ABSTRACT

Title of Thesis:	Computational Support for Bridging Analogies
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Analogies are comparisons between two topics in terms of relational similarity, such as comparing a spring and a flexible table in terms of how they both exert explain upward force on your hand. Far domain analogies --- analogical comparisons between topics that seem very different on the surface, such as the solar system and an atom --- have been identified as being useful for creative ideation. However, people struggle to benefit from them. In this thesis, I explore how bridging analogies, analogies that bridge between a knowledge anchor that is familiar to the problem solver and a target analogy, can aid in allowing innovators to benefit from far domain analogies. Utilizing a breadth-first search in a graph of concepts from Wikipedia, we identified bridging analogies that connect a participant's knowledge anchor to a far domain analogy. We conducted a think-aloud study in which participants were asked to brainstorm on three design challenges, alternating whether they were provided only distant analogies or far analogies and bridging analogies tailored to their knowledge anchors. Using qualitative analysis of the think-aloud data we observed that bridging analogies aided

participants in producing more abstract solutions instead of more direct translation of the analogies in their solution. Our results imply that bridging analogies can effectively aid innovators in benefitting from far domain analogies when creative problem solving.

COMPUTATIONAL SUPPORT FOR BRIDGING ANALOGIES

by

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Chapter 1: Introduction

Climate change, how to navigate life in a pandemic, and ensuring equitabilities for all are a few complex issues we face today as human beings. Humans have been solving complex problems like these for thousands of years, such as Stonehenge, the pyramids, and communication across long distances. At one point in time, complex problems required humans to find solutions. While it isn't always known precisely how someone solved these problems, it is possible that some may have benefitted from the use of **analogies** to find solutions.

An analogy can be defined as having similar structural qualities regardless of its surface lack of similarities (Gentner & Markman, 1997). Cognitive scientists have modeled analogy in terms of structural mapping, which is like saying if I have a concept A and another concept B, there are structural similarities that map A to B, which makes them analogous (Gentner, 1983; Holyoak & Koh, 1987; Holyoak & Thagard, 1989). Some examples of these analogies would be comparing a plumbing system to a city grid due to its structural elements of guiding a component through a system of passageways, comparing clothing to a turtle shell due to the structural concept of clothing and turtle shells both protecting the wearer from harmful elements(cold and weather for humans, attackers for turtles), an electric battery being like a reservoir because both hold some component of a container for later use or a more famous example life and a box of chocolates because you never know what you are going to get. (Holyoak & Thagard, 1989). These analogies can be beneficial in solving complex problems. They can allow a problem solver to understand the issue

in a new light and allow them to apply their knowledge and innovatively solve the problem.

Some innovations have been created because of the interactions with analogical material. For example, the computer conceived from the jacquard loom, a seventeen-year-old created a landmine detector whose inspiration was from a piano, and Thomas Edison used parts of his phonograph to create the kinetoscope. Without these innovations, the world would be a much different place today. These inventions were conceived with the help of far domain analogies. Distant domain analogies are no different from analogies in terms of structural similarity as their defining feature, but they are typically from different knowledge domains. These analogies from across disciplines can be mapped together by their structural similarities instead of the apparent similarities to analogies closer in the knowledge domain (Gentner & Markman, 1997).

Issues with Far-field analogical adoption

It would be ideal if one could decide to look at a far domain analogy and be able to produce something new, but it is not that simple. Just because someone is given an analogical reference, the subject is not guaranteed to use that reference to solve the problem (Gick & Holyoak, 1983). They also found that when students knew there was information relevant to solving the problem in a story, they were more likely to solve the problem using the analogical reference material. However, if they were not explicitly told that there was relevant information, they made the analogical connection less often (Kokkalis et al., 2013).

Researchers have also built upon Gick and Holyoak's work by conducting similar studies. A study was conducted with 126 participants in the first experiment and 240 participants in the second experiment, which yielded similar results to Gick and Holyoak (Kubricht et al., 2017). In the first experiment, participants were given the Duncker's radiation problem. They were put in a group where the analogy was either provided verbally, verbally with a diagram, or verbally and with animation. What they found in the first experiment was that the animation and verbal condition produced more analogical transfers without any hint provided. The verbal group was able to get the solution with a hint provided, but fewer participants were able to solve the problem without guidance. For the second experiment, researchers dropped the diagram and verbal condition and just used the verbal and the verbal and analogy conditions. Results were similar to experiment one, where participants were more likely to provide the target solution if they had a verbal explanation and an animation.

Other studies have also found muted or neutral effects of far-domain analogies. For example, a study was conducted with 71 undergrad students at Carnegie Melon University. Participants were provided near or far analogical information during the brainstorming process during the study. They offered either one near analogy or a set of descriptions for three distant analogies. The participants were divided into three groups and were provided the stimuli before problem solving or during a break in problem solving. Neither the relationally similar stimuli nor the distant stimuli exhibited any significant improvement in the quality or number of ideas. They did observe a difference in the number of ideas in these conditions as opposed to a control group, but not in the variety of the ideas provided (Tseng et al.,

2008). While several factors may be at play in determining whether people benefit from far-domain analogies, such as timing (Tseng et al., 2008), the fact remains that people do not always benefit from far-domain analogies even when they are likely to be helpful.

In a landmark study comprised of five separate experiments, scaffolding is essential in analogical adoption. In experiment one, participants were provided with a story analogy and asked to solve Duncker's radiation problem. Experiment one showed that participants who read the story first and were explicitly told that there might be an aspect of the story that relates to the problem were more likely to propose a solution to the problem with elements of the analogous story. Experiment two comprised three conditions where participants each received a separate story or none. Researchers found that participants were more likely to propose the analogous solution if the story was more analogous.

For experiment three, researchers attempted to see if solving the analogous problem first aided in transferring the analogous material to the radiation problem. They found that less than 50% produced partial or complete dispersion solutions. During the Experiment, four participants had access to three different stories and were allowed to read them at any point in time during their brainstorming. Results of this experiment indicated that again if participants were explicitly told that the stories that they were reading were related to the solution, then they were able to solve the problem with the target solution 90 % of the time, as opposed to 20% of the time without being told the story held a similarity. Experiment five was similar to experiment four, with the primary difference being the timing of the introduction to

the story, and there was only one story instead of three. Findings again showed that when participants were told the stories contained a hint to the problem, then they were more likely to solve the problem with the target solution (Gick & Holyoak, 1980). These experiments demonstrated that analogical adoption significantly increases with just a little bit of assistance.

Several studies, primarily in education, suggest that scaffolding is required to benefit from analogies. For example, a study analyzed the effects of analogies in classrooms (Richland et al., 2007). They found that students who were given more scaffolding about the analogies could better understand the analogical material presented to them. Scaffolding was delivered in multiple different ways. Teachers would present the analogical material during instruction verbally and visually. They would use spatial cues to demonstrate the corresponding elements between the analogy and the source material, use physical gestures for demonstration, and use mental imagery or visualizations to aid in transferring the analogical material. The effectiveness of the teaching methods was attributed to how familiar the analogies were to the source material being presented and to reducing the processing demands on the students.

Similarly, there are findings that, compared to other forms of scaffolding, relational scaffolding, which involves guiding a student through systematic comparisons between observable phenomena and corresponding modeled events (Jee & Anggoro, 2019), allowed students to score higher on posttests. The students had the same amount of instruction time before the test. The only difference was the type of scaffolding the students received. Across two experiments, each consisting of more

than 100 students, they found that relational scaffolding was more conducive to the children's performance on their post-test.

In a study conducted to assess whether the format in which the scaffolding is presented played a role in the effectiveness of the bridging content, they found that students could perform better (Matlen et al., 2011). They provided 4th and 5th graders with a pretest, instruction following the pretest, and a posttest to assess the effectiveness of the instruction. They observed that when 4th graders were given visuals scaffolding to the target concept, students performed better on the post-test than those who were only provided with the target concept (Matlen et al., 2011).

Bridging analogies

Bridging analogies are a specific form of scaffolding that has shown promise for supporting analogical reasoning. Bridging analogies can be defined as a series of guiding analogies to aid in the formulation of further reasoning about the given problem (Yilmaz et al., 2006). Bridging analogies have the potential to act as the hints described previously (Gick & Holyoak, 1980). Bridging analogies are composed of a bridge and anchor (Clement, 1993). An anchor is a concept in which a person knows, so Clement et al. use the example of a spring and a book on a table. Spring is the analogy anchor that someone has knowledge of and the book on a table is the target solution because of the upward force the table exerts on the book. According to Clement, a bridging analogy is a third example that exhibits characteristics of both the target solution and the anchoring analogy.

Multiple studies found that bridging analogies can be useful scaffolding in educational settings. In a cross-country study, Researchers found that in countries

with higher cognitive support for analogies, the students' science and math scores were higher than in countries without those supports (Richland et al., 2007). They recorded classrooms from Japan, the U.S., and Hong Kong to determine this. They then randomly selected ten recorded video sessions from each country and analyzed the teaching methods. Teachers in Hong Kong and Japan provided more support for bridging analogies and visuospatial scaffolding, leading to higher math and science scores in those areas. The addition of bridging analogies as scaffolding aided the children in performing better on test scores.

Similarly, there is evidence that analogies can support students' conceptual understanding of a topic. A study conducted with 21 physics students in a secondary school began by asking the students questions to get a baseline for the participants' understanding of the topic of upward force (Bryce & MacMillan, 2005). Researchers then provided four analogies that demonstrated force concepts to the participants. After being provided with the analogies, the students were asked to go back and reassess their answers. Bryce et al. found that all the students could discuss why people don’t fall through the floor due to upwards force, instead of the original 29% at the beginning of the study who could demonstrate this concept. Additionally, 12 out of the 21 participants demonstrated on a deeper level what was occurring on the floor, which provided an upward force. Thus, the study shows that bridging analogies can be used as scaffolding to aid students' conceptual understanding of a topic.

The paper discussed the successful analogical transfer when students were given bridging concepts from the source to the analogy(anchor). Students were not only witnessed incorporating Analogies of their own in discussions but were also

observed altering their mental models. This shows that bridges can aid people in developing analogies for complex problems.

Systems for Creative Ideation

There have been previous systems that have allowed innovators to benefit from analogies. However, these systems do not utilize bridging analogies in their systems. The following systems were designed to retrieve analogical information from databases but do not utilize bridging analogies.

An experiment utilized machine learning techniques, such as keyword extraction and clustering techniques, to develop a way for participants to benefit from analogies (Hope et al., 2017). Their study consisted of 38 Amazon Mechanical Turk workers participating in redesigning an existing product. The experiment included three ways of providing analogies for the participants. There was an analogy condition where participants would search far mechanism analogies. The second condition was considered the baseline in that it acted like a standard search engine would behave pulling near mechanism products. Finally, the third condition was randomized, providing results that would randomly draw near and far mechanism product analogies. While the system pulled out both near and far analogies, their system did not retrieve analogies that existed between these domains to help innovators bridge the gap between disciplines. The mechanism of this tool is less about people being able to bridge gaps when adopting analogical information and more related to what is needed to search for both near and far analogies.

To evaluate the study results, three judges decided on whether the ideas produced were good creative ideas or not. Two out of three judges agreed that good ideas made 46% of the ideas produced. For the random condition, 37% of the ideas conceived were deemed good, and 30% of the ideas were considered good for the baseline condition. Additionally, when all three judges agreed, 38% of the analogy condition were good ideas, 22% of the random condition were good ideas, and 21% of the baseline condition were considered good ideas. These allude to the fact that participants can be more creative when provided with far mechanism analogies for brainstorming than if they are only supplied near mechanism analogies. Again, this alludes to the fact that distant analogies can be helpful, but it is not a system to aid users in bridging gaps between their knowledge and further domains.

In addition to the prior study, another study utilized similar methods to determine the effectiveness of far domain inspiration on brainstorming (Duflou & Verhaegen, 2011). Using keyword mining and clustering techniques, they produced a tool called PAnDA which participants used during brainstorming. The tool condensed products into three separate categories: similar products, products with low similarity, and products not considered comparable.

Forty-eight students were recruited from five different engineering and product design programs for the experiment. Participants were then divided into four groups. Participants engaged in three design sessions which consisted of brainstorming on a provided problem. The first session lasted 15 minutes and served as an introduction to the study. The second and third sessions were 20 minutes, and this is when the PAnDA tool was introduced. During the second and third sessions,

participants were either given the tool for the whole 20 minutes, not given the tool at all, given the tool for 10 minutes, then had it taken away, or they were given the tool after 10 minutes of brainstorming. Results of the study indicated little statistical significance in the quality of the ideas produced with or without the tool. However, participants who engaged with the tool could provide more variety and novelty in their responses.

This is the closest system that we have come to aid in bridging analogies. However, it is not directly related to bridging analogies. They have found a way to categorize analogies based on their domain distance. Still, it lacks focus on getting the user from the near domain analogy to the far domain analogy through bridging analogies. It is more like a domain sort for analogies.

Researchers have also proposed a way to search for distant analogies using the same corpus of product ideas as Hope et al. Researchers devised a search method that abstracts the search solutions using machine learning techniques such as NLTK to find relevant analogies (Gilon et al., 2018). Once the system was designed, tests were conducted comparing the three systems with the proposed solution. Compared to the other three available systems, they found that their system did not locate the most relevant analogies or the most distant but instead completed both tasks of finding an appropriate distant analogy better than the other systems. This continues to leave the area of bridging analogies open to further exploration. The researchers have demonstrated an effective tool for extracting relevant domain distant analogies but again fall short of providing the necessary scaffolding for adopting far domain analogies.

In a study conducted with engineering students which utilized the word-tree method of brainstorming to produce innovative ideas and create analogies, the word tree method was applied to brainstorming. The word tree method uses key-problem descriptors to abstract the problem into single verbs to aid in formulating analogies and novel ideation (Linsey et al., 2012). Once the problems could be broken down into action verbs, one would search for solutions based on the verb they abstracted out of the problem.

To test this method, researchers recruited students at the University of Texas. They were all a part of the senior capstone program for product design. Students were split into two groups, the control group, and the word tree group. Studies took place across two sessions. One session lasted two hours, and the follow-up session lasted an hour. During the first 45 minutes, the participants in the control group used any brainstorming method they had been taught, and the word tree group used the technique. After the initial 45 minutes, the participants could use a computer to search for inspiration.

This experiment found that participants using the word tree method produced more analogies than the control group (23.3-7.6). Additionally, they also found no analogies produced in the participant's final ideas. The maximum amount of the usage of the analogy being 64%, while the minimum was 15%. Finally, they also documented the searches of the participants. They used them to find that the participants in the control group performed no searches outside of the provided problem domain. In contrast, 6 of the participants in the word tree group performed searches outside of the field of the provided problem. These results show that

participants can produce analogies using the word tree method, but there is no support for how to maximize the benefit from the analogies they provided.

After this, the researchers conducted a follow-up study with 982 senior mechanical engineering students. The students were divided into 13 groups, but only 12 were used to analyze the results. During this study, all the groups were required to use the word tree method to brainstorm. After brainstorming with the word tree method, the groups were asked to identify five analogies, two analogous domains, and three patents. 11 out of 12 groups were able to identify five analogies, 9 out of 12 located analogous domains. They identified three useful patents using the proposed method. These results again show that the word-tree method can help identify analogous material during brainstorming, but there is nothing that supports the use of analogies. They were only concerned if participants were able to make the analogies.

Another study proposed an algorithm that utilized patents to develop a way to search patents and link them (Fu et al., 2013). They conducted a study that used four experts in design. These experts had worked in product design for at least ten years and had an educational background in engineering or industrial design. The algorithm utilized latent semantic analysis and Bayesian algorithms to link and pair the patents.

Design sessions were conducted in a similar space for all four designers. They were given the patents and asked to link them and place them, in proximity to each other, based on their functional similarity. After doing this, they were asked to evaluate the algorithm, which completed the same tasks as the designers. Results indicated that the algorithm could do what the expert did. They also suggested that the algorithm may structure the patents differently but that the structure allowed for novel

connections to be made between the patents. Remarkably, this system can accurately link the patents as well as experts, but again there is no support on how one would benefit from using this system. Experts may be able to make sense of it, but is it accessible to those outside the domain of expert designers without the support of bridging analogies?

Another system which has been designed to aid inventors in creating novel solutions is TRIZ. TRIZ is a tool which aids in the user being able to think about the problem they are trying to solve in a different manner using design principles. TRIZ provides a structured way for the user to find appropriate principles for their problem by thinking about their problem in terms of "contradictions" between design parameters (e.g., increase strength without decreasing weight) and provides pre-determined links to design principles that may overcome these contradictions (e.g., use composite materials), along with examples of these principles (e.g., fiberglass surfboards) (Moehrle, 2005). The pre-determined schematic mapping through contradictions and principles is a powerful way to search for analogies; however, to benefit from the principles, the user is expected to have sufficient engineering knowledge to understand and apply the principles. The method is also a best fit for inventors who need to solve a technical problem in mind. It is not a simple tool which anyone facing a brainstorming challenge can pick up and engage with to solve their issue quickly and efficiently.

Another tool which has been developed which begins to get at the idea of bridging concepts is Arrowsmith. Arrowsmith takes two articles on PubMed and finds linking papers between the two concepts (Smalheiser et al., 2009). The papers that get

linked are not necessarily linked in a way which is obvious either. They do not have to be about the same topic or include the same author, but they do have to have concepts which have been explored in both edge papers. The underlying concept here of finding links between literatures and concepts that may have been missed is similar to bridging, and suggests the potential of bridging; but it has not yet been connected with the setting of analogical innovation.

The studies and tools discussed in this section highlight a significant need for more research into a system for providing bridging analogies. Due to this, we developed a means for participants to interact with far domain analogies with scaffolding in the form of bridging analogies.

A proposed system for supporting analogical innovation with bridging analogies

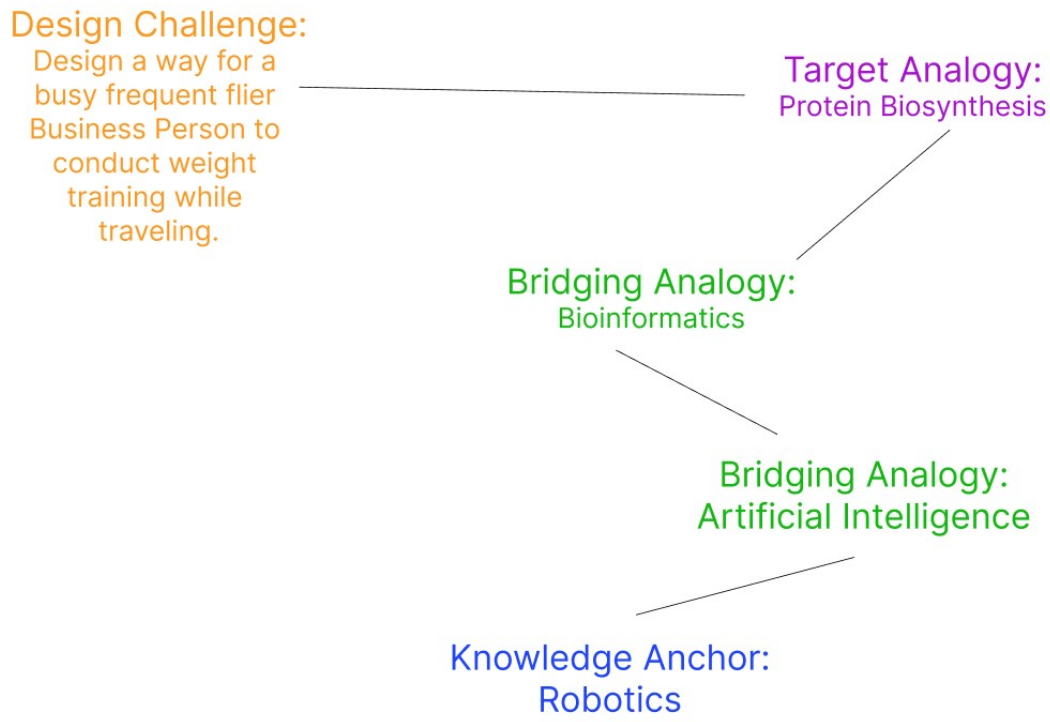


Figure 1: Example of bridging analogies path

Based on prior studies, we hypothesize that bridging analogies can help bridge the conceptual gap between a user's knowledge and the target analogy provided to them (Limon et al., 2002). Bridging analogies allow the participants to connect the participant's area of expertise with the presented target information, which can be conceptually misunderstood. The role of bridging analogies is to provide those conceptually misunderstood ideas differently to assist someone interacting with them to bridge the concepts. It may also have the potential to introduce cognitive conflict, which has been shown, in some cases, to play a role in conceptual change (Limon et al., 2002). Cognitive conflict is when inferences between data have inconsistencies

(Cosier & Rose, 1977). Therefore, we believe that bridging analogies will effectively aid users in creative brainstorming.

In this thesis, I propose a way of utilizing bridging analogies which will aid innovators in leveraging far analogies from unfamiliar domains to solve their current problems. We know how to calculate the shortest path between two nodes from graph theory. The shortest path problem consists of the problem of finding the shortest path between two nodes by finding the vertices in between (Yu & Yang, 1998). Building on this idea, I will explore how nodes in the shortest path between a knowledge anchor and a target analogy might be used as bridging analogies to aid in analogical problem solving.

A website called sixdegreesofwikipedia.com was used to test this system to determine bridging analogies between two areas of knowledge. Six degrees of Wikipedia uses a breadth-first search to locate the shortest distance between two. Wikipedia pages.

A breadth-first search is an algorithm that allows for the shortest path to be found between two vertices. It uses a top-down analysis of the nodes in each layer between the vertices. The algorithm will analyze each node at a given layer before moving on to the next layer when determining the shortest path between two vertices (Beamer et al., n.d.).

Wikipedia is not defined as a graph but as a relational database. This presents an opportunity to extract relational material from it. Fortunately, six degrees of Wikipedia allowed the relational material embedded in Wikipedia pages to be traversed without it being strictly a graph of knowledge. This fact allowed researchers

to use Wikipedia as a source for bridging analogies because the BFS is crossing relational material between two vertices. It is conceptually relevant nodes within Wikipedia pages that SixDegreesofWikipedia.com was utilized to determine the bridging analogies for the study.

An example of the process of sixdegreesofWikipedia.com can be seen in Figure 1. The example comprises finding a path between the Nervous System and Induction Loop. We have an analogy to an induction loop, but the person is unaware of that. However, they are familiar with the concept of the human nervous system. The system would then provide connecting nodes which could serve as bridging analogies between the two seemingly unrelated concepts.

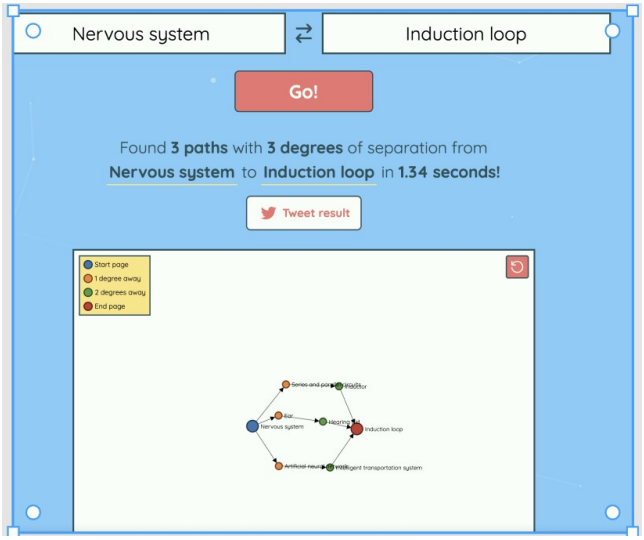


Figure 2: system used to determine relevant bridging analogies

The nodes between the induction loop and the nervous system may act as bridging analogies to help a user better understand precisely what the problem is and what will allow them to make an efficient analogy to solve their current problem.

The primary contribution of this thesis is a set of empirical results from a think-aloud user study that tests this concept. To preview, they found that participants

could effectively use the bridging analogies to aid in original ideation. These results suggest that bridging analogies are effective in stimulating novel inventiveness.

Chapter 2: Method

Task and Design

The study was composed of 3 sessions lasting twenty minutes each, where participants were given a design problem and some analogical stimuli and asked to generate ideas for the design problem. Our primary concern was to study the effect of bridging analogies. Our primary comparison is between being given only analogies and some bridging analogies.

One subproblem the study addresses is the issue of interaction. How should users interact with the analogies? Is it more beneficial to operate like a recommender system offering precise recommendations of one or a few nodes based on what the system knows about the user, or should it work like a map for a user to explore the various bridging examples being shown?

Initial thoughts are that a map-based approach would be most successful. According to McCaffery, users are more likely to solve a problem when breaking down an item into its most obscure properties (McCaffrey 2012). Having multiple unrelated concepts could allow users to break down the concepts to locate their connection. This would help obtain the necessary pieces required to stimulate Analogical transfer. On the other hand, a recommender system may be beneficial as it constrains the user to think across one domain, producing fewer novel ideas than a system with fewer constraints. However, there must still be constraints, which makes the proposed system of analogies ideal for the problem above.

Thus, our study will compare the following conditions:

1. **Analogy only.** Participants will be given the analogy and nothing else.

2. **Bridging recommendations**. Bridging search with a ranking system in the attempt to find a solution.
3. **Bridging map.** Finally, the final scenario will utilize a map of the bridging analogies to see what solutions participants would come up with. The order of scenarios will be counterbalanced among participants to ensure that order effects do not control results.

