

VIRTUAL PROBLEM-BASED LEARNING

The design of a virtual reality toolkit to assist 5th grade students with ADHD during problem-based learning.

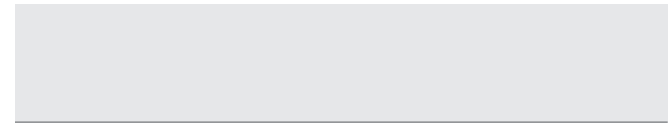
DMITRI KNAPP

Department of Graphic Design
College of Design
North Carolina State University
Raleigh, North Carolina

» May 10, 2020

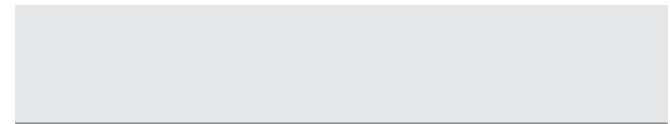
Submitted in partial fulfillment of the requirements for the degree of Master of Graphic Design.

DEREK HAM



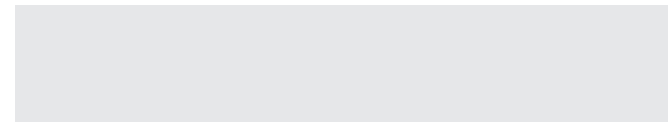
Chair

KERMIT BAILEY



Reader

HELEN ARMSTRONG



Reviewer

Special Thanks

- » *Denise Gonzales Crisp, for our Skype call, three years ago, convincing me to come to NC State.*
- » *Derek Ham, your continued guidance throughout this program and for your inspiring work ethic to push the boundaries of design thinking.*
- » *Helen Armstrong, your devotion to accessibility design inspired me to do this research.*
- » *Barbara Willis, for always being available for questions and your unlimited knowledge regarding teaching students with ADHD.*

THANK YOU!

To my committee members and all of the faculty at the College of Design, the knowledge and inspiration you provide every day has made me into a better designer and a better human being. You have opened up doors that I never knew existed and for that I am forever grateful.

To my parents, no matter how difficult this program got, you always had my back. I couldn't ask for more supportive and loving parents and I hope that I can continue to make you proud!

To my studio mates, I don't think I could have done this without you. From pulling all-nighters to hours of critiques to Truly Thursdays. You all have made this possible and I am extremely lucky to call you my cohort, my friends, and my family.

To the experts in teaching, our conversations and in person shadowing has allowed me to understand the user and the learning environment beyond what research could provide.

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VIRTUAL PROBLEM BASED LEARNING

Problem based learning (PBL) relies on the student-centered discovery of new knowledge that can better prepare students for real world problems. For students with learning disabilities, specifically Attention Deficit Hyperactivity Disorder (inattentive dominant) (ADHD-I), a lack of executive function control can result in failed learning outcomes. Experiential learning, like virtual reality (VR), has been viewed as a means to overcome some of these challenges, however teachers do not have a system, incorporating VR, to assist students with ADHD-I during the PBL process. This research explores how a web-based program and a VR creation space can assist 5th grade students with ADHD-I during PBL.

PBL - ADHD - VR

CONTROL THE EXISTENCE OF MATTER

Ivan Sutherland described the ultimate display as one that could control the existence of matter. He envisioned the transportation of a user, out of their current environment, ridding them of any preexisting stimuli, and transporting them into a reality that is as engaging as reality (Jerald, 2016). He depicted a display that could materialize a chair real enough to sit in. VR has not yet achieved this level of realism however if it did would that display be classified as the ultimate?

In this fast-paced world, our interests, attractions, and perception of novelty change from day to day and from user to user. A chair felt as comfortable for one user might feel uncomfortable for another. Visual stimuli that would distract one user might not distract another. As a result, the digital world is seeing a flux of modular and customizable landscapes to give users the agency to refine their own experience into their “ultimate display”.

Component based systems can give the freedom to modify an experience if one size does not fit all. Made of simple parts, components can be selected, depending on the objective, and combined to tailor the communication between the user and the digital environment. This design exploration aims to apply a component-based system to a group of users who have difficulties controlling their attention in a learning environment where control is placed in the users hands.

“The ultimate display would, of course, be a room within which the computer can control the existence of matter.”

— Ivan Sutherland

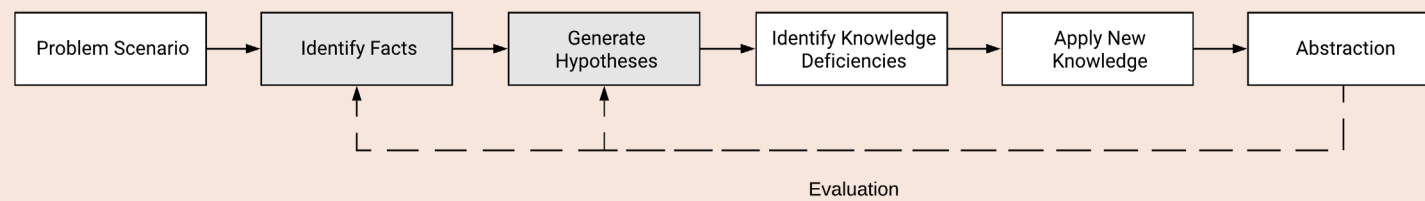


Figure 1 (Above)

Problem Based Learning Process

(Silver, 2004)

THE SITUATION

PROBLEM BASED LEARNING

Learning environments can assist students to learn complex ideas, meet lifelong friends, and make discoveries that can inspire future activities and endeavors. In recent years curricula have seen a shift from **traditional** top down, teacher driven approaches, towards student-centered discovery (Figure 2.0). This new method allows typical developing learners (TLDs) to discover ideas by observing situations, collecting and organizing knowledge, and combining that knowledge into a hypothesis to construct a creative solution (Sajadi and Khan, 2011; Silver, 2004). One of these student-centered approaches is **problem based learning** (PBL). (Figure 2.1). This constructivist inspired approach shifts a teacher's role from the knowledge provider to that of a facilitator, guiding students with prompts rather than lessons (Narayan et al., 2013; Honebein, 1996). Students undergo independent or group work to imagine, play, create, share, and reflect on new ideas as they steer the learning process and solve complex problems. Strong short-term memory, organization skills, concentration, and the capability of sustained attention are critical skills to succeed in a PBL environment (Sajadi and Khan, 2011). TLDs often excel in this environment due to their ability to focus and stay organized. Conversely, students with low working memory and poor organization skills can find PBL a challenge and in some cases fail to achieve the desired learning outcomes (Sajadi and Khan, 2011; Adams et al., 2009; Loe and Feldman, 2007). Among this group of students are those with attention deficit hyperactivity disorder (ADHD).

Traditional Learning

- » *Learning based on repetition.*
- » *Materials are primarily textbooks and workbooks.*
- » *Teachers disseminate information to students*
- » *Students are recipients of knowledge.*
- » *Assessment is through testing, correct answers.*

Problem Based Learning

- » *Learning is interactive, building on what the student already knows.*
- » *Materials include primary sources of material and manipulative materials.*
- » *Teachers have a dialogue with students, helping students construct their own knowledge.*
- » *Assessment includes student works, observations, points of view, and tests.*
- » *Process is as important as the product.*

Inattention Pain Points

- » *Difficulties with focusing*
- » *Task completion*
- » *Sustained attention*
- » *Organization.*

JUSTIFICATION

PROBLEM BASED LEARNING AND ADHD

ADHD is a neurodevelopmental disorder characterized by inattention, hyperactivity-impulsivity, or a combination of both (DSM V, 2013). While each type of ADHD can lead to difficulties within a PBL environment, this exploration focuses on the most common subtype of ADHD: inattentive (ADHD-I). Difficulties with inattention can include, focusing, task completion, organization, and sustained attention for long periods of time (DSM V, 2013) (Loe and Feldman, 2007). In 2016, approximately 9.6% or 2.4 million K-12 students were diagnosed with ADHD, making up nearly a tenth of the school's population. (6-11) (Danielson et al., 2018). As more schools incorporate PBL in their curricula, solutions to assist these users in this style of learning is vital.

In regard to learning disabilities there is little research to suggest that PBL is the right fit for all types of learners. A PBL environment embraces unstructured exploration which requires strong metacognitive skills for organization and autonomous discovery of new knowledge (Silver, 2004). This method of learning is beneficial for some learners; however research has shown that students with ADHD-I lack executive function control which diminishes their metacognitive load for sustained attention, concentration, and organizational skills (Loe and Feldman, 2007; Brown, 2019).

Attention can be affected by both controlled and uncontrolled circumstances that change based on the user's interests. Users with ADHD-I can experience moments of distractions and hyperfocus. This design exploration only focuses on distractions however there are many possibilities for design to assist users who have moments of hyper focus and can't progress with a task. Distractions can arise from

a lack of interest in the subject matter, a greater interest in a different subject matter, the intensity, novelty, or attractiveness of a different element in the scene (Nelson and Erlandson, 2007; Zentall et al., 1985).

To assist this problem, experiential learning has been viewed as a means to overcome some of these challenges (Ip & Li, 2015; Mayer, 2009; Moreno and Mayer, 2007). However, multimedia resources like virtual reality have seen little research in design exploration for ADHD-I users. Concerns regarding VR in a PBL environment question the teacher's ability to facilitate, provide necessary feedback during early stages of learning, manage unexpected learning outcomes, and peer to peer collaboration (Ip & Li, 2015). Conversely, VR can bring benefits to ADHD-I participation by blocking out external sensory stimuli that can increase focus, control of the perceptual environment, and assist in the organization of knowledge (Abdullah et al., 2019; Capelo et al., 2018; Chen et al., 2011; Parsons et al., 2007).

This design exploration aims to explore a VR-based kit of parts that can assist 5th grade students with ADHD-I when organization, attention, and concentration become a limiting factor during the PBL process. In addition, this exploration recognizes the teacher's involvement within a virtual PBL process and how feedback is presented when the user is in the headset.

Experiential Learning

"Experiential learning is a process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience"
(Kolb, 2014)

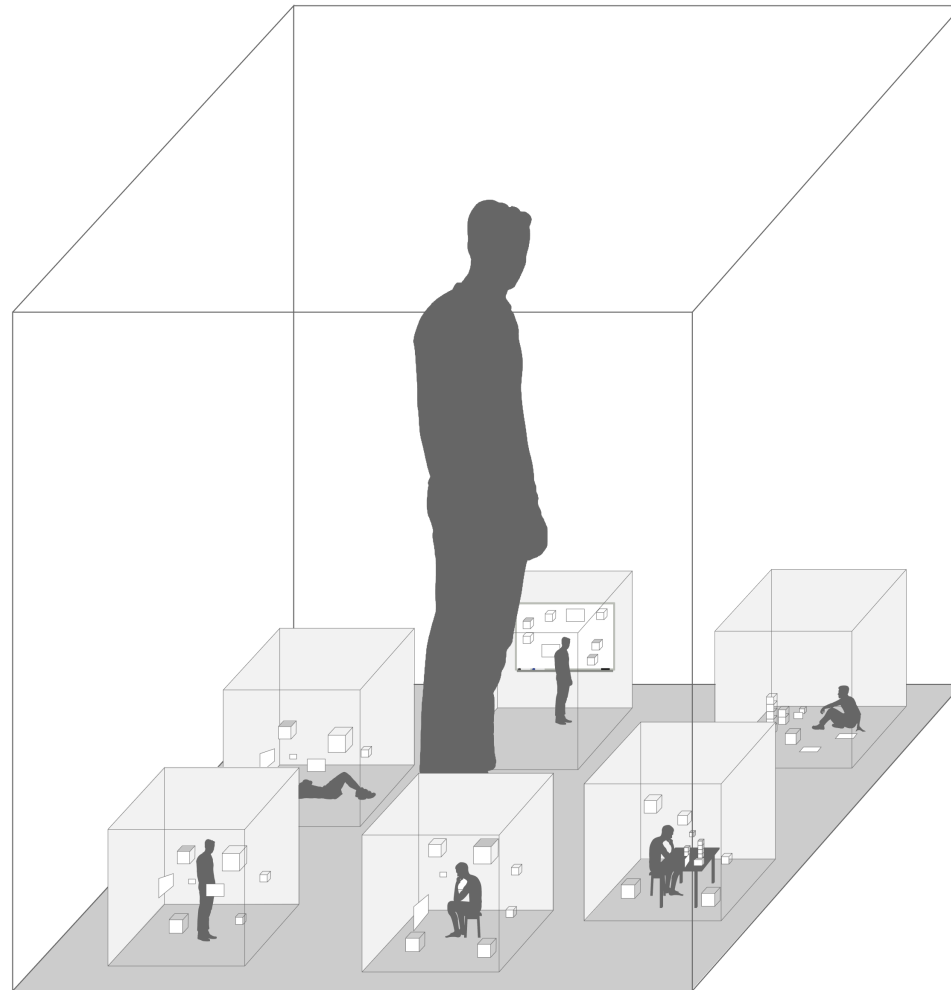


Figure 2 (Above)
Teacher's perspective of the design system.

