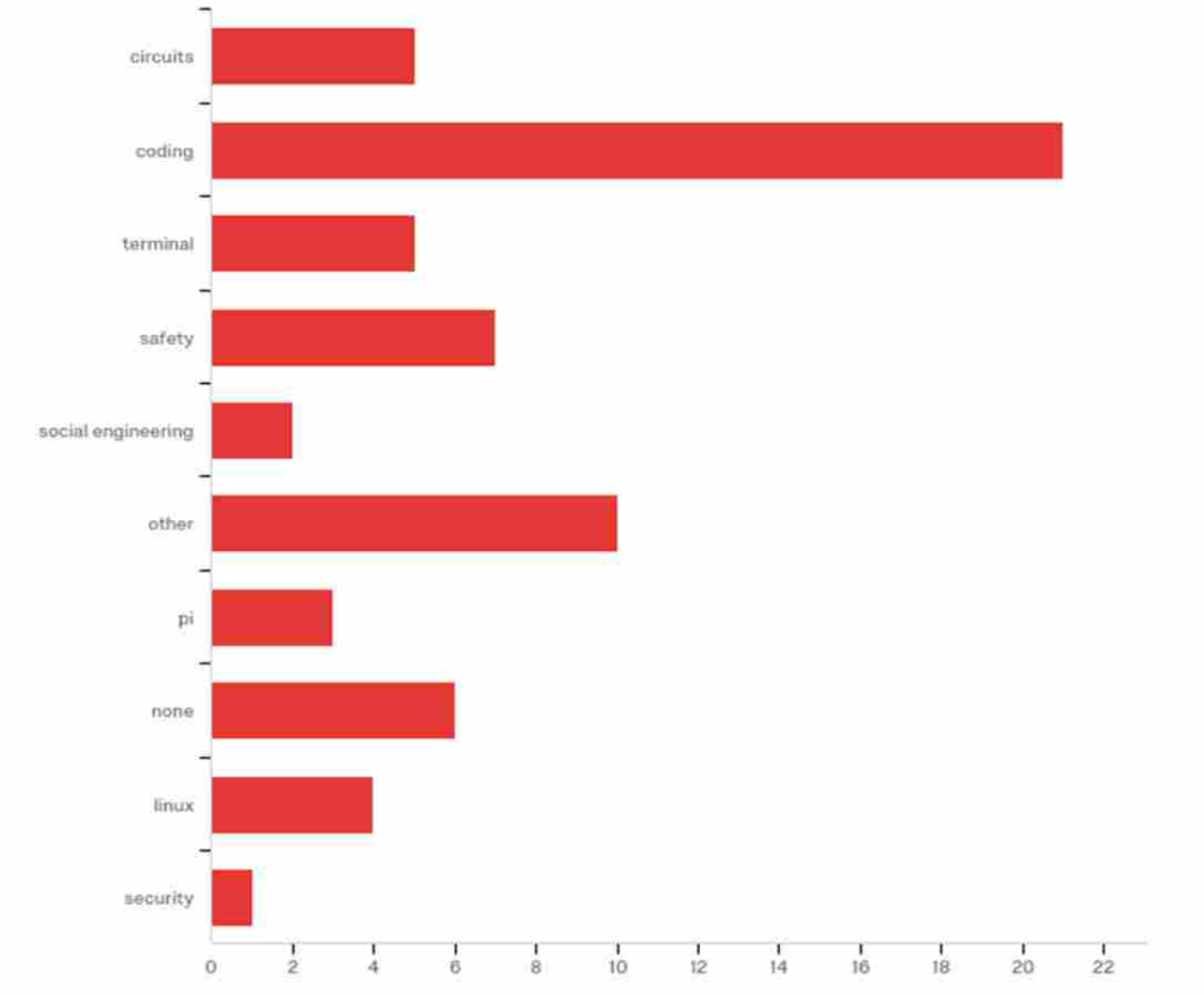
5	Somewhat disagree	2.13%	1
6	Disagree	0.00%	0
7	Strongly disagree	0.00%	0
	Total	100%	47

Q6 - Which topics covered in the classes were you already familiar with (i.e. heard of, learned about, or previously came in contact with)?

Which topics covered in the classes were you already familiar with (i.e. he...
no topics, it was all new to me
kinda
none of them
leadership
everything, i taught the class
some coding, forensics
heard of/came in contact with programming
I knew how to be safe online
Python coding electronics and building circuits the cryptography used in capture the flag
Python some internet safety ciphers
Python, Phishing
I was familiar with topics concerning programming
Coding (not w/ python) , some internet safety
HTML
n/a
I was familiar with the technology
Commandlines and Python from GCC 2015
I wasnt familiar with any of the technologies that were covered
i don't really know
Terminal/command lines programming coding

None
python, terminal
comp. forensics
computer safety, i also knew some stuff about circuits
security
Computer safety circuits coding programming
Strong passwords coding
Electrical circuits, command line, python, linux
Python, linux, some html. cryptography
Linux, cyber patriot, command line
python, linux, types of attacks
basic code
the password quesser
Internet safety, wifi, hacking, social injening
programming
Social engineer
Internet Safety
Programming
Most of it except the actual commands
what a raspberry pi is
Python
coding and LED lights
I had a tec class in 7th grade
Circuiting w/ the pi
None
led programing
Circuts and raspberry pi

Q6 - Topics



Answer	%	Count
circuits	10.64%	5
coding	44.68%	21
terminal	10.64%	5
safety	14.89%	7
social engineering	4.26%	2
other	21.28%	10

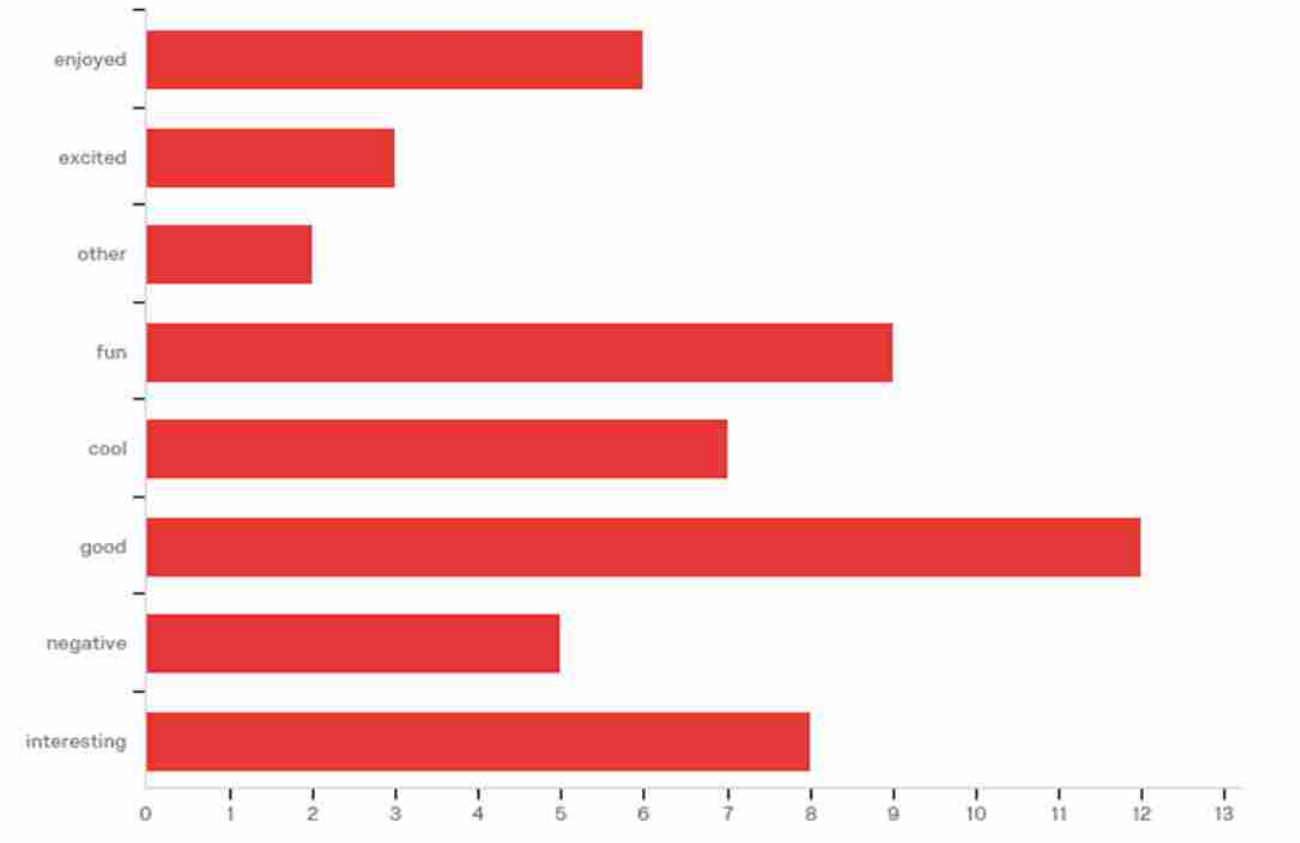
pi	6.38%	3
none	12.77%	6
linux	8.51%	4
security	2.13%	1
Total	100%	47

Q7 - What are your feelings about what you are learning in the classes so far?

What are your feelings about what you are learning in the classes so far?
giddy, excited
i was good
i think they are interesting. i will need a few things to go over again but it's been great
pretty cool
so awesome!
:)
it's all interesting
I really liked all the new things i learned
i have really enjoyed the classes. I have learned a lot about the security aspect of technology
I think it's been very interesting. i've enjoyed learning about everything
I feel confident about coding but guessing passwords and decoding messages is a challange
I am really enjoying what I have been learning
some of it was really hard-but all of the classes have been fun! I didn't know a lot so it has been fun to learn more and hear cool stories :)
I love it! it's all so interesting
i am loving everything i am learning
ive been learning a lot and it's been really fun
I understand some of it, i'm not sure how much i'll be able to use it without help and/or instruction
it's very interesting
it is good information for people to know

I've really enjoyed it. I feel like i've come a long way during this camp.
slightly confusing but very interesting
i feel good. i really like this field, i can see myself going into this profession
hard to follow
I feel like I've learned a lot about terminals
i wish there was a little more info on cyber security and coding and hacking and everything in general
i think it's great i've really enjoyed this
I think the things we are learning are really cool
i'm really excited to learn more
i love it! i need some reassurance on a few things, but for the most part, i'm good!
interested, want to learn more
`I'm enjoying it a lot - I learned to use new linux tools
they're fun
it's super cool
hard! but fun :)
it's cool, but kind of scary
fun
it's really cool, but i'm kinda bored
they are fun
cool! a bit weird but stuff basically makes sense
They are fun and interesting
They are fun, but there should be a little more explanatory
So fun! Definitely want to come again
good
awesome
I really like these classes and learning new things
i am feeling good about it
I get excited when I can know how i can apply the skills that I am learning

Q7 - Topics



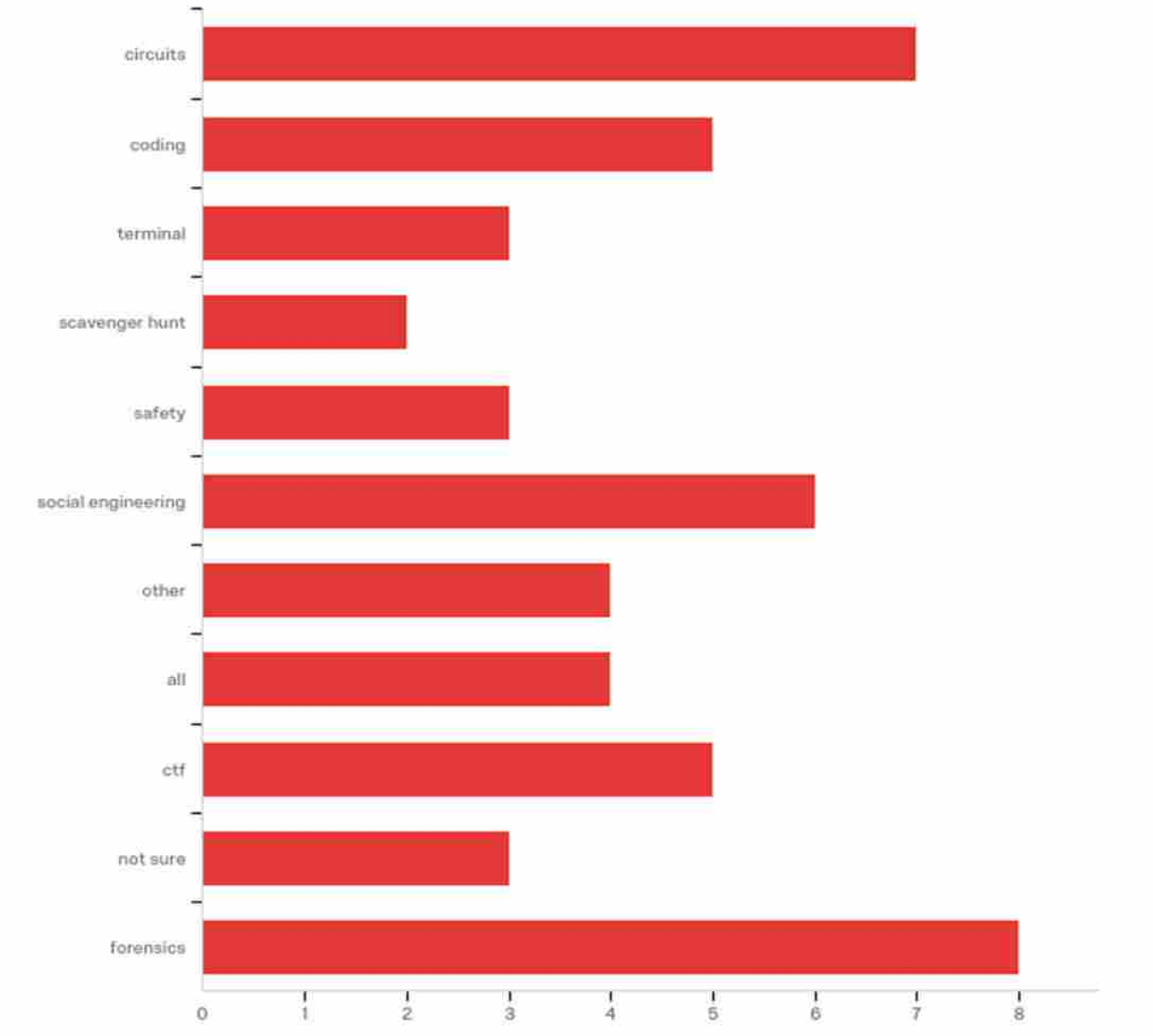
Answer	%	Count
enjoyed	12.77%	6
excited	6.38%	3
other	4.26%	2
fun	19.15%	9
cool	14.89%	7
good	25.53%	12
negative	10.64%	5
interesting	17.02%	8
Total	100%	47

Q8 - What has been your favorite class? Why?