The details of the recommendation and map conditions are described below.

To avoid any overlap of ideas, users will be given a random problem from three different pre-selected problems from the previous brainstorming sessions. In each scenario, the participants will be given a particular problem to ensure that any results from the study can't be attributed to prior problem-solving. In addition to randomizing the problems, the order in which the scenarios are issued will be chosen randomly. There will be no specific order of scenarios given to any participants. The randomization will be able to prevent any results which could be attributed to only seeing results in a particular problem since participants were able to get better at the task over time.

Materials

Source Problems and Target Analogies

We selected design problems that require creativity, where the solutions should not be obvious. Still, the problem is also not too complex (requires specialized knowledge to develop any possibly practical solution, such as a problem that requires participants to have a strong background in how 3D polymers worked to manipulate them.)

Our requirements for the analogies, on the other hand, are as follows:

- relevant to the problem (i.e., should be able to specify the mapping but also spark a solution idea that might be different from the obvious one)
- from a different domain
- likely to be at least outside knowledge of participants

The research team generated these analogies.

The selection of analogies and problems will be fixed for all participants. The problems people will be solving, and their given analogies are as follows.

Problem	Far Domain Analogy	Explanation of Analogy
Design a way to enable young children to interact with aquatic animals. In marine environments while keeping both the animals and the children safe.	***Negative room pressure***: Isolation technique used in hospitals and medical centers to prevent cross contamination	Is also about ***isolating*** people from harmful elements (i.e., disease-bearing agents in hospitals)
Design a way for a busy frequent flyer businessperson to do weight training wherever they go.	***Protein Biosynthesis***: Core Biological process, occurring inside cells, balancing the loss of cellular proteins (via degradation or export) through the production of new proteins	Contains the core concept of ***increasing in size*** when an element is added to them (Adding water to weights to increase weight, or adding more protein to the muscle when deteriorated)
Design a way to protect babies from all the elements while being carried	***Surface-to-air missile:*** Ground launched missile designed to attack aerial targets	Is about ***protecting natives*** from harmful elements which aim to invade their native territory in some manner (A

		missile hitting a nearby building, while harmful diseases, or external events could harm a baby)

Table 1 Design problems and Far domain analogies

Bridging Analogies

Participant	Knowledge Anchor	Bridging analogy	Bridging analogy	Far domain analogy
P1	Human computer interaction	Brain	Amino acid	Protein biosynthesis
P6	Robotics	Artificial intelligence	Bioinformatics	Protein biosynthesis
P10	Graphic design	Future studies	Pandemic	Negative room pressure

Table 2 Examples of bridging analogies.

Bridging analogies were obtained in the following way. First, a pre-survey was conducted to understand their knowledge base. This yielded domain specific knowledge for the users. Questions were asked, such as what is the participant's current area of study? What areas of knowledge do you consider yourself proficient in? These questions allowed us to have a starting node. To find a solution to the shortest path between a participant's knowledge anchor and the provided far domain analogy.

The search from sixdegreesofwikipedia.com is not always perfect, such as when it found a node for a Wayback machine when finding the shortest path between Human-Computer Interaction and Negative room Pressure. Still, most examples were more effective in bridging the gaps between the target analogy and knowledge

anchor, which is the area of knowledge the participant stated they had a significant understanding of. These can be seen in the connections between Human-Computer Interaction and Protein Biosynthesis, Brain, and Amino Acid. It can also be observed when connecting Health Technologies and Surface-to-air missile with Chemistry and World War 2. Additionally, in the connection between Graphic Design and Negative Room Pressure with Future Studies and Pandemic.

Selection for the map's sessions will be based on the first three nodes presented when finding connections. When searching for the shortest path during early iterations, there could be hundreds of paths between the two depending on the edge analogies. Since adding hundreds of analogies would overwhelm a user, which we determined through iterative pilot testing of the system and procedure, it was decided that only three paths would be used for the map system. When selecting the paths, it was decided that there would not be any repetition of nodes. If one of the first three paths contains a previous node's repetition, it will be excluded, and the researcher will move to the following path without any repeats.

When selecting paths for the map session, rather than choosing nodes from right to left, selection will be made starting from the first path on the lefthand side and continuing down until the first three are chosen. This can be seen in Figure 1, where the researcher would start in the top left-hand corner and move down. The next group of paths down contains a duplicate so that the following path would be the one directly to the right of the top left corner. The researcher would again go down until they could select three paths with no repetitions if there were more paths

then the researcher would not go to the next column but would instead continue down the far-left column until they had three paths.

Repetitive nodes tend to present themselves when traversing paths from left to right when finding paths. Therefore, selecting them moving from top to bottom will aid in eliminating any potential knowledge bias from the researcher that could present itself. If this were the case, the study would be more tailored to the researcher's area of knowledge than the participant's, thus altering the study results. The other issue that could arise is that the selection process would be up to the researcher. The selection method would not be able to be reproduced and is dependent on the researcher who selected the paths.

Figure 3 Example of path selection

Since the recommender session utilizes only one path, the first path that displays itself when searching for paths between information nodes will be selected. This ensures a uniform process when selecting all nodes and will aid in curbing potential biases.

The bridging conditions will not include links to outside pages. Some prior knowledge is assumed, and short descriptions are provided. The user should be thinking about how the bridging analogies link together. Drawing from McCaffery, the hopes are to (inspire) users to break down the analogies to more abstract features to see how they relate. The main idea of our hypothesis is that users shouldn't require extra information to draw from.

Participants

Participants were recruited using listserv emails. The only requirement for participating in the study was that the participant was 18 years old or over. A total of 12 participants took part in the study. Except for one, they were undergraduate or graduate students—most being at the University of Maryland and one from Montgomery College. One participant was a product designer and not affiliated with any university.

Procedure

Session Component	Duration
Map (No Stimuli provided) - participants were given the design challenge and asked to ideate with no added stimuli provided.	10 minutes
Map (stimuli provided) – Participants were asked to ideate on the same design challenge as the map condition with no stimuli provided, but were given access to a Figma document with three paths of analogies, their descriptions, and an accompanying visual	10 minutes
Recommender (No stimuli provided) - Participants were asked to ideate	10 minutes

on a new design challenge without any provided stimuli	
Recommender (Stimuli provided) - Participants were asked to ideate on the same design challenge in the Recommender session without any stimuli provided, but they were provided access to a Figma document with one path of analogies, their descriptions, and an accompanying visual	10 minutes
Analogy (No stimuli provided) – Participants were given a new design challenge and asked to ideate with no provided stimuli	10 minutes
Analogy (Stimuli provided) – Participants were asked to ideate on the same design challenge given in the Analogy session with no stimuli provided, but were access to a Figma document which contained a single analogy with a description and an accompanying visual	10 minutes

Table 3 Example timeline of a Zoom session

All study procedures were conducted remotely via Zoom. Upon logging on to the zoom meeting, the participant will be instructed on what is required to participate in the study. They were informed that they were allowed to use paper, a whiteboard, or Google Docs to assist in brainstorming. In addition, they were told that thinking aloud is encouraged. Which session they were given, and which order was determined using a shell script that randomized the options.

Upon completing the initial information provided to the participant, the first session began. Again, participants were informed that thinking aloud is encouraged and that they had 10 minutes to complete the first brainstorming session.
A link was provided to the google doc where they documented their final designs. After the initial 10 minutes, they were asked to report their top 3 designs for their given problem.

Once they completed documenting their ideas, they were provided with a link to a Figma page which contains one of the three scenarios mentioned above. They either had a map of bridging analogies, a recommended path of bridging analogies, or just one analogy. Again, participants were encouraged to think aloud. After ten minutes, they were asked to document their top 3 answers.

Participants were allowed to draw diagrams as well. If they were using scratch paper or a whiteboard, the participants were asked to upload a photo of their visual brainstorming to the google doc.

The next brainstorming session began when the participants had completed documenting their brainstorming and their final ideas. Participants were given a new problem to solve and a new Figma link. This process repeated itself three times for each different scenario a participant agreed to participate in. When the sessions were completed, a participant had a google doc with their solutions to the design problems and any supporting documentation.

Data Preparation and Analysis

The Data collected needed to be prepared to analyze the results effectively. Approximately 11 hours of video recordings were transcribed using web-based transcription software to do this. The recordings of each participant were broken apart into map, recommender, and analogy sessions for each participant to allow for more straightforward navigation of the videos.

An informed grounded theory approach was taken when analyzing the data. Informed grounded theory can be defined as a qualitative approach to analyzing data in which the research and the final product are grounded in the literature (Thornberg, 2012). Before analyzing the data, a literature review was conducted to ensure sufficient understanding of the prior work on Analogies.

First, videos were uploaded into NVivo, a qualitative data analyzing software. Once a video was uploaded, they were analyzed to add timestamps and quotes at those timestamps. These timestamps turned into the beginning codes where users interacted with the analogies. An open coding process was then used to code the timestamps. Some examples of codes were Expanding possibilities, abstract translation, and expressing confusion. These codes we then refined into a higher category of Using or Evaluating the analogies. Evaluating occurred whenever a participant would interact with the analogies in the process of understanding how they related to the problem. Codes that fell into the analogies code were when a participant expressed an idea using the analogies.

The two codes that researchers were concerned with under the Using category were abstract translation and direct translation. This analysis was informed by prior

literature on different transfer forms from examples and analogies. These criteria included the transferal of structural features or a transfer of surface features. When a participant incorporated underlying mechanisms or functions of the analogy, it was considered an abstract translation because the participant captured essential properties related to the problem. A surface translation of features can be defined as when basic features were transferred, such as using pipes in a final solution for a problem when given the plumbing analogy. This literal translation takes the literal structure of plumbing. It proposes a solution to a given problem instead of using the underlying function of diverting an element across a particular path that would have been considered a structural transferal (Eckert & Stacey, 2003; Siangliulue et al., 2015). Participants either abstracted the analogy and incorporated it into their final ideas, directly used surface translations in their final ideas, or did not use any analogy in their final solution, which researchers were less concerned with because our focus was to understand how bridging analogies could aid brainstorming.

Upon completing each video, walkthrough memos described how the participants interacted with the analogies. Memos were used to give an overall impression of the study that had just been observed. The question in the memos was how the participant was interacting with the analogies. Additionally, this allowed further interpretation of the codes obtained while analyzing the videos for the first time.

Once a more refined understanding of the codes was established, participant stories were created based on the codes and the memos collected. Three stories were made for each participant in the study. There was one story for each session of the

conducted research. This means that there was a total of 36 stories written. The stories were similar to the memos. They focused on answering how the participants were using the analogies, but the memos afforded more deviation from the research question. Memos incorporated similar aspects but were not restricted to answering how the participants' ideas came from the codes in which the participant stories were.

These stories then allowed researchers to develop idea journeys for each participant. Idea journeys were created for each session of each participant's study. There were 36 idea journeys made for the study. The idea journeys focused on the idea itself rather than what the participant was doing. The journeys were written from the idea's perspective to understand better how the participant came up with the idea. This manner of analyzing aided in further refining codes and interpretation of results.

Chapter 3: Results

Summary Descriptives

The primary codes observed in the study can be seen in the following tables.

Evaluating

Table 3: codes pertaining to the evaluation of the analogies

Using

Code Type	Examples	Description	Occurrences
Direct translation	"A shuttle water bus with glass" (P11)	Participant was provided the analogy of Negative room pressure and used the glass rooms in the photo to translate a surface level similarity to their ideas	30
Abstract translation	"A pill for each muscle you'll like to target. These pills will weaken the particular muscle fibers based on the number of pills you take." (P10)	The analogy they used to derive this idea was fermentation and protein biosynthesis. They had noted for protein biosynthesis an idea for something like steroids and noted probiotics for fermentation. The combination of these two already abstracted ideas became the pill they describe.	18
Expressed Connections	"The first thing I am thinking about is fluid dynamics, and this is literally just that." (P4)	The analogy provided was Negative room pressure and P4 was able to connect their knowledge of Fluid Dynamics to the structural mechanics of Fluid Dynamics	6

Expanding Possibilities	"Do these ideas have to be realistic?" (P12)	This was stated P12's map session. Their analogies were User Interface, Cyberwarfare, Pandemic, Negative Room Pressure,	8
		Human Factors and Ergonomics, Engineering Controls, Simulation, Field Hospital. Especially during the map session where this occurred the most frequently expanding of what's possible seemed to stem from the overwhelming aspect of connections the participant was attempting to make.	

Table 4 codes pertaining to the use of analogies

Ways of interacting with analogies

The following are not the main results of this thesis; however, they provide context for understanding the primary analysis of how people interacted with analogies depending on whether they had bridging analogies. What we found is that participants consistently interacted with analogies in similar ways. How analogies were used consistently came down to evaluating analogies and using analogies. Participants rarely did not use the analogies. However, there were a couple of instances where the analogies were not used. For example, P3 asked during the think-aloud if they needed to use the analogies because they were struggling with understanding how they related.

Evaluating

Dismiss as irrelevant

When evaluating the analogies, multiple participants dismissed the analogies as irrelevant to the given problem.

For example, during the recommender session, when they were developing ideas for the problem of designing a way for a frequent flier businessperson to conduct weight training wherever they go. They were given the target analogy of Protein Biosynthesis. From their knowledge anchor of Human-Computer Interaction, they were provided with the bridging analogies of Brain and Amino Acid. P4 had considerable trouble understanding why a frequent flier would want to perform weight training while they were traveling. They made multiple comments that alluded to this idea, such as,

> *"The last thing you want to do at an airport or when you're traveling is exercise, that's you're not in the mindset. And if you see an exercise area or equipment, you just don't want to do that."*

This participant struggled consistently through the study to connect the problem and the analogy. However, they were not the only participants who deemed the analogies irrelevant. Multiple other participants thought similarly and conveyed comparable messages about the analogies being unrelated to the problem statement.

Uncertainty/confusion

When evaluating the analogies, participants consistently expressed uncertainty in how the analogies related to the given problem.

Some participants would express confusion, such as P1. They were given the target analogy of Negative Room Pressure during the map session. From their

knowledge anchor of Bioinformatics, they were provided with the bridging analogies of Nanobiotechnology, Cyberwarfare, Pandemic, Health and Safety of Nanomaterials, Perception, and Lung. While they were designing a way for children to interact with marine animals in an aquatic environment while keeping both the children and animals safe, P1 was visually interacting with the analogies when they exclaimed,

*"**I am confused** because they seem pretty irrelevant, like nanobiotechnology."*

Almost immediately after expressing this confusion, they were able to produce a connection between perception and lung, which led to them producing an abstract idea using concepts from perception.

Similarly, during P10's map session, while designing ways for a busy frequent flier businessperson to conduct weight training wherever they go. Based on their knowledge anchor of User Experience Design, they were provided the target analogy of Protein Biosynthesis. They were provided with the bridging analogies of Amino Acid, Protein Design, Fermentation, Engineering, Immune System, and Physical Attractiveness. P10 created a Figma whiteboard where they put all the analogies provided. They would use virtual sticky notes to make notes next to each analogy relating to potential ideas. While doing this, they claimed,

*"**These feel so random**, that's why it's pretty hard to brainstorm."* A minute later, they produced their first idea, which incorporated abstract concepts from the analogies provided. This was a prominent code seen across all participants except for one who was not as vocal during their think-aloud as other participants.

While confusion was expressed across multiple participants, and just as many participants dismissed the analogies as irrelevant, elements of those same analogies

that participants would dismiss would end up in their final solutions. Consider P6's map session when they were ideating a way to protect babies from all the elements while being carried. They had the knowledge anchor of Machine learning and were provided with the target analogy of a Surface-to-air Missile. They also had access to the bridging analogies of the Cuban Missile Crisis, Afghanistan, Fighter Aircraft, Speech Recognition, Cyberwarfare, and Game Theory. During this session, they began by looking at the Figma doc to better understand the provided analogies. They voiced,

"Do babies need protection from cyber warfare while being carried now?

***I'm not able to understand why** we have cyber warfare over here."*

This confusion was again followed by more confusion, which ultimately led them to an idea that incorporated all the analogies on the map.

P6 was one of the only participants who came up with an idea that incorporated all the analogies provided. Others may have developed ideas that utilized a few of the analogies, but no one other than P6 contained them all.

Another example was observed with P9, who was ideating a way for a busy frequent flier businessperson to conduct weight training. They had the knowledge anchor of the Korean Language and were given the target analogy of Protein Biosynthesis. The bridging analogies they had access to were Convergent Solution and Translation (Biology). They began as other participants did by interacting with the analogies. This is almost immediately followed by confusion stating,

*"Protein biosynthesis, **What?** These are really unrelated to the topic."*

This confusion then led to the formulation of an idea by using a personalization

strategy.

P9 produced ideas relating to ideas surrounding protein biosynthesis and Korean language. The ideas they had surrounding protein biosynthesis especially were direct translations, such as protein tablets which enhanced weight training. However, they were still deriving from an analogy that they initially did not understand how they related.

Using

The way the participants interacted with the analogies held some insights into how they used the analogies. There were two primary codes for how they used analogies. Participants either expressed connections with their knowledge domains when interacting with the analogies or produced an idea from interacting with the analogies.

Expressing connections

Expressing connections was one way that participants interacted with the analogies, but it was also less frequently used by most of the participants. When participants expressed connections, it could have been done by making an analogy to another area of knowledge, or they could have made a connection to a different form of knowledge.

For example, In P1's map session, when they were ideating a way for children to interact with aquatic animals, during which they had the knowledge anchor of Bioinformatics and were given the target analogy of Negative Room Pressure. The bridging analogies provided were Perception, Lung, Cyberwarfare, Nanobiotechnology, Pandemic, and Health and Safety Hazards of Nanomaterials. P1

mentioned that they intentionally expressed confusion over how the analogies related. After this confusion, they produced an idea involving XR for the interaction. During the think-aloud after writing the idea, they said,

> *"**I got the inspiration from the perception** because I realized perhaps it does not really matter whether all the animals are real as long as children perceive it is real, so we could use the AR or VR."*

This connection between perception and XR allowed the participant to provide an answer to the question.

This could also be seen in P4's analogy session. They were devising a solution for a way for children to interact with marine animals while keeping the animals and children safe. The target analogy was Negative Room Pressure. During the session, they said,

> *"The first thing I'm thinking about is fluid dynamics, **and this is literally just that**."*

They produced initial thoughts about the problem, and after continuing to evaluate the analogies, they were able to have an idea that stemmed from this initial confusion. The connection between their knowledge and the analogies allowed the participants to contemplate how the provided analogy could be incorporated into their final idea(s).

Generating ideas

Participants used analogies to create ideas for the problem provided to them. Except for two participants, the others used analogies to devise a solution to the problem. Even with the two participants whose direct idea may not have stemmed from the analogies, that was not the case for each scenario they were given. The two

participants above who produced ideas unrelated to the analogies did not consistently provide solutions with no relation to the analogies. It was only evident that the analogies played little to no role in their answers in one of their sessions.

This was observed in P5's study during the map session. P5 used virtual reality, a provided analogy, in one of their solutions. However, during the recommender session, the solutions they gave did not directly relate to the problem they were solving.

As previously mentioned, this was not a common occurrence. It was only recorded in two participants' sessions and not for all their ideas. Even in P5's recommender session, they produced ideas related to analogies, just not all of them.

Impact of bridging analogies

Codes	Analogy Session count	Map session count	Recommender session count
Dismiss as unrealistic application	3	5	4
Expressed Confusion	10	10	6
Personalization	1	2	3
Scenario Creation	5	0	1
Expressed Connections	7	8	8
Idea from analogy	15	24	18
Abstract translation	3	11	3
Direct translation	9	6	15
Expanding possibility	2	5	1
Noting possibility	2	5	1
Reformulation	1	0	0

Table 5 Occurrences of codes across sessions

We now discuss the primary analyses relating to our core questions about bridging analogies. Table 6 shows the distribution of codes across the map, recommender, and analogy sessions. This section will elaborate on these differences with detailed descriptions of the cases from the think-aloud data. Our analysis revealed three main themes, 1) Bridging analogies had little effect on the confusion of analogies, 2) There was less scenario creation and personalization with bridging analogies, and 3) Bridging analogies enabled deeper and more expansive ideation with analogies.

Bridging analogies had little effect on the confusion of Analogies.

As shown in table 6, there is slight differences in how participants evaluated the analogies. Dismissing the analogies as unrealistic was a common code across all the sessions. Participants were typically similar in their reactions to the analogies they ignored. They would claim that the analogies were not relevant, and then they would continue brainstorming. In some instances, the dismissed analogy would end up in their final solutions. One participant asked if they had to use the analogies, but this was close to the end of the session they were working on, and they were not dismissing them as irrelevant to the problem. They stated that many analogies were overwhelming and increased their confusion. In their follow-up answers, they said:

> *The map didn't really help me with the problem. They did remind me of a direction I hadn't thought of, but the stimulus was more confusing than helpful.*

While it is similar to the dismissal of the analogies, typically, the stimuli's dismissal occurred at the beginning of the session, and more participants responded positively toward the map of analogies in their follow-up answers.

P2 began the map session by interacting with the Figma document. They were brainstorming on the design challenge of designing a way for children to interact with marine animals keeping both the animals and the children safe. Their knowledge Anchor was Psychology, and the target analogy was Negative room pressure. The bridging analogies provided were perception, lung, public health, engineering controls, Peking University, and SARs. They produced a couple of ideas based on one of the analogies provided. After building on ideas, they came to a couple of analogies, such as public health, which prompted them to state,

"Just seeing and reading about public health and like the negative room pressure and stuff. ***Like that's got nothing to do with this****."*

Nevertheless, immediately after this, P2 continued to produce new ideas and build on those newly formed ideas using analogies.

They were not the only participants to express this dismissal of the analogies relating to the problem. Five out of 12 participants in the studies dismissed the analogies as irrelevant at some point.

Participants did tend to express more confusion during the map and analogy sessions, with both having the same number of instances for that code. The recommender session produced almost half of the confusion of the other sessions. An idea tended to be formulated shortly after expressing confusion, as seen in the idea journeys.

Consider P1's analogy session; In this session, they brainstormed on the design challenge of designing a way to protect babies from all the elements while being carried. The target analogy of a surface-to-air missile was the only stimuli provided. When they first saw the analogy, they had initial confusion when looking at the surface-to-air missile analogy provided during the analogy session, but within moments produced an idea that revolved around protecting babies from gun violence.

Participants exhibited uncertainty about the analogies despite the two very different stimuli provided in the map session and the analogy session. For expressing confusion, both codes had the same number of occurrences. Regarding dismissing the analogies, the map session had two more dismissals than the map, but the recommender was one higher than the analogy. Even though the recommender produced less confusion, there was still a similar amount of uncertainty about how the analogies related to the problem participants were attempting to solve.

Less personalization and scenario creation with bridging analogies

Personalization was less common in the analogy and map sessions because only one participant represented all three instances of this code across both sessions. The Recommender session had more variety regarding who was attempting to personalize the scenario to solve the problem.

Time Stamp	**Event**	**Description**
08:43	Analogy Interaction	Skateboarding, food
9:11	Confusion	How do any of these things relate to weight training

9:30	Confusion	Wouldn't have thought about food and weight training
10:02	Making Connections	They need to recover and work not just train
10:30	An idea	They could recover while working
11:00	An idea	Training could be the fliers' job
11:20	Personalization	What do I do when I travel?

Table 6 P7's Recommender session idea journey

An example of personalization came from P7, who brainstormed a way to devise a way for a businessperson to participate in weight training while traveling (Figure 4). Their knowledge anchor for this session was skateboarding with food and cell(biology) as the bridging analogies to get to the target analogy of protein biosynthesis. P7 struggled during their recommender session to find the connections between the analogies and the problems. They were often observed expressing confusion about the relationship between problems and analogies. They were ultimately able to produce a couple of ideas relating to the problem. Still, after struggling to determine how the analogies related, they attempted to use personalization to create ideas. They asked themselves,

"What do I do when I travel"?

Participants like P7 attempted to make the problem personal to utilize the analogy to solve the problem presented. This was observed only in a few participants out of all the participants. Three out of twelve participants used this strategy when ideating.

Scenario Creation was the only way of evaluating analogies in which bridging analogies changed how participants evaluated the provided analogies. There were no

instances of participants attempting to create a scenario to solve the problem during the map session, and there was only one during the recommender session. However, there were five instances of multiple participants creating a fictional scenario to solve the problem using the given analogy.

Time Stamp	Event	Description
25:11	Analogy Interaction	Surface-to-air Missile
25:29	Expanding Possibilities	Let's throw practicality out the window
26:02	Scenario Creation	What if the baby is actually a secret spy
26:31	An idea	Their stroller is actually a cockpit with detachable drones that detect harmful elements
27:54	Building on prior ideas	There would need to be a waste disposal system
29:02	Building on prior ideas	Versatile transportation so the stroller can go anywhere
31:00	Building on prior ideas	The cockpit should have windshield wipers
32:29	Building on prior ideas	Vents to facilitate drag and to improve air quality for the baby

Table 7 P10's Analogy idea journey

This is evident in P10's analogy session, as shown in figure 5. They were ideating on the design challenge of protecting a baby from all the elements while being carried. The target analogy was surface-to-air missile. They began the session by interacting with the analogy. Upon seeing the analogy, they immediately exclaimed,

"let's throw practicality out the window."

Shortly after, they created a scenario to help them incorporate the analogy into the problem. They stated, “let’s assume the baby is actually a secret spy.”