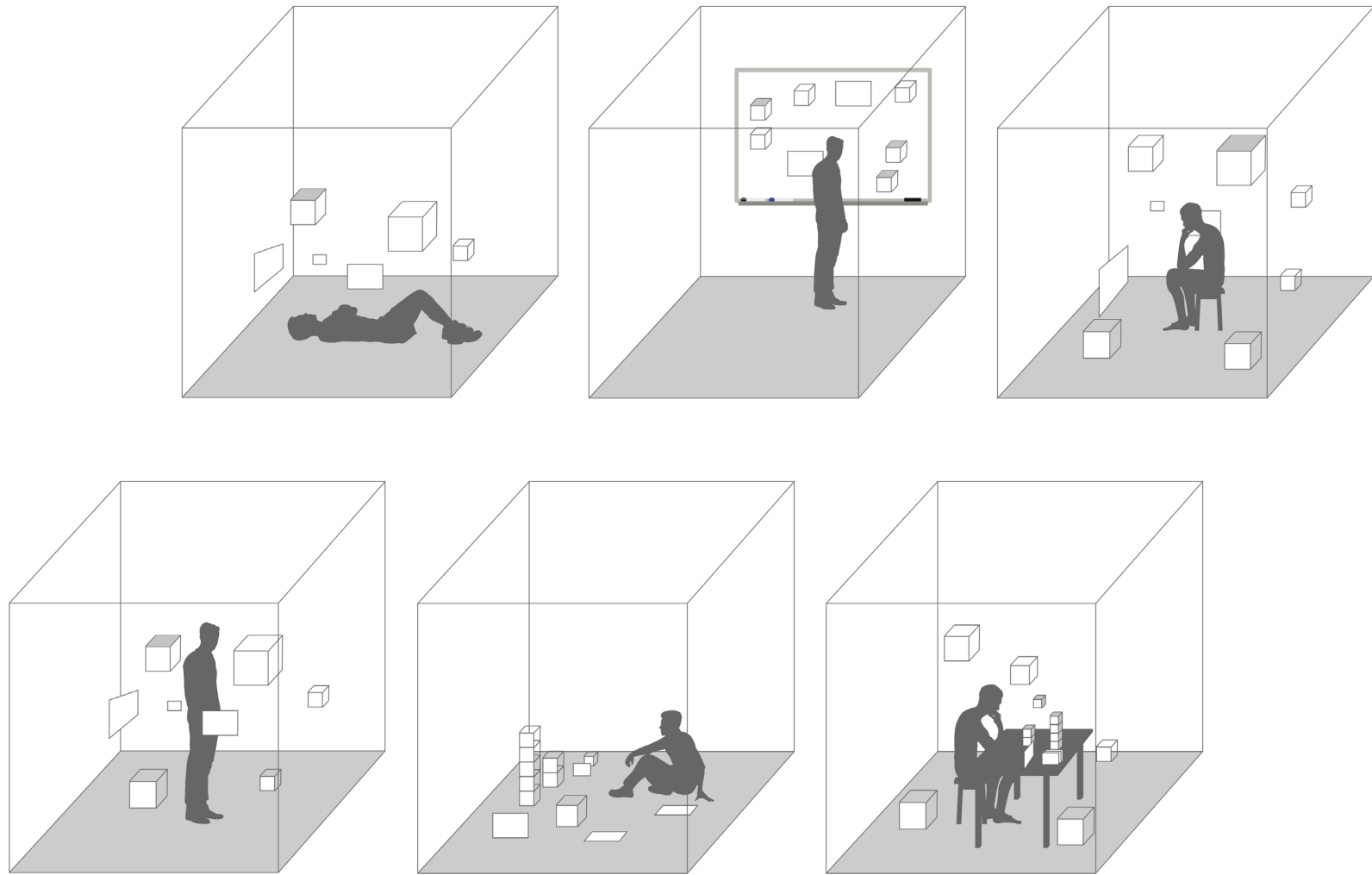


Figure 3 (Above)
Student's perspective of the design system.

Oculus Quest (Below)

Pros: *Does not need an external computer or cables to operate.*

Cons: *Costs 300-600 dollars.*



ASSUMPTIONS

For the purposes of this investigation, I assume that 5th-grade children with attention-based behavioral disorders are physically able to use a virtual reality headset and have an interest in learning through a virtual environment. The VR headset that this exploration is designed for is an Oculus Quest. The Quest does not need an external computer or cables limiting the distractions associated with tactile stimuli. I assume that the experience will not be limited by the Quest's RAM and storage capacities. Current costs for this type of headset range from 300-600 dollars. I assume that in the future the cost for both of these pieces of hardware will decrease to an affordable amount. I assume that teachers are aware and comfortable with the setup of VR and that the school has the right infrastructure for the implementation of VR headsets. I assume that teachers are trained to detect attention based behavioral disorders and actively want to help children keep their attention. I assume that these children are on medication or have mid-level attention issues, resulting in maximum effectiveness of the system. I am not curing attention-based disorders; this investigation is only explored as an aid for attention behaviors.

Distractions are based on a student's interests, their idea of novelty, and what they see as attractive to their eye. Because each student is different, this system would take some decision making from the teacher and the student to understand what combination of tools and parts generate the least amount of distractions.

LIMITATIONS

This thesis is focusing on children who have ADHD-I and I am aware that hyperactivity is a part of ADHD, however, I will not be exploring the disruptive nature of the hyperactivity in this investigation. Due to both time and Institutional Review Board (IRB) limitations, this investigation will not observe children with ADHD-I in a school setting and will not test if the system decreases distractions. Virtual reality has the affordance to block out external stimuli, including audio and visual, and replace them with computer generated stimuli. Regarding these studies, I am only exploring visual stimuli however other senses such as auditory can be explored to assist students with ADHD in PBL. This research is an exploration of possible solutions to this specific problem however future research can dive deeper into the implementation and further exploration of other sensory stimuli that create distractions.

ANNOTATED BIBLIOGRAPHY

To understand this problem space further, I reviewed existing literature to learn how 5th grade students experience ADHD, how resource rooms and PBL coexist, and how cognitive loads can be managed through VR. To locate this knowledge, I used the following keywords: “ADHD-Inattention in 5th Graders”, “VR and cognitive load”, “VR and ADHD”, and “VR and PBL”. In addition to searching through the web of science, I explored books and preexisting media to understand different angles to the problem space. This bibliography consists of the titles of each piece of literature and the knowledge that I took away.

ADHD-I

(DSM V, 2013)

Diagnostic and Statistical Manual of Mental Disorders

(Loe and Feldman, 2007)

Academic and Educational Outcomes of Children with ADHD

(Shalev, 2007)

Computerized Progressive Attentional Training (CPAT) Program: Effective Direct Intervention for Children with ADHD

TAKEAWAYS

Diagnosis factors of ADHD-I; prevalence of disorder; age of most impacted user.

ADHD mental and physical limitations; interventions; strategies and services.

Types of attention : Orienting Attention; Selective Attention; Sustained Attention; Executive Attention

ADHD-I (CONT.)

(Paas, 2010)

Cognitive Load Theory: New Conceptualizations, Specifications, and Integrated Research Perspectives

Interactions between working memory, long term memory and the cognitive load theory.

(Martinussen, 2011)

Teachers Reported Use of Instructional and Behavior Management Practices for Students with Behavior Problems: Relationship to Role and Level of Training in ADHD

Teacher management tactics for students with ADHD; Resource Rooms; Antecedent Approaches; Consequence Based Approaches; Executive Functions; Users Pain Points

PBL

(Sajadi and Khan, 2011)

An Evaluation Of Constructivism For Learners With ADHD: Development Of A Constructivist Pedagogy For Special Needs

Constructivism advantages for TDLs; Constructivism disadvantages and ADHD-I; role of teacher in PBL; ADHD pain points in PBL; experiential learning.

(Narayan et al., 2013)

Constructivism - Constructivist Learning Theory

Assimilation and Accommodation; Active Learning Process; Difference between constructivist and traditional learning

(Silver, 2004)

Problem-Based Learning: What and How Do Students Learn?

Learning outcomes of PBL; Importance of collaboration in PBL; PBL learning cycle; reflection in PBL; Flexible knowledge; Motivation in PBL

PBL (CONT.)

TAKEAWAYS

(Honebein, 1996)

Scaffolding and Achievement in Problem-Based and Inquiry Learning: A Response to Kirschner, Sweller, and Clark (2006)

Knowledge construction; Inquiry Learning; Creating Structure within PBL

(Honebein, 1996)

Seven Goals for the Design of Constructivist Learning Environments

Realistic and Relevant Contexts; Framework for designing learning environments.

PBL AND VR

(Abdullah et al., 2019)

Virtual reality to Improve Group Work Skill and Self-directed Learning in Problem-based learning Narratives

Interactions for VR during PBL; Blended Learning; Cognitive Stimulation in VR.

(Ip & Li, 2015)

Virtual Reality-Based Learning Environments: Recent Developments and Ongoing Challenges

Challenges of VR in constructivist learning environment.

(Moreno, 2004)

Personalized Messages That Promote Science Learning in Virtual Environments

High immersion does not translate to more things are learned.

COGNITIVE LOADS IN VR

(Nelson and Erlandson, 2009)	<i>Managing Cognitive Load in Educational Multi-user Virtual Environments: A Reflection on Design Practice</i>	Multimedia learning principles; Cognitive Load Reducing Methods; Split Attention; Spatial Reorganization; Offloading stimuli to other channels; Interaction Signaling
(Honebein, 1996)	<i>Distractibility in Attention/Deficit/Hyperactivity Disorder (ADHD): The Virtual Reality Classroom</i>	Distractors within a VR headset of a classroom; Moving objects and attention; size of objects and attention; color of objects and attention
(Abdullah et al., 2019)	<i>The Value of Attention Aware Systems in Educational Settings</i>	Diversity in Learning Environments; Cognitive Styles; Adaptable system based on attention levels; teacher actions when attention is diverted in VR
(Ip & Li, 2015)	<i>Cognitive State Monitoring and the Design of Adaptive Instruction in Digital Environments: Lessons Learned from Cognitive Workload Assessment Using a Passive Brain-computer Interface Approach</i>	Accessing Learners; Adaptive Instructions; Working memory management using machine learning
(Moreno, 2004)	<i>ADHD Assessment and Testing System Design based on Virtual Reality</i>	Using eye tracking and electroencephalogram to determine what sensory stimuli are distracting within a VR headset of a classroom environment.