What has been your favorite class? Why?
internet safety. i like to be aware about what's around me
everything
i have liked the coding topics
hacking...it's self explanatory
circuits, i taught it
forensics - cuz :)
OSINT it was really fun!
i liked doing things with raspberry pi
I really enjoyed the forensics and the electronics. I really enjoy the hands on and easily applied aspect to these classes
Electronics. I got to try and do different things on my own, but i had help. I also got to work with my hands
Python because to me it was similar to Java so I was able to get it pretty fast
My favorite class was the one about computer forensics because i am interested in pursuing a career in that area.
Internet safety- i learned the most and the guy told us some really awesome stories!
Forensics-the presenter and information was all very interesting
i liked the one where we learned the commands for terminal because now i can navigate it.
when we learned how to use the terminal and simple commands, it was really interesting to learn whats behind what's going on the screen
social engineering because i think the manipulation and getting information is really cool
the bread board circuits
i am not sure
The forensics because the mystery interests me
encoding messages into images because it's very interesting and fun. It's cool to understand how it's done
terminal, because i have learned so many cool things, like how to hack and get apt and etc.
comp. forensics
circuits it was fun to experiment with that

planetanium because i got to sleep lol jk i liked learning about the white hat hackers
i really enjoyed hacking (the scavenger hunt) as i think i'll really enjoy the escape the room. it's my favorite because i really enjoy it
the scavenger hunt, because it was hands on and challenging
capture the flag because i like puzzles and competing
capture the flag! it's logical and makes me think
CTF or social engineering, they interest me and have some background
capture the fag! it's the most challenging
anything coding
social engineering
social injening
all of it - because it's all new to me.
all
internet safety, because I learned they work with FBI
social engineering
IDK the coding classes were cool
lynx because it is hands on
forsencis because it is very easy to understand with the right directions
LED lights. The experimenting with it
idk
forensics
i like CTF because you are competing and learning at the same time
the computer class it is fun because i get to learn about programming
i have enjoyed all the classes

Q8 - Topics



Answer	%	Count
circuits	14.89%	7
coding	10.64%	5
terminal	6.38%	3
scavenger hunt	4.26%	2

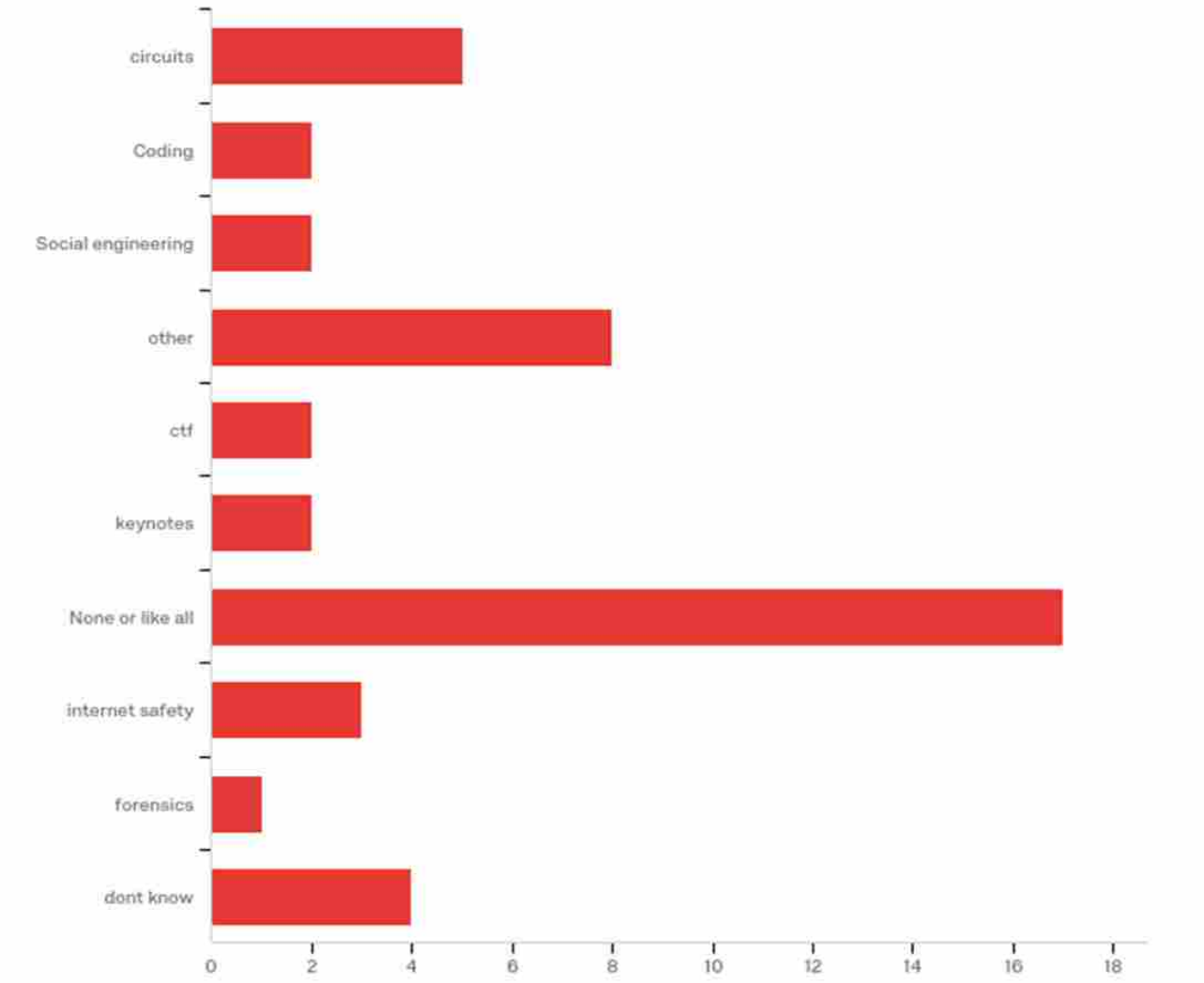
safety	6.38%	3
social engineering	12.77%	6
other	8.51%	4
all	8.51%	4
ctf	10.64%	5
not sure	6.38%	3
forensics	17.02%	8
Total	100%	47

Q9 - What had been your least favorite class? Why?

What had been your least favorite class? Why?
coding. it made me feel dizzy
idk
i'm not sure
planetarium, i fell asleep
terminal, i taught it
none of them-i enjoyed them all
none. they were all cool
nothing
I have enjoyed every class always something to learn.
social engineering. There wasn't a lot of hands on with it.
Decoding the clues on that website
I didn't have a least favorite class because i liked them all
Coding. It doesn't come to easily for me right now. I'm confident i can learn it-but it's still hard.
putting hidden messages in pictures, because it wasn't very interesting and wasn't presented very well
n/a
The electrical stuff with the LED's, I like the C.S. stuff better
Forensics, i dont think the workings of the hardware part is very interesting

CTF
i dont know
I didn't really have one. I've enjoyed it all!
They've all been very interesting and enjoyable.
i mean i dont have one cuz every class i had i learned something new and cool
ive liked everyone of them
sitting at computer for 7 hours
wednesday when we didnt really do much we just sat playing minecraft and other games
i didnt enjoy sitting at a computer for a long time
the circuit class because they were going really slow
social engineering because i'm somewhat socially awkward
the stuff that isn't learning (ex: sponsor keynotes) because they're cool, but I get bored easily and I like to learn.
circuits, slow, boring, unclear directions
internet safety - i knew most of the information
the password protect
first keynote
i dont know
none
nothing
They all kind of meshed
i have not had one
lectures wasnt my fave but they werent bad. basically everything's cool
dangers online because we have heard about it many times
none, all have been fun
i like them all
phishing
circurity was kind of boring
none of them
the circuits portion because the person didnt know exactly what/how she was teaching us

Q9 - Topics



Answer	%	Count
circuits	10.87%	5
Coding	4.35%	2
Social engineering	4.35%	2
other	17.39%	8
ctf	4.35%	2
keynotes	4.35%	2

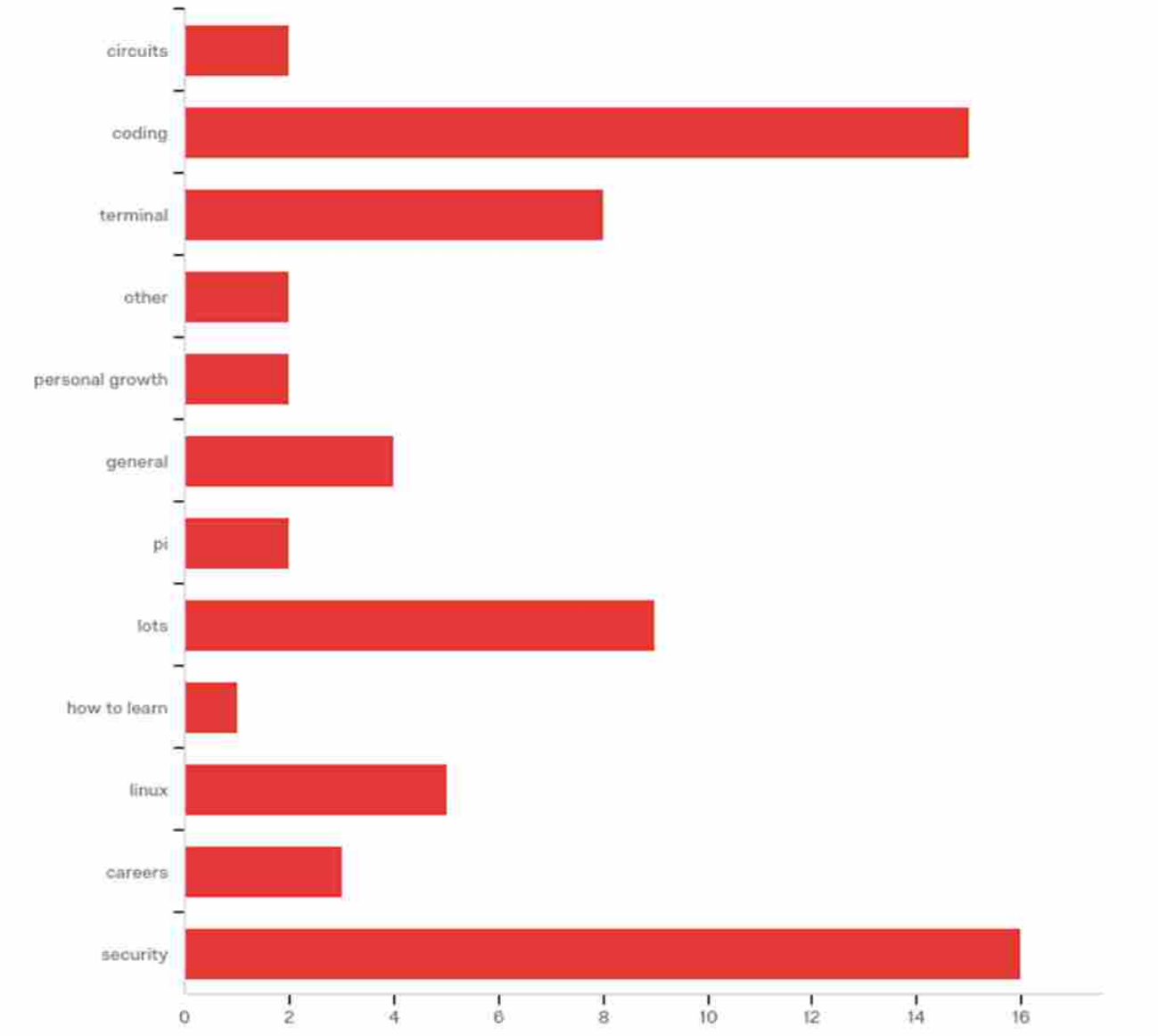
None or like all	36.96%	17
internet safety	6.52%	3
forensics	2.17%	1
dont know	8.70%	4
Total	100%	46

Q10 - What do you feel you've learned from the classes?