Creating a fictional scenario allowed them to incorporate the analogy of surface-to-air missiles in their final solutions to the problem. Almost half of the participants, at one point in time during their sessions, attempted to use this strategy to provide a solution to the given problem.

Ideation with Analogies

The following results pertain to how the participants ideated with the given analogies. Across all sessions, participants could be observed making connections to other domains of knowledge which aided them in ideating on the given problem. P6 connected Iron man and all the analogies provided to them in the map session.

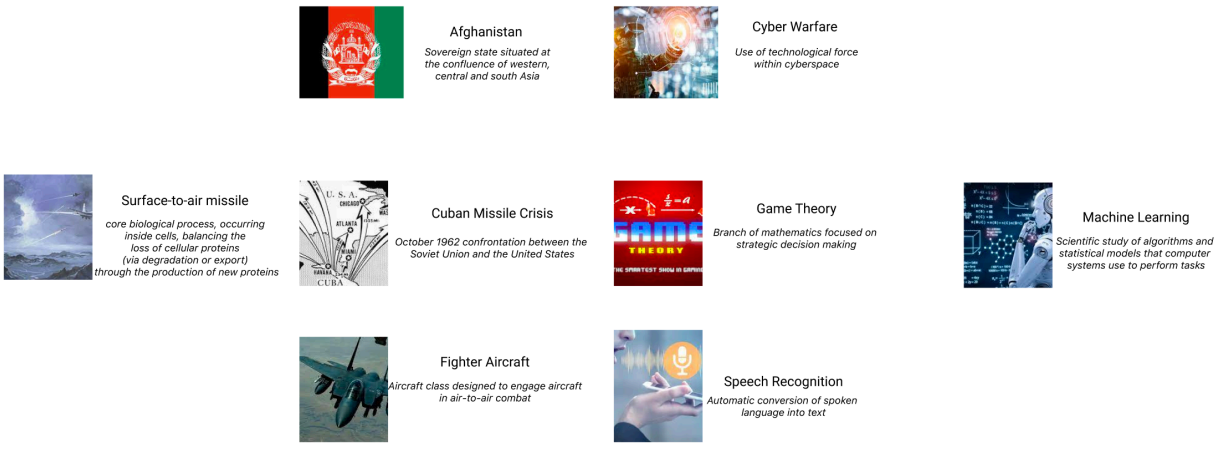


Figure 4 P6’s Map stimuli

At the beginning of the map session, P6 was interacting primarily with their knowledge anchor of Machine Learning and the closer related bridging analogies of speech recognition and cyber warfare. They were ideating on the design challenge of

protecting a baby from all the elements while being carried. P6 was struggling to find the connection between the analogies and the problem. They questioned the relevance of multiple near domain analogies throughout the whole session. They finally created an idea involving a suit that operated like the iron man suit. After they produced the idea, they could make the connections between the analogies provided and the solution they devised. They said,

"The first place Tony Stark went was Afghanistan after building the iron man suit, so yeah, this idea incorporates all of the analogies on this list." This was the only example where participants could express a connection between all the analogies. Typically, participants would describe a relationship between one analogy and a concept nearer to their knowledge domain. P4 connected fluid dynamics, which they knew about, and negative room pressure, a far domain analogy.

Bridging analogies enabled deeper and more expansive ideation with analogies.

Bridging analogies did seem to afford the participants a deeper understanding of the problem. This often led to a broader range of solutions to the problem being given to them.

This can be seen in the number of abstract translations from the analogies provided. Multiple participants could produce more abstract solutions for the problem provided during the map sessions.

Consider P10's Map session when they were solving the problem of designing a way for a frequent flyer businessperson to perform weight training while traveling. Their knowledge anchor was User Experience Design, and the target analogy was

Protein Biosynthesis. The bridging analogies provided were physical attractiveness, amino acid, protein design, fermentation, engineering, and immune system.

During P10's map session, they utilized multiple strategies to use the provided analogies effectively. They put the analogies on a separate whiteboard and took notes on potential ideas to keep track of their thoughts. For example, they put modular design with engineering (bridging analogy), probiotics with fermentation (bridging analogy), and weights that look like handbags next to physical attractiveness (bridging analogy). This allowed them to expand their understanding of what is possible and produced the abstract idea of a pill that targets a specific muscle and weakens it. This would enable the frequent flier to walk around the airport performing the same activities while increasing the strain necessary to increase muscle mass.

Another example can be seen in P2's map study.

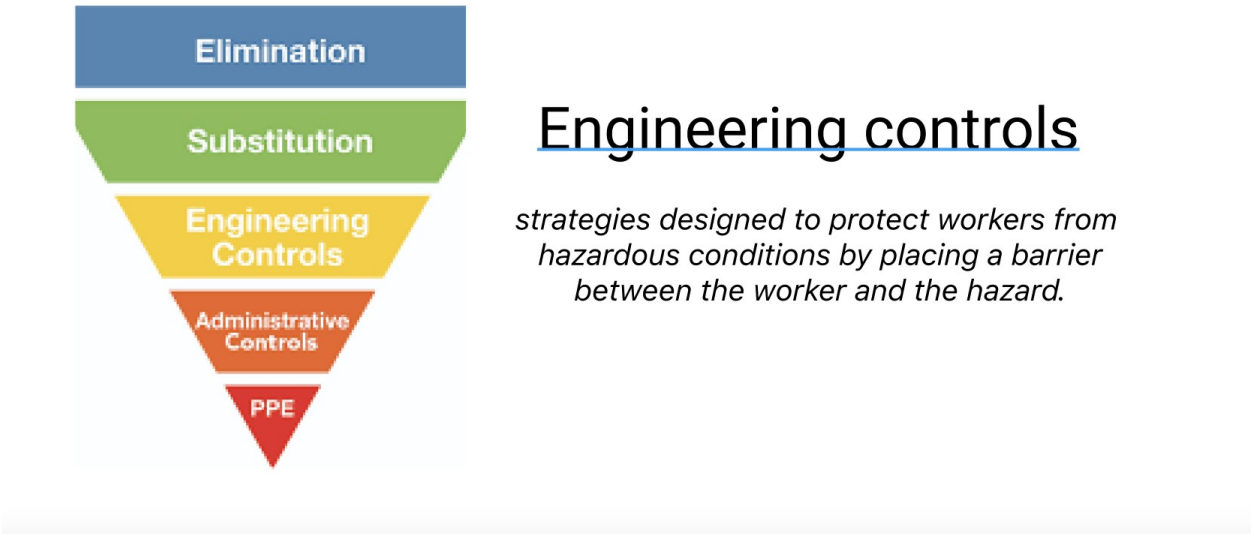


Figure 5 Close up of engineering controls analogy from P2's map session

Take, for example, P2's map session. They were ideating the design challenge of designing a way for young children to interact with aquatic animals keeping both the animals and children safe. Their knowledge anchor was Psychology, and they were provided the target analogy of Negative room pressure. The bridging analogies provided were perception, lung, public health, engineering controls, Peking University, and SARs. P2 saw the hazardous conditions analogy they were supplied and used the visuals to define what would be needed to keep animals and children safe. They went through each tier on the visual analogy for engineering controls (bridging analogy), seen in Figure 7. They determined what would be needed to keep both the animals and children safe using the ideas from the hierarchy. For example, P2 produced the idea of gloves for the PPE tier and training for the admin control tier. They said that children should have to view training or tutorial to interact with the animals under adult supervision. They then were able to build on the idea they came up with and pushed them further by utilizing other analogies. They incorporated other analogies, such as lung, by producing the concept of respiratory PPE for the children while interacting with the animals and using the idea of isolation from negative room pressure.

The abstraction mentioned above contrasts with the direct translations during the analogy-only sessions. A direct translation happened when the participants used the analogy in their solution, but there was no abstraction of the analogy to understand its basic concepts.

Figure 6 Analogy provided during P11's analogy session The analogy session for P11 offers an insight into the code of direct translation. They were brainstorming on the design challenge of designing a way for children to interact with aquatic animals keeping both the animals and children safe. They were provided with the target analogy of Negative room pressure, as shown in Figure 8. During this session, they were less vocal than other participants. Due to this, their screen share information became the primary source of determining how they interacted with the analogies. They were given the analogy of negative room pressure. In the photo which accompanied the description, there were multiple glass rooms. This prompted them to produce the idea of a glass room that the children could go into to interact with the marine animals in their environment (Negative Room Pressure).

Another example came from P12's analogy session. They were ideating on the problem of designing a way for a busy frequent flier businessperson to conduct weight training wherever they went and were provided with the target analogy of Protein Biosynthesis. P12 incorporated different techniques to produce ideas for the problem, leading them to some abstract answers. Still, they also created an idea of a

tool to track the amount of protein that a flier is intaking while they are traveling (protein biosynthesis). They directly incorporate protein in their answer with no use of underlying mechanisms of protein biosynthesis, as opposed to the more complex mechanisms of protein biosynthesis, which could have led to richer analogies and ideas.

P11's idea is directly related to the photo of Negative room pressure (Target Analogy) in which glass rooms were adjacent, and P12's idea directly incorporated protein intake from protein biosynthesis (Target Analogy). These examples are valid solutions to the problem they were given but do not indicate a deeper understanding of the underlying concepts of the analogies provided.

Another interesting idea became apparent when participants were ideating with the bridging analogies. Participants could break out of the functional fixedness (McCaffrey, 2012), which can occur when brainstorming to expand their idea of what is possible as a potential solution to the problem (McCaffrey, 2012). It was most common to observe the participants developing their idea of what was possible during the map session, which provided the most significant quantity of bridging analogies.

Time Stamp	Event	Description
34:00	Analogy Interaction	Cyberwarfare, pandemic, human factors and ergonomics, engineering controls, field hospital, Negative room pressure
34:34	Confusion	I am unsure how all these analogies are related to each other

35:35	Expressing Connections	It is interesting that they are like a network themselves. They all impact each other.
36:27	Expanding possibilities	Do these ideas have to be realistic?
36:30	Constant Analogy Interaction	Left the Figma document open next to the answer sheet
36:38	An idea	There could be a pool with digital marine animals, sensory information could be added to the experience, so the children could experience sensations marine animals feel
41:20	An idea	Create a realistic digital experience. Would need to collaborate with marine biologists

Table 8 P12's map session idea journey

This can be seen in P12's map session. They were attempting to find a solution for designing a way for young children to interact with marine animals while keeping both the animals and children safe. Their knowledge anchor was User Interface and they were provided with the target analogy of Negative room pressure. The bridging analogies provided consisted of Cyberwarfare, Pandemic, Human factors and ergonomics, Engineering controls, Simulation, and Field hospital. They began as the others before them by interacting with the analogies. After some initial confusion about how the analogies related, they could express connections between the given analogies. After making the connections, they began expanding on their idea of what was possible. They asked during the session, "do these ideas have to be realistic?" This broadening of their mind allowed them to produce novel ideas.

One way of ideating, which was limited to only one participant (P10), was noting what was possible with the given analogies. This was only observed during their map session when they were ideating on designing a way for a busy frequent flier businessperson to conduct weight training wherever they go. Their knowledge anchor was User Experience Design, and the target analogy provided was Protein Biosynthesis. They were provided with the bridging analogies of amino acid, protein design, fermentation, engineering, immune system, and physical attractiveness. This participant consistently interacted with the analogies by creating a whiteboard with the analogies on it so that they could make notes about relevant ideas. This allowed them to make connections and ideate in a way that was not observed in the other participants.

They were also the only participant who reformulated the given problem to incorporate the provided analogies. When solving the challenge of protecting babies from all the elements while being carried, they produced the idea of assuming the baby was a secret spy, allowing them to utilize the analogy of a surface-to-air missile in a manner unobserved by any other participant. Their first idea after creating this scenario was that their stroller could transform into the cockpit for the baby, which is operated much like a drone. They used the idea to incorporate a way for the baby to relieve themselves hygienically and an air filtration system that would be a part of the cockpit.

Subjective experiences of bridging analogies

All participants, except two, found the bridging analogies helpful in the follow-up forms. An example of the analogies not being helpful was recorded by P8 when they stated,

> *"No, they were very off-topic, so I felt they were not an effective stimuli to bring more ideas."*

P2 mentioned that they preferred to have single analogies provided so that they could focus on that one analogy.

> *"I didn't understand the connection between them, it was more helpful just to see single items- I found myself trying to understand the relationship between items instead of the items themselves."*

Another participant said something similar concerning the map. They stated that they found the map session more confusing than helpful, which is consistent with the data gathered in their think aloud, where they asked if they had to use the stimuli because they found it too confusing.

> *"The map didn't really help me with the problem. They did remind me of a direction I hadn't thought of, but the stimulus was more confusing than helpful. They did help me think of related concepts, but on the whole, they weren't that helpful."*

However, other than these examples, the other answers indicated that the bridging analogies helped think about the problems differently. P6 said, "*They gave cues and stimuli to provoke formation and further development of ideas that struck me. For instance, "machine learning" gave me many ideas since that is a field, I have experience working on."*

Some indicated that the most helpful bridging analogies were the ones they found relevant to the problem, but this arbitrary claim will vary depending on who views those specific analogies.

Chapter 4: Discussion

In this thesis, we sought to investigate the method to present bridging analogies during creative problem solving and to what extent the bridging analogies aided in the usage of the analogies. We found that bridging analogies helped participants think more abstractly about the given problem instead of simply providing an analogy.

Results are consistent with a couple of neurological studies that showed that stimuli, regardless of their domain, cause similar brain regions to activate (GoucherLambert et al., 2018; Hay et al., 2019). This can be seen in the fact that there wasn't a difference in the number of solutions produced across all sessions. Even in studies where participants no longer had ideas during the no stimuli condition of all sessions, they could provide more solutions once they were provided with stimuli.

Our results suggest that bridging analogies help bridge the gap between far domain analogies and near domain analogies. Our data also provide insight into the mechanisms by which bridging analogies might be helpful for analogical innovation. For example, as in the map sessions, interacting with many bridging analogies seemed to provide more opportunities to break away from what McCaffrey calls functional fixedness. In these sessions, we observed participants breaking down different elements of the analogies and determining their relationship on a deeper level.

The role of confusion in analogical innovation

The role of confusion also deserves a more profound discussion. Confusion or some other sort of dismissal tended to occur before producing some of these ideas. It

stands to reason that the confusion was a catalyst for the participants to break down the elements of the analogies to find the links between them. The confusion tended to stem from the far domain analogies, while the dismissing of analogies was more likely to occur with near domain analogies. The dismissal was less about finding the connections than already having a clear understanding. At the same time, the far domain analogies seemed to be more apt to require participants to break down the provided analogies.

Taken in a Predictive processing lens the confusion which accompanies the analogy and map sessions could be attributed to prediction errors occurring when the participants interact with the stimuli (Keller & Mrsic-Flogel, 2018). The prediction errors could motivate participants to update their mental models of the stimuli. Additionally, when learning new material, introducing some unpredictability while learning can lead to better long-term performance (Bjork, 1994). It stands to reason that unpredictability triggers prediction errors and allows for participants to make the connections that are required to benefit from the far-field analogy.

However, this also presents issues for the adoption of such a tool. If our brains are wired to minimize prediction error, then intentionally creating that confusion in ourselves may not be enjoyable for people. It seems to matter to what extent this confusion/prediction error is induced. A study found that people are not averse to challenging tasks even when presented with a less cognitively intensive option to explore (Wu et al., 2021). Implying that there is some sort of ideal level of both cognitively challenging, and enough familiarity to be able to minimize prediction errors. Where this spot exists when brainstorming is unclear, but it stands to reason

that the bridging analogies provided in the map session aided in allowing an anchor for participants to effectively manage the prediction error occurring with the stimuli. In relation to adopting this as an effective system for use, whatever method of delivery for the stimuli would seem to need to be set up in a way that allows for less control on the user's part. This may not be the case, but more studies would need to be conducted to verify this idea.

Why did the bridging analogies only seem to help in the map (but not recommender) interfaces?

The reason as to why the recommender session seems not produce the effect to a similar degree as the map sessions is not entirely clear. It seems to have something to do with the fact that the map induces more confusion while simultaneously providing bridging analogies. This would allow a participant to be required to think a little deeper to engage with the stimuli. In the analogy, session participants were able to experience high levels of confusion, but they did not have the bridging analogies to aid in bridging the gap between the problem and the target analogy. In the recommender sessions, participants were typically given only four analogies. Without the confusion, it seemed to make it easier for a participant to remain within their near domain knowledge and find it necessary to reach out to find those deeper level connections. For example, in P10's recommender session, their ideas were more technological focused, devising ideas surrounding VR and HUDs instead of health-related topics, which would draw their solutions more towards the far domain analogy. This can also be seen in P6's recommender session. They produced ideas involving robotics, which was their near domain analogy, and

computer vision to aid in weight training instead of using concepts from protein biosynthesis or bioinformatics.

Condition	Confusion	Bridges
Analogy	High	No
Recommender	Low	Yes
Map	High	Yes

Table 9 Representation of confusion across sessions

Table 9 shows how confusion and bridging analogies were present in different ways across the conditions. Further studies would be needed to determine the exact cause of this accurately, but a promising working theory to test might be that both sufficient confusion and the presence of bridging analogies might be needed to support inspiration from far-field analogies.

While there are some more theoretical aspects of the results, one thing is apparent when looking at the data. During creative ideation, a mix of analogies, some far, some near (to the knowledge anchors), has a role in aiding problem solving. In a similar fashion to where both near and far domain analogies produced activation of similar brain regions, it can be said that there is more to be understood than just that these two similar types of stimuli activate the same areas of the brain (Hay et al., 2019). Interacting with areas outside of one's knowledge domain is a path to breaking out of the functional fixedness described by McCaffrey. The bridging analogies allow the problem to be constrained. It is as if the two-act as tug of war partners, but in an endless cycle where there can be no loser, the outcome is novel ideation.

Limitations and Future Work

The study was conducted in a way to provide rich data for analysis. This allowed solid details and insights into mechanisms. However, the richness of the data set required researchers to take a descriptive approach to the work. We can't make causal claims because there wasn't enough data to perform statistical analysis. Future studies should follow up with a study that allows for sufficient data to test causality.

Additionally, this work solely focused on the process of the participant's brainstorming activity. Future work should address the outcomes as well. Determining if there is an effect on the quality of solutions provided will be of benefit to continue to refine the system to best benefit those who use it.

Testing the theory which has been presented in the discussion section of this paper is also important to continue testing. Isolating variables further to be able to verify that the theory presented in this thesis is accurate is a valid area for future work.

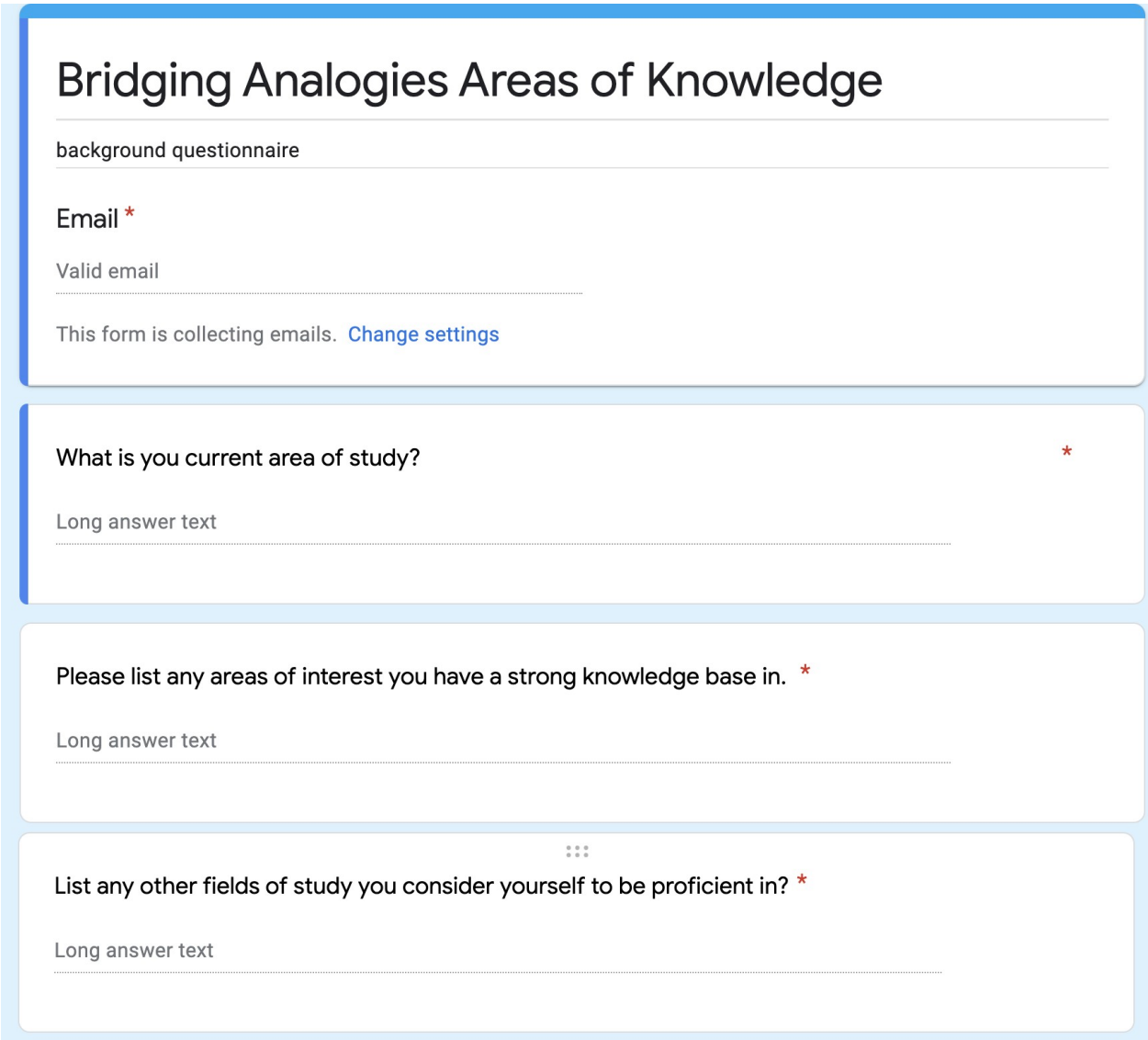
Another aspect for exploration would be finding differences in neural activity during these different sessions. Is there something happening in the brain just before an idea occurs that can be pointed to as a marker that a process has occurred that can be manipulated further? This would be an exciting way to precisely determine the difference between the map and the other sessions. What made that specific order of stimuli produce the results that it did?

Finally, determine the most effective way to deliver this information. Are these interactions best suited to a web-based interface which users could interact with? Given the level of immersion involved, producing these effects in a virtual

environment (VR) could yield exciting results. This could also be accomplished with Augmented reality (AR), which I suspect would have different effects. It becomes imperative when thinking about the other ways the stimuli can be presented to understand the affordances of each one.