External Stimuli	Definition
Visual	Seeing
Auditory	Hearing
Olfactory	Smelling
Gustatory	Tasting
Vestibular	Sense of Balance
Tactile	Touching
Thermoreceptive	Feeling Temperature
Proprioceptive	Sense of Self Movement and Body Position

Figure 4 (Above)

*Types of External Sensory Stimuli
(Haverkamp, 2013)*

**Grey sections indicate unexplored work.*

CONCEPTUAL FRAMEWORK

ADHD - STIMULI - VR - PBL

In the process of remembering information, a user experiences periods of perception and reflection (Chun and Johnson, 2011). Both are important for storing information in a user's working memory and encoding as long-term memory however they both use different internal and external resources (Chun and Johnson, 2011). According to Chun and Johnson, perceptive processes use external stimuli from the environment and reflective processes can work without the past external stimuli being present. Regarding PBL, both processes are critical for making decisions and problem solving however they both require attention, concentration, and the ability to modulate between multiple pieces of information (Chun et al., 2011). Due to the limitations with executive functions, students with ADHD-I can experience limitations with perception based on the visual and contextual and organizational complexity of an environment.

Types of External Stimuli. External stimuli are perceptual processes that we experience that can inform internal stimuli to encode into a long-term memory. External stimuli can manifest as reading a book, hearing a rainforest, smelling a flower etc. Although students with ADHD-I in a PBL environment experience many types of external stimuli, this exploration focuses only on visual stimuli that can impact attention, concentration, and organization based executive functions.

Types of Internal Stimuli. Internal stimuli are processes that are informed by external stimuli. Decreasing stimuli and in an environment and can assist the decision-making processes and offload the need for memory. As a result, internal stimuli can become less detrimental to the learning process for students with ADHD-I due to the decrease in visual and contextual complexity of the environment.

Brown’s Model of Executive Functions. Brown’s model explains the impairments of ADHD-I through six buckets, representing each executive function. Although each function can work together to disrupt learning for students with ADHD-I, I am focusing only on the activation and focus buckets for this exploration. These buckets include pain points such as organization, concentration and attention (Brown, 2019).

Project Complexity Factors Framework. Visual and contextual complexity can make up the external sensory stimuli that disrupts learning for students with ADHD-I. This is where my virtual reality based toolkit lives. This toolkit does two things in this framework, first it blocks out many of the external stimuli that would be present in a PBL environment. Second, it allows for the visual and contextual complexity to be controlled by an outside force, the teacher, and allows the student to control the environment with a set of virtual tools that this design exploration addresses. (Bakhshi, 2015)

Internal Stimuli	Definition
Thoughts	An Idea or Option
Memories	Storage of Information
Imagery	Experience of Visual Information without External Stimuli
Decision Options	Multiple Ideas or Opinions
Problem Solving	Identification of Possible Solutions to a Situation at Hand
Self-Directed Processes	Initiative of Diagnosing Ones Learning Needs

Figure 5 (Above)
Types of Internal Sensory Stimuli (Chun and Johnson, 2011; Chun et al., 2011)

*Grey sections indicate unexplored work.

The Metacognitive Framework. This process depicts each phase of PBL. Broken into five stages, this exploration only addresses the sorting of knowledge, breaking down of the problem, finding relationships, and mapping out a solution.

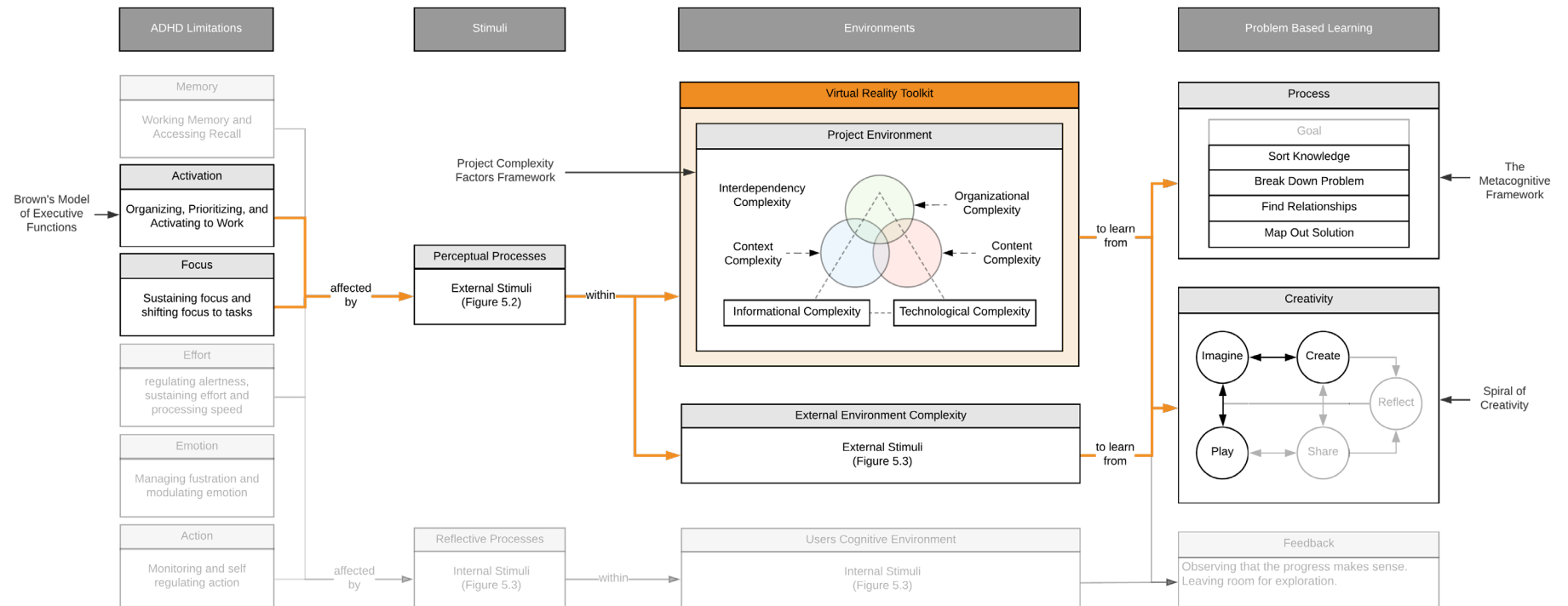
Spiral of Creativity. PBL is composed of trial and error with moments of reflection and collaborative discussions to discover new knowledge. Influenced by the spiral of creativity, this framework depicts each step without a starting point implying that a student can start anywhere in the process. This allows for the flexibility for a student with ADHD-I to find what works best for them in this process. This study explores how a student plays, imagines, and creates within a virtual environment (Resnick, 2017).

Synthesis. This visualization prompts the product of my investigation (Figure 6). Using a VR headset and a toolkit to assist with attention, concentration and organization, a student with ADHD-I can manage their external stimuli to control unwanted disruptions during the creativity stages of PBL. Once the stimuli are blocked it can provide a greater chance for working memory to encode as long-term memory indicating that the student has learned.

Figure 6 (On Right Page)

Synthesis of Adapted Framework

**Grey sections indicate unexplored work.*



PRIMARY RESEARCH QUESTION

How can the design of a virtual reality toolkit assist a 5th grade student with ADHD-I during problem-based learning?

SUBQUESTIONS

- 01 How can a **virtual web browser** assist an unfocused student with ADHD-I to collect visual reference assets for a project?
- 02 How can a **virtual toolkit** assist an unfocused student with ADHD-I throughout a problem?
- 03 How can the design of a **virtual reality background** assist a student who has attention fatigue?

DEFINITION OF TERMS

Virtual Reality. A head-mounted display that simulates an experience not found in the current environment.

Toolkit. The combination of a kit of parts and virtual panels designed to assist in limiting distractions and increase focus within a virtual reality scene.

Kit of Parts. Pre-designed and pre-made components that live within a virtual reality scene. These parts are aimed to assist in focusing a user with ADHD.

Virtual Panels. 2D planes that appear in a virtual environment that contain interactions that can be selected to assist in making the scene.

Assets. Digital images or text that can be collected from a web browser and transported into virtual reality.

Problem Based Learning. A student-centered pedagogy in which students learn about a subject through the experience of solving an open-ended problem.

Cognitive Overload. Results when a student has to process too much sensory information, resulting in the inability to learn.

Attention-Deficit / Hyperactivity Disorder. A mental health disorder, developed by a chemical imbalance in the brain, that causes the inability to stay focused for a long length of time.

Distraction. The act of losing focus due to a user's interests, their idea of novelty, and what they see as attractive to their eye.

Focus. The state or quality of having or producing clear visual definition of a topic or specific problem.

Engagement. A category of user experience characterized by attributes of challenge, positive affect, endurability, aesthetic and sensory appeal, attention, feedback, variety/novelty, interactivity, and perceived user control (O'brien and Toms, 2008).

Disengagement. This occurs when participants made an internal decision to stop the activity, or when factors in the participants' external environment caused them to cease being engaged (O'brien and Toms, 2008).

METHODS

Case Study and Precedent Analysis. I started this exploration with in-depth investigations, focusing on ADHD-I through the lens of attention. I looked at existing research and in-market design solutions to find a problem space where design could intervene.

Interviews with Stakeholders. To understand the user of this system, I met with people who have firsthand experiences with the disorder.

Personas, Journey Map, and Scenario. To humanize the users, I aggregated interviews and case studies to develop personas of the student with ADHD-I and the teacher. I then applied these personas to a journey map to establish possible pain points within a problem-based learning environment. Lastly, I created a scenario to expose the pain points and how my system aims to solve them.

Visual Studies, Prototyping, and Research Through Design. To explore my visual studies I conducted “I wish” sessions and testing through user feedback to develop a series of solutions that can inspire future design research and act as a solid foundation for real-world implementation.