What do you feel you've learned from the classes?
classified
i learned a lot
i have felt to maybe be a little more cautious with my passwords and what i post
patients and such
nothing
how to better improve my skills
lots of stuff
i learned how to do python
I have learned more about security and about a more technological skills
Ive learned to better code, and how people can hack me
Not really learned but more confident in everything
i have learned a lot of new things and I hope to be able to apply it.
How to protect my info, puser, the threat of hackers, and the basics of coding
How to be safe online, the basics if linux, python computer forensics, vim, and how to better operate computers
i have learned how to use/program a computer
I've learned how to use the terminal, i've learned some jobs involved with C.S.? about computer forensics
i've learned about some coding and encryption, which is pretty fun.
how to use a linux and raspberry pi system
how important it is to have strong passwords

I've learned how to code and use commands
The parts of a computer (ish) basic coding techniques for penetration testing ways to prevent (limit) malware attacks, etc.
how to become and prevent hacking and thinking more I just learned so much
how to better use technology
i have learned how to light up an LED on a bread board, and I know some computer commands
more about making stronger passwords
what security is and the different parts of it
what cyber security is and jobs that pertain to it
i think i've learned a bit of the baiscs and some ways to find more information i've also discovered some more careers i might be interested in.
more python, coding in general and logic
command lines, coding, terminology, what to do next to follow in this career path
being comfortable with the linux terminal, circuits - i had never done that before
a little bit more about coding and cool hacking facts
a lot
too much my head hurts
how to better protect myself, how to get into things i need indirectly
a lot
some stuff about coding. but i will probably forget all of it
linux
stuff
how to operate raspberry pi
how to figure out password, what lynics are, and what not to do for passwords
i learned a lot
how to be safe and know more about computers
i have learned how to program
to hack, program
basic coding commands

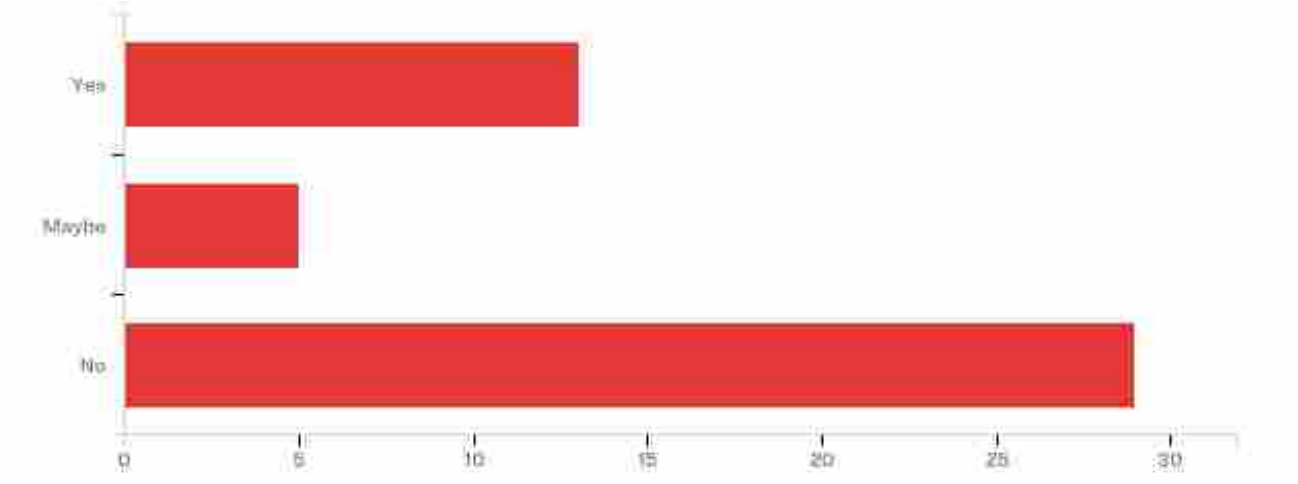
Q10 - Topics



Answer	%	Count
circuits	4.35%	2
coding	32.61%	15
terminal	17.39%	8
other	4.35%	2

personal growth	4.35%	2
general	8.70%	4
pi	4.35%	2
lots	19.57%	9
how to learn	2.17%	1
linux	10.87%	5
careers	6.52%	3
security	34.78%	16
Total	100%	46

Q11 - Have you ever participated in an escape room experience before?

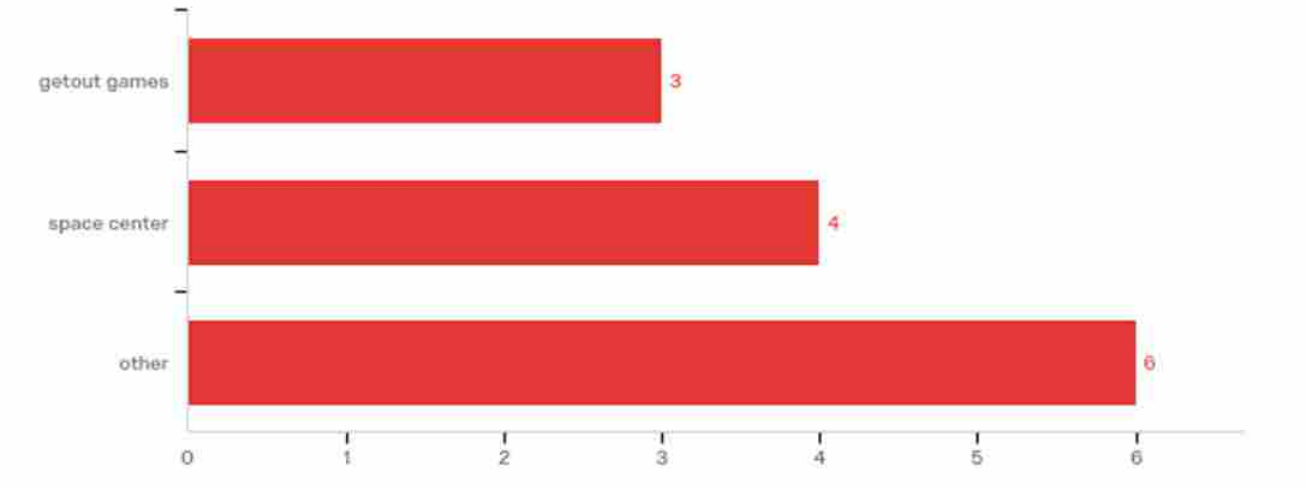


#	Answer	%	Count
1	Yes	27.66%	13
2	Maybe	10.64%	5
3	No	61.70%	29
	Total	100%	47

Q12 - Please give the name of the escape room facility, the name of the room, and a brief description:

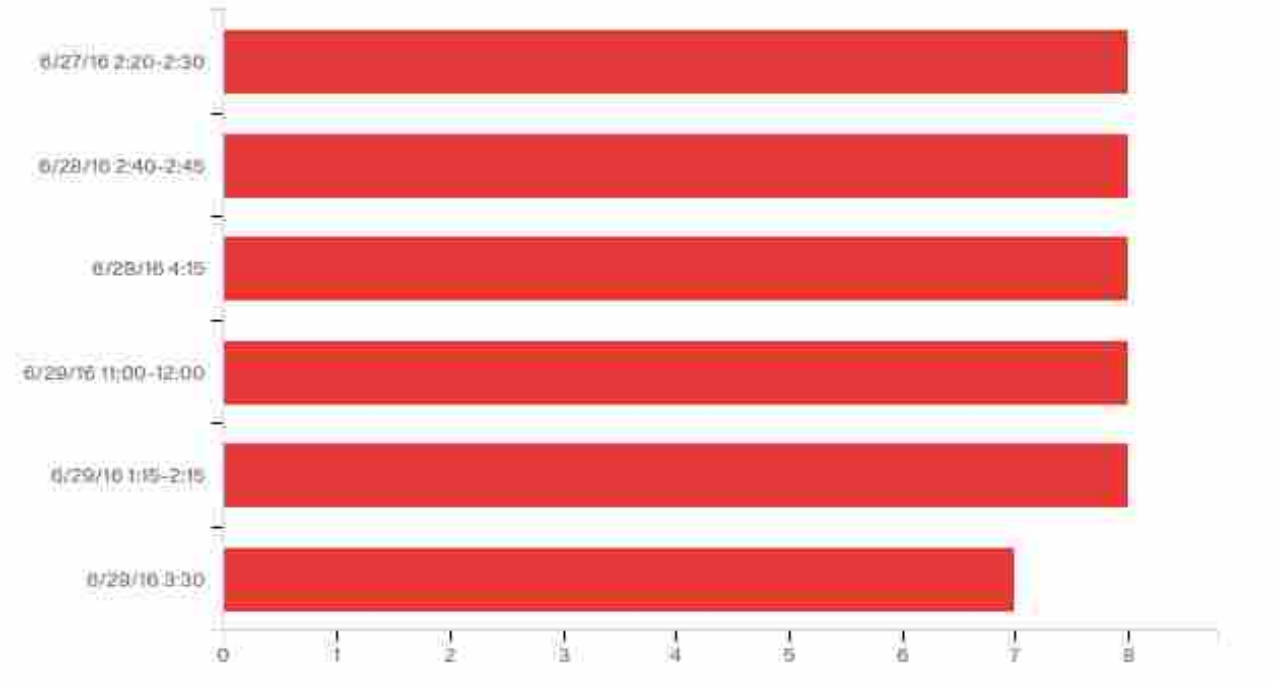
Please give the name of the escape room facility, the name of the room, and...
birthday party (place i dont remember) you go through a "teleporter" thing and it's a lot like this thing we did!
i played in the first session and volunteered at CM SEC and field trips
alcatraz games it was a bus
space center. we have a space mission to solve
Escape Room, Museum escape, in a medieval museum and had to unlock stuff.
get out games and the same simulator in PG three different times.
get out games. Mummy room- find clues in mummy tomb to get out (in one hour) zombie room- run from zombie while finding clues to get out. Provo Heist- find clues in office to get out before they come back. Nuclear reactor- find clues in office to cancel the bomb before it goes off.
get out games, heist room, computer and tech stuff with numbers and puzzles
planetarium in american fork, UT. I dont remember the room name. We piloted an Alien ship and dodged asteroids. no coding involved.
video game. escape the room
discovery space center. i have but i dont remember them calling it that.
BYU

Q12 - Topics



Answer	%	Count
getout games	25.00%	3
space center	33.33%	4
other	50.00%	6
Total	100%	12

Group



Answer	%	Count
6/27/16 2:20-2:30	17.02%	8
6/28/16 2:40-2:45	17.02%	8
6/28/16 4:15	17.02%	8
6/29/16 11:00-12:00	17.02%	8
6/29/16 1:15-2:15	17.02%	8
6/29/16 3:30	14.89%	7
Total	100%	47