Appendices

Appendix A: Areas of Knowledge Form



Bridging Analogies Areas of Knowledge

background questionnaire

Email *

Valid email

This form is collecting emails. Change settings

What is you current area of study? *

Long answer text

Please list any areas of interest you have a strong knowledge base in. *

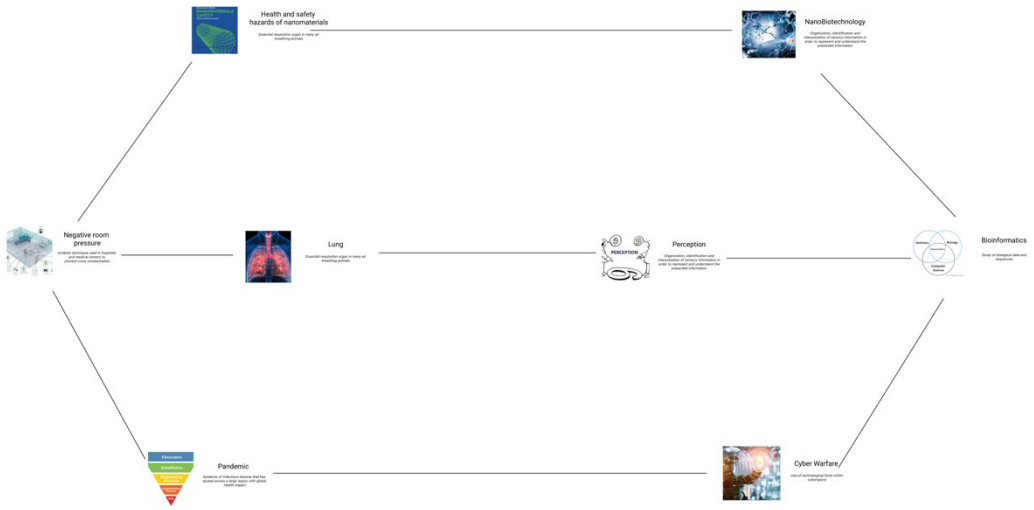
Long answer text

List any other fields of study you consider yourself to be proficient in? *

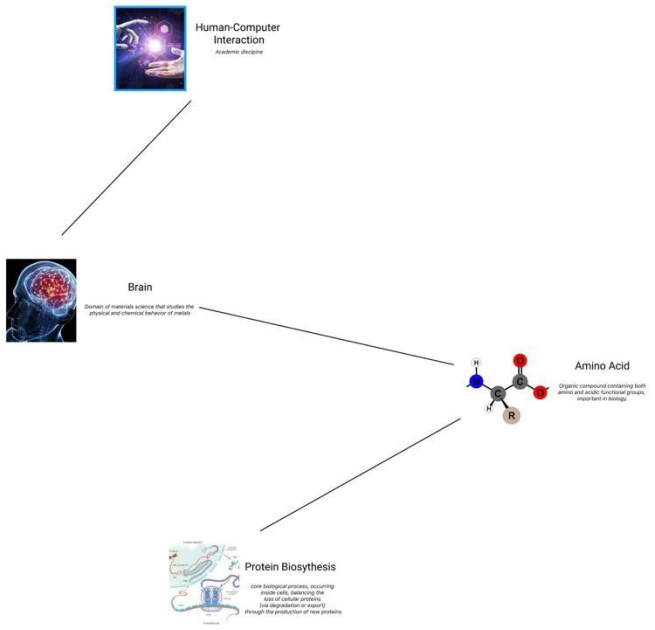
Long answer text

Appendix B: Provided Stimuli

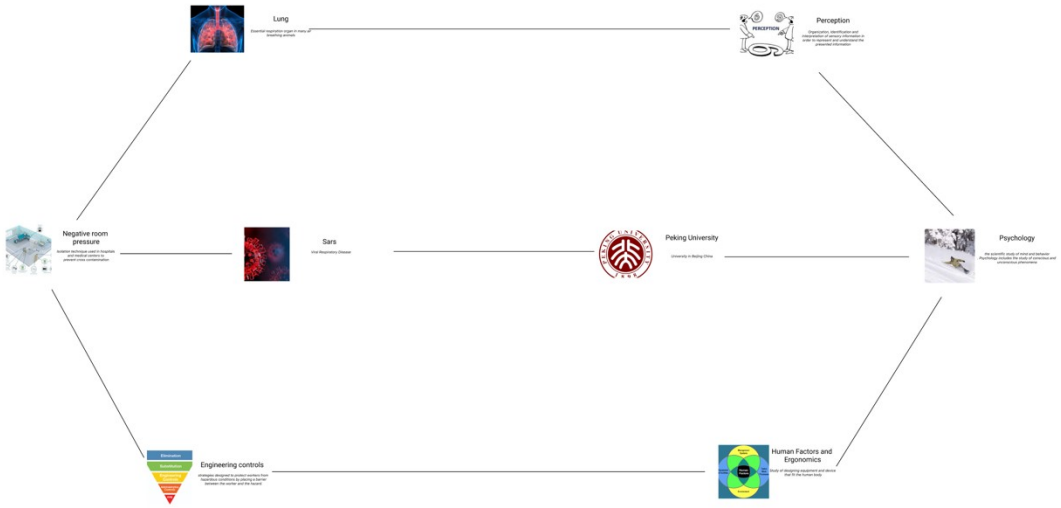
P1:



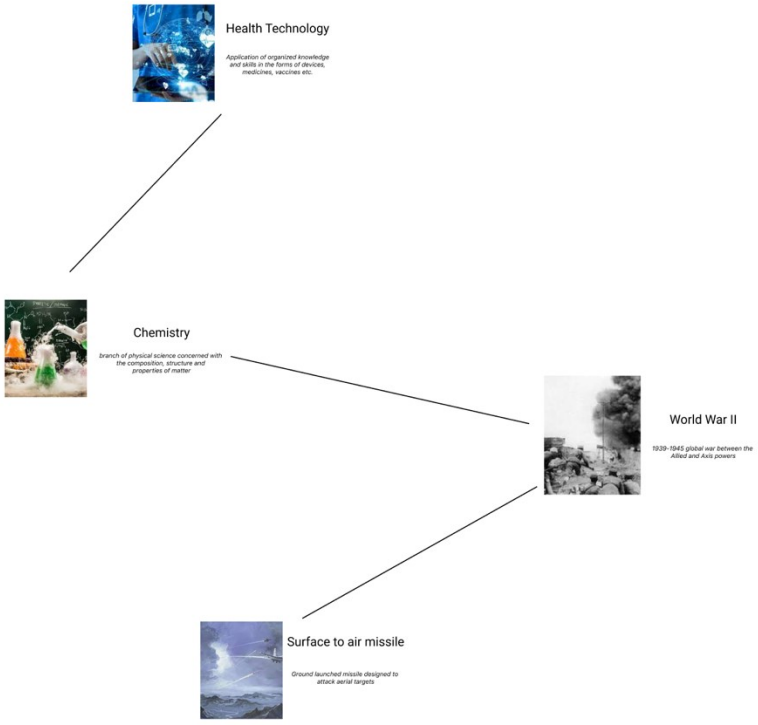
Map stimuli



Recommender Stimuli P2:



Map stimuli



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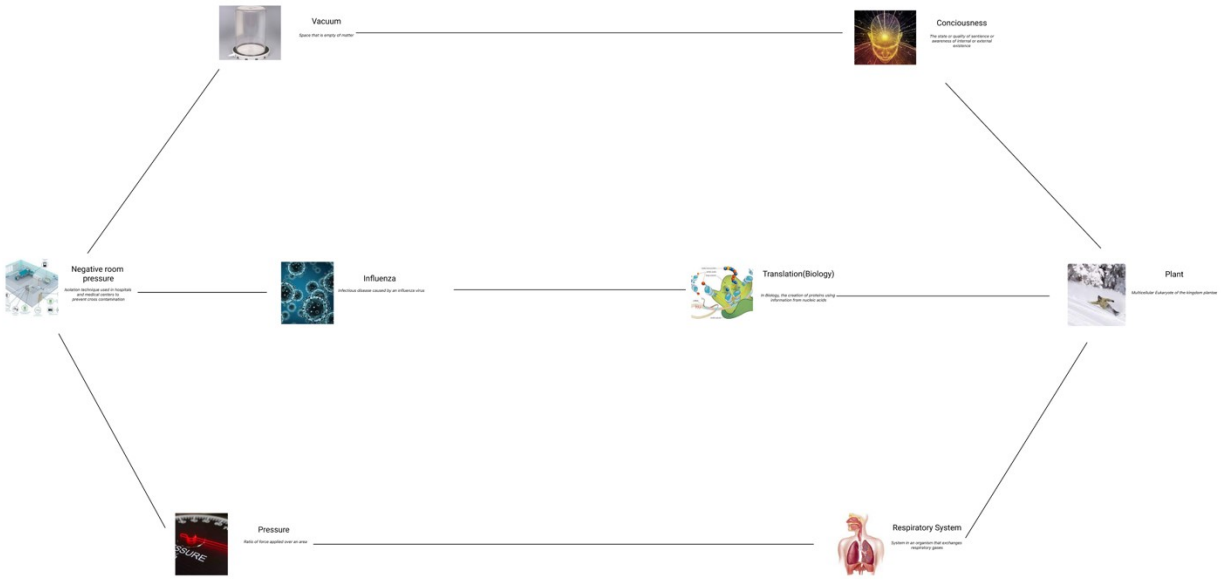
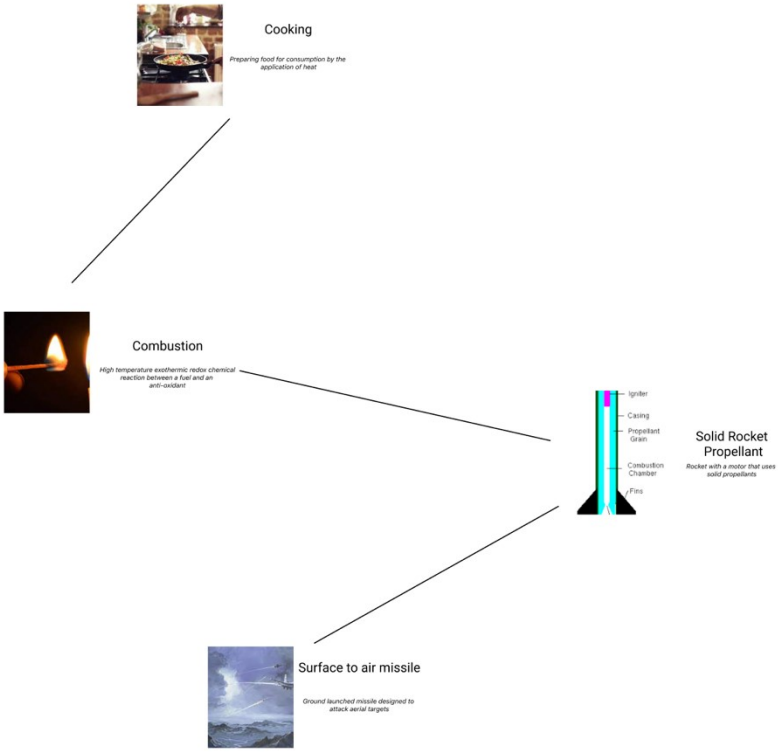
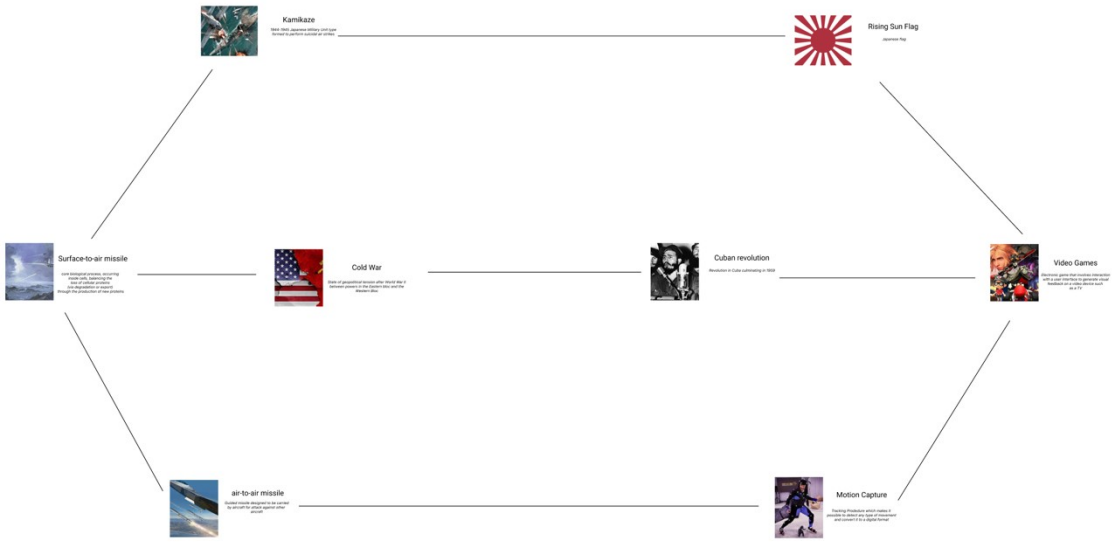


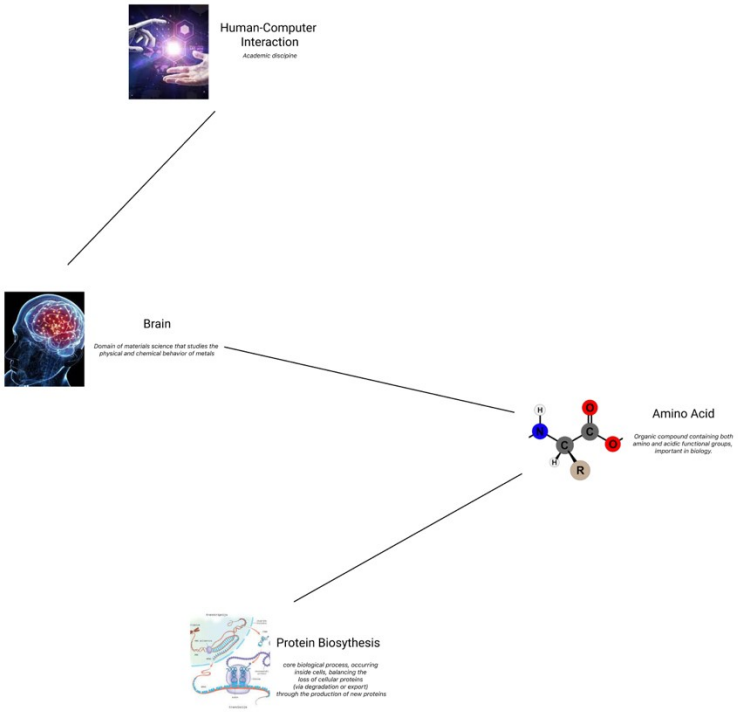
Map Stimuli



Recommender stimuli P4:



Map stimuli



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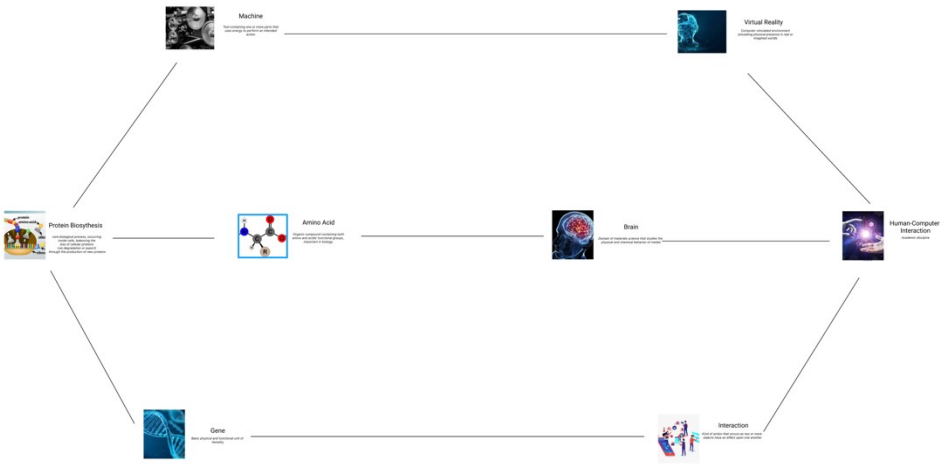
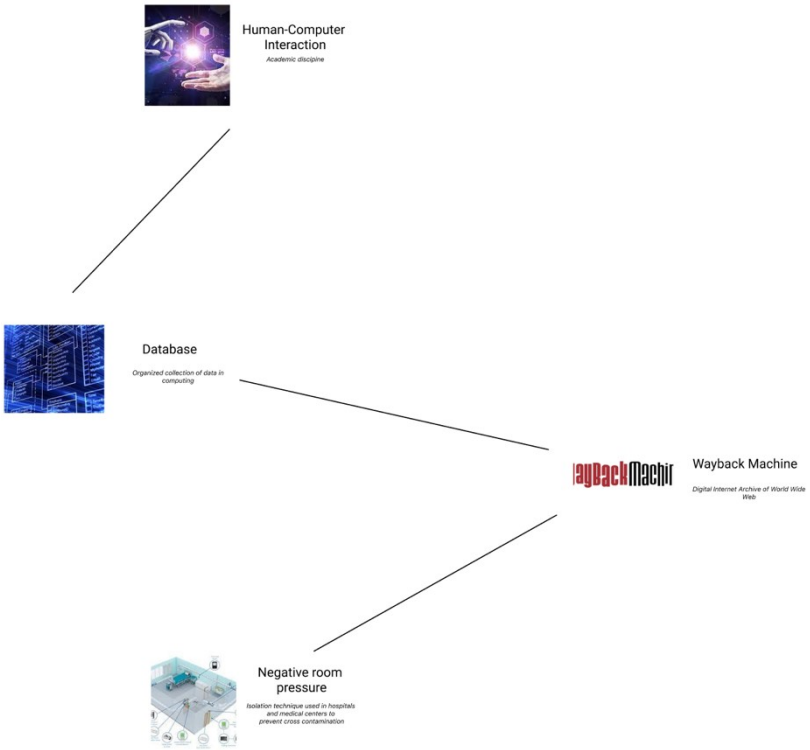
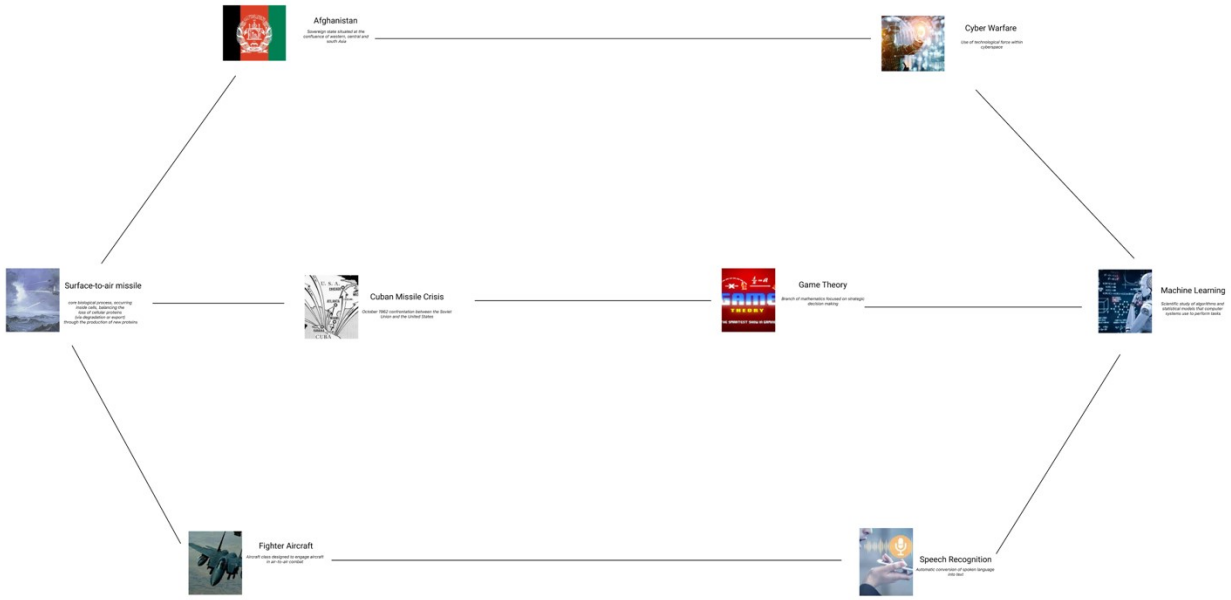


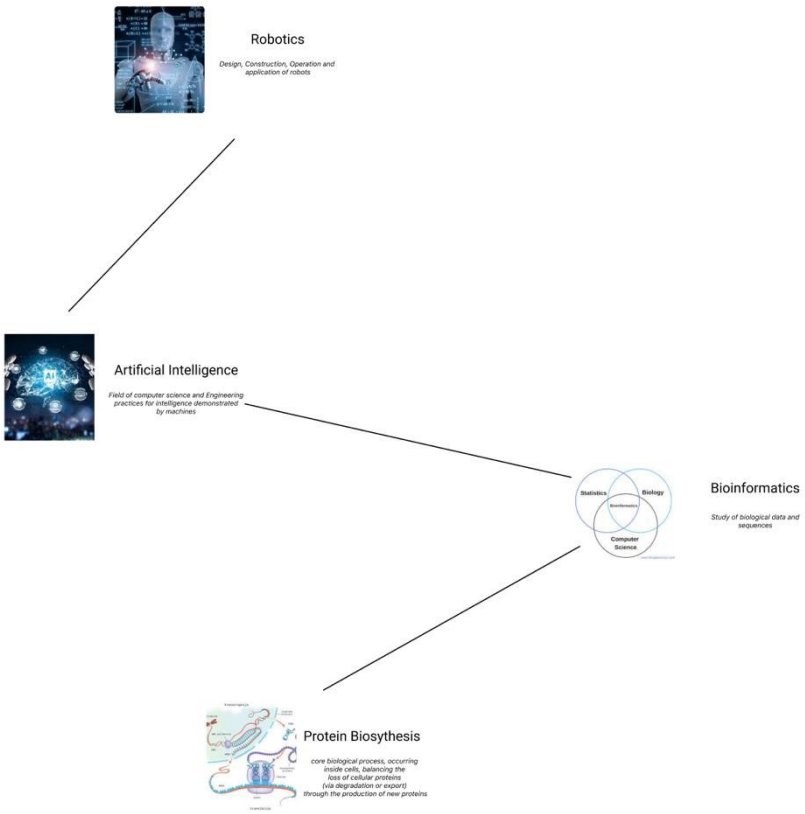
Map Stimuli



Recommender stimuli P6:



Map Stimuli



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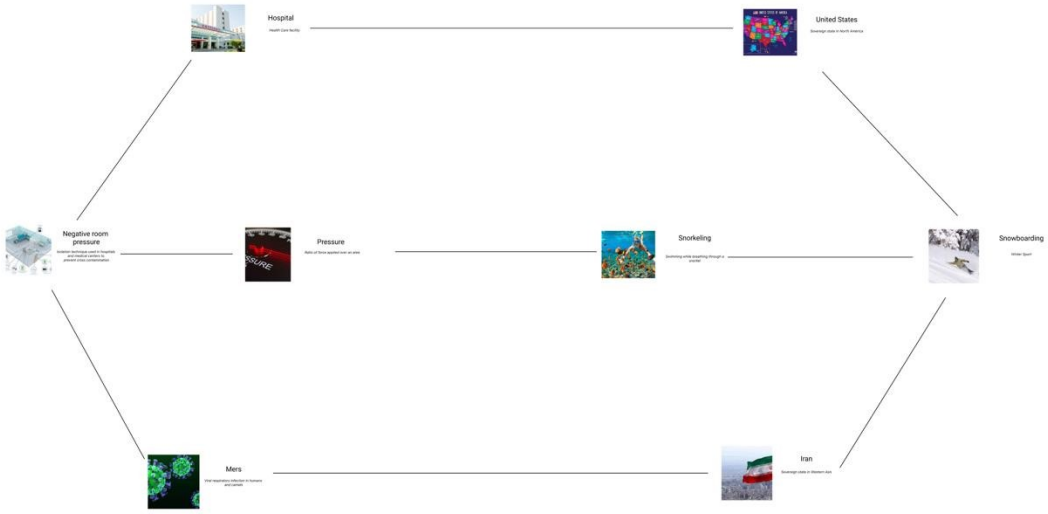
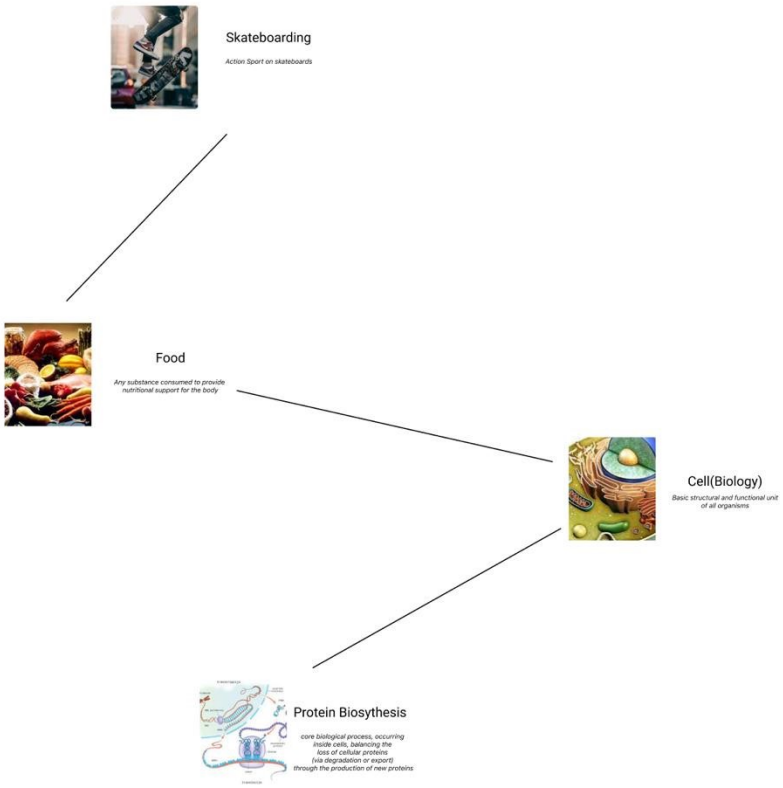
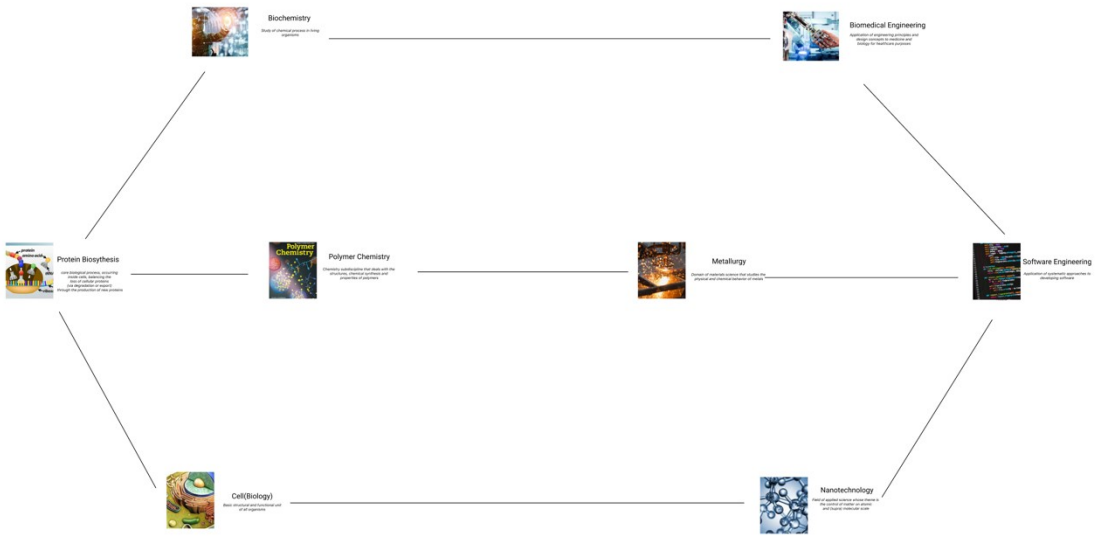