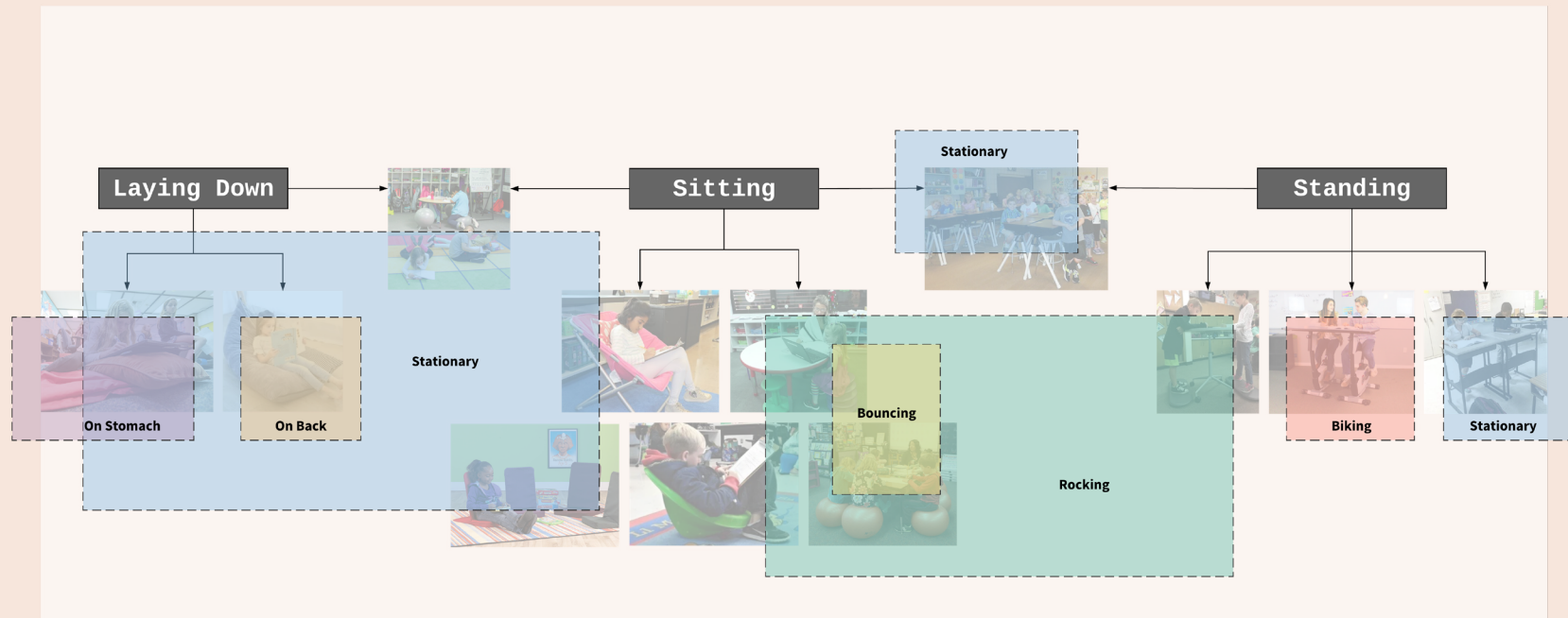


Figure 7 (Above)
Flexible Seating Options

PRECEDENTS

In this exploration, I looked at several VR experiences and methods for keeping attention on the task at hand. Regarding VR I found experiences that consist of room size painting and sculpting platforms, training experience simulations, and stationary 360-degree pictures of real or past-life. These experiences led me to find gaps in how environments are visualized to either distract from the real task or immerse the user further into the task.

Medication-Based Treatments. 62% of children and adults are taking ADHD medication (Danielson et al., 2018) in the form of methylphenidate-based (Ritalin) and amphetamine-based (Adderall) to combat inattention (Wilens, 2010), however, these medicines can create nervousness and other side effects (FDA, 2018). Less than half of these cases received behavioral treatment in the past year (Danielson et al., 2018) however research shows that ADHD symptoms can be further minimized when combined with other methods such as behavioral treatments (DuPaul, 2011).

Flexible Seating. Flexible seating is a method of providing different seating options to the learner so they can experience the information in a comfortable position to limit distractions (Figure 7). The downside to this seating arrangement is that children with ADHD still have sensory stimuli that prevents them from focusing on the reflection period to its fullest.



Figure 8 (Above)
Neo Trie VR experience.



Figure 9 (Above)
Rumii VR experience.



Figure 10 (Above)
Labster VR experience.

PRECEDENTS

VR IN SCHOOLS

Class VR. This teaching platform provides educational content for children in VR. The teaching apps are displayed within a futuristic room that takes the viewer to an unfamiliar location.

Neo Trie VR. Allows students to create geometric shapes to assist in learning math in VR (Figure 8).

Discovery Education. Discovery Education takes subjects like math, science, and social studies and visualizes them with a concrete context so the viewer can learn the topics through familiar objects.

Rumii VR. Rumii is a collaborative virtual space that allows users to share information for an educational purpose. In this environment, you can screen share, browse the web, and look at the same content across 20 individual users (Figure 9).

TRAINING EXPERIENCE SIMULATIONS

Labster. Using Daydream, undergraduate biology students can access a world-class laboratory and run simulated experiments (Figure 10).

EON Reality. Collaborative training in VR using semi-abstract semi-simple simulations including body parts for surgeries and machinery for maintenance training.

STATIONARY EXPERIENCES

Google Expeditions. Using google cardboard a user can view world locations (Figure 11).

Netflix within Oculus Go. In this experience, users are transported to a rustic living room where they are sitting on a couch and have the ability to view Netflix through a TV screen.

Lifeliqu. Lifeliqu is a VR museum that allows users to see both location-based environments and the inner workings of living things (Figure 12).

DISTRACTION BLOCKERS

RescueTime. This productivity app acts as a distraction blocker that manages time and access to certain sites that can be distracting.

Quiet Time Privacy Lounge Chair. This chair takes away all distractions for the user. It is designed with extremely tall back and arms, blocking out all external distractions.

Hocus Focus. Hocus Focus creates focus by hiding screens that have not been in use. This limits the number of distractions so a user can focus on one thing at a time (Figure 13).

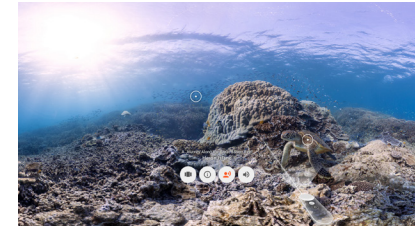


Figure 11 (Above)
Google Expeditions experience.

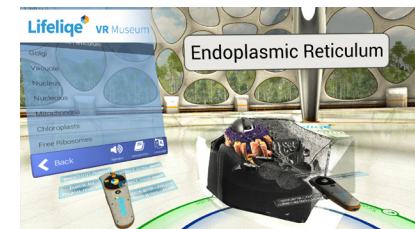


Figure 12 (Above)
Lifeliqu VR experience.

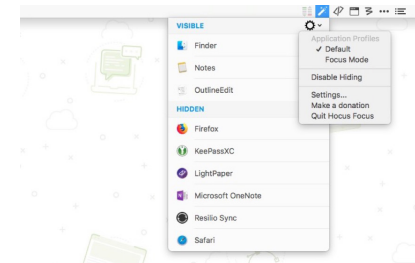


Figure 13 (Above)
Hocus Focus experience.



Figure 14 (Above)

Tiltbrush tools and in virtual experience.

PRECEDENTS

VIRTUAL REALITY SCENE CREATION

Google Tilt Brush Virtual Panel Tools. The purpose for Tiltbrush is more of a sculpting and free drawing platform. With a plethora of tools at a user's disposal, creativity to create forms and models seemed limitless. When it comes to PBL and solving problems using Tilt Brush it becomes more limited. Drawing in air can take some time to get the hang of especially if the user is not used to the action. Handwriting words specifically can have its limitations regarding legibility due to depth perception. This freedom when drawing can generate visual stimuli quickly as a scene is added to. Tilt Brush also comes with the capability to import image assets however the process could be difficult for the standard user (Figure 14).

Using Tilt Brush to make many of these studies, I found that virtual panels became a challenge to find when they were taken off of the controller and placed into the scene. A user who has difficulties with organization can get easily frustrated and could have difficulties with this feature.

Time to Onboard a TLD User : 6 days

Google Blocks. The purpose of Google Blocks is also a sculpting one, however with a limited palette of tools and colors, the scene's visual stimuli can be easily managed. Limited tools can result in easier memory of each tool's function and operation of the handheld controllers. 3D models, via Google Poly are linked directly to the tools the user has access to increasing ease of use when importing assets. Image assets are available to import into a scene however a user can't do it alone. While a user is in VR, another person must use the virtual mirrored desktop app to select an import asset button and select the image of their choosing. Once the user in VR takes the headset off, the button disappears from the screen because the sensor in the headset doesn't sense a person using the headset, thus putting the program in sleep mode (Figure 15).

Time to Onboard a TLD User : 4 days

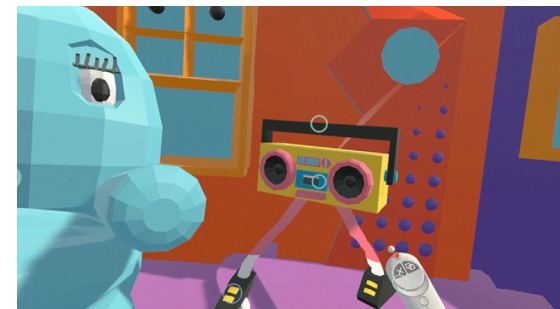
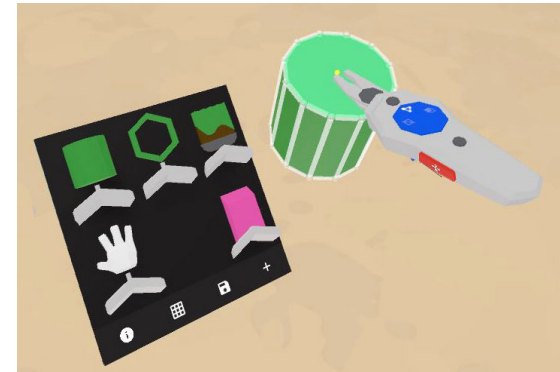


Figure 15 (Above)

Google Blocks Tools and in virtual experience.

PERSONAS

Micha Traore. Diagnosed as having a high level of ADHD-I, however his medicine does not eliminate all limitations. When multiple visuals or text-based stimuli appear his field of view he can easily get unfocused. Activities that require memory-based tasks are his biggest struggles in the classroom. He is aware that he has these limitations and actively tries to control them with no avail.

Jose Valez. A student who has difficulties with reading because of ADHD-I. He does a good job controlling his attention limitations when it comes to visual representations however when text appears, he tends not to be interested in it, resulting in limited focus and can get easily distracted.

Hayes Tompkins. Experiences a medium-low level of ADHD-I but it is enough to result in difficulties with making decisions and finishing projects that he starts. He loves working with his hands and picks up tactile based tasks quickly.

Bentley Adams. Adams is a rockstar of a teacher. She loves helping her students and finding new methods to help them learn. She currently practices problem-based learning and is actively trying to implement more digital solutions within the learning process.

Figure 16 (On Right Page)
Personas used in this thesis.



Micha Traore
(student)

Task Limitations

Concentration
Math Disabilities
Memory Based Tasks

Cognitive Abilities

Reading: Medium
Interpreting Images: Low

Learning Preference

Tactile
Digital

Hobbies

Basketball
Social Media (Tik Tok)



Jose Valez
(student)

Task Limitations

Focusing
Reading Disabilities
Handwriting Disabilities

Cognitive Abilities

Reading: Low
Interpreting Images: High

Learning Preference

Tactile
Digital

Hobbies

Legos without instructions
Woodworking
Card Games



Hayes Tompkins
(student)

Task Limitations

Focusing
Finishing a Project
Decision Making

Cognitive Abilities

Reading: High
Interpreting Images: Medium

Learning Preference

Tactile
Digital

Hobbies

Video Games (Fortnite)
Going on Hikes
Movies (Marvel)



Bentley Adams
(special ed teacher)

Teaching Goals

Helping everyone in the class
Streamlining teaching strategies
Setting up students for the future

Teaching Preference

Problem Based Learning for
special needs students

Learning Preference

Tactile
Digital

Hobbies

Video Games (Mario Kart)
Social Media (Facebook)
Pokemon Go

Virtual Web Browser

Web-based program that can modify a users experience when connected to that users profile.

How can a **virtual web browser** assist an unfocused student with ADHD-I to collect visual reference assets for a project?

Figure 17 (On Right Page)

Adapted from Mayer and Moreno's Cognitive Overload Scenarios (Mayer and Moreno, 2003)

**Grey sections indicate unexplored work.*

SUBQUESTION 01

VIRTUAL WEB BROWSER

In the beginning stages of PBL, students collect digital resources (images and text), known as assets, that can assist or inspire exploration for the given project (Silver, 2004). These predetermined searches can be guided by the teacher or a student can undergo a **free search session**. During a free search, students can experience varying amounts of visual stimuli that can make it hard to focus and make decisions. The degree of which an image can distract a user can vary depending on the student's interests, their idea of novelty, and what they see as attractive to their eye. Younger students that are in 5th grade, can have trouble controlling their attention level on their own and this trait can extend to later years (DSM V, 2013). This thesis explores automatic and user enabled tools to manage ADHD limitations during a free search session during PBL.