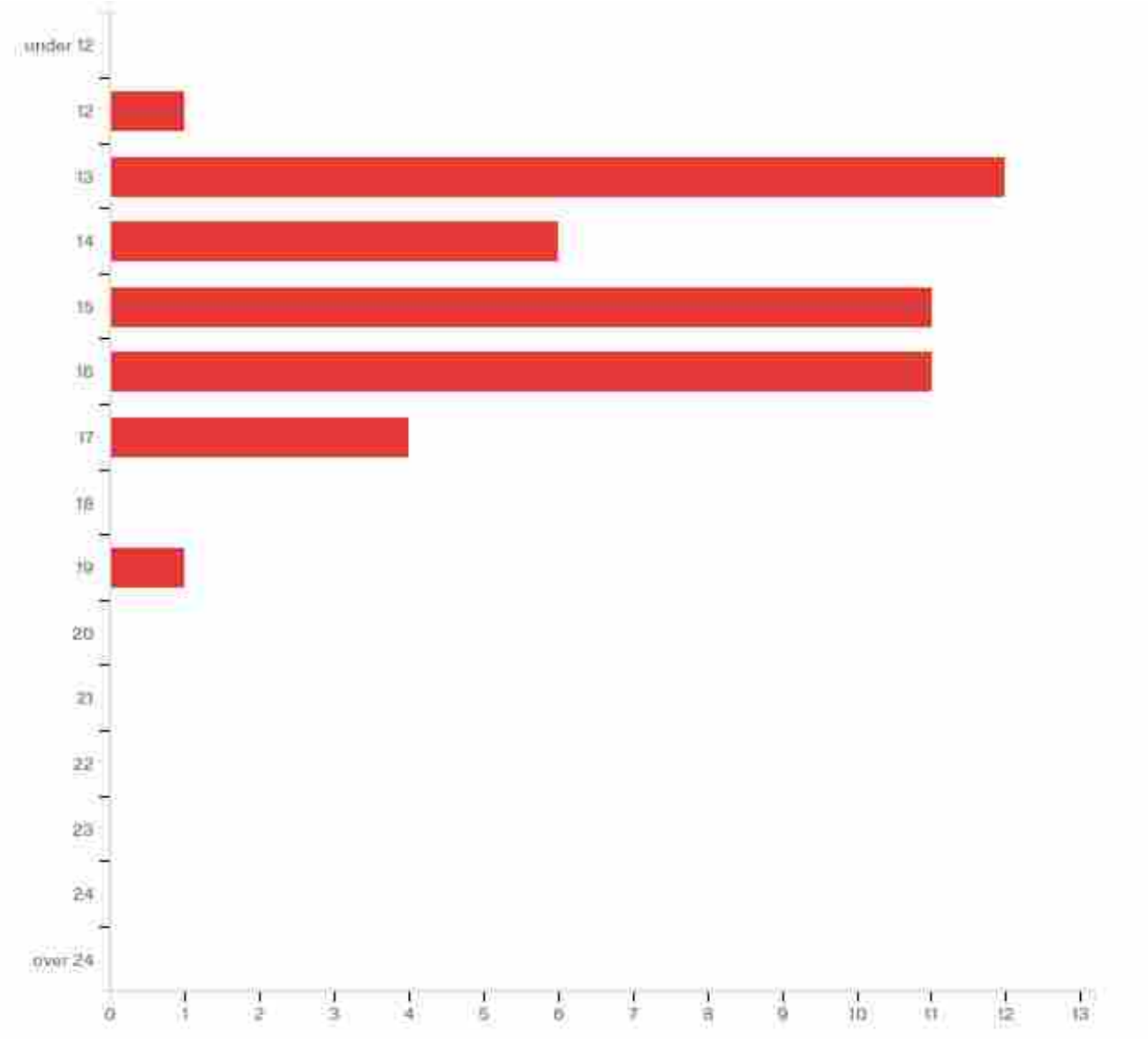
A.2

Post-Experience Survey

All GCC Post-exp

Post-experience

Q4 - Age



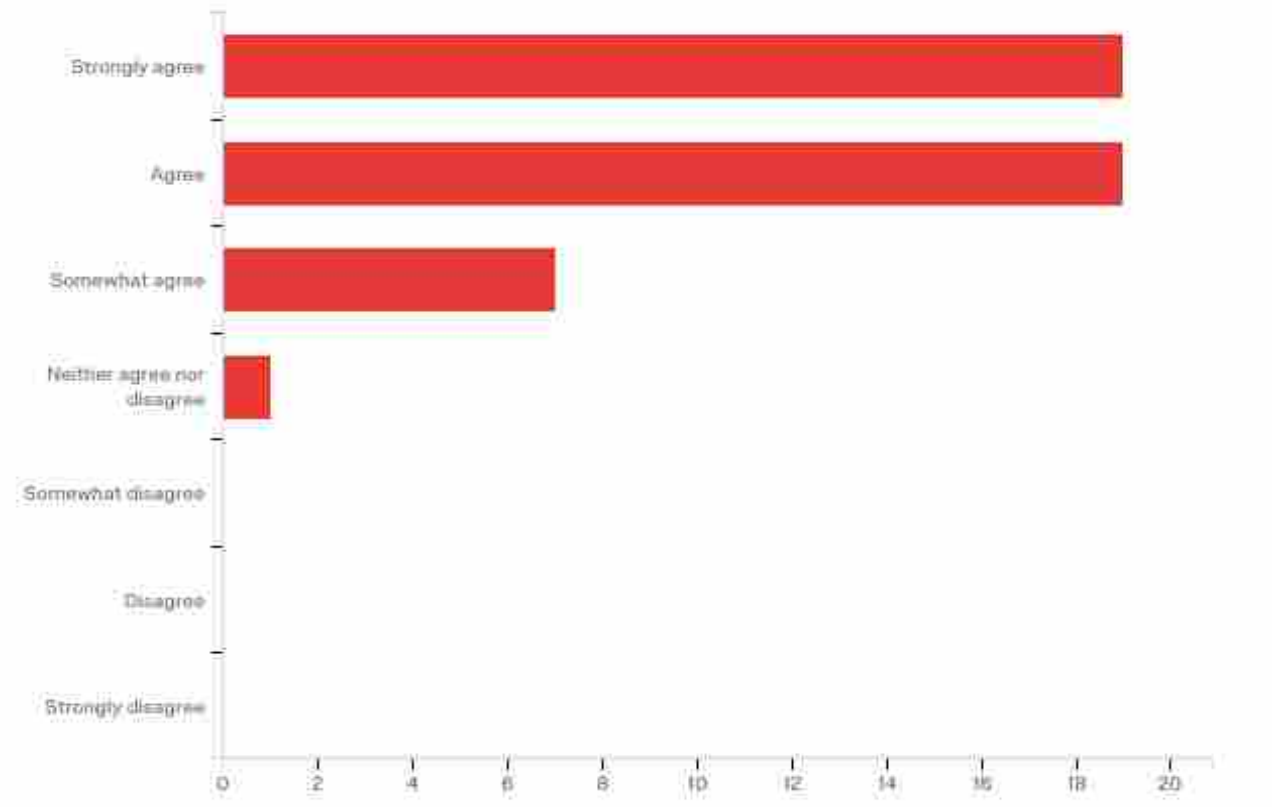
#	Answer	%	Count
1	under 12	0.00%	0
2	12	2.17%	1
3	13	26.09%	12
4	14	13.04%	6
5	15	23.91%	11
6	16	23.91%	11
7	17	8.70%	4
8	18	0.00%	0
9	19	2.17%	1
10	20	0.00%	0
11	21	0.00%	0
12	22	0.00%	0
13	23	0.00%	0
14	24	0.00%	0
15	over 24	0.00%	0
	Total	100%	46

Q3 - What time did you start the escape room?

What time did you start the escape room?
4:15
3:30
3:30
3:30
3:30
3:30
1:15
1:15
1:15
1:15
1:15
1:14
1:30
1:15
11:00
11
11:00
11:00
11:00
1045
11
11 am
2:40
2:45
2:40
2:40

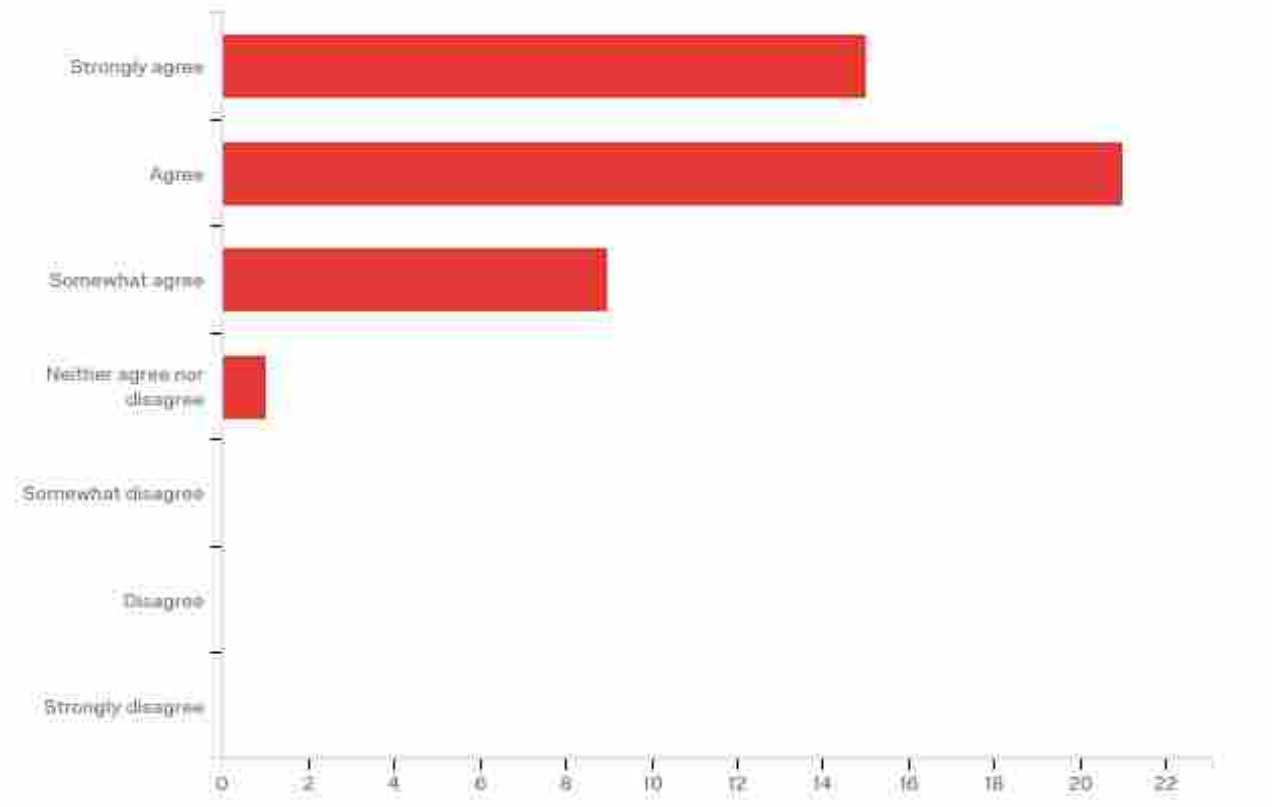
2:45
2:45
2:40
2:40
2:22
2:30
3:30
2:30
2:25ish
2:30
2:30
2:20ish
4:15
4:15
4:15
4:15
4:15
4:15
4:15
4:15

Q7 - Indicate how much you agree with or disagree with the following statement: "I feel confident in my ability to learn new technologies".



#	Answer	%	Count
1	Strongly agree	41.30%	19
2	Agree	41.30%	19
3	Somewhat agree	15.22%	7
4	Neither agree nor disagree	2.17%	1
5	Somewhat disagree	0.00%	0
6	Disagree	0.00%	0
7	Strongly disagree	0.00%	0
	Total	100%	46

Q9 - Indicate how much you agree with or disagree with the following statement: "I feel confident in my ability to use new technologies".



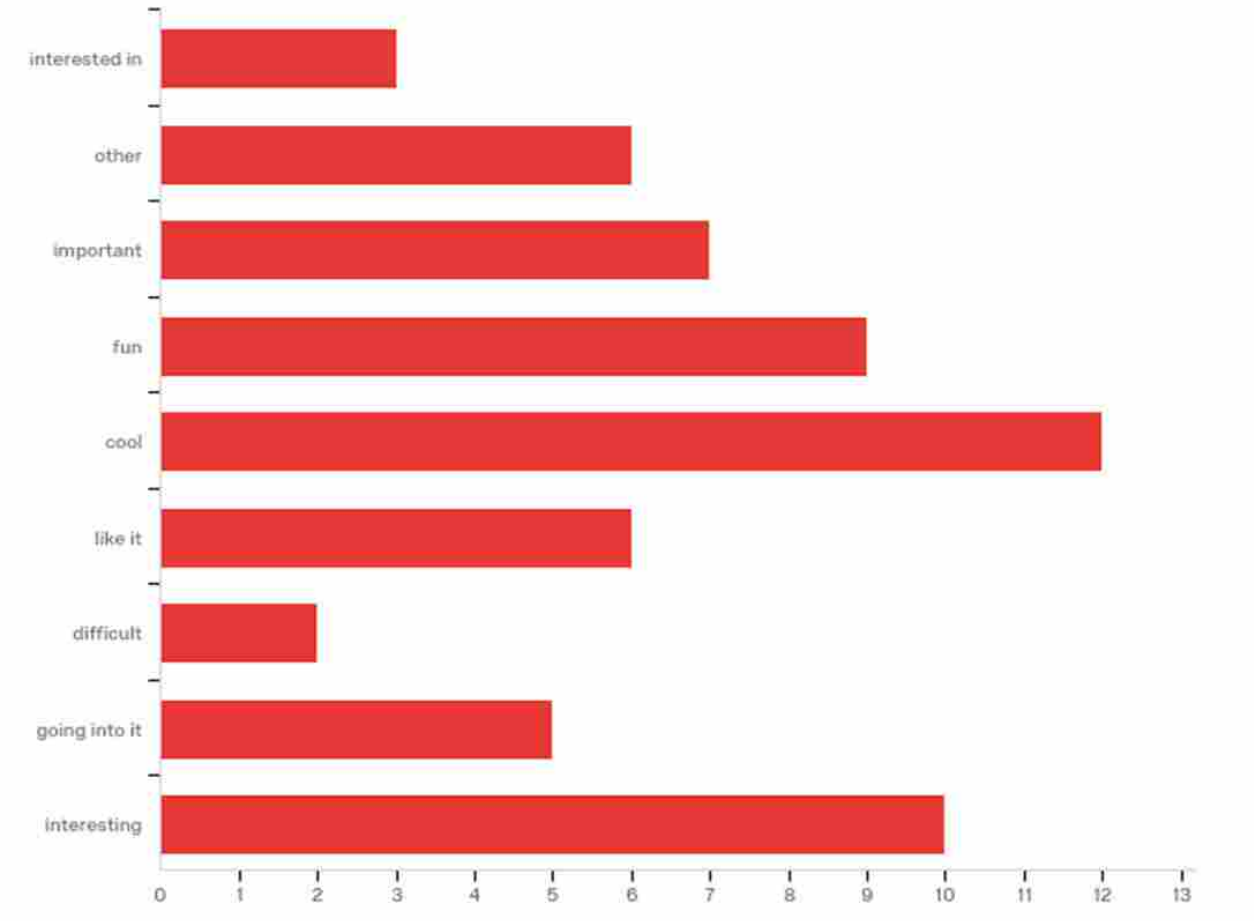
#	Answer	%	Count
1	Strongly agree	32.61%	15
2	Agree	45.65%	21
3	Somewhat agree	19.57%	9
4	Neither agree nor disagree	2.17%	1
5	Somewhat disagree	0.00%	0
6	Disagree	0.00%	0
7	Strongly disagree	0.00%	0
	Total	100%	46

Q5 - What are your feelings toward cybersecurity?

What are your feelings toward cybersecurity?
it is cool
good i hope
grateful
it's awesome
its very interesting
it is interesting and fun!
i love it
It's awesome and surely needed. Very interesting
i think it's cool
It's interesting and I would learn more about it
i feel that it is very important and without it there could be a lot of problems
i have found that i really like it and i am likely to use it in my future career
cyber security is very important
it's really fun to learn about and consider as a job-i would just not be good at it
hard
It's freakin cool
It's very cool and interesting and new
It is a good thing to be aware of
it'll be the future and it involves a lot of the world
I think it's interesting but pretty tricky and complicated
it is important and very interesting
it's very interesting
It is very interesting and I want to learn more about it
i am very interested and hope to learn more
I think cyber security is really cool, and it would be fun to do.
Interested, want to further my knowledge, I'll be back for GCC next year!