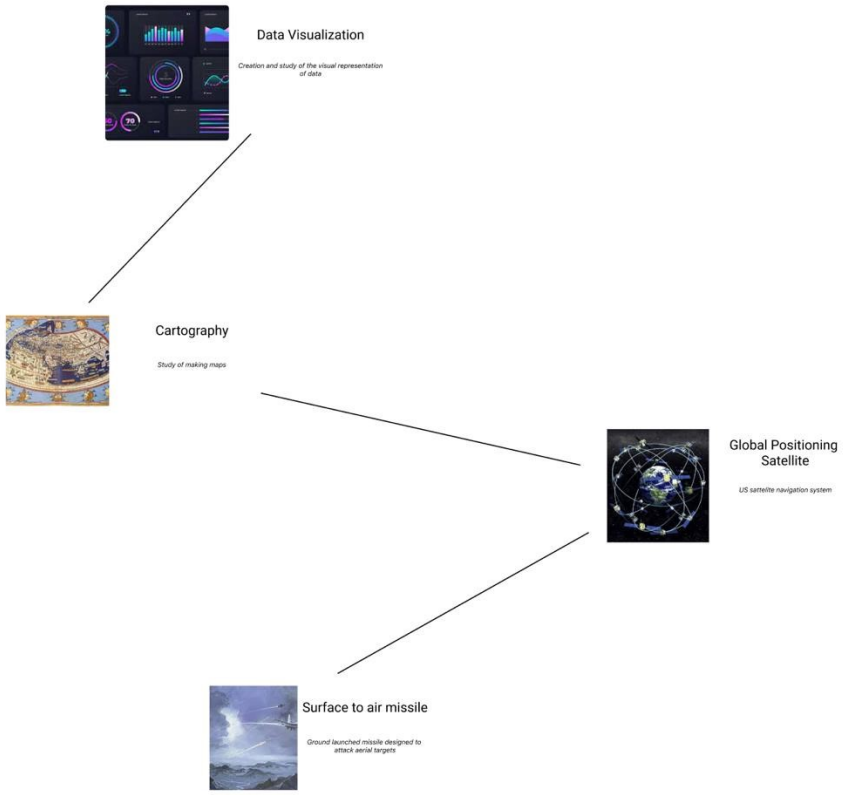
Map Stimuli



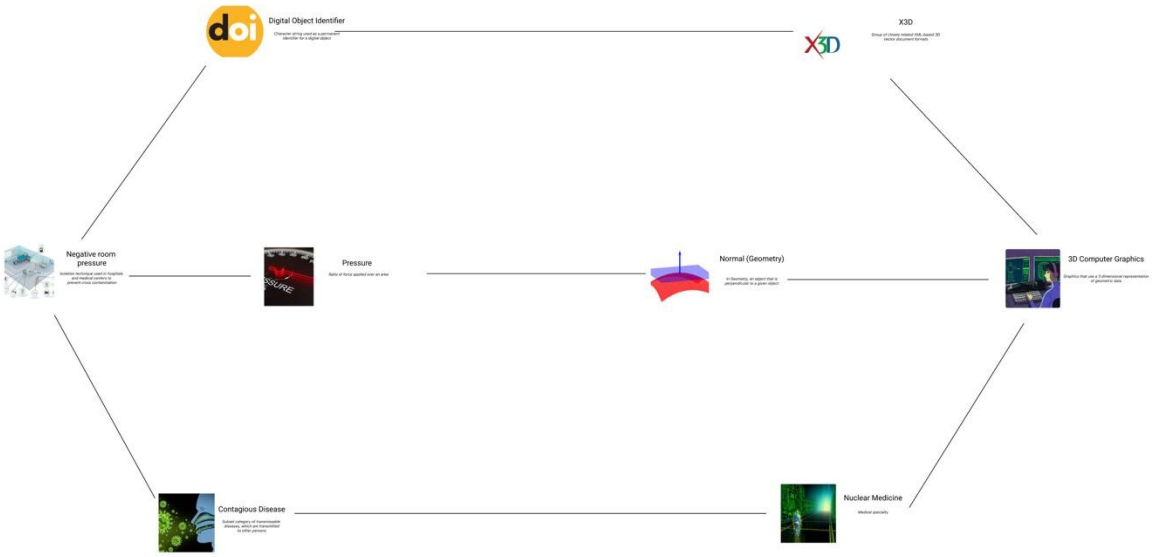
Recommender Stimuli P8:



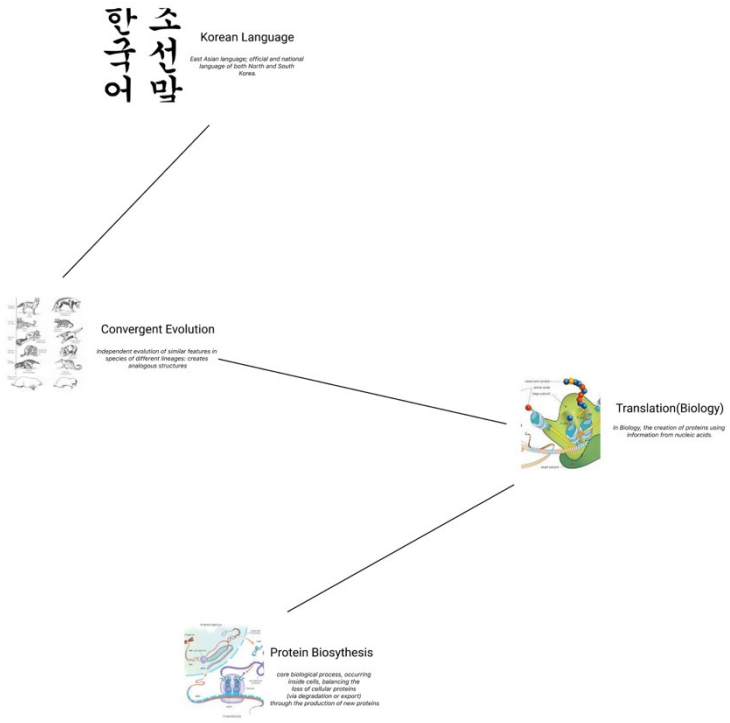
Map Stimuli



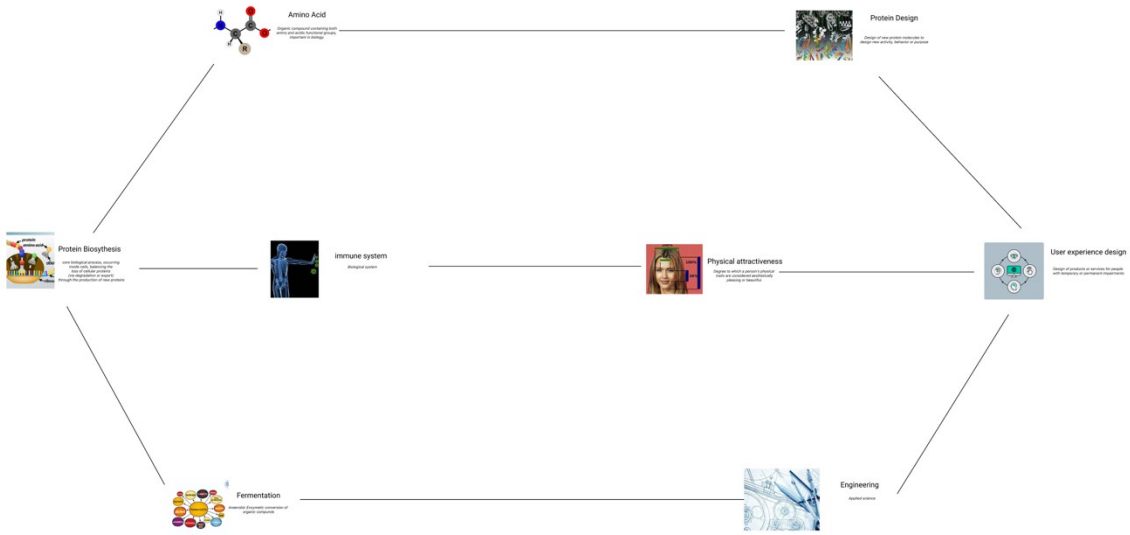
Recommender Stimuli P9:



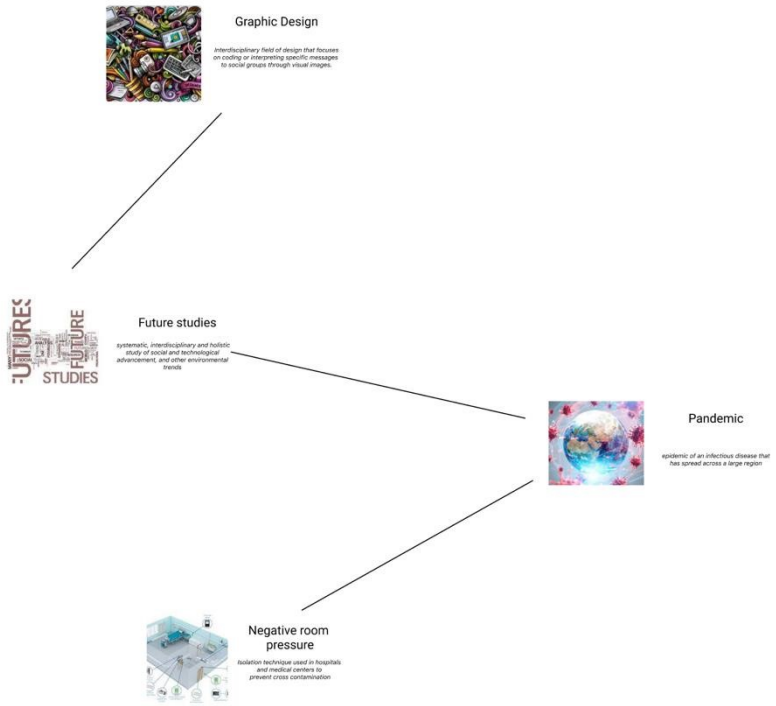
Map Stimuli



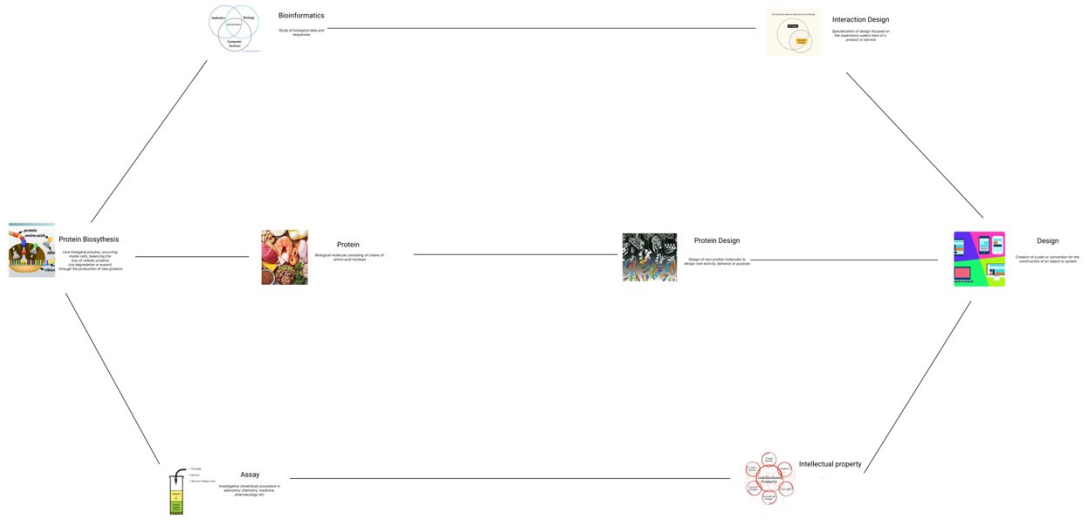
Recommender Stimuli P10:



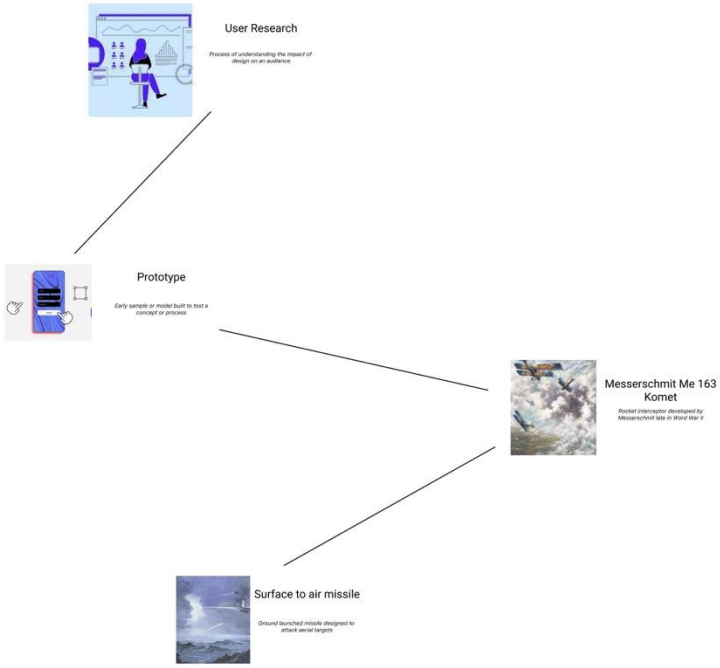
Map Stimuli



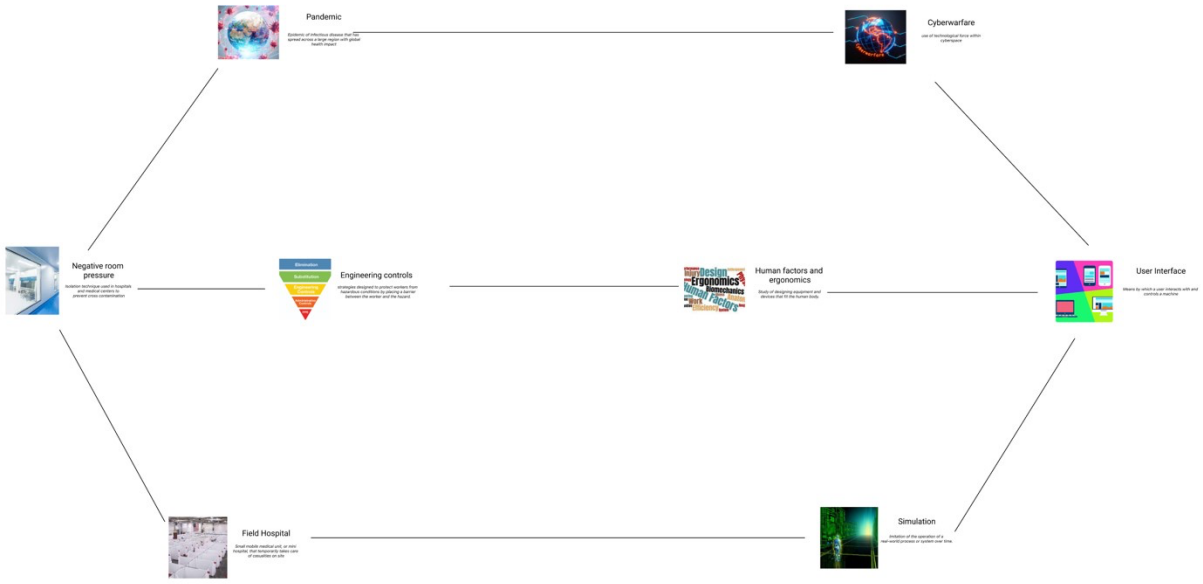
Recommender Stimuli P11:



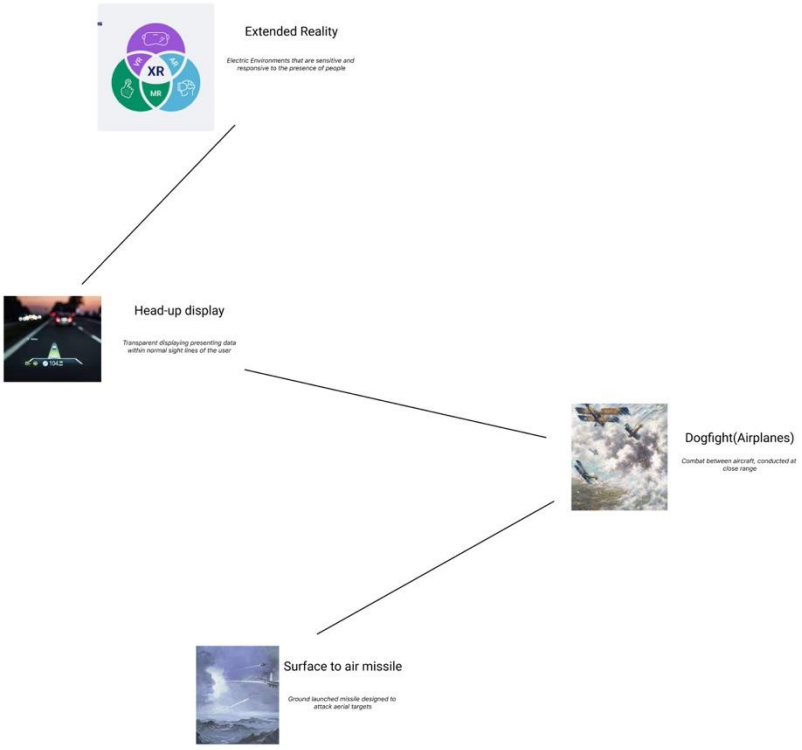
Map Stimuli



Recommender Stimuli P12:



Map Stimuli



Recommender Stimuli

Analogy Stimuli:

Surface to air missile

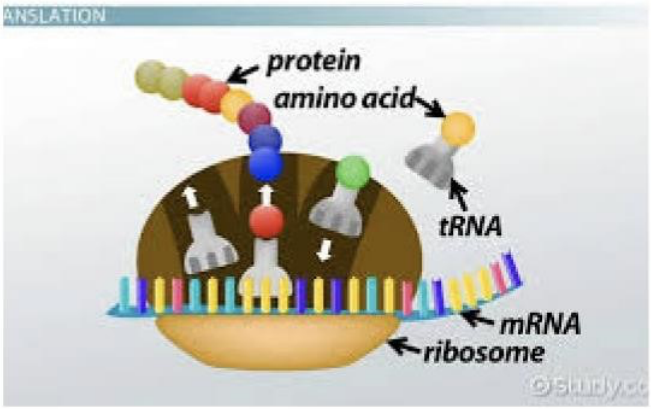
Ground launched missile designed to attack aerial targets

Protecting babies from all the elements Design Challenge

Negative Room Pressure

Isolation technique used in hospitals and medical centers to prevent cross contamination

A way for children to interact with aquatic animals Design Challenge



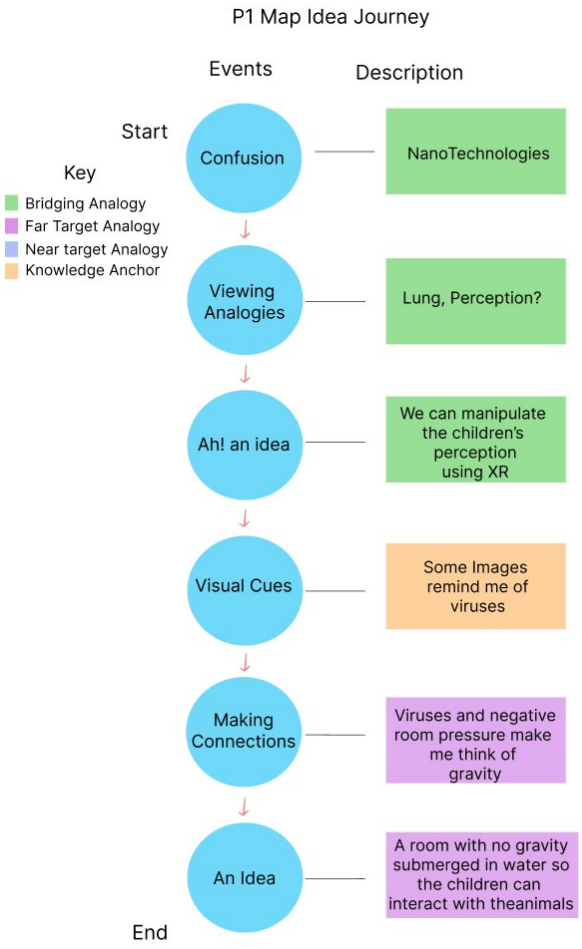
Protein Biosynthesis

core biological process, occurring inside cells, balancing the loss of cellular proteins (via degradation or export) through the production of new proteins

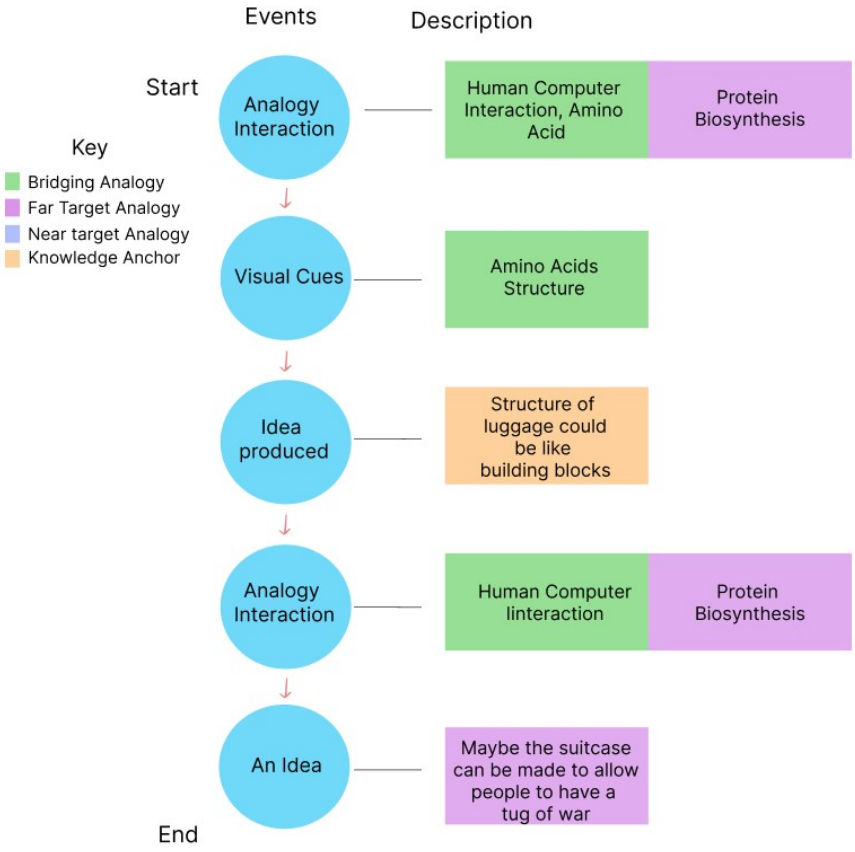
A way for a frequent flier businessperson to do weight training Design Challenge

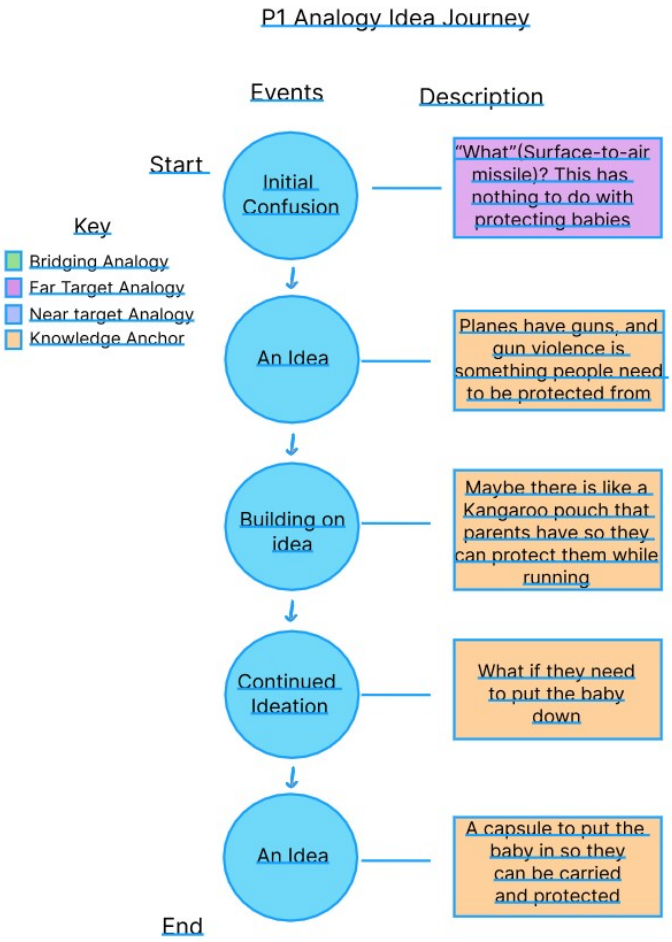
Appendix C: Idea Journeys

P1:



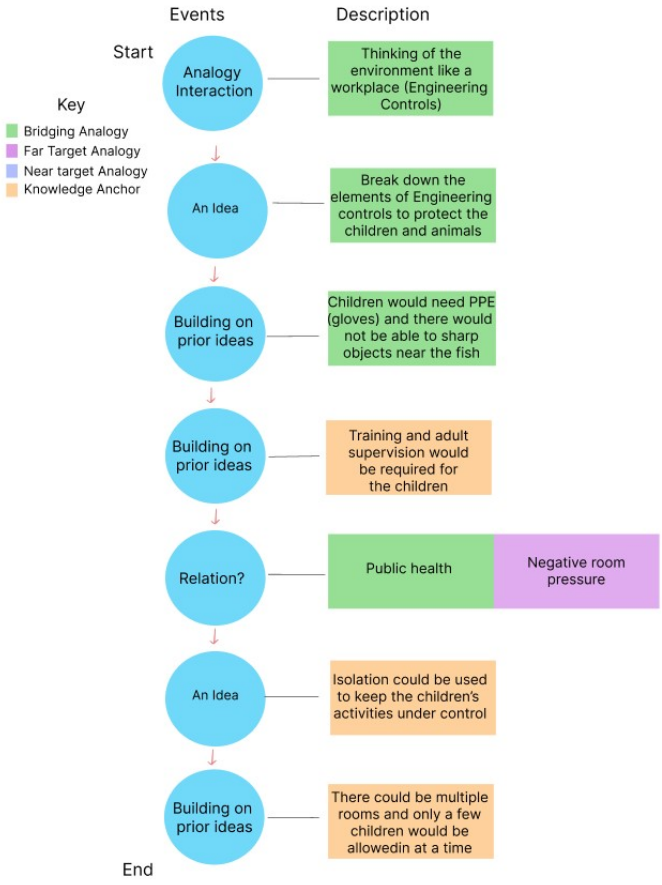
P1 Recommender Idea Journey



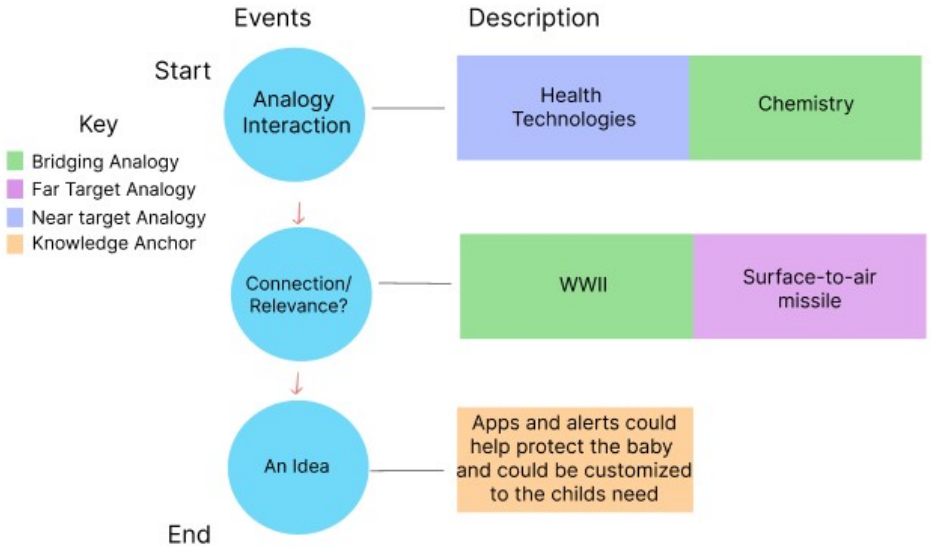

P1 Analogy Idea Journey
Events
Description
Start
Initial Confusion
"What"(Surface-to-air missile)? This has nothing to do with protecting babies
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
An Idea
Planes have guns, and gun violence is something people need to be protected from
Building on idea
Maybe there is like a Kangaroo pouch that parents have so they can protect them while running
Continued Ideation
What if they need to put the baby down
An Idea
A capsule to put the baby in so they can be carried and protected
End

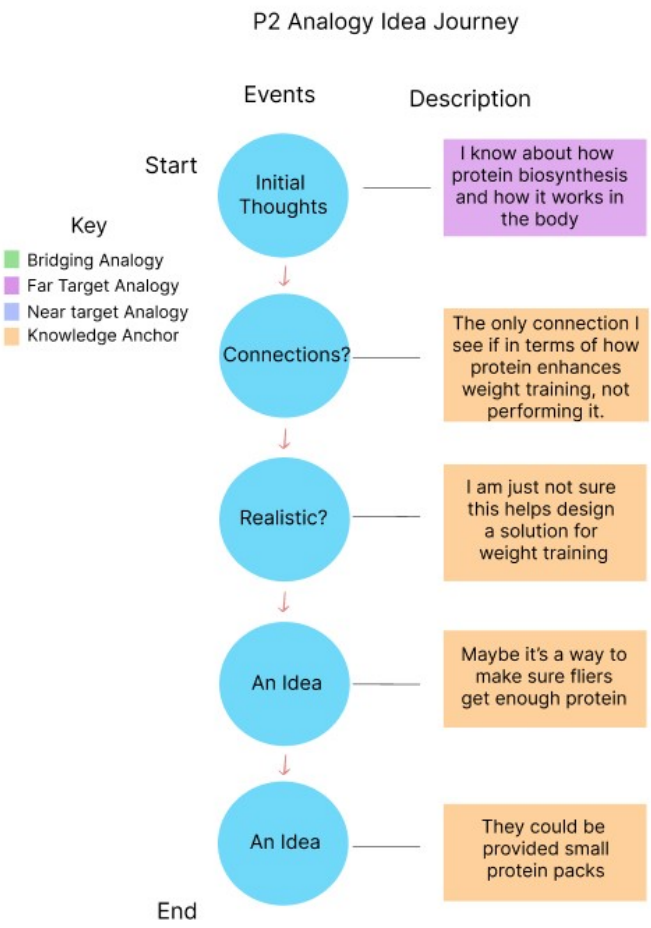
P2:

P2 Map Idea Journey



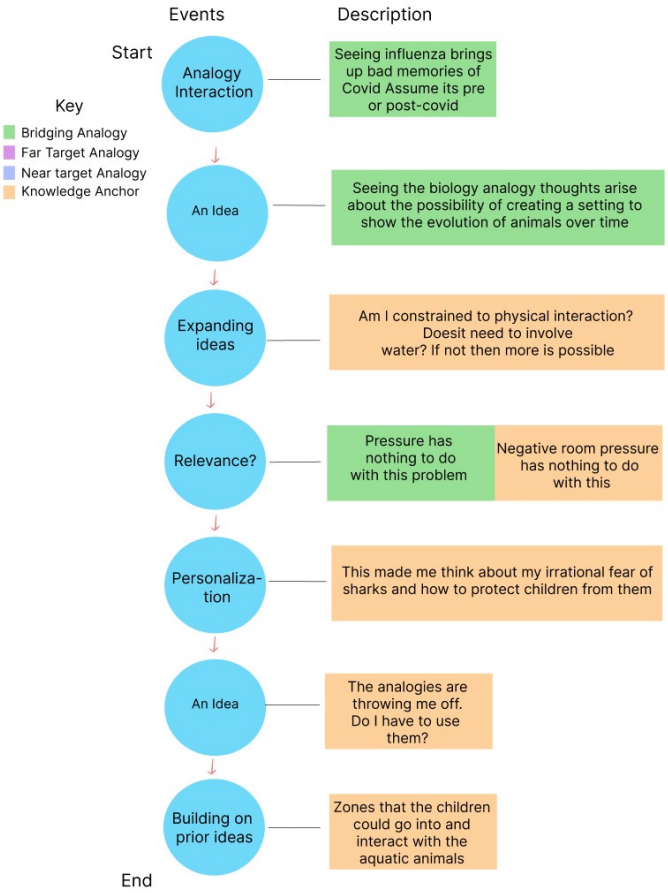
P2 Recommender Idea Journey

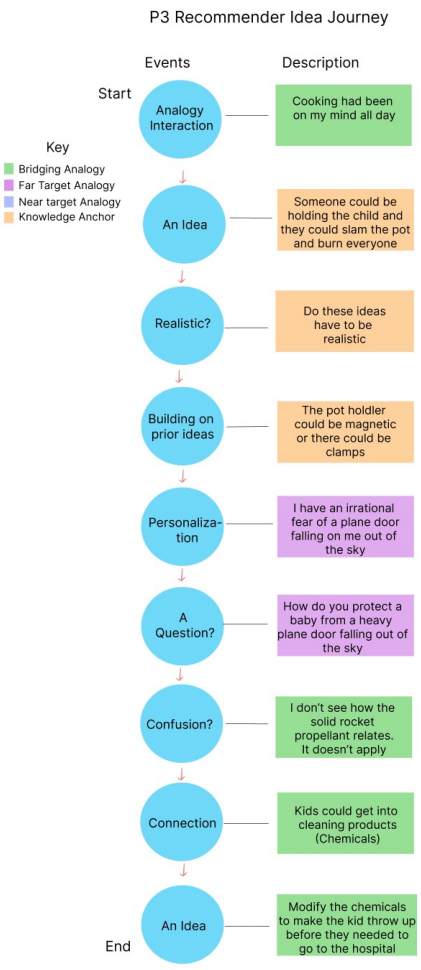


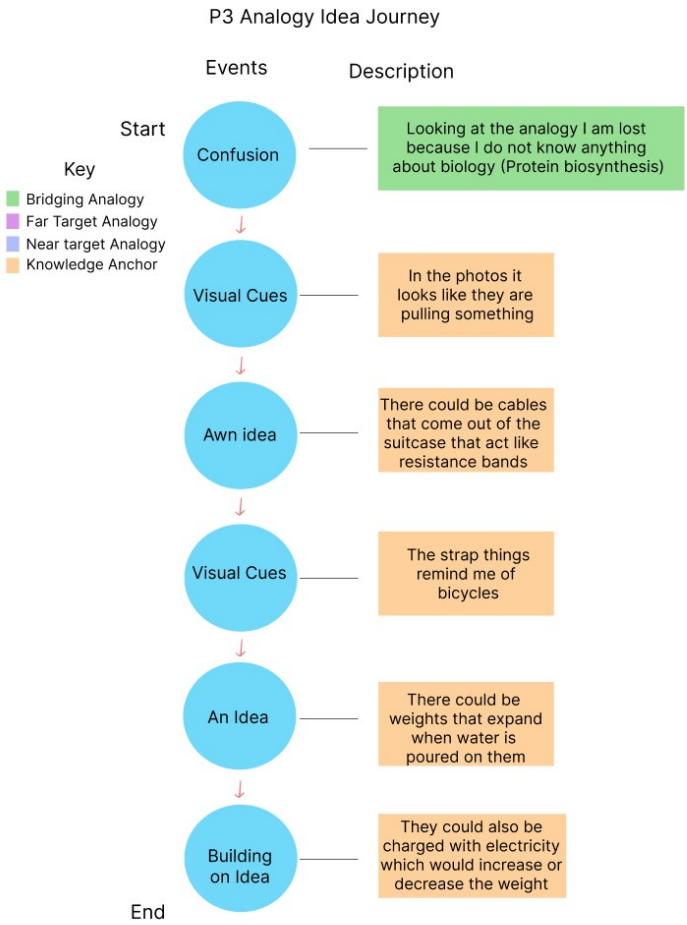

P2 Analogy Idea Journey
Events
Description
Start
Initial Thoughts
I know about how protein biosynthesis and how it works in the body
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Connections?
The only connection I see if in terms of how protein enhances weight training, not performing it.
Realistic?
I am just not sure this helps design a solution for weight training
An Idea
Maybe it's a way to make sure fliers get enough protein
An Idea
They could be provided small protein packs
End

P3:

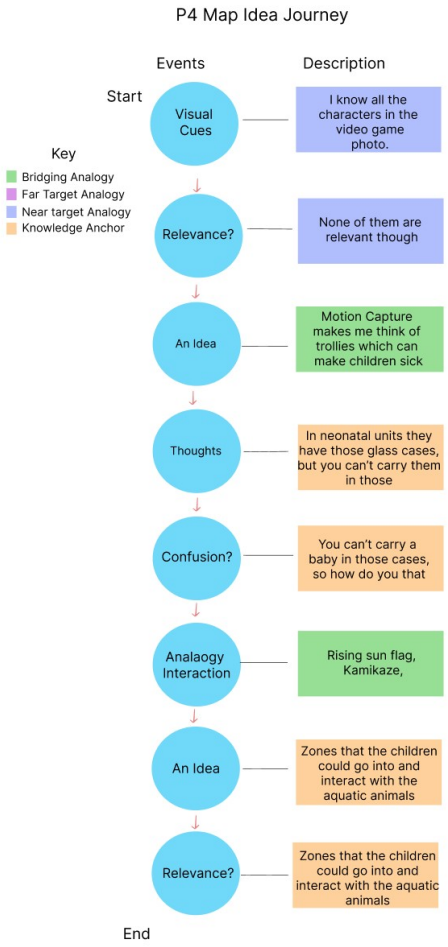
P3 Map Idea Journey

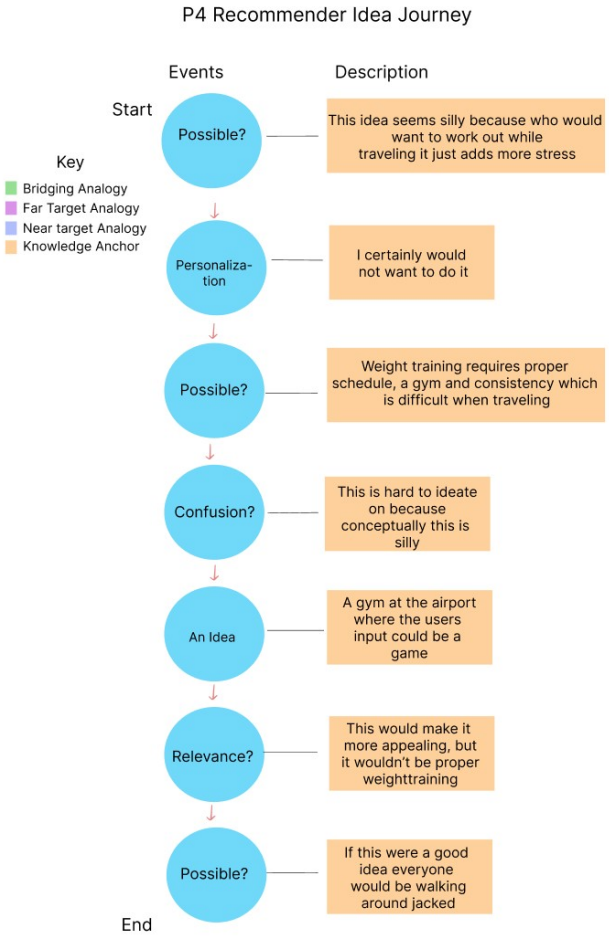


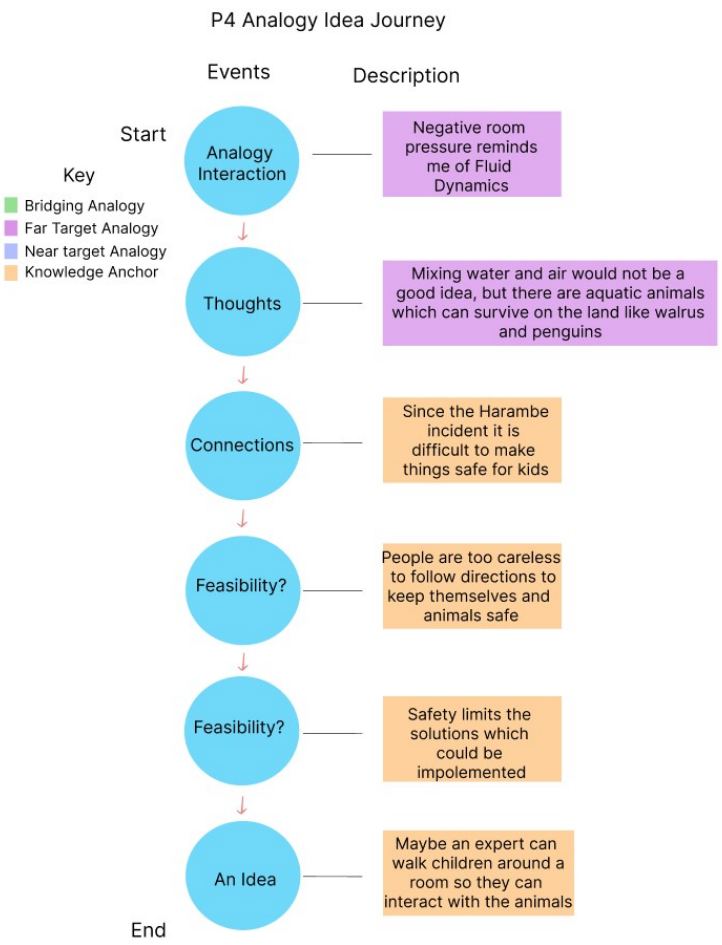

P3 Recommender Idea Journey
Events
Description
Start
Analogy Interaction
Cooking had been on my mind all day
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
An Idea
Someone could be holding the child and they could slam the pot and burn everyone
Realistic?
Do these ideas have to be realistic
Building on prior ideas
The pot holdler could be magnetic or there could be clamps
Personaliza-tion
I have an irrational fear of a plane door falling on me out of the sky
A Question?
How do you protect a baby from a heavy plane door falling out of the sky
Confusion?
I don't see how the solid rocket propellant relates. It doesn't apply
Connection
Kids could get into cleaning products (Chemicals)
An Idea
Modify the chemicals to make the kid throw up before they needed to go to the hospital
End


P3 Analogy Idea Journey
Events
Description
Start
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Confusion
Looking at the analogy I am lost because I do not know anything about biology (Protein biosynthesis)
Visual Cues
In the photos it looks like they are pulling something
Awn idea
There could be cables that come out of the suitcase that act like resistance bands
Visual Cues
The strap things remind me of bicycles
An Idea
There could be weights that expand when water is poured on them
Building on Idea
They could also be charged with electricity which would increase or decrease the weight
End

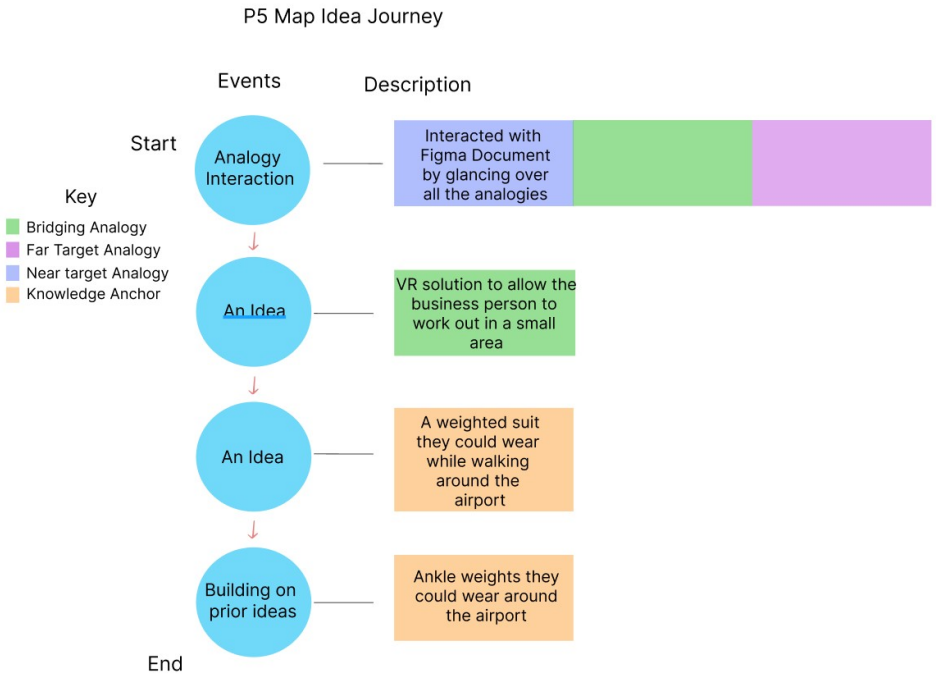
P4:


P4 Map Idea Journey
Events
Description
Start
Visual Cues
I know all the characters in the video game photo.
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Relevance?
None of them are relevant though
An Idea
Motion Capture makes me think of trollies which can make children sick
Thoughts
In neonatal units they have those glass cases, but you can't carry them in those
Confusion?
You can't carry a baby in those cases, so how do you that
Analaogy Interaction
Rising sun flag, Kamikaze,
An Idea
Zones that the children could go into and interact with the aquatic animals
Relevance?
Zones that the children could go into and interact with the aquatic animals
End

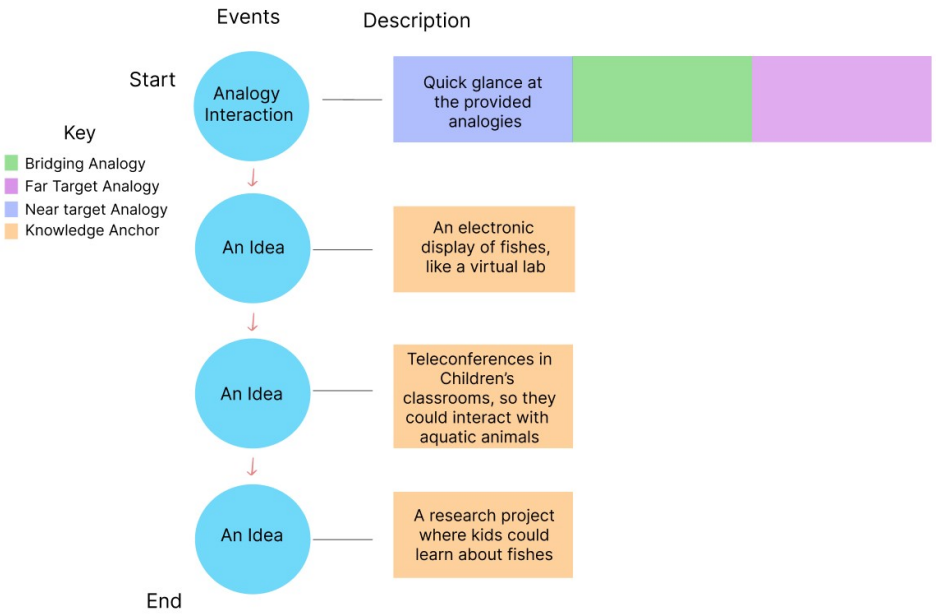

P4 Recommender Idea Journey
Events
Description
Start
Possible?
This idea seems silly because who would want to work out while traveling it just adds more stress
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Personaliza-tion
I certainly would not want to do it
Possible?
Weight training requires proper schedule, a gym and consistency which is difficult when traveling
Confusion?
This is hard to ideate on because conceptually this is silly
An Idea
A gym at the airport where the users input could be a game
Relevance?
This would make it more appealing, but it wouldn't be proper weighttraining
Possible?
If this were a good idea everyone would be walking around jacked
End


P4 Analogy Idea Journey
Events
Description
Start
Analogy Interaction
Negative room pressure reminds me of Fluid Dynamics
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Thoughts
Mixing water and air would not be a good idea, but there are aquatic animals which can survive on the land like walrus and penguins
Connections
Since the Harambe incident it is difficult to make things safe for kids
Feasibility?
People are too careless to follow directions to keep themselves and animals safe
Feasibility?
Safety limits the solutions which could be impolemented
An Idea
Maybe an expert can walk children around a room so they can interact with the animals
End

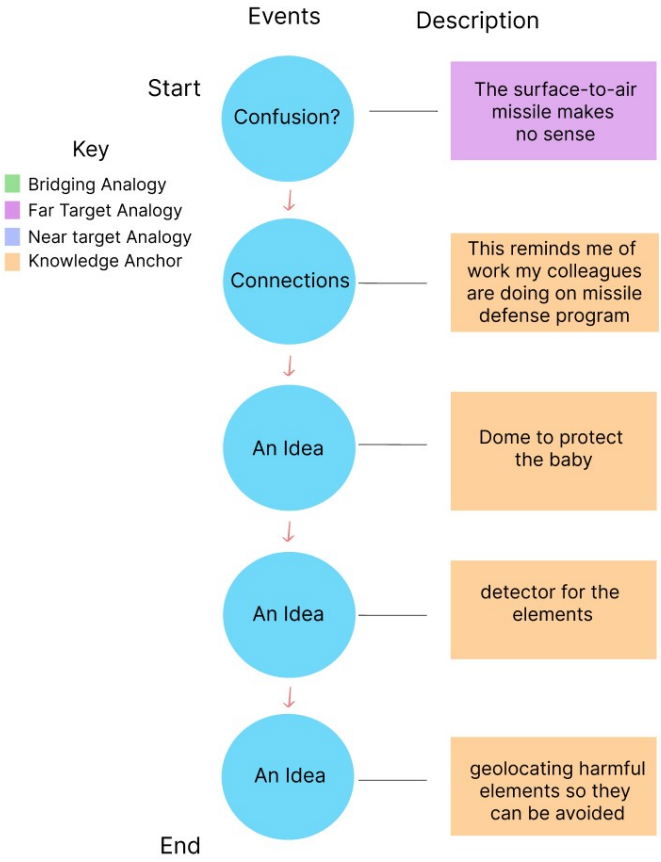
P5:


P5 Map Idea Journey
Events
Description
Start
Analogy Interaction
Interacted with Figma Document by glancing over all the analogies
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
An Idea
VR solution to allow the business person to work out in a small area
An Idea
A weighted suit they could wear while walking around the airport
Building on prior ideas
Ankle weights they could wear around the airport
End

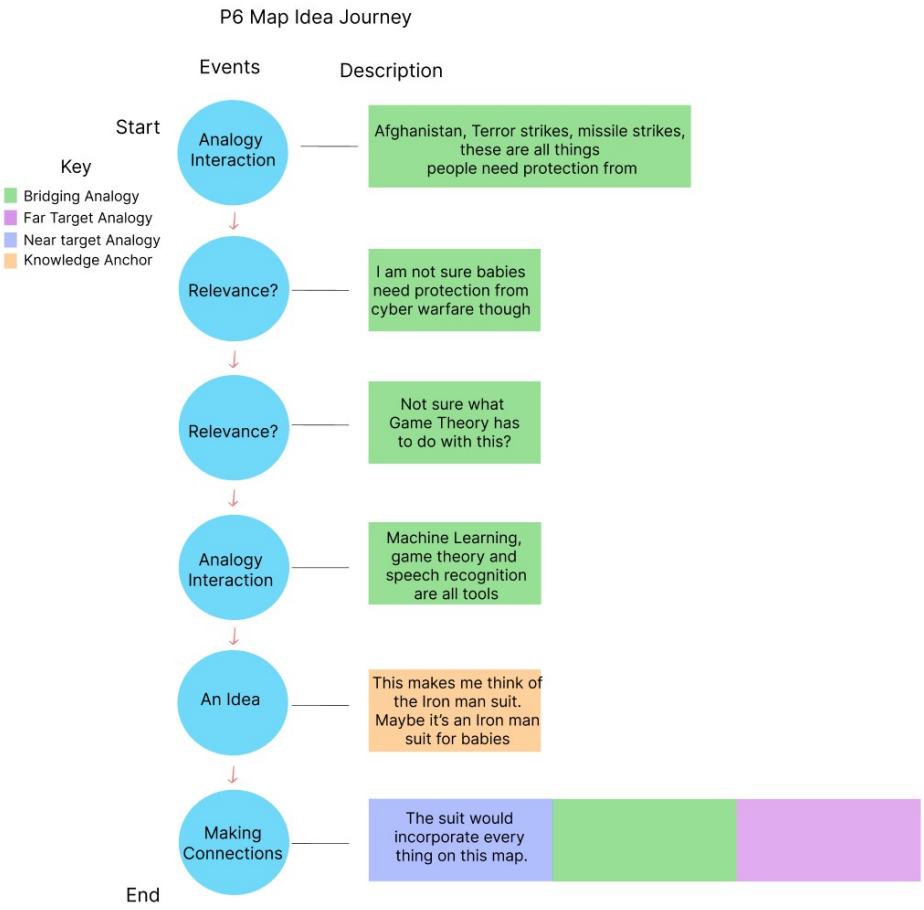
P5 Recommender Idea Journey



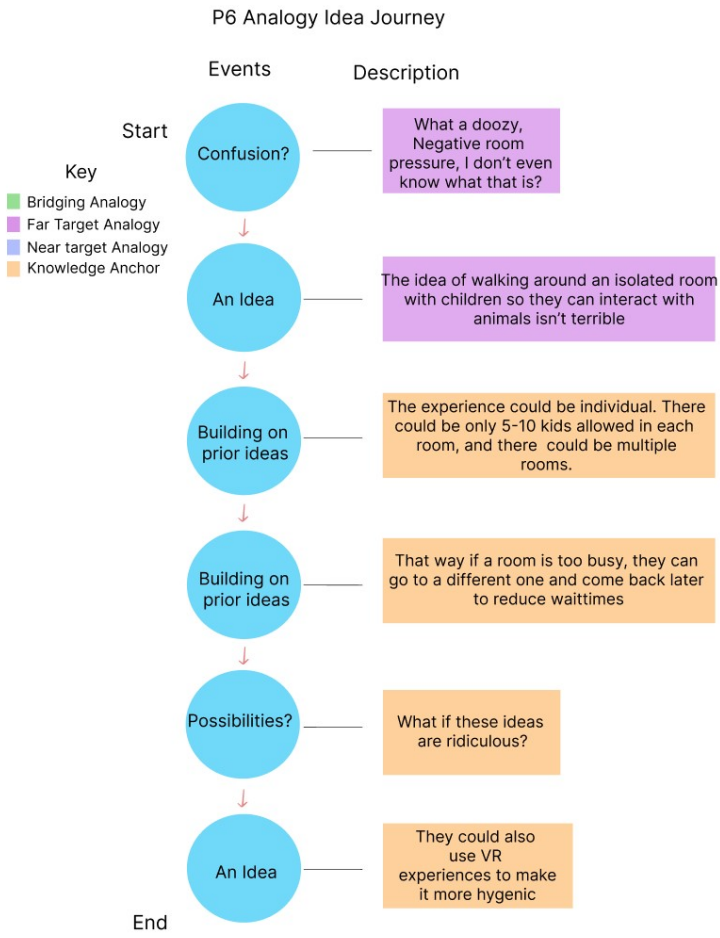
P5 Analogy Idea Journey



P6:

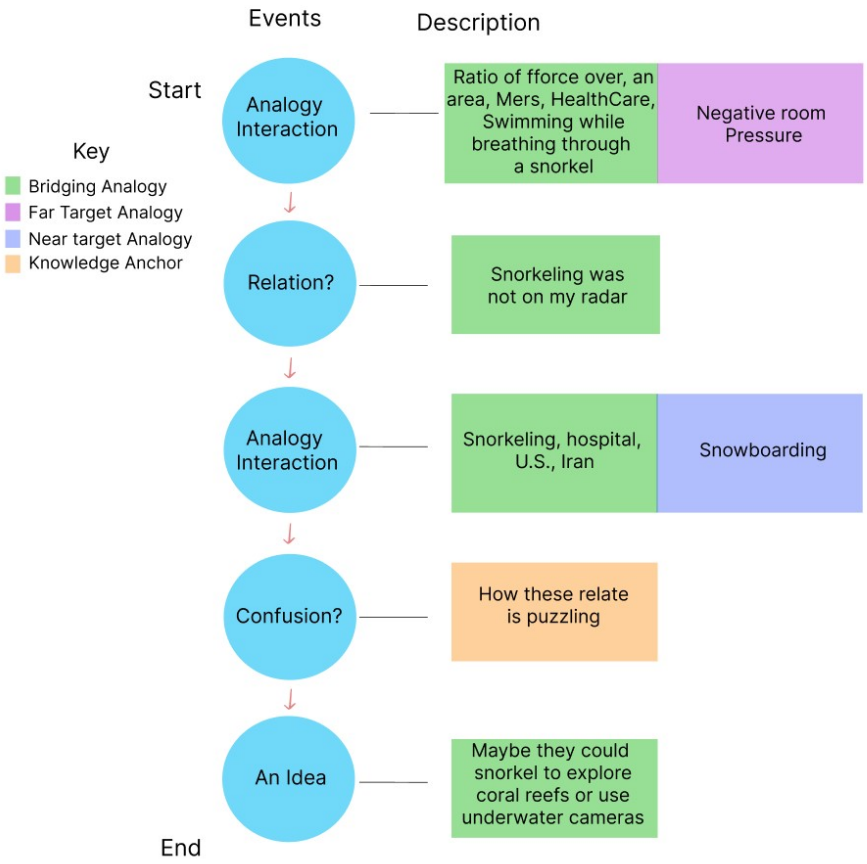

P6 Map Idea Journey
Events
Description
Start
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Analogy Interaction
Afghanistan, Terror strikes, missile strikes, these are all things people need protection from
Relevance?
I am not sure babies need protection from cyber warfare though
Relevance?
Not sure what Game Theory has to do with this?
Analogy Interaction
Machine Learning, game theory and speech recognition are all tools
An Idea
This makes me think of the Iron man suit. Maybe it's an Iron man suit for babies
Making Connections
The suit would incorporate every thing on this map.
End


P6 Recommender Idea Journey
Events
Description
Start
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Confusion?
I don't know anything about Protein Biosynthesis is that a natural process?
Relevance?
Bioinformatics, that doesn't seem to have any relevance.
Making Connections
Robotics is a tool, so I am sure there is a way to use it to aid in weight training
Ai is a tool, so I am sure there is a way to use it to aid in weight training
An Idea
There could be an online experience with a personal trainer using haptic feedback and robotics.
Building on prior ideas
Robot would help facilitate the interaction between trainer and client
Feasibility?
This is not a very plausible idea. It doesn't seem like the best idea because it's sloppy
End

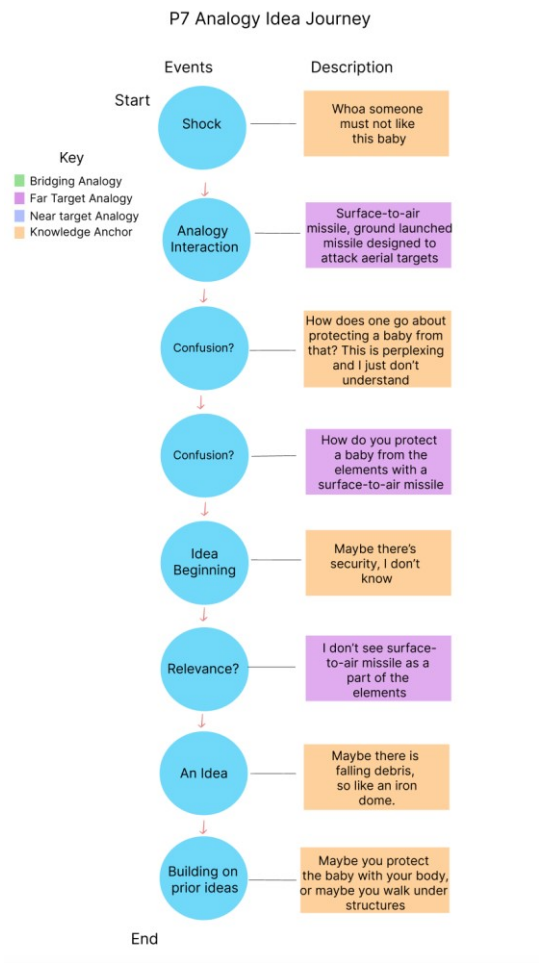

P6 Analogy Idea Journey
Events
Description
Start
Confusion?
What a doozy, Negative room pressure, I don't even know what that is?
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
An Idea
The idea of walking around an isolated room with children so they can interact with animals isn't terrible
Building on prior ideas
The experience could be individual. There could be only 5-10 kids allowed in each room, and there could be multiple rooms.
Building on prior ideas
That way if a room is too busy, they can go to a different one and come back later to reduce waittimes
Possibilities?
What if these ideas are ridiculous?
An Idea
They could also use VR experiences to make it more hygenic
End

P7:

P7 Map Idea Journey

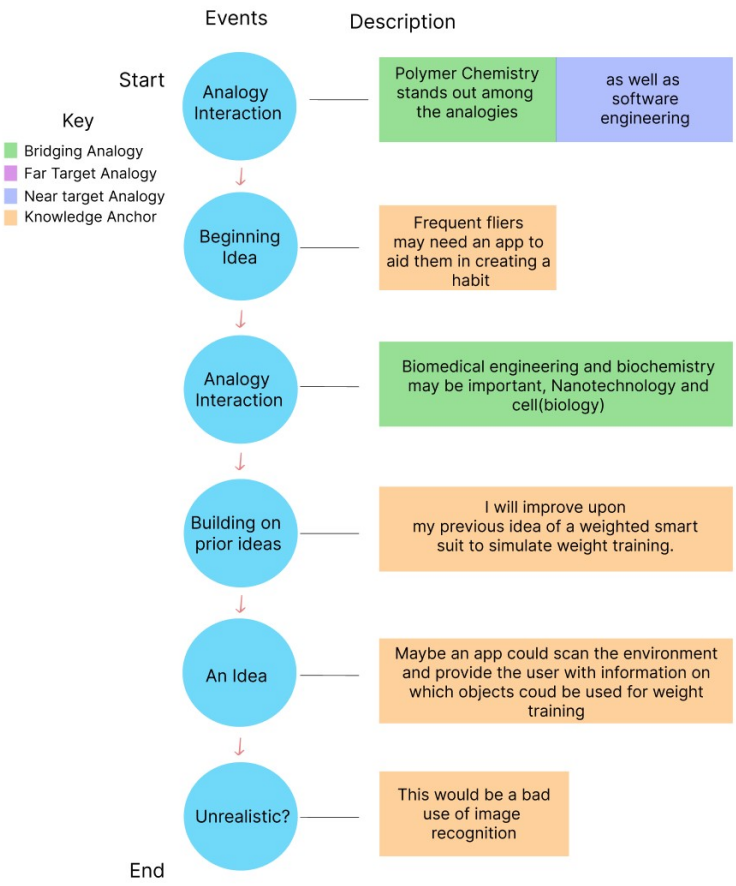



P7 Recommender Idea Journey
Events
Description
Start
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Analogy Interaction
Skateboarding
Food
Confusion
How do any of these things relate to weight training
Confusion
Wouldn't have thought about food and weight training
Making Connections
They need to recover and work not just train
An Idea
They could recover while working
An Idea
Training could be the fliers job
Personaliza-tion
What do I do when I travel?
End

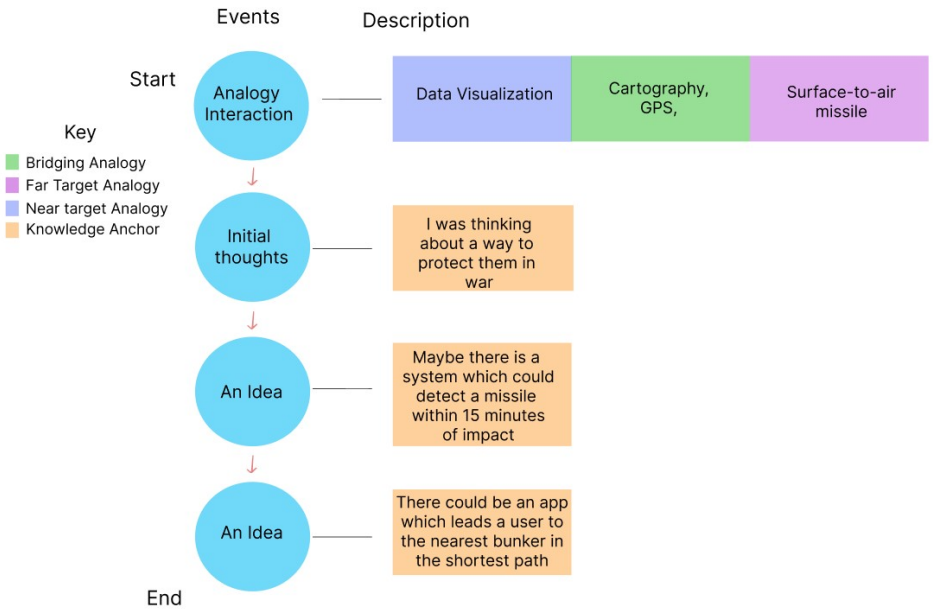

P7 Analogy Idea Journey
Events
Description
Start
Shock
Whoa someone must not like this baby
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Analogy Interaction
Surface-to-air missile, ground launched missile designed to attack aerial targets
Confusion?
How does one go about protecting a baby from that? This is perplexing and I just don't understand
Confusion?
How do you protect a baby from the elements with a surface-to-air missile
Idea Beginning
Maybe there's security, I don't know
Relevance?
I don't see surface-to-air missile as a part of the elements
An Idea
Maybe there is falling debris, so like an iron dome.
Building on prior ideas
Maybe you protect the baby with your body, or maybe you walk under structures
End

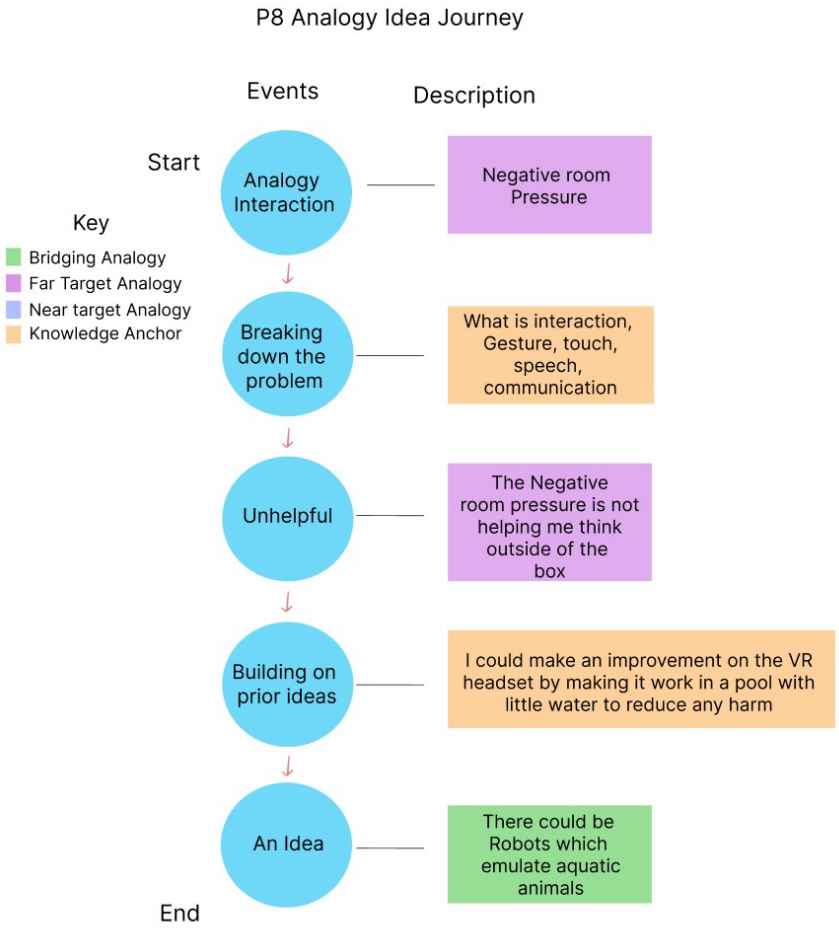
P8:

P8 Map Idea Journey

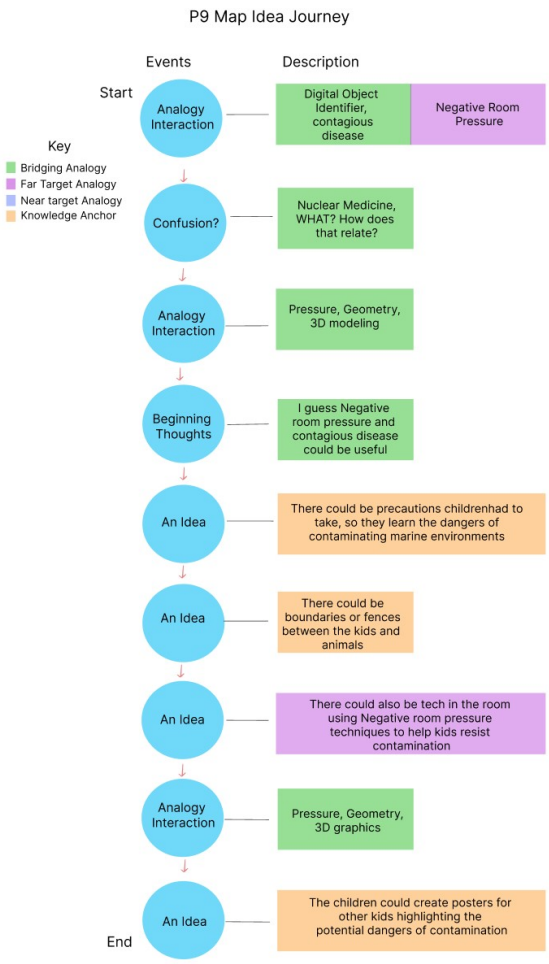


P8 Recommender Idea Journey

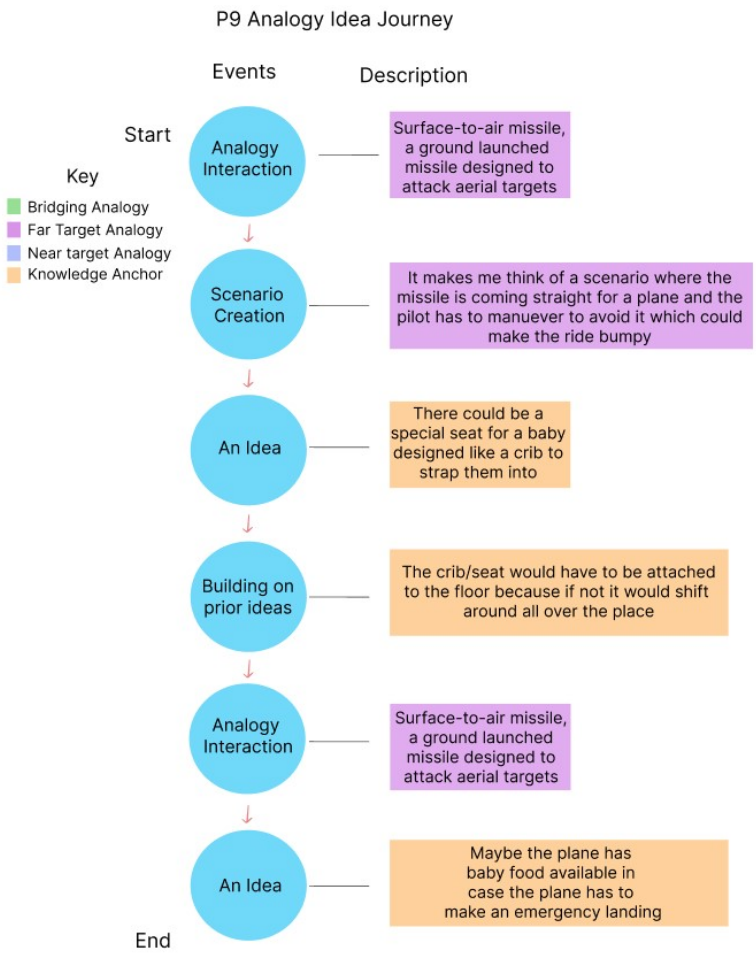



P8 Analogy Idea Journey
Events
Description
Start
Analogy Interaction
Negative room Pressure
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Breaking down the problem
What is interaction, Gesture, touch, speech, communication
Unhelpful
The Negative room pressure is not helping me think outside of the box
Building on prior ideas
I could make an improvement on the VR headset by making it work in a pool with little water to reduce any harm
An Idea
There could be Robots which emulate aquatic animals
End

P9:

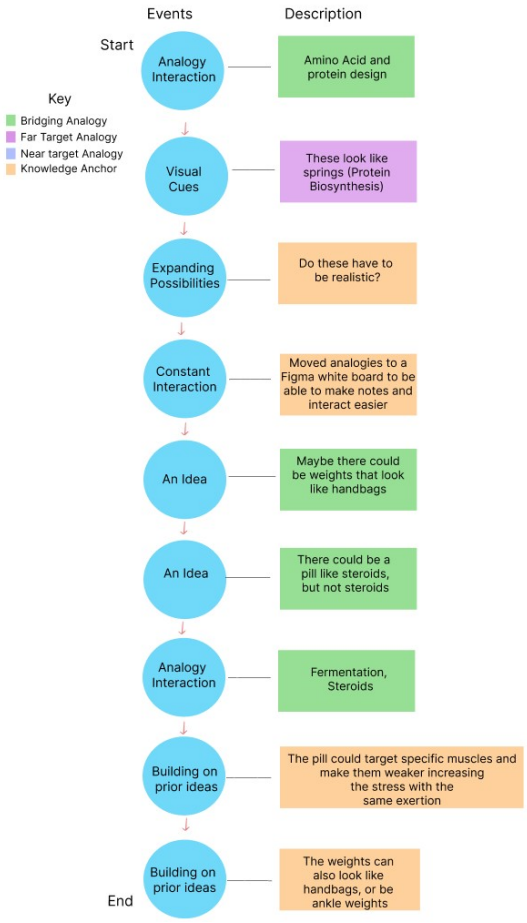

P9 Map Idea Journey
Events
Description
Start
Analogy Interaction
Digital Object Identifier, contagious disease
Negative Room Pressure
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Confusion?
Nuclear Medicine, WHAT? How does that relate?
Analogy Interaction
Pressure, Geometry, 3D modeling
Beginning Thoughts
I guess Negative room pressure and contagious disease could be useful
An Idea
There could be precautions childrenhad to take, so they learn the dangers of contaminating marine environments
An Idea
There could be boundaries or fences between the kids and animals
An Idea
There could also be tech in the room using Negative room pressure techniques to help kids resist contamination
Analogy Interaction
Pressure, Geometry, 3D graphics
An Idea
End
The children could create posters for other kids highlighting the potential dangers of contamination

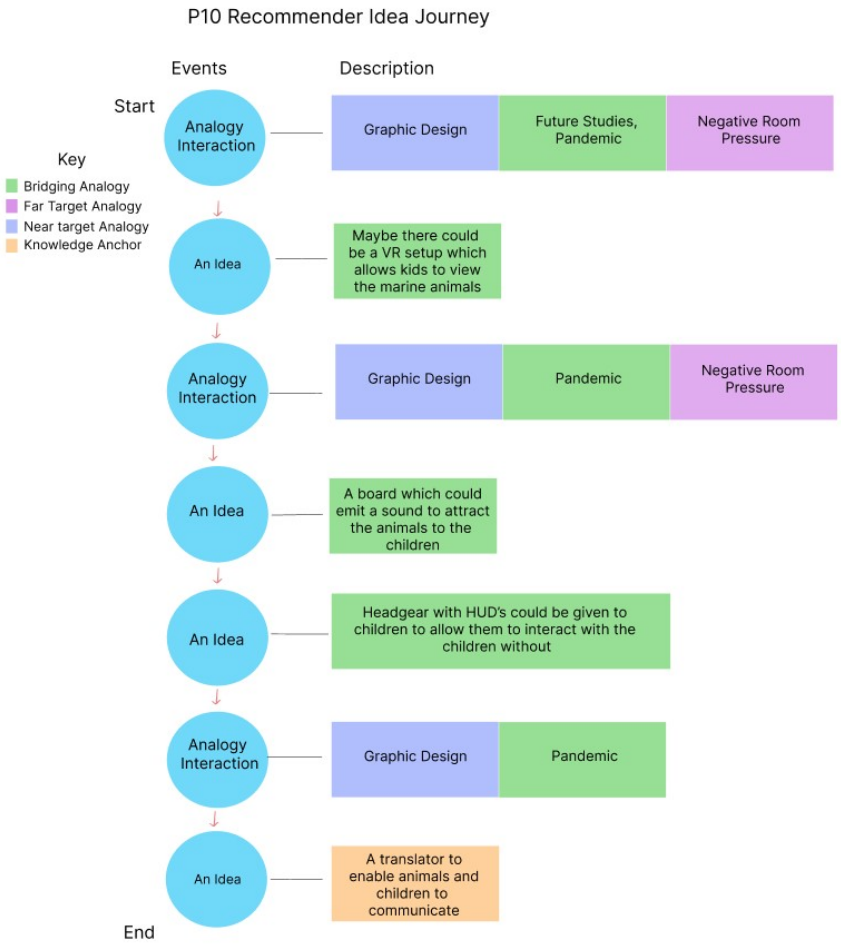

P9 Recommender Idea Journey
Events
Description
Start
Analogy Interaction
Korean Language
Convergent Evloution, Translation
Protein Biosynthesis
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Confusion?
Protein Biosynthesis, WHAT? That is not related to this at all. That is not a way for them to do weight training
Analogy Interaction
Going back through the analogies to look at Korean Language
An Idea
Maybe this could be for Korean business people
Relevant?
A Korean businessperson would have trouble with motivation going to the gym, so it wouldn't be very effective
An Idea
They may be motivated if they exercsied in a group
Personal Knowledge
I know Korean people like group efforts
An Idea
It could be like a buddy system that they could help track each other's progress
End

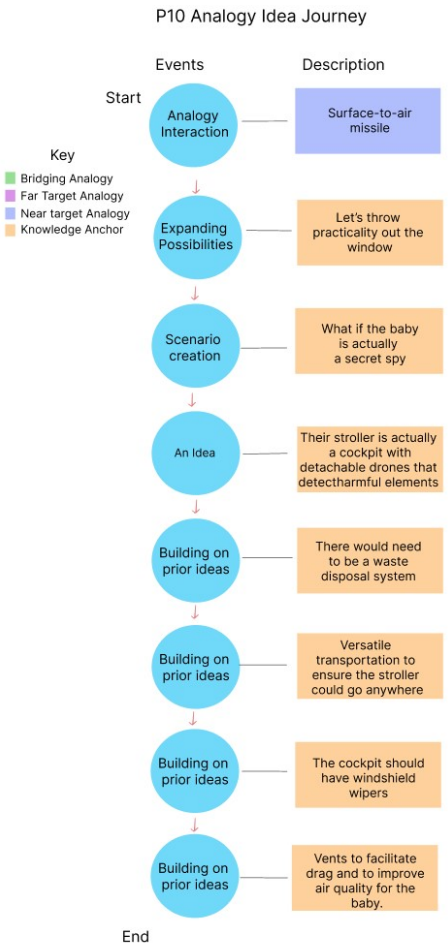

P9 Analogy Idea Journey
Events
Description
Start
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Analogy Interaction
Surface-to-air missile, a ground launched missile designed to attack aerial targets
Scenario Creation
It makes me think of a scenario where the missile is coming straight for a plane and the pilot has to manuever to avoid it which could make the ride bumpy
An Idea
There could be a special seat for a baby designed like a crib to strap them into
Building on prior ideas
The crib/seat would have to be attached to the floor because if not it would shift around all over the place
Analogy Interaction
Surface-to-air missile, a ground launched missile designed to attack aerial targets
An Idea
Maybe the plane has baby food available in case the plane has to make an emergency landing
End

P10:

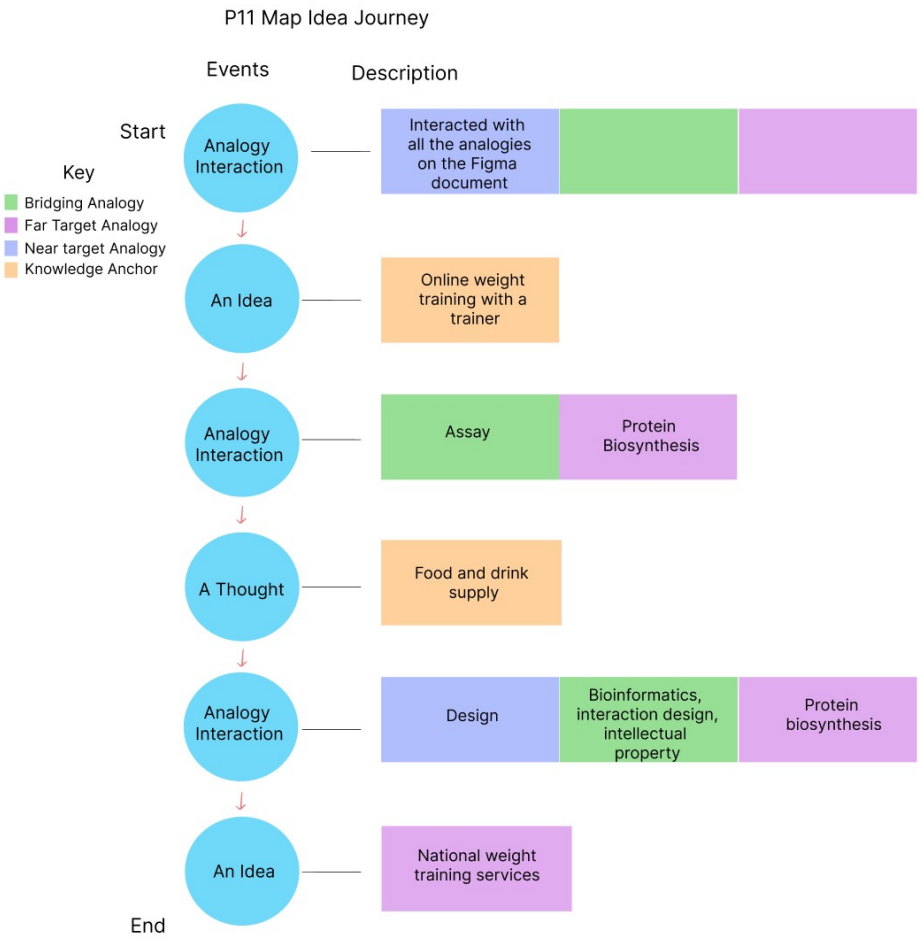
P10 Map Idea Journey

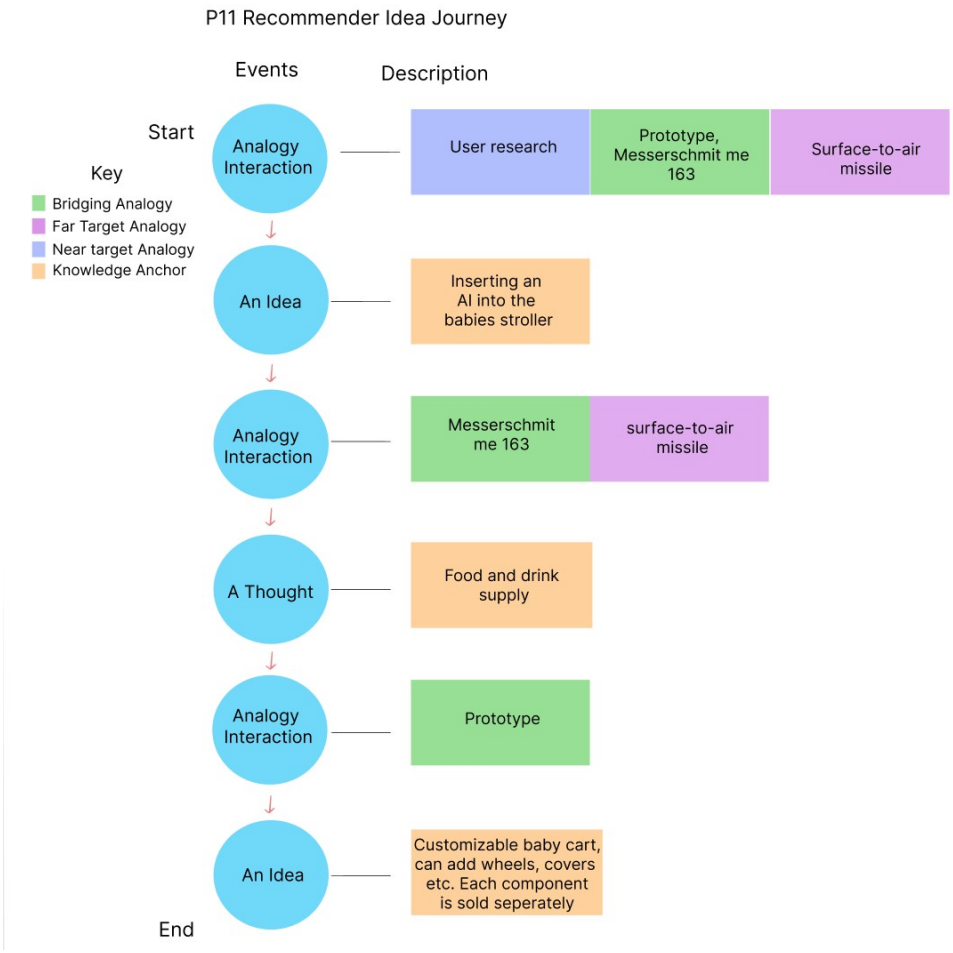


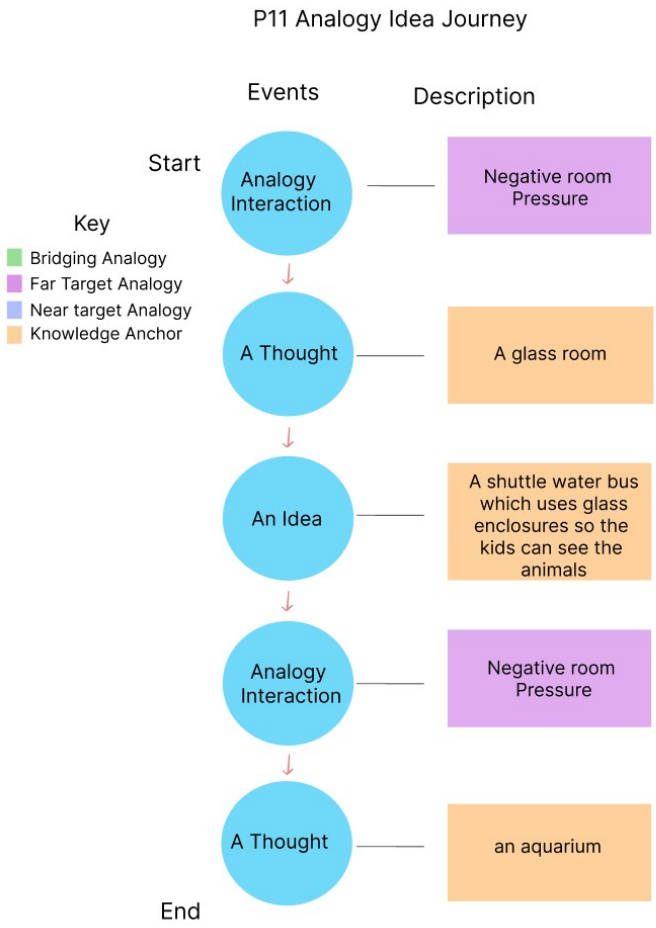

P10 Recommender Idea Journey
Events
Description
Start
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Analogy Interaction
Graphic Design
Future Studies, Pandemic
Negative Room Pressure
An Idea
Maybe there could be a VR setup which allows kids to view the marine animals
Analogy Interaction
Graphic Design
Pandemic
Negative Room Pressure
An Idea
A board which could emit a sound to attract the animals to the children
An Idea
Headgear with HUD's could be given to children to allow them to interact with the children without
Analogy Interaction
Graphic Design
Pandemic
An Idea
A translator to enable animals and children to communicate
End


P10 Analogy Idea Journey
Events
Description
Start
Analogy Interaction
Surface-to-air missile
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Expanding Possibilities
Let's throw practicality out the window
Scenario creation
What if the baby is actually a secret spy
An Idea
Their stroller is actually a cockpit with detachable drones that detectharmful elements
Building on prior ideas
There would need to be a waste disposal system
Building on prior ideas
Versatile transportation to ensure the stroller could go anywhere
Building on prior ideas
The cockpit should have windshield wipers
Building on prior ideas
Vents to facilitate drag and to improve air quality for the baby.
End

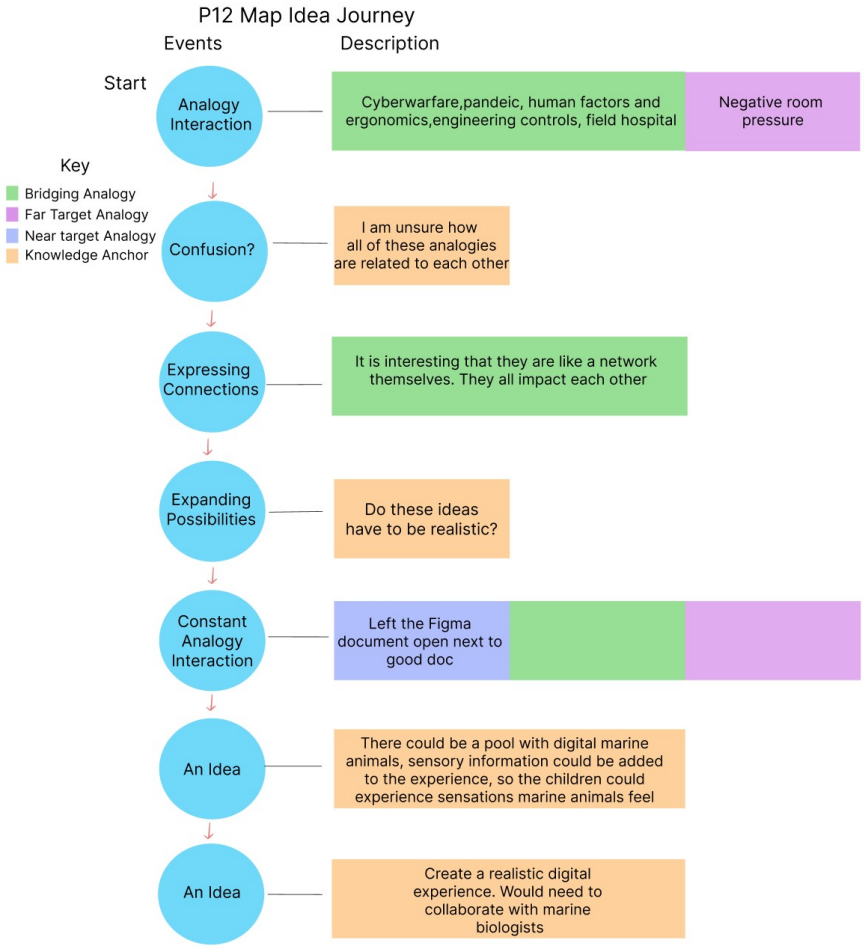
P11:


P11 Map Idea Journey
Events
Description
Start
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Analogy Interaction
Interacted with all the analogies on the Figma document
An Idea
Online weight training with a trainer
Analogy Interaction
Assay
Protein Biosynthesis
A Thought
Food and drink supply
Analogy Interaction
Design
Bioinformatics, interaction design, intellectual property
Protein biosynthesis
An Idea
National weight training services
End

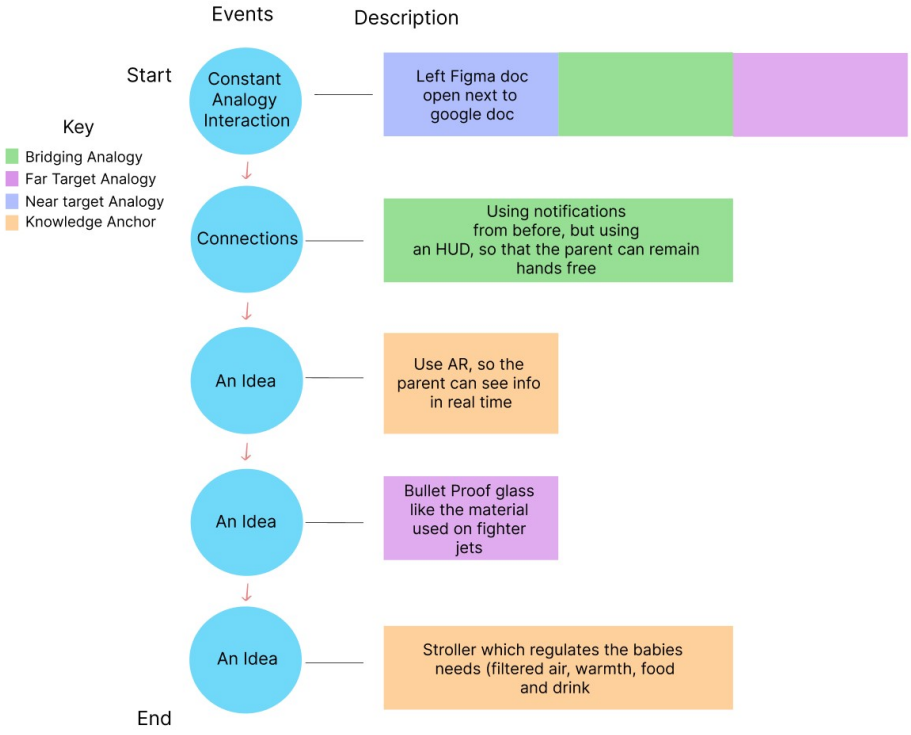

P11 Recommender Idea Journey
Events
Description
Start
Analogy Interaction
User research
Prototype, Messerschmit me 163
Surface-to-air missile
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
An Idea
Inserting an AI into the babies stroller
Analogy Interaction
Messerschmit me 163
surface-to-air missile
A Thought
Food and drink supply
Analogy Interaction
Prototype
An Idea
Customizable baby cart, can add wheels, covers etc. Each component is sold seperately
End


P11 Analogy Idea Journey
Events
Description
Start
Analogy Interaction
Negative room Pressure
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
A Thought
A glass room
An Idea
A shuttle water bus which uses glass enclosures so the kids can see the animals
Analogy Interaction
Negative room Pressure
A Thought
an aquarium
End

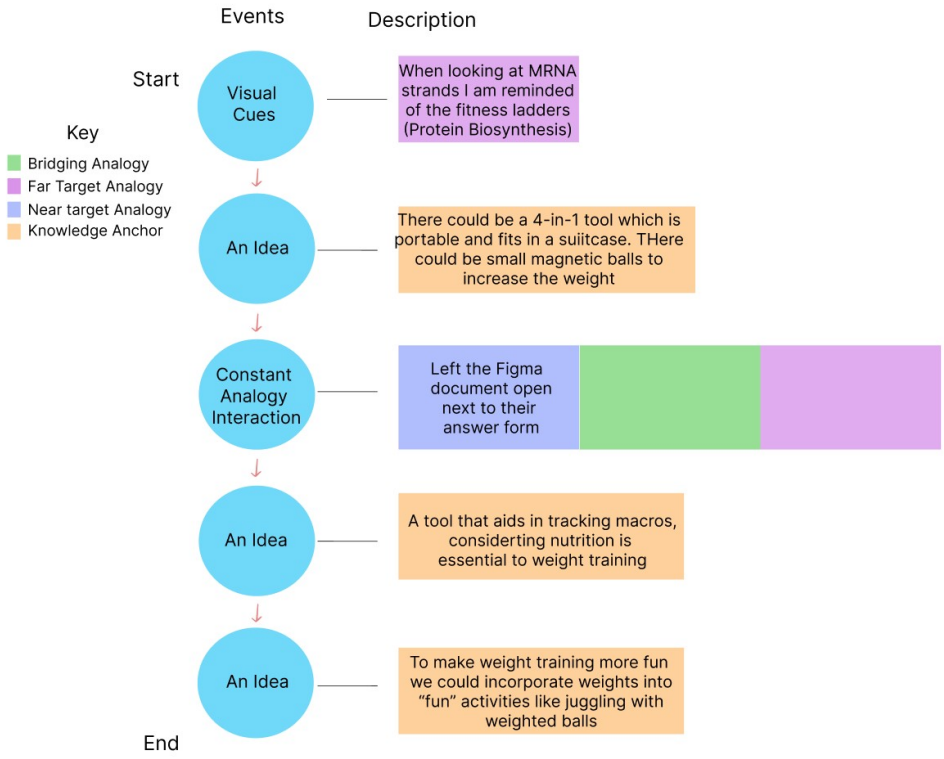
P12:


P12 Map Idea Journey
Events
Description
Start
Analogy Interaction
Cyberwarfare,pandeic, human factors and ergonomics,engineering controls, field hospital
Negative room pressure
Key
Bridging Analogy
Far Target Analogy
Near target Analogy
Knowledge Anchor
Confusion?
I am unsure how all of these analogies are related to each other
Expressing Connections
It is interesting that they are like a network themselves. They all impact each other
Expanding Possibilities
Do these ideas have to be realistic?
Constant Analogy Interaction
Left the Figma document open next to good doc
An Idea
There could be a pool with digital marine animals, sensory information could be added to the experience, so the children could experience sensations marine animals feel
An Idea
Create a realistic digital experience. Would need to collaborate with marine biologists

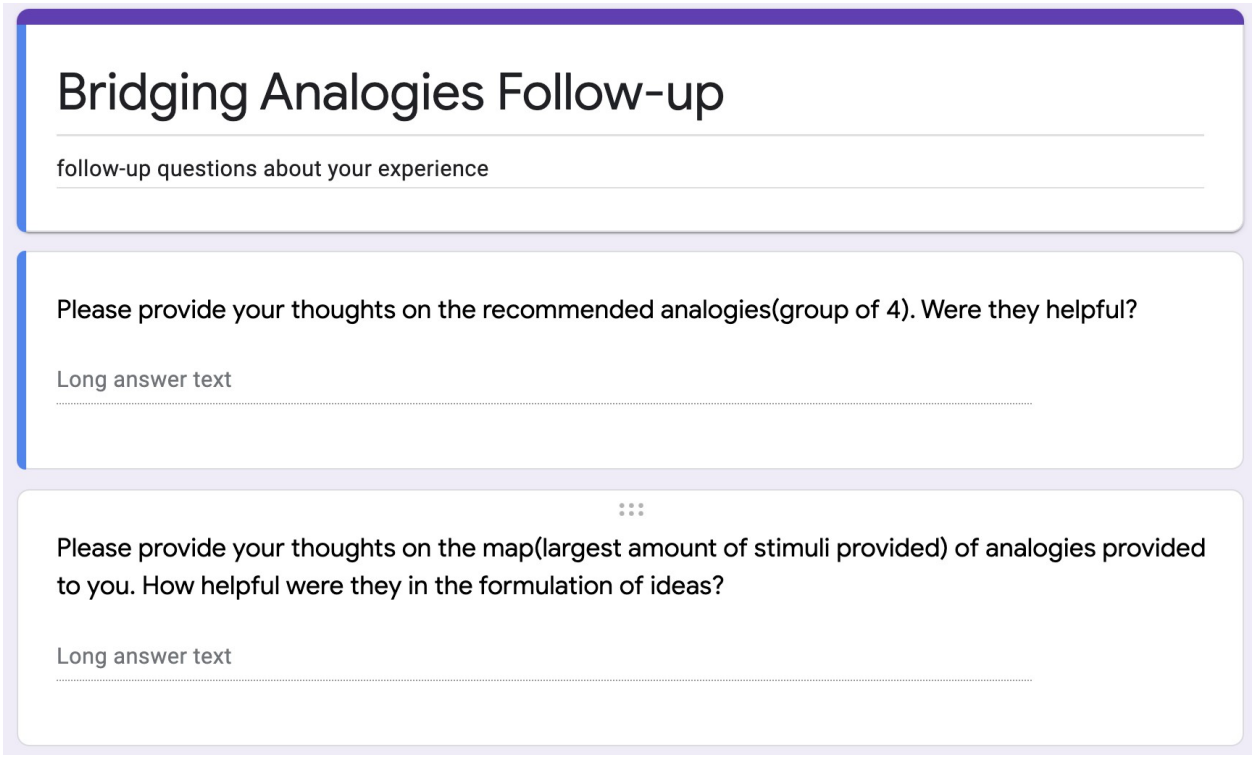
P12 Recommender Idea Journey



P5 Analogy Idea Journey



Follow-up Form:



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