Assets can be found in websites, scanned from textbooks, photographed from reality or discovered from other mediums. Though collectible assets are vast, this exploration focuses on collecting images and text from a browser window to use for an iteration session in VR. Due to the time it takes to find and collect these resources, limitations including attention and organization can result in failed learning outcomes such as in depth researching, managing projects, and applying content to the real world. Using Mayer and Moreno's cognitive overload framework this thesis explores how the design of a browser-based program can assist an unfocused and unorganized student when discovering and collecting assets for VR (Mayer and Moreno, 2003) (Figure 17).

Free Search Session

When a user is searching without any guidance from the teacher.

Overload Scenario	Design Principle	Load Reducing Methods
Visual channel is overloaded by processing of essential information	Modality	Off-load information from visual to verbal channel
Both channels are overloaded by essential processing demands	Segmentation Pretraining	Present information in bite size pieces Provide pre-training of segments of information within larger system
One or both channels overloaded by essential and incidental processing of extraneous material	Coherence Signaling	Eliminate interesting but extraneous information Provide cues on how to process information
One or both channels overloaded by essential and incidental processing of confusingly presented material	Split Attention (Spatial) Redundancy	Place related words and pictures near each other Eliminate multiple forms of identical material
One or both channels overloaded by essential processing and representational holding	Split Attention (Temporal)	Present pictures and words simultaneously to minimize need to access past-information in working memory

WHAT ARE THE DEPENDENCIES?

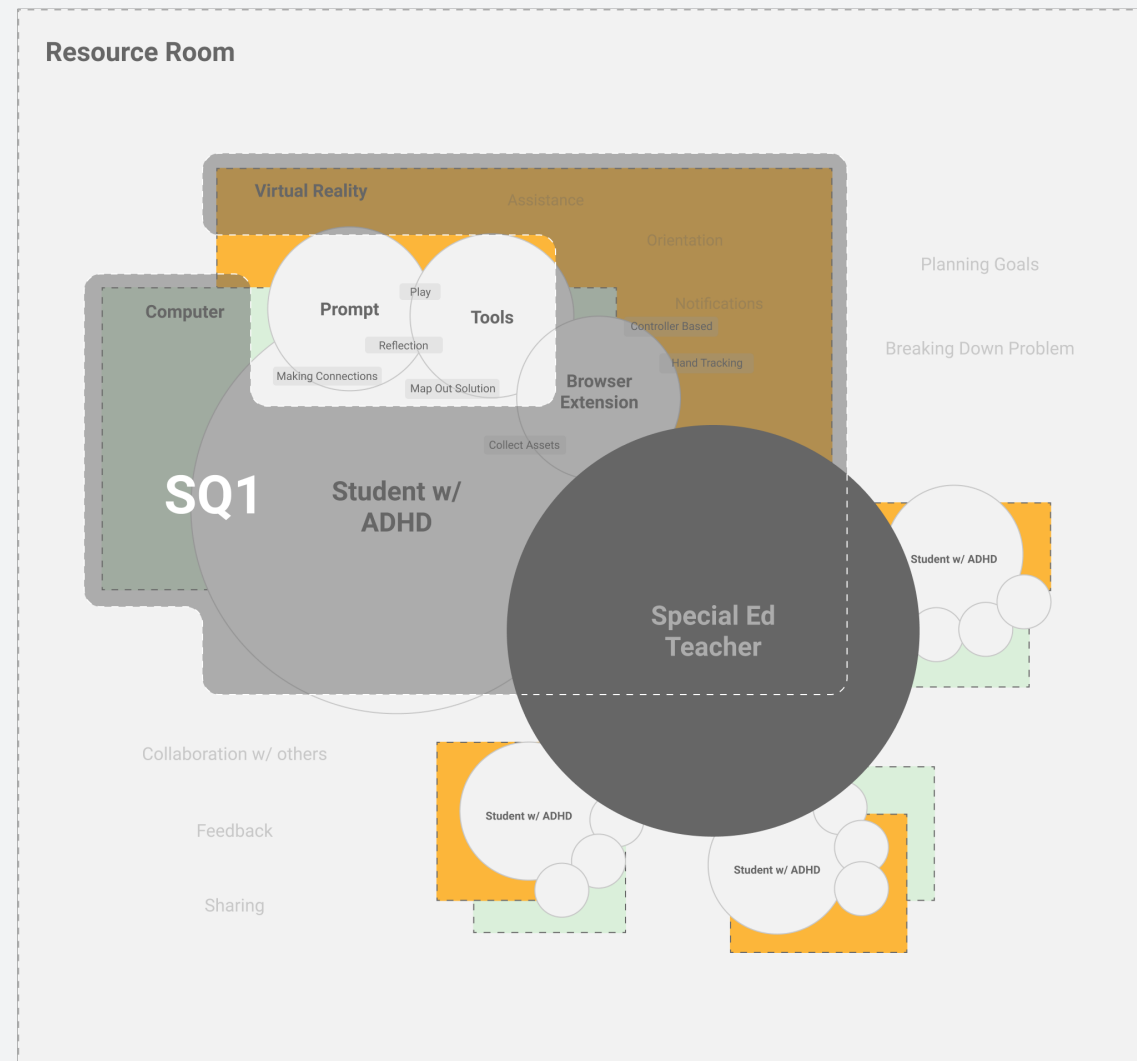


Figure 18 (Right)

Dependencies of virtual web browser in the design system.

**Grey sections indicate unexplored work.*

WHAT PARTS OF PBL IS THIS INCORPORATED?

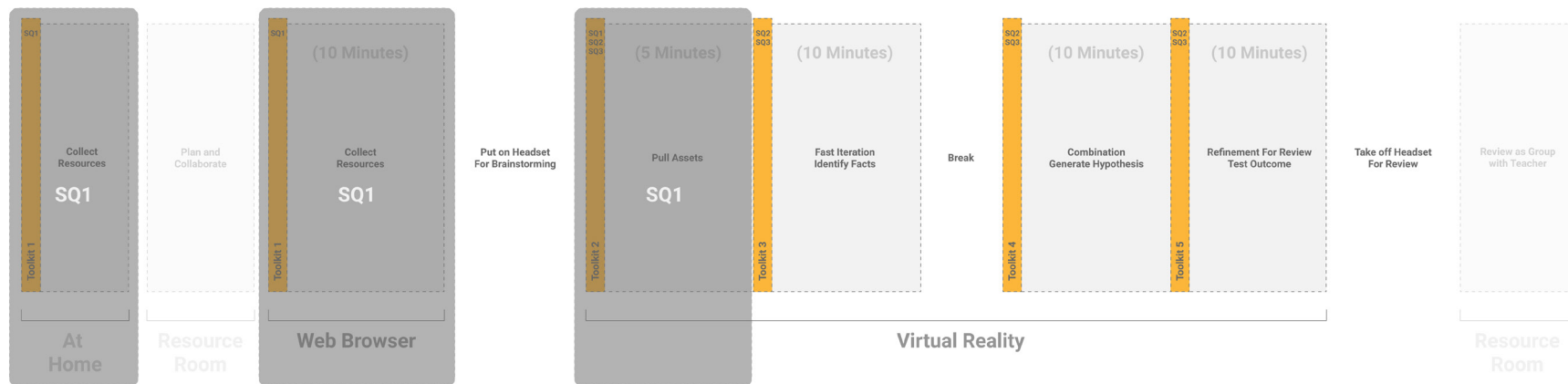


Figure 19 (Above)

Parts of PBL where a user will experience a virtual web browser.



Figure 20 (Above)

*Typing in VR using Logitech's keyboard
for HTC Vive.*

Web Browsers and Attention. Web browsers exist both on PCs and in VR. Both environments have the affordances of viewing, reading, typing, clicking, scrolling, and dragging. Pairing the affordances with ADHD limitations can give the student the capability to search and collect assets in a browser before they put the headset on, both at home and in school, and while they are discovering knowledge in the headset at school only. Once a user navigates to a page that has heavy visual stimuli the program activates tools that are automatically activated or managed by the user to turn on and off. Affordances of VR and PC based web browsers were used in the exploration of these tools; however, the scenario focuses primarily on web browsers on a computer.

Web Browsers and VR. The current journey to collect an asset and import it into VR can be a challenge if the user has not interacted with VR or computers on a regular basis. Importing an image asset into VR requires the use of a browser window, a computer connected to VR and a VR headset. On a computer, users must learn to save images, navigate computer directories, and once in VR, find certain options within a subset of menus (Figure 21). A program placed on a browser window can link directly to a user's project. Unlike a PC asset saving functionality is not available in VR, however, a browser window can be present in the environment. To search through a browser within VR a user is limited to typing on a virtual keyboard. Speech dictation is not yet available in VR. Though research has not indicated that students have limitations typing in a physical setting, outside of external distractions, research was limited regarding typing within a virtual environment using controller based or hand tracking capabilities

Web Browsers and PBL. During the PBL process there are three places where this exploration lives (Figure 19). At home, where students can collect digital assets to bring to class and use for PBL. In the resource room, where students can decide on assets to be imported into VR and when students are in VR and need additional source material.

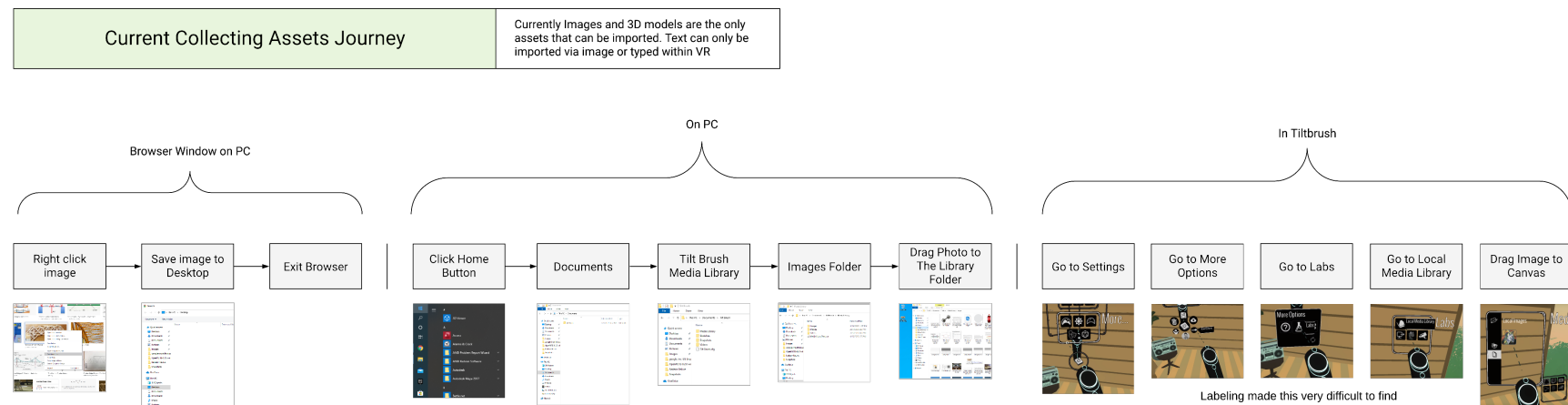


Figure 21 (Above)

Current journey of collecting assets in virtual reality.