I really like it and want to go into a profession that has something to do with it
I like it and I want it to be my major in college
It's a field I want to go into
i think it is really fun and interesting. Most likely something I would be interested in.
it is fun
i think it is cool
it's cool, i think i would really enjoy going into it. Maybe i need a little more practice :)
It's cool, and important
it's cool, i dont know that i'd want to do it as a job but maybe
it's important
it's difficult
i like it
Cyber Security is a necessary thing to learn
I love it
fun
I feel like it would be a fun career
I think it is fun and educational
fun!
it is cool
It's great

Q5 - Topics



Answer	%	Count
interested in	6.52%	3
other	13.04%	6
important	15.22%	7
fun	19.57%	9
cool	26.09%	12
like it	13.04%	6
difficult	4.35%	2
going into it	10.87%	5

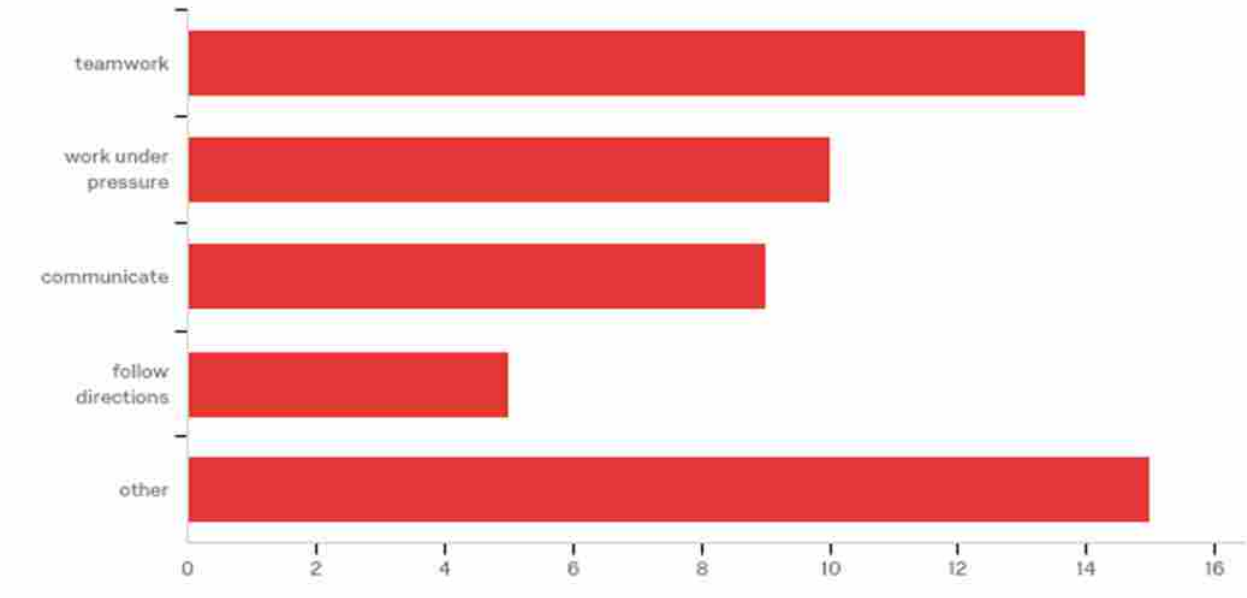
interesting	21.74%	10
Total	100%	46

Q4 - What do you feel you learned from the "escape the room experience"?

What do you feel you learned from the "escape the room experience"?
it was cool
dale is a jerk
don't let the computer freeze
idk
it was hard
i didnt really get really far but i learned the controls of the pilot
to work well with other people, to stay calm under pressure
how to manage a team, and rely on other people
i learned how to better work with others
what it's like to be in star trek
i learned how to better work as a team and under pressure
i learned how to work as a team in a high pressure environment
i learned to work together as a team
we had to communicate to work the ship. everyone had to know what was happening and work together and think to solve problems
nothing
how to follow rules
it's hard to stay in one place but we need to talk to each other for anything to work
we need to all communicate
we can sometimes over complicate things. we also need to communicate better
team work is extremely important and dont over complicate things.
you have to communicate
you need to talk to each other to succeed
i learned not to trust everyone ok lol follow directions when people of authority tell you is best especially when others yell a you to not too

i feel i became somewhat of a better leader
I learned how to use a new technology and to stay calm in emergencies. I also learned how to solve problems
New skills, ability to communicate and work as a team
When you're in/on a team, you have to communicate really well
grace under pressure
how to work as a team
You need to work as a team and check your controls. Always!
i need to learn to program better
i learned it is important to keep calm in stressful situations
next time i should speak up for the position i want
i learned how to work with programs under stress
figure out who your momentum people are at the beginning! also read things (diagnose the problem) properly before trying to fix them
nothing much, just that i know squat about programming
stressful but fun
it was so fun!
comms is the worst job. you dont do squat
i learned how to focus on my job
control panic. dont try to yell at anyone
don't stress listen to the captain
that we need to work as a team
do not panic!
don't panic
to listen to others

Q4 - Topics



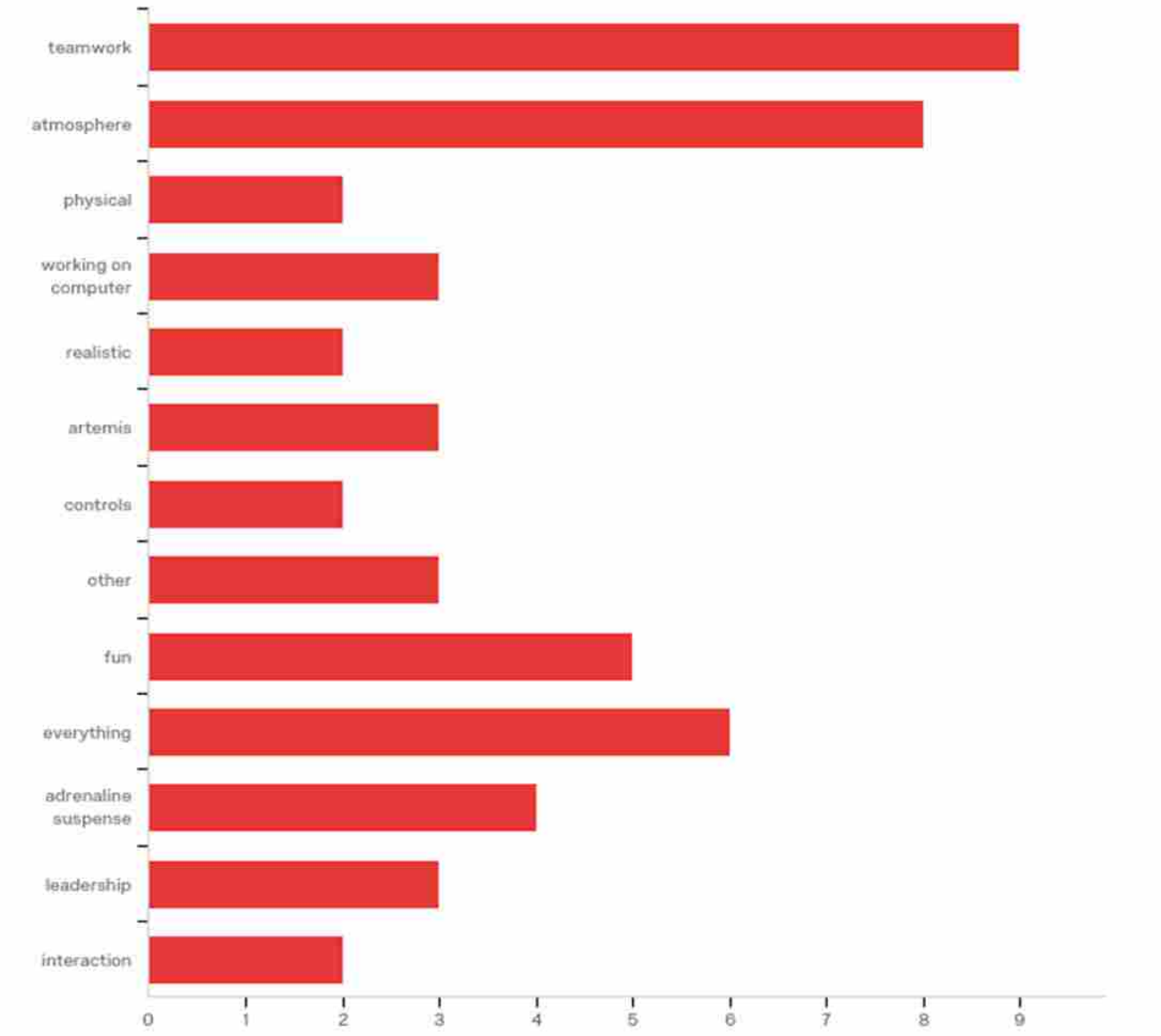
Answer	%	Count
teamwork	30.43%	14
work under pressure	21.74%	10
communicate	19.57%	9
follow directions	10.87%	5
other	32.61%	15
Total	100%	46

Q10 - What did you enjoy most about the experience? Why?

What did you enjoy most about the experience? Why?
it was good
leading
it was so realistic
we got to work as a team and i enjoyed my role
it seemed realistic
it was really fun and i want to go again. doing flight simulators is fun!
i enjoyed that we were in a virtual world!
i enjoyed the atmosphere and technology
it was told with in a story. It applied things we already learned
it was fun and an interesting way to teach cybersecurity
i enjoyed being able to work as a team because i know that i can learn new things better when i am part of a team
i think the experience is very fun because it is immersive and helps to create an environment that is both fun and team building
i loved everything
the atmosphere! the chairs were really cool as well as the computers! the engineers computers were my favorite!
it being creepy
everything the adrenaline the idea
navigating was fun because i go to watch the ship
i dont know
i enjoyed the atmosphere and sense of reality
working the computer because i thought using it was cool
working on the computer
the technology is cool
I loved it! I loved firing weapons and escaping with time to space. It was amazing
I kinda liked being in charge because I have control issues
I enjoyed working with my team to get things done

something new i had never done, defiantly a highlight for the week
getting to crawl into a tiny space to find incriminating evidence
it was fun to work as a team and complete the mission
working on the main computer under the table
Probably all the suspense
everything
i enjoyed the team work that was needed and the main idea because it is interesting
flying...well sitting in the pilots seat
prob the colorful animation and the cool-looking team
fixing things! cause i like solving things. also having yall laughing at us was hilarious
the fact you guys started laughing at us
weapons
working with a team
i got to pick a lock
i loved the adrenaline rush
team work and problem solving
being the captain, i like being in charge
idk i like all of it
the suspense. it was full of adrenaline
working as a team
yes it was great

Q10 - Topics



Answer	%	Count
teamwork	19.57%	9
atmosphere	17.39%	8
physical	4.35%	2
working on computer	6.52%	3

realistic	4.35%	2
artemis	6.52%	3
controls	4.35%	2
other	6.52%	3
fun	10.87%	5
everything	13.04%	6
adrenaline suspense	8.70%	4
leadership	6.52%	3
interaction	4.35%	2
Total	100%	46

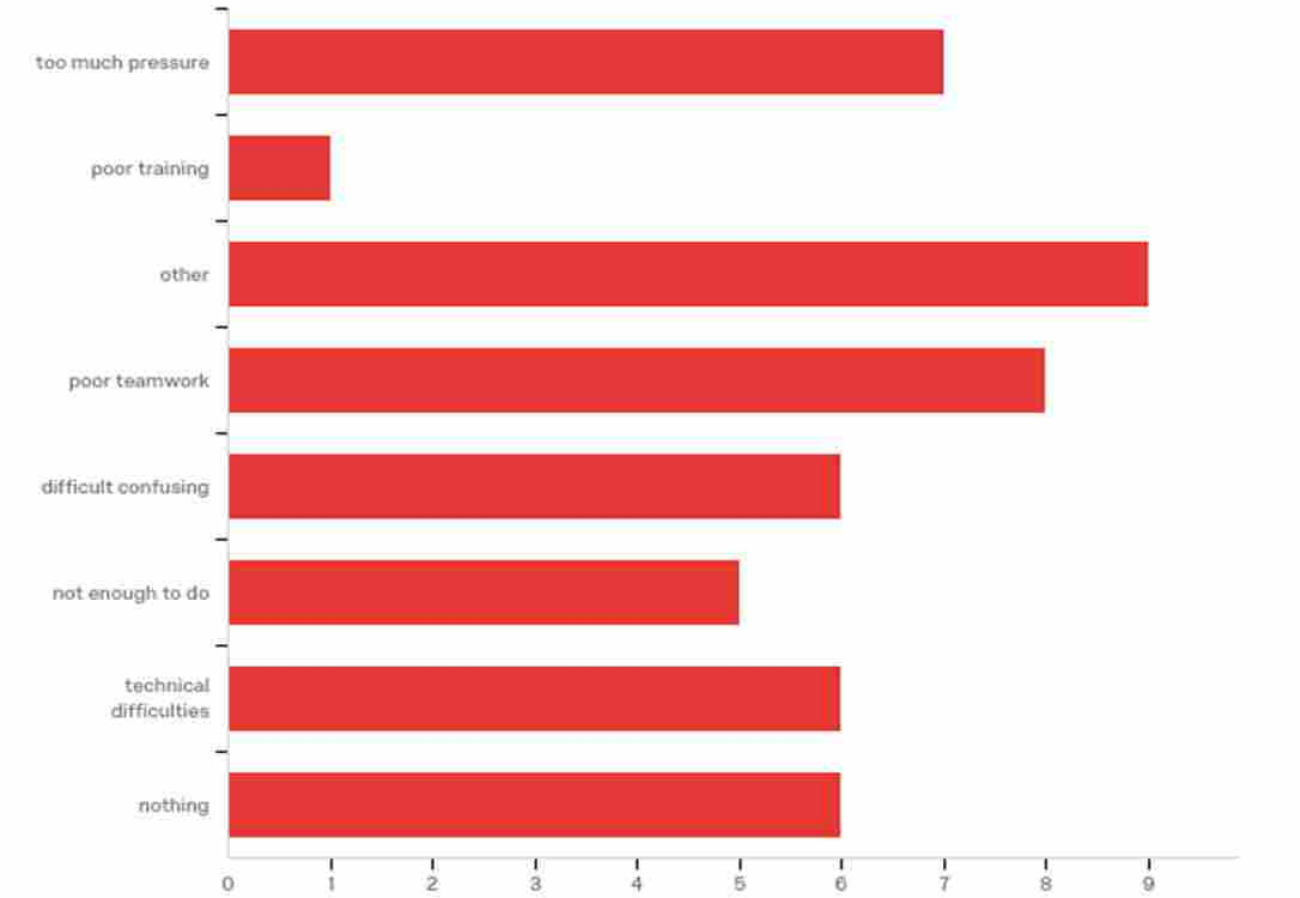
Q11 - What did you enjoy least about the experience? Why?

What did you enjoy least about the experience? Why?
nothing
dale being a jerk
the computer froze up!
Alyssa Betrayed me!
it was confusing
it was hard because it was hard to turn and fly and to learn when i should go to ? and what position i needed to be in for the mapping person.
-
it was kinda stressful i guess
intense music. it makes me nervous
i didnt really enjoy how people would ignore something or say to focus on the problem more
there wasnt really a part that i enjoyed the least but the most stressful when we couldn't find where to put the file when the oxygen went down
i did not enjoy how we could not help others figure out their jobs. As we were sometimes left with no help
i didnt like being under so much pressure
I was tech support, and thus did not get to do a lot. It would be nice to have a real job and a pad for the mouse under the communications table ~

nothing
?
my team didnt talk to me :(
nothing
i think the sense of pressure overwhelmed me
the frustration with not knowing how to solve the problem
i didnt enjoy dying
not being able to do much, we didn't get very far
not having as much time, more time would have been fun
i feel i had very little to do as captain
I wish that we were able to all be more involved
moved a little slow
our ship would sometimes not let us go forward and it was very frustrating
the system bugs made it more difficult to complete the mission
figuring things out at the beginning
Not feeling like I understood what I was doing
some glitches
i did not enjoy the level of difficulty
that i was standing mostly around person even with repairs there was an extra person sitting out.
there were a lot of technical difficulties -they distracted me from the game
not knowing what i was supposed to do for unity
i knew nothing about programming and we ended early
malfunctions but fun
nothing
everybody was yelling
it was hard to listen to the captain when she wouldn't make decisions
how slow the plane is
people didn't listen to me
nothing

the captain
panic
the time

Q11 - Topics



Answer	%	Count
too much pressure	15.22%	7
poor training	2.17%	1
other	19.57%	9
poor teamwork	17.39%	8
difficult confusing	13.04%	6
not enough to do	10.87%	5

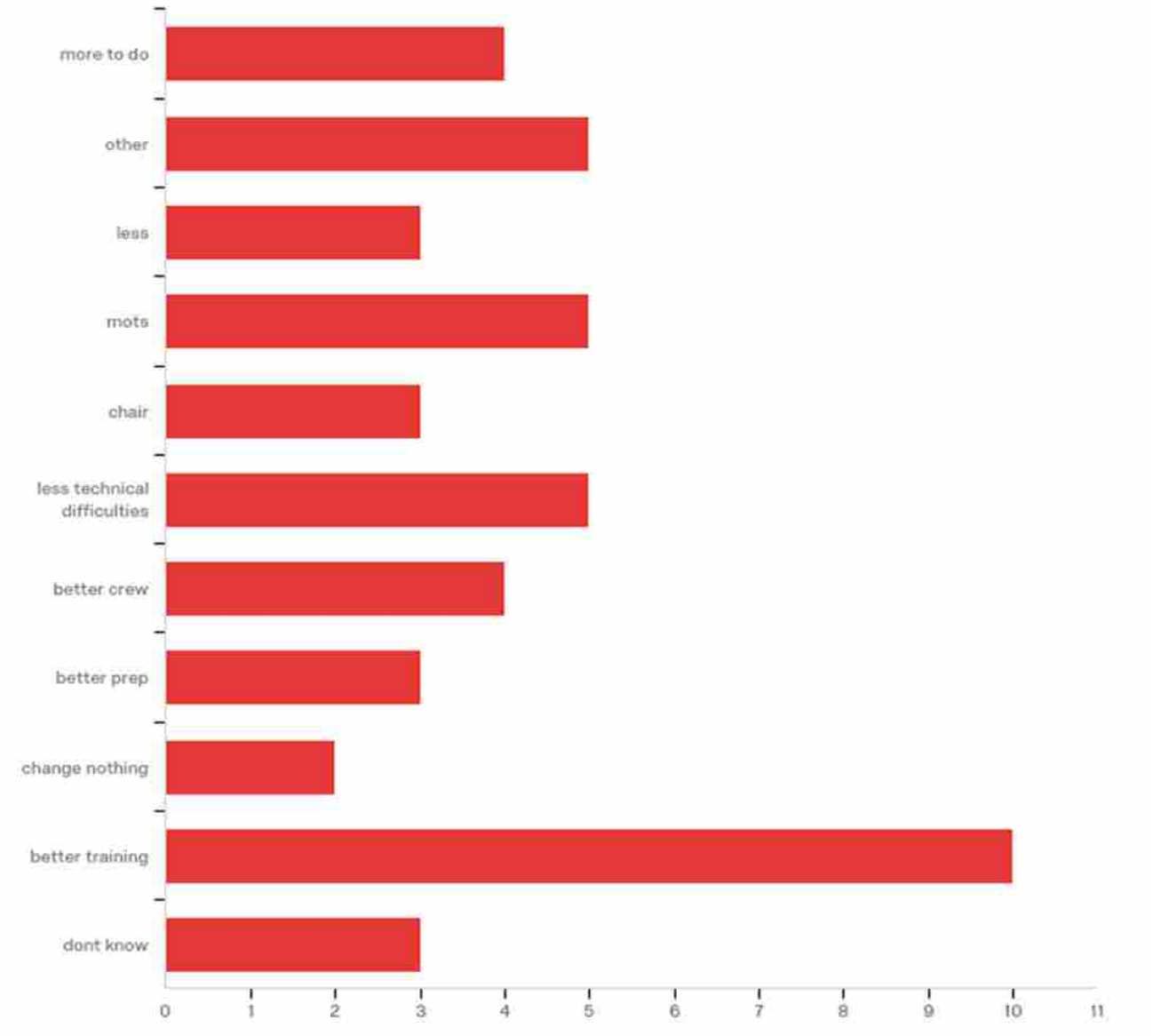
technical difficulties	13.04%	6
nothing	13.04%	6
Total	100%	46

Q12 - What one thing would have made your experience better? Why?

What one thing would have made your experience better? Why?
idk
dale not being rude
if the computer had not froze up!
if my friend hadn't betrayed me!
to understand it more
it would've been great to maybe make the weapons easier to use i guess
uniforms to immerse us deeper in the world
knowing how to pick locks better
remembering to copy a file. It made trying to restore oxygen hard
more practice with the positions
more knowledge about what would be happening because i feel i would've done a little better
more time explaining jobs and more interaction between team members
less dramatic music
more fog-lights-and etc. that would have made it super fun!
less complicated
?
nothing! it was lots of fun
if we knew what we were doing
i feel like i had a lot of responsibility put on me, so sharing that responsibility would be easier
had hints earlier
if we didnt over complicate it
doing more things, it was boring when I wasn't doing anything

a chair, my legs started hurting after standing for so long
it would be cool to try it in a different experience
having more issues to solve so we had things to do
a mirror behind the engineering station to watch the screen
if we could have actually gone forward in our ship
having more to do. My job was "science" and all i did was tell them to turn right or left and the rest of the time I just kind of sat there :/
more attacks-to make it more exciting
Not having so many malfunctions
less glitches i understand
better advice from control (helm didnt know different controls nor did engineering
more energy ships, b/c it would be more exciting
less tech issues
if i had been told what to do. other than maybe learn things for instance some more ? . having a maintenance person assisting rather than having people abandoning their stations would have been great.
if we had a little more help in training
less malfunctions
less stress
if comms had more things to do
the weapons station needs a chair.
every body staying at their station
rumbling chairs. better crew
nothing it was all good and fun
a crew that listens
better instructions about what to do
idk

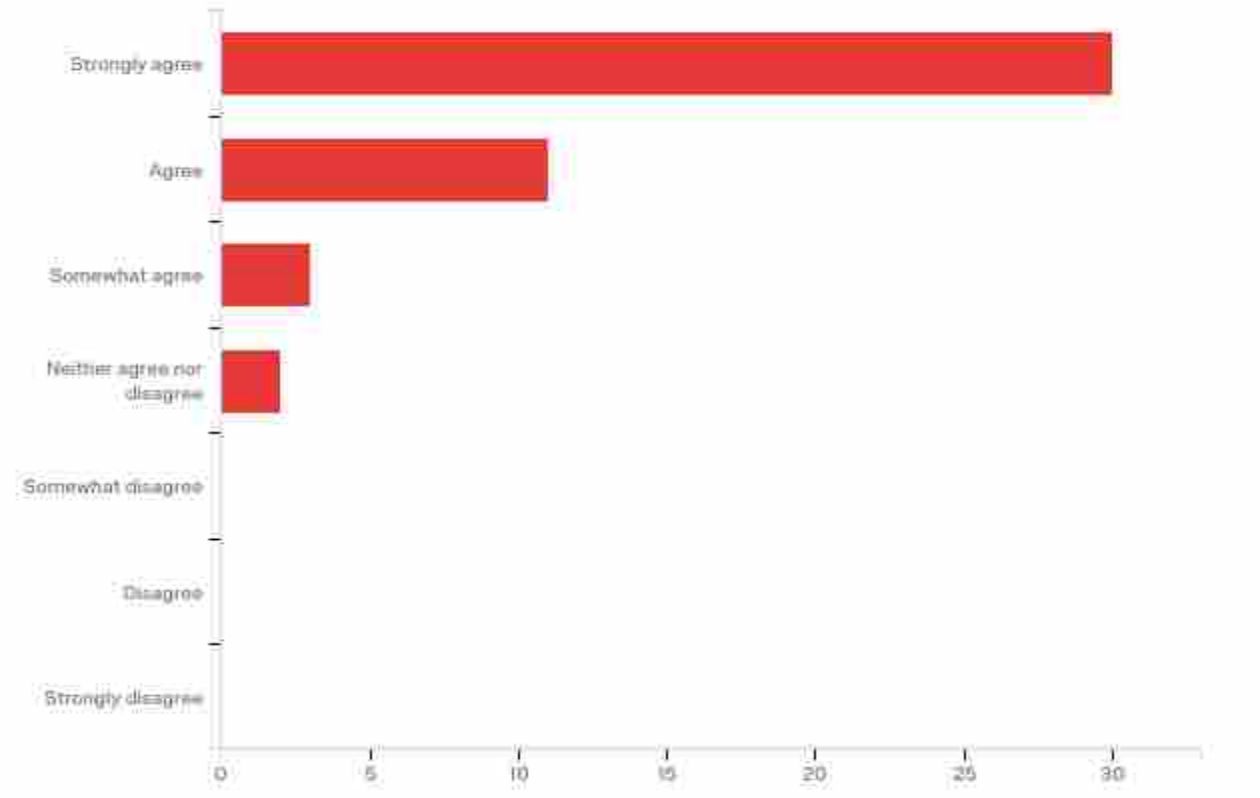
Q12 - Topics



Answer	%	Count
more to do	8.70%	4
other	10.87%	5
less	6.52%	3
mots	10.87%	5

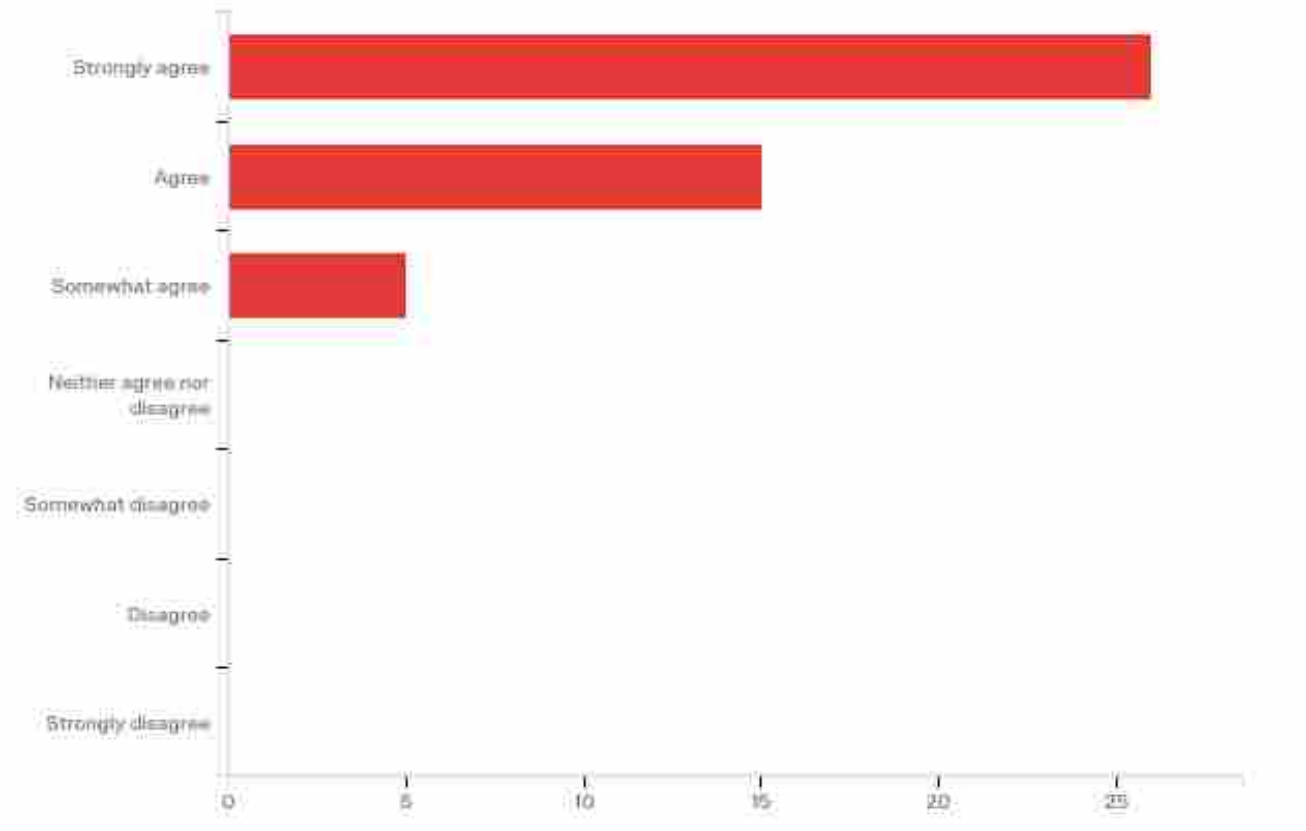
chair	6.52%	3
less technical difficulties	10.87%	5
better crew	8.70%	4
better prep	6.52%	3
change nothing	4.35%	2
better training	21.74%	10
dont know	6.52%	3
Total	100%	46

Q13 - Indicate how much you agree or disagree with the following statement: "The escape room experience was fun".