SUBQUESTION 01

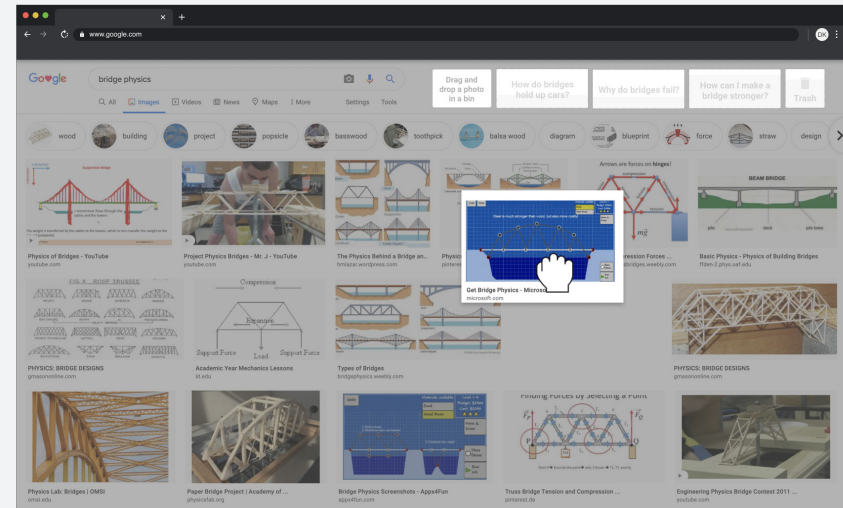
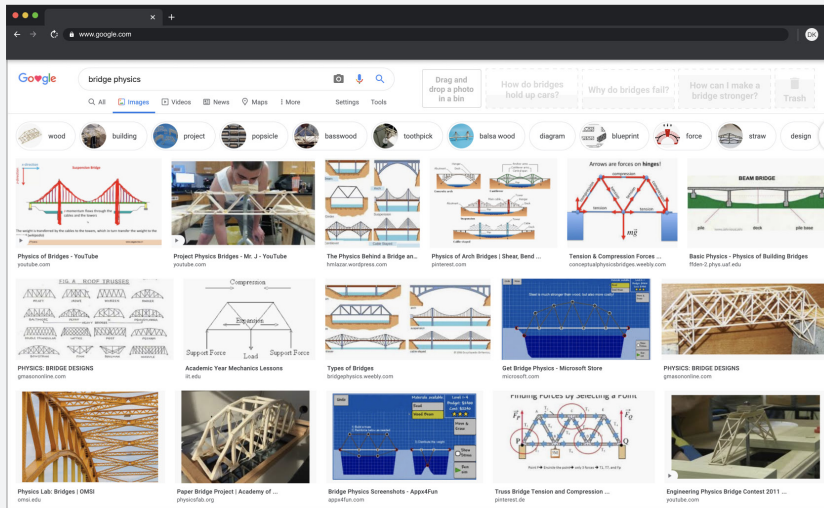


Figure 22 (Above)

Dragging assets to browser-based containers connected to a virtual environment.

SUBQUESTION 01

HOW THE SYSTEM WORKS

This system requires setup by the special education teacher and the primary teacher. In collaboration, the two teachers create new projects that act as a container for students to drop assets that they wish to use in VR. After the creation of a project the teachers have access to their class and any users who have special needs. This system gives the teacher the option to add tools to a user's profile if they have limitations like attention or focus.

Once a user signs in, containers appear on each page that act as a portal between the browser window and the user's creation scene. On the browser, users can add assets to these containers, labeled with predefined prompts. Users also have the ability to delete assets if they are deemed too distracting or unnecessary to the project. If a user deletes or adds an image to the wrong bin by accident they can click on the associated bin and revert the action. Bin quantities, capacity, and prompts can be managed by the teacher depending on the project type. Research has indicated that Icons and words should be used to assist a user's working memory by limiting the amount they would have to decipher (Mayer and Moreno, 2003). To help motivate students, the teacher can place a container limit to signify collection goals for that project. If a user navigates to a stimuli rich page, additional tools that the teacher has pre-selected will activate, providing help to the user until a user goes to a less stimulating page.

If you like a photo drop it in one of these bins.

How do bridges hold up cars?

Why do bridges fail?

How can I make a bridge stronger?

 Trash

Figure 23 (Above)

Browser-based containers to send assets to a VR environment.

User of This Tool

The appropriate user for this tool is one who has mild inattention and awareness for their limitation because it requires a user to toggle on and off the features.

Coherence

"Eliminate interesting but extraneous information" (Mayer and Moreno, 2003)

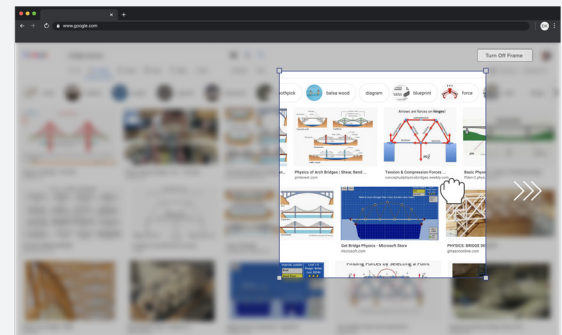
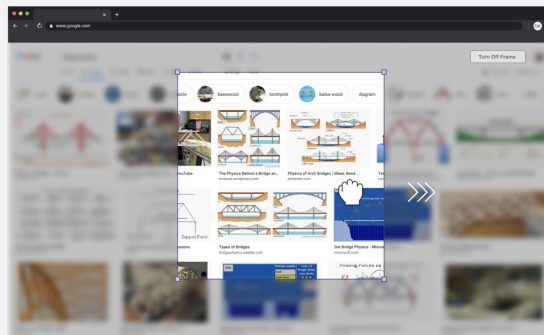
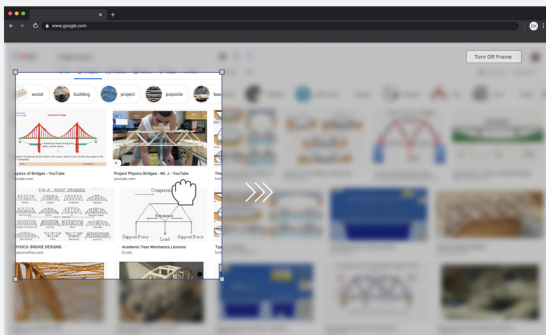
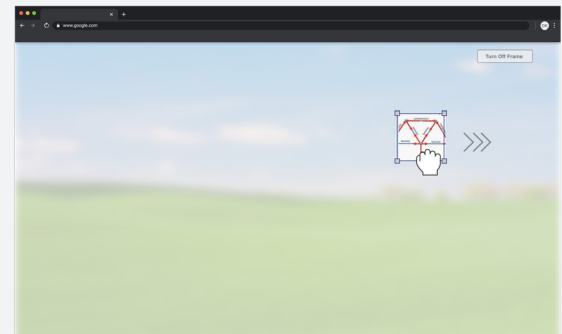
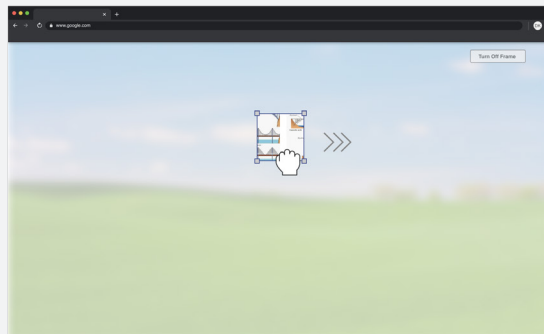
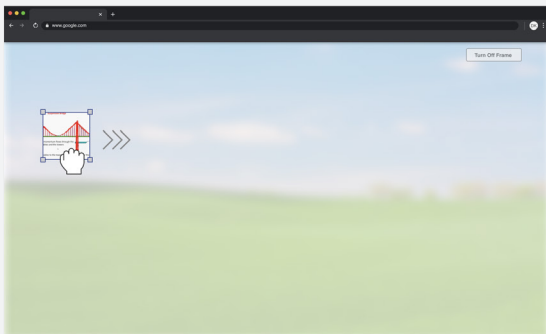
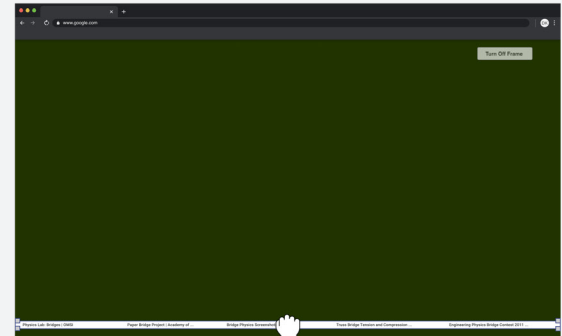
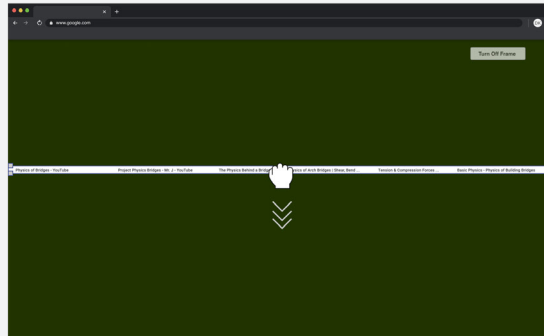
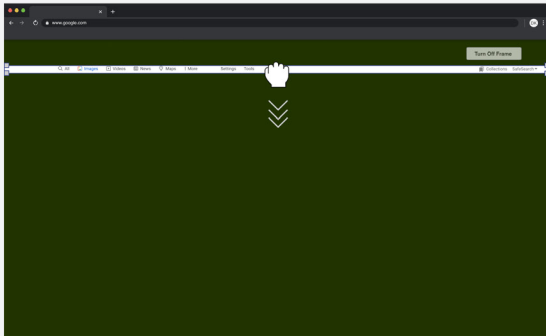
Figure 24 (On Right Page)

Browser-based Framing Tool to allow users to focus their field of view on lines of text, certain images or multiple images to assist the decision making process.

SUBQUESTION 01

INCLUDING OR EXCLUDING VISUAL STIMULI

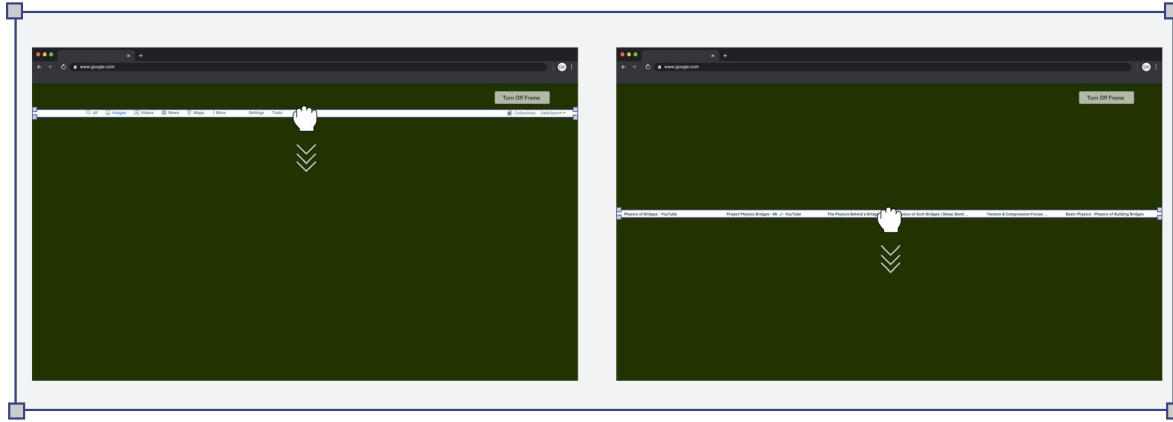
Searching for images can bring users to interfaces that include many assets (images and text) that compete for the user's attention. This feature automatically places a frame that minimizes the visual stimuli on the page. A user can change the frame size by dragging the corners to the desired size. The negative space of the frame can include high contrast colors, limited vision to the background, or calming images to provide the user with a place to rest in case of attention fatigue (Lee, 2014). This feature can be used as a method to search for different options or once a user has identified a photo(s) or text(s) of interest they can block out unnecessary visual stimuli to increase focus.



User of This Tool

The appropriate user for this tool is one who has mild inattention and awareness for their limitation because it requires a user to toggle on and off the features.

on the page. A user can change the frame size by dragging the corners to the desired size. The negative space of the frame can include high



SUBQUESTION 01

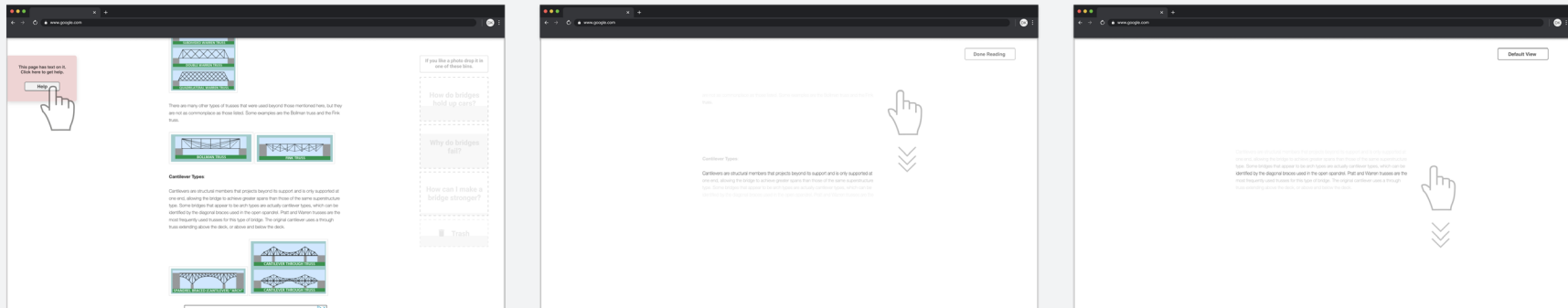


Figure 25 (Above)

Line Reader Tool to assist users who have trouble focusing when reading.

Split Attention (Temporal)

"Present pictures and words simultaneously to minimize need to access past information in working memory." (Mayer and Moreno, 2003)

Including or Excluding Text. In addition to images, text can distract users. Research shows that students with ADHD can struggle with reading comprehension due to attention limitations (DSM V, 2013). These limitations can result in a user skimming a body of text instead of actively reading it, resulting in minimal information retention within their working memory. Avoiding unnecessary multitasking, this tool uses the affordance of scrolling to guide the users gaze, one line at a time. As the user scrolls, the highlighted line stays in the center of the page and brings attention to the next line. Visibility of surrounding lines becomes diminished, but still visible, giving the user the ability to know where they are in a paragraph. Due to limitations with multitasking, this feature leveraged single interactions to make the tool easier to use (Loe and Feldman, 2007). This functionality can allow a user to move quickly through a body of text or slow down and read line by line for increased reading comprehension.

Signaling

"Provide cues on how to process information" (Mayer and Moreno, 2003)

of actively reading it, resulting in minimal information retention within their working memory. Avoiding unnecessary multitasking, this tool uses the affordance of scrolling to guide the users gaze, one line at a time. As the user scrolls, the highlighted line stays in the center of the page and brings attention to the next line. Visibility of surrounding lines becomes diminished, but still visible, giving the user the ability to know where they are in a paragraph. Due to limitations with multitasking, this

Segmentation

"Present information in bite size pieces"
(Mayer and Moreno, 2003)

SUBQUESTION 01

COMPLETE SEPARATION FROM VISUAL STIMULI

This feature allows a user to single out an image of their choosing if the other visual stimuli become too distracting. In Mayer and Moreno's framework, segmentation, or the presentation of information in bite size pieces, can reduce cognitive load and increase working memory (Mayer and Moreno, 2003). After isolating, the user has the option to either go back to see all options or drag images into an asset bin. The isolate tool and select and compare tool require user interaction to turn on and off the functionality, making this feature difficult for someone who can't control their inattention. If the teacher pairs the user with the slideshow tool, the user can bypass the visual stimuli from Google's search page and arrive in a stimuli free environment automatically.

Figure 26 (On Right Page) (Top)

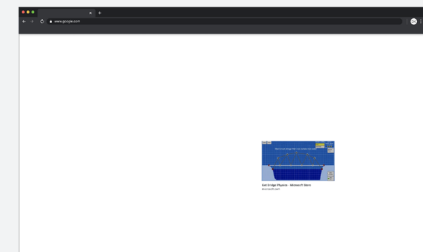
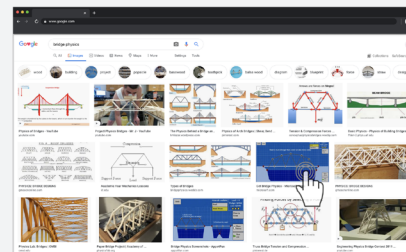
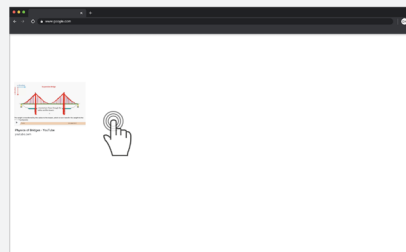
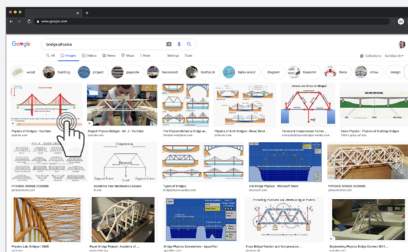
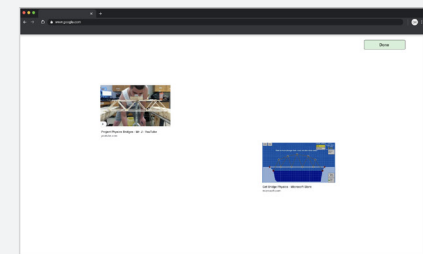
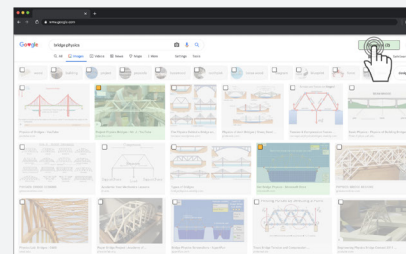
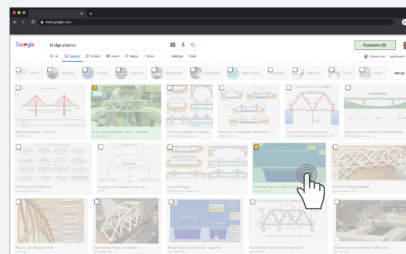
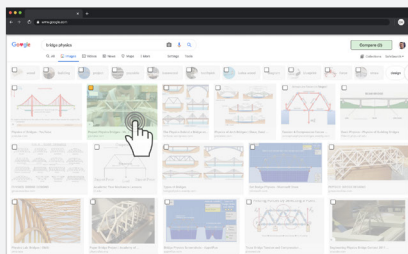
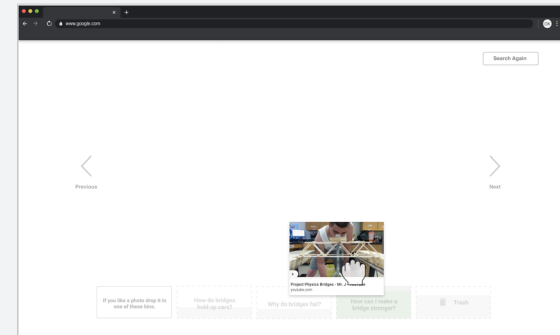
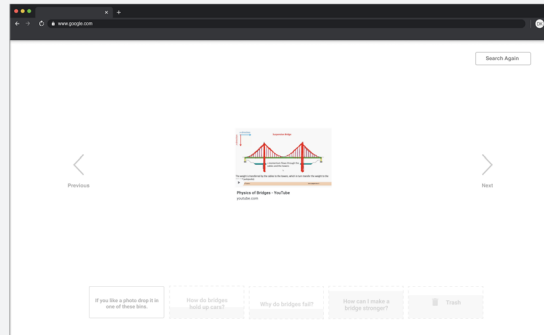
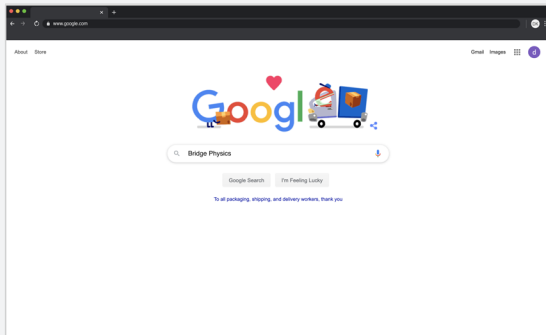
Slideshow Tool to automatically hide visual stimuli from the users.

Figure 27 (On Right Page) (Middle)

Select and Compare Tool to allow a user to choose what stimuli they wish to keep disposing the others.

Figure 28 (On Right Page) (Bottom)

Select and Deselect Tool to allow quick hiding of visual stimuli to assist in the decision making process.



SUBQUESTION 01

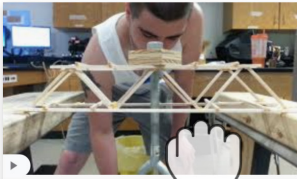
www.google.com

DK

Search Again

Previous

Next



Project Physics Bridges - Mr. J. L. ...
youtube.com

If you like a photo drop it in one of these bins.

How do bridges hold up cars?

Why do bridges fail?

How can I make a bridge stronger?

Trash

SUBQUESTION 01

RESULTS OF THE STUDY

Interactions such as isolation, deletion, inclusion and exclusion can provide the student with the tools that allow them to exert/enact their agency to find and collect assets both outside and inside VR. Controlled by a teacher, bins can be assigned to a project, connecting the beginning stages of PBL with the stages performed in VR. Single interactions, based on the affordances of a browser window, helped limit a user's need to multitask, freeing up cognitive load. Design principles from Mayer and Moreno's cognitive overload framework exposed opportunities to reduce visual loads, however, modality, pretraining, and split attention (spatial contiguity) were not used in this research, providing opportunity for further explorations (Mayer and Moreno, 2003). Regarding assets, explorations focused more on image and text assets however there are many other types of assets that can be imported into VR and are useful for the discovery process of PBL.

Virtual Toolkit

A non-interactive image that provides boundaries to a virtual experience.

How can a **virtual toolkit** assist an unfocused student with ADHD-I throughout a problem?

SUBQUESTION 02

VIRTUAL TOOLKIT

Jason Jerald explains how communication between VR and humans depends on the *harmonious interaction* between the virtual environment and the user (Jerald, 2016). This thesis defines harmonious interaction as the management of visual stimuli and novelty for creative freedom and attention. This definition can be broken up into the following four questions which were explored in this study:

- » How can an interaction limit visual stimuli?
- » How can an interaction limit novelty?
- » How can an interaction promote creative freedom?
- » How can an interaction improve attention?

Inherently, virtual reality can limit external visual stimuli when the headset is placed on the users' head, however, control over visual stimuli, that the user creates, is tied to the tools they have access to. Current virtual creation programs give users a variety of tools and an empty environment for untrammelled creativity. Unstructured freedom like this can cause users with ADHD to experience difficulties when starting a project, making decisions, and keeping their focus when stimuli increase. The application of a structured toolkit can assist users when exploring a problem by providing a starting place, assisting the organization of content, and managing the cognitive load when visual stimuli are added. This study explores how a toolkit can provide a user with enough structure without limiting creativity and maintaining harmonious interaction.

"A mind that is stretched by a new experience can never go back to its old dimensions."

— Oliver Wendell Holmes Jr.

Harmonious Interaction

The management of sensory stimuli and novelty for creative freedom and attention

WHAT ARE THE DEPENDENCIES?

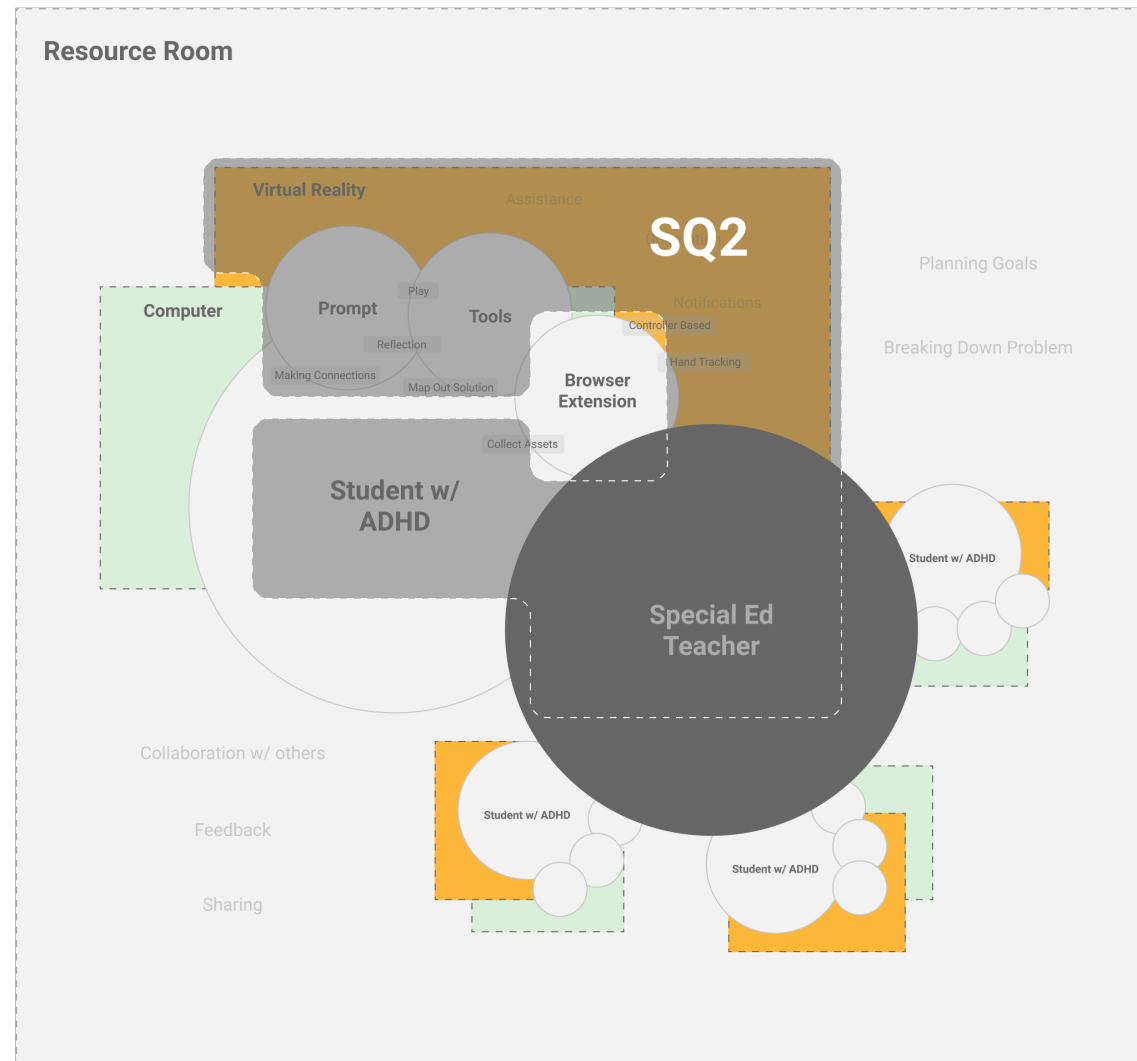


Figure 29 (Right)

Dependencies of a virtual toolkit in the design system.

**Grey sections indicate unexplored work.*

WHAT PARTS OF PBL IS THIS INCORPORATED?

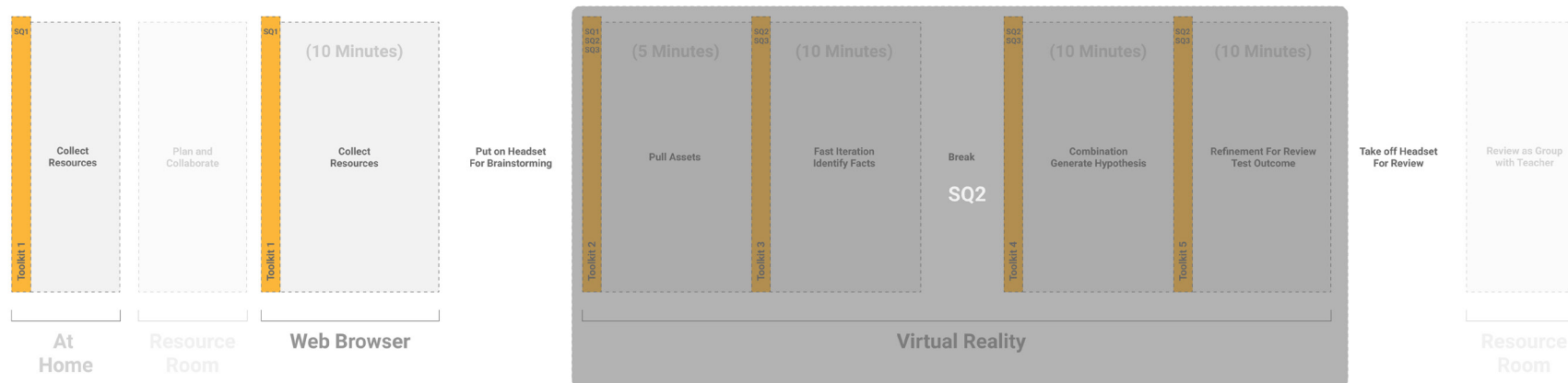


Figure 30 (Above)

Parts of PBL where a user will experience a virtual toolkit.

Pictures of near by bridges	Pictures of successful bridges	Pictures of failed bridges
Drawing The Bridge	Sculpting The Bridge	Notes on Failed Attempts
Test Bridge #1	Test Bridge #2	Test Bridge #3

Pictures of bridges	Drawing Board
Sculpting The Bridge / Notes on Attempts	Tested Bridges

Figure 31 (Above)
Segmenting virtual floor with phases of PBL to limit amount of objects looked at one time.

SUBQUESTION 02

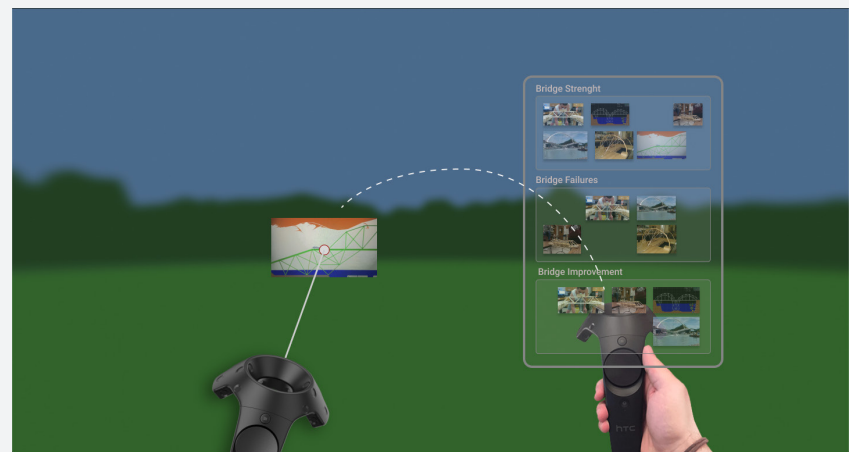
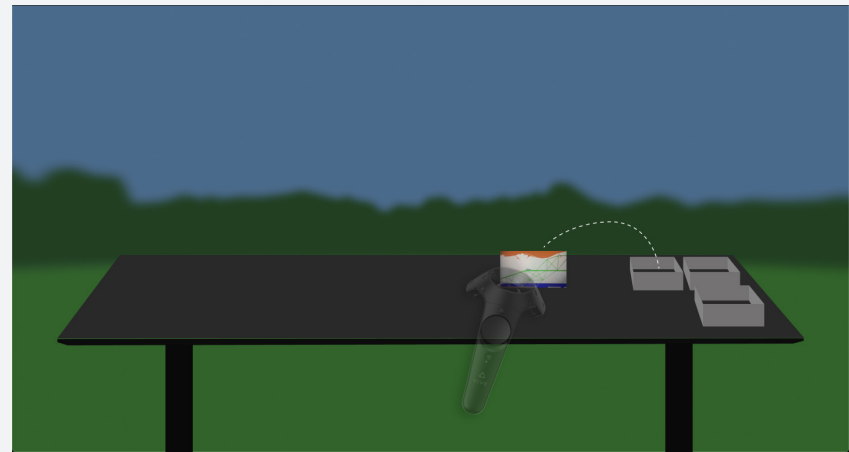
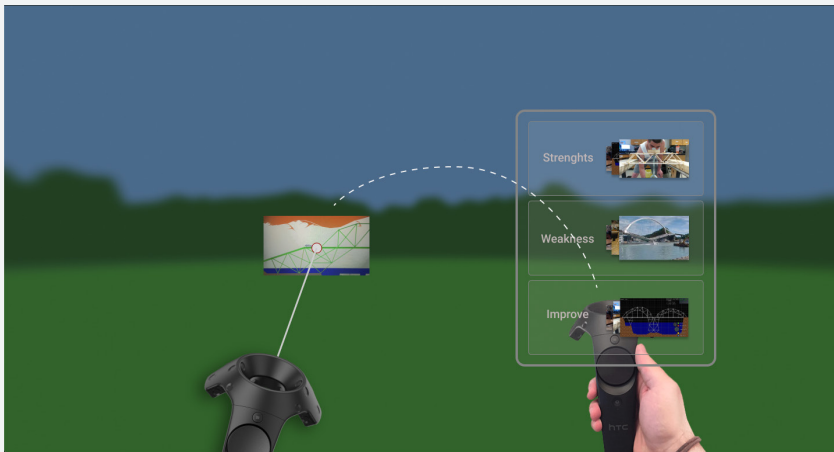
IMPORTING ASSETS INTO VR

When a user first enters the creation space, they can start by bringing collected assets into their scene and organize the content based on the project. A user can access these assets through virtual panels, in virtual bins, or the assets could already be organized in the scene without the user’s interaction. When importing assets, quantity and novelty can affect the experience. Quantity can lead to a heavier cognitive load whereas novelty can place a strain on the users working memory if the assets have not been seen for a longer period of time (Mayer and Moreno, 2003). Allowing a user to select an asset, one at a time, can provide an opportunity to compare multiple images and start making mental connections. If novelty becomes an issue, setting an expiration date for each asset could keep users from seeing old assets. Pulling assets from tactile based virtual bins could provide a user with more agency and give them a connecting experience with a physical classroom. This could decrease anxiety if the program is unfamiliar to the user.

Organization Methods. Organization methods can