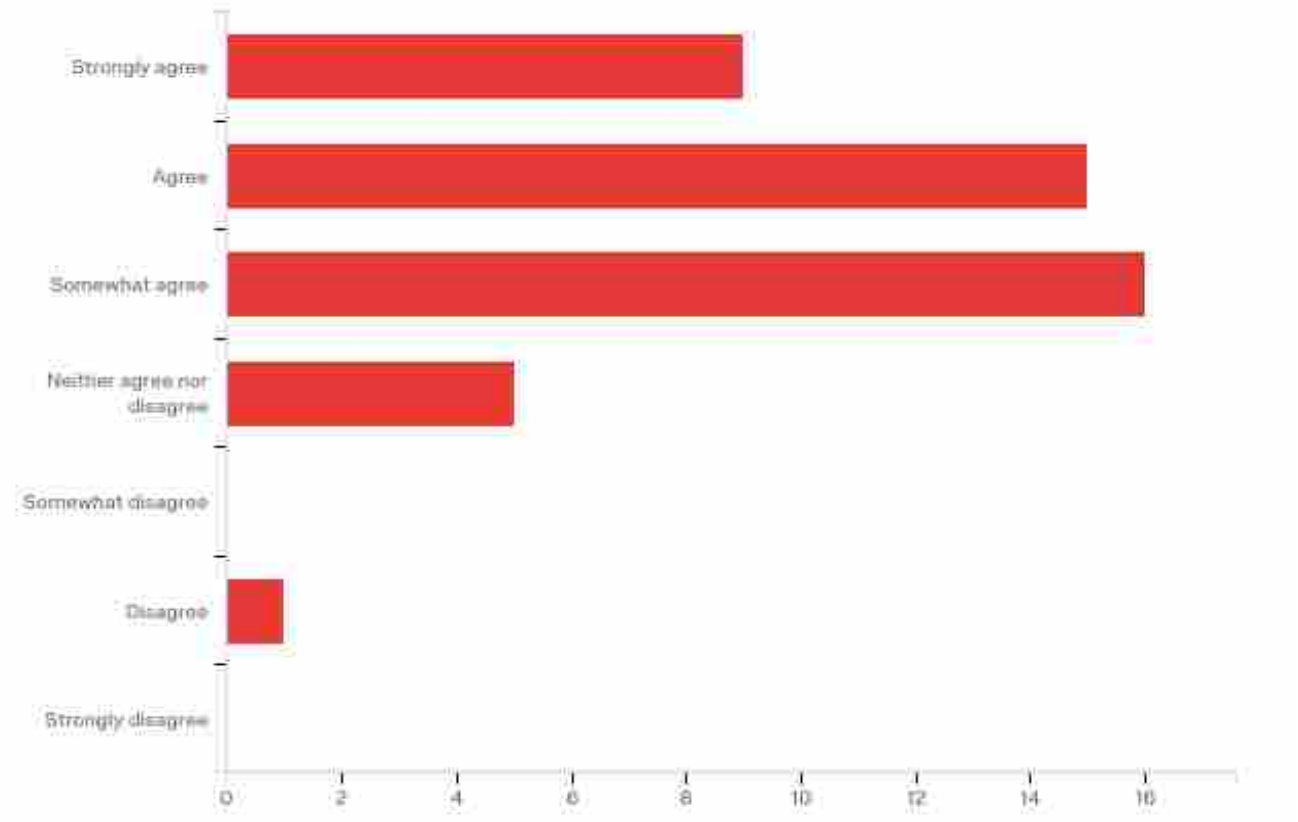
#	Answer	%	Count
1	Strongly agree	65.22%	30
2	Agree	23.91%	11
3	Somewhat agree	6.52%	3
4	Neither agree nor disagree	4.35%	2
5	Somewhat disagree	0.00%	0
6	Disagree	0.00%	0
7	Strongly disagree	0.00%	0
	Total	100%	46

Q19 - Indicate how much you agree or disagree with the following statement: "The escape room experience was engaging".



#	Answer	%	Count
1	Strongly agree	56.52%	26
2	Agree	32.61%	15
3	Somewhat agree	10.87%	5
4	Neither agree nor disagree	0.00%	0
5	Somewhat disagree	0.00%	0
6	Disagree	0.00%	0
7	Strongly disagree	0.00%	0
	Total	100%	46

Q14 - Indicate how much you agree or disagree with the following statement: "The escape room experience helped me learn concepts taught in classes".



#	Answer	%	Count
1	Strongly agree	19.57%	9
2	Agree	32.61%	15
3	Somewhat agree	34.78%	16
4	Neither agree nor disagree	10.87%	5
5	Somewhat disagree	0.00%	0
6	Disagree	2.17%	1
7	Strongly disagree	0.00%	0
	Total	100%	46

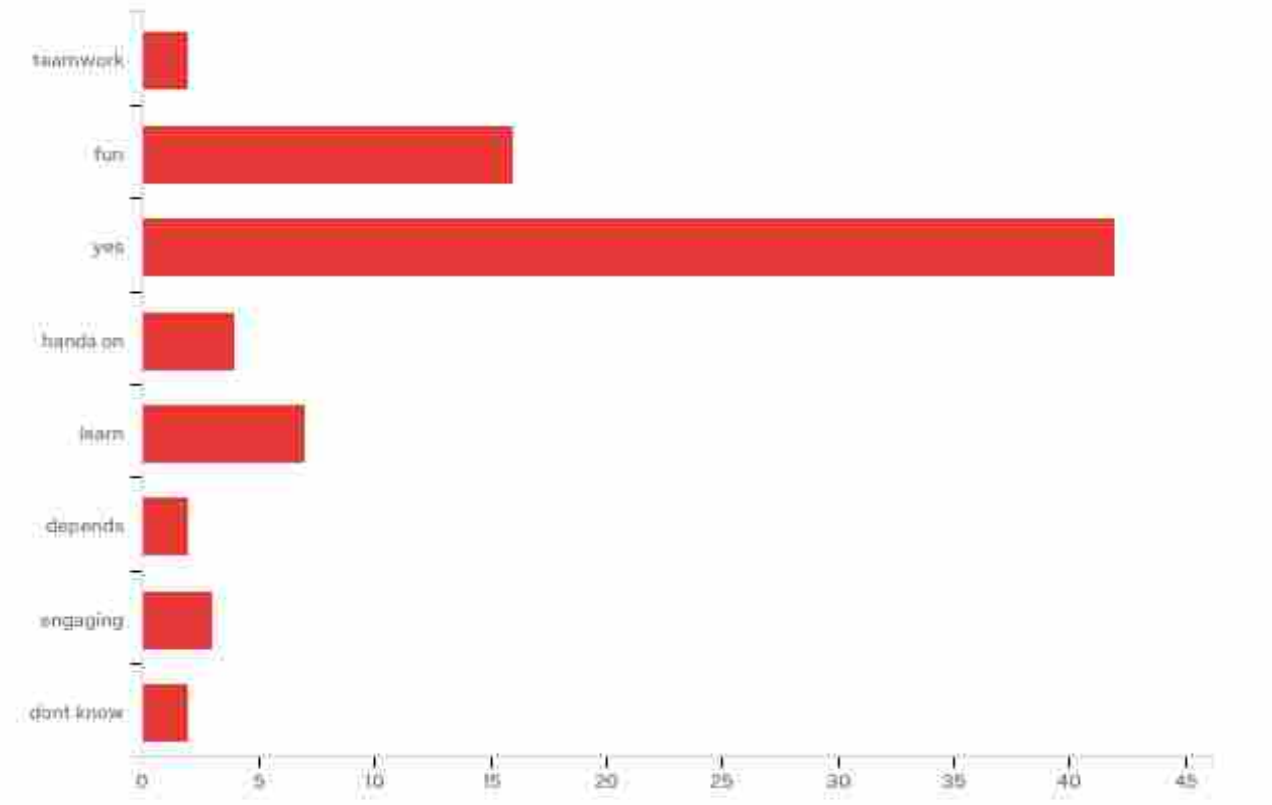
Q16 - Would you participate in a similar experience for a different subject matter? Why or why not?

Would you participate in a similar experience for a different subject matte...
idk
sure
yes!
idk
yes, it was fun
most likely. it was engaging and it makes me remember what i learned
yes! i love to imagine different worlds so this was amazing
yes! high pressure and application is a great catalyst for learning
yes. it's fun. i like doing things in context-even if the context is sci-fi
yes because escape rooms are fun
yes, because it was a very fun experience
yes this experience is so engaging and hands on that it could be helpful when learning other things
yes. like the hands on experience
Yes. it let us get to know other girls and have fun working together at the same time

yes
yes
yes, it teaches teamwork and coding (apparently)
yes
definitely because this is a great way to use things taught
yes, i think simulators are really cool and fun
yea because then you are using it in real life
yes, applying concepts you learned makes you remember them better
Yes i would play escape the fate again a hundred times over! i love playing star trek in a way
Most defiantly because this was entertaining
yes, because i enjoy doing things like this
absolutely, fun challenge to participate in, would do it again
yes, because it was fun and engaging
Yes, it was fun and I would participate in another one to get better at it to learn tricks
yes-it was a cool hands on experience
Yes because it was fun
yes because it was a cool experience
i think it depends on the subject
yes as long as there is more activity
yes it's fun
totally
yes because it is fun
sure why not
yes, because it was awesome!
yes, it is always fun to have hands on experience
yes. i learned a lot and enjoyed it.
yes. overall it was fun
yes because it is fun
yes to learn more and work as a team

yes, because it was fun
maybe it depends on my mood
yes

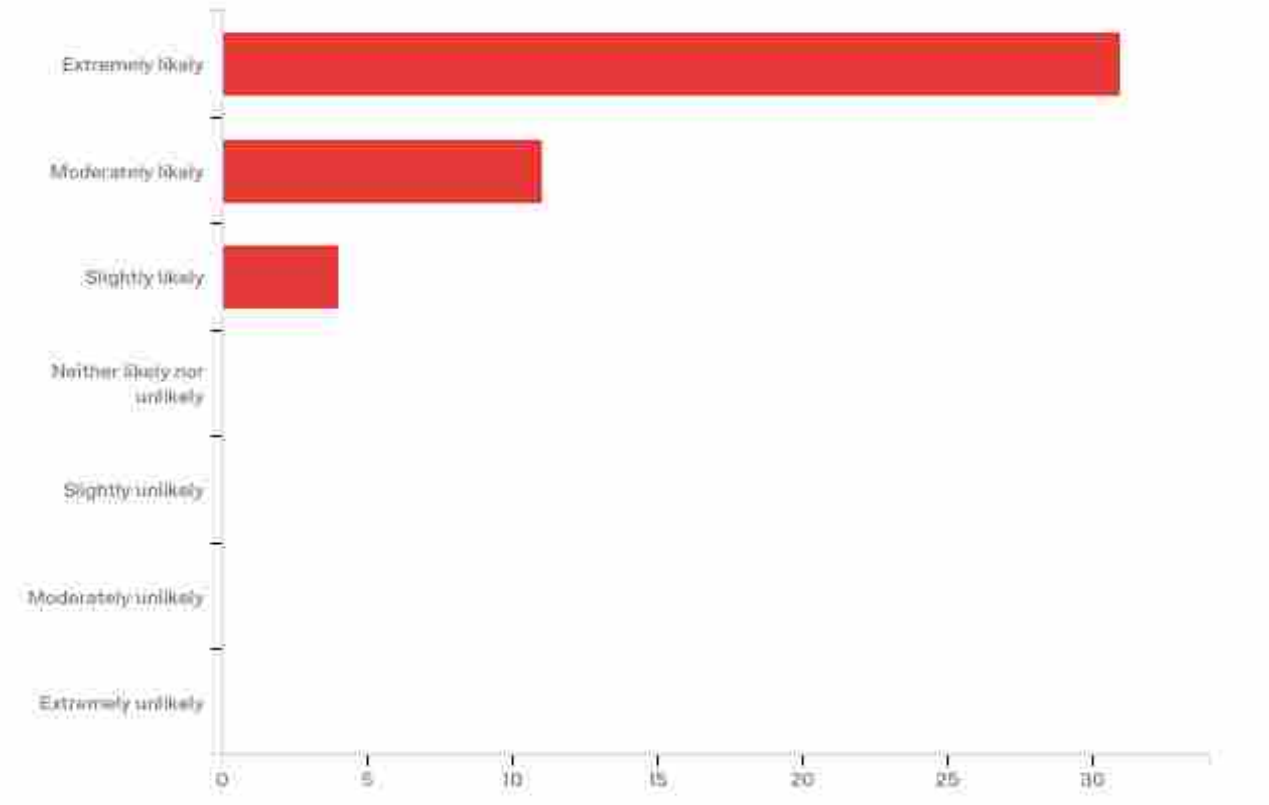
Q16 - Topics



Answer	%	Count
teamwork	4.35%	2
fun	34.78%	16
yes	91.30%	42
hands on	8.70%	4
learn	15.22%	7
depends	4.35%	2

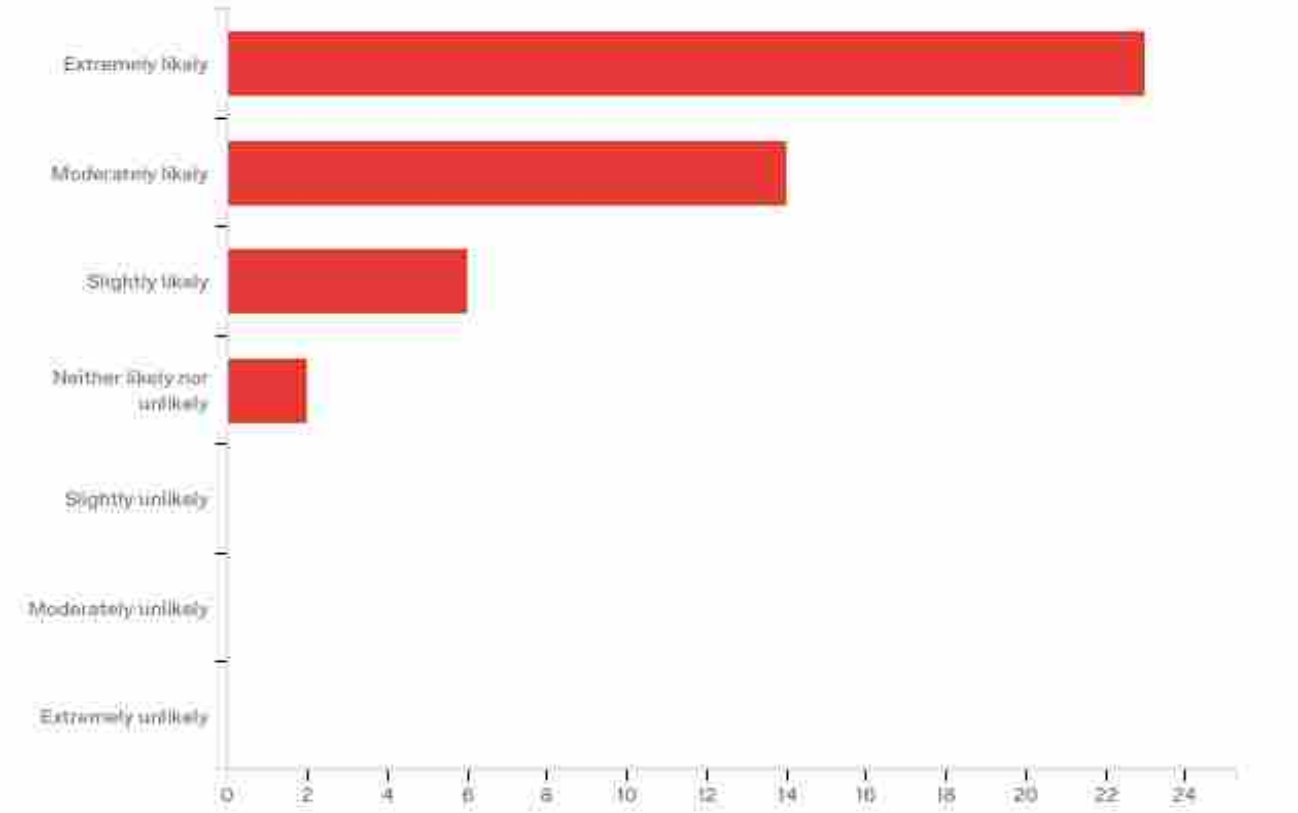
engaging	6.52%	3
dont know	4.35%	2
Total	100%	46

Q17 - How likely are you to recommend this experience to a friend?



#	Answer	%	Count
1	Extremely likely	67.39%	31
2	Moderately likely	23.91%	11
3	Slightly likely	8.70%	4
4	Neither likely nor unlikely	0.00%	0
5	Slightly unlikely	0.00%	0
6	Moderately unlikely	0.00%	0
7	Extremely unlikely	0.00%	0
	Total	100%	46

Q18 - How likely are you to continue with cybersecurity education?



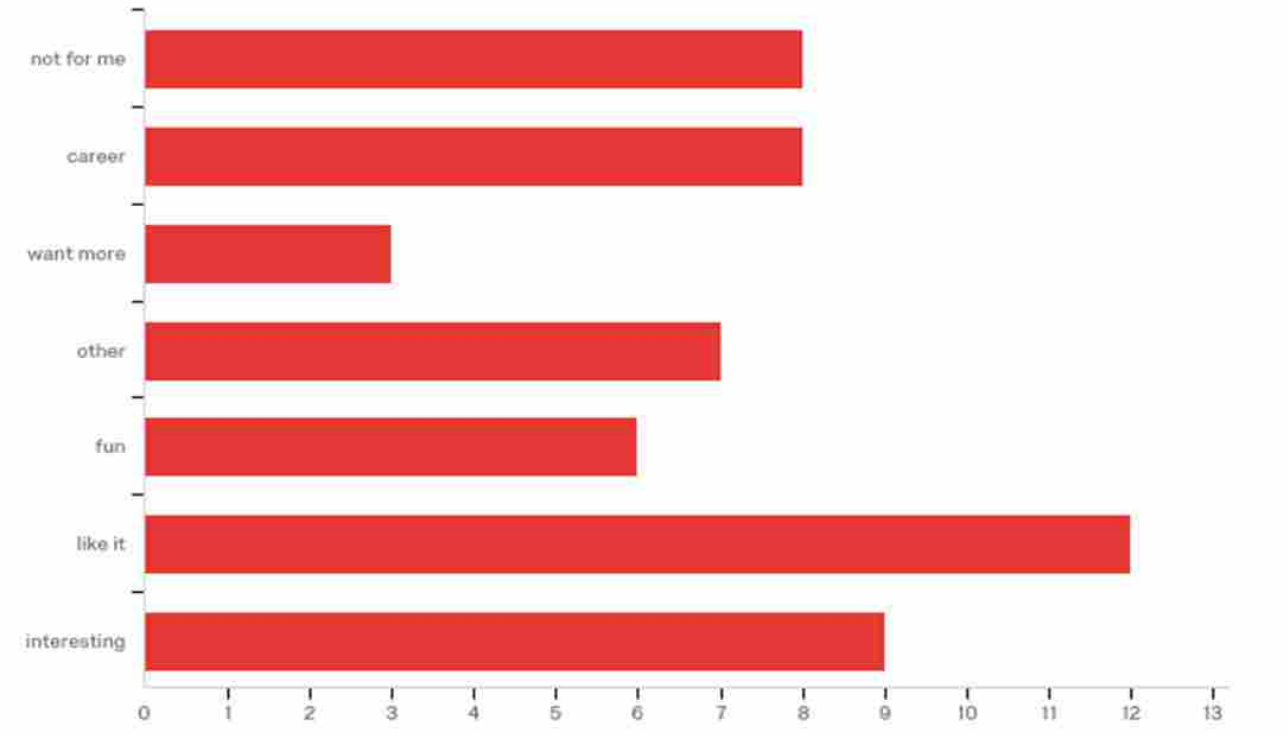
#	Answer	%	Count
1	Extremely likely	51.11%	23
2	Moderately likely	31.11%	14
3	Slightly likely	13.33%	6
4	Neither likely nor unlikely	4.44%	2
5	Slightly unlikely	0.00%	0
6	Moderately unlikely	0.00%	0
7	Extremely unlikely	0.00%	0
	Total	100%	45

Q20 - Why?

Why?
because
is there a reason? i loved it!
because one of the degrees i'm working has an emphasis in it and i enjoy it.
because
because it is fun and interesting
i really like it and i would love to have a computer science major
Because i learned a lot and found out all the pros of this field of study
i enjoy what i learn, but i don't enjoy sitting in front of a computer for long periods of time.
because tech interests me but maybe something else than cybersecurity
i like to learn about cybersecurity but i dont know if i want to pursue a career
i enjoy computers and the ability to modify in a positive way is appealing
i like computers it was really neat!
Although i like the field, i have already considered the medical field- i also think i could help more people with something like that. Cyber security is my second career field but it's still less likely to happen
because i want this job real bad
cyber security is interesting and unknown. it's new technology and i really like it
it's a very beneficial area of education that can help even if it doesnt involve a career.
i have some interest through i'm not sure if i want to go into it
it was interesting
i really like coding and computers. i want to learn more about them
i really enjoyed the part of the camp where we did more than just sit at the computer playing games. Like escape the room, the planetarium was cool, and hacking was pretty cool but also not what I expected.
i'm really interested in hacking and cryptography, and i want to be able to protect myself
i think that it would be a good career for me.
i am interested in the field and understand well enough to learn more
because it is really fun and interesting these types of things

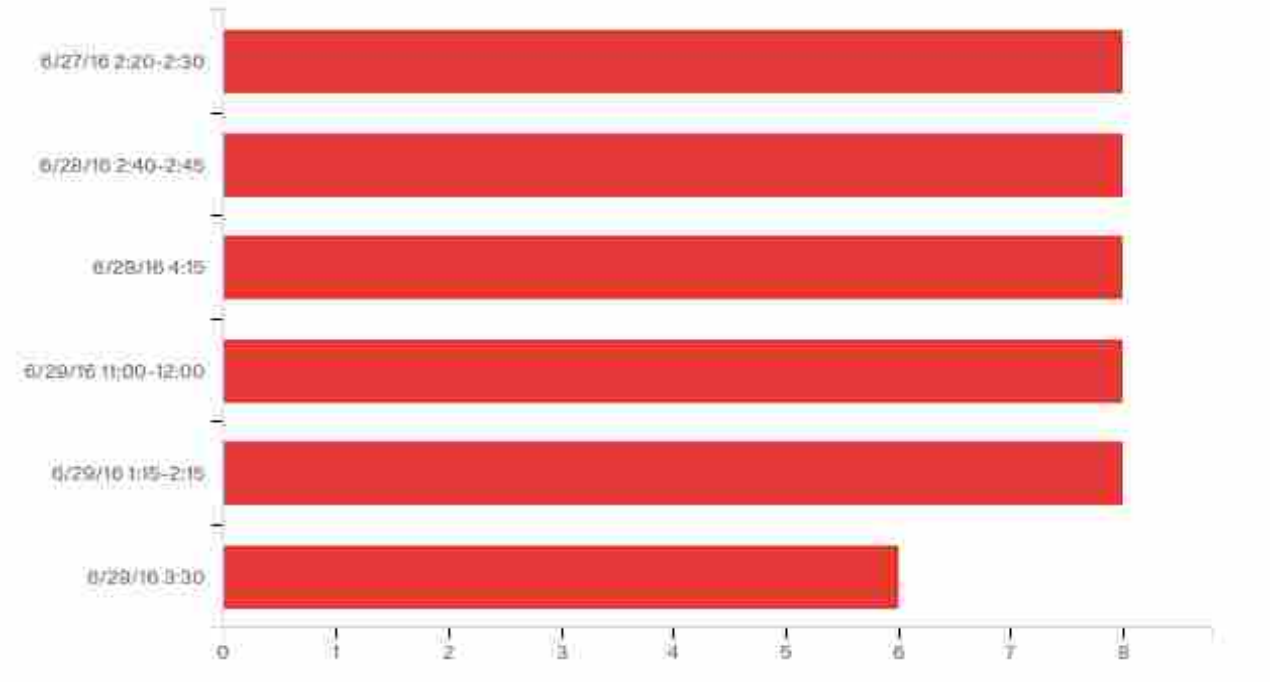
because I've attended this camp 2 years in a row and I will be coming back. I want to pursue a career in cyber security
because its enjoyable although somethings might not be for me! :)
i like it
i find it very interesting
i really would enjoy being a detective of sorts thank you for doing this amazing experience. i really appreciate your hard work for this camp :)
even though it's cool and important, it dont think it's what i want to do with my life. Maybe i'll continue with it after college, but currently i'd like to focus more on what I need for my career.
it's interesting and fun, but i've already more or less figured out where/what i want to study
im enjoying this so much
because it is interesting
because it's important
i think it is an excellent career for women
i enjoy it. good career option.
it is very interesting
it is way cool. The career in general is super fun.
it is fun and i want to learn more about computers
because it's interesting and fun
because i liked it

Q20 - Topics



Answer	%	Count
not for me	19.51%	8
career	19.51%	8
want more	7.32%	3
other	17.07%	7
fun	14.63%	6
like it	29.27%	12
interesting	21.95%	9
Total	100%	41

Group



Answer	%	Count
6/27/16 2:20-2:30	17.39%	8
6/28/16 2:40-2:45	17.39%	8
6/28/16 4:15	17.39%	8
6/29/16 11:00-12:00	17.39%	8
6/29/16 1:15-2:15	17.39%	8
6/29/16 3:30	13.04%	6
Total	100%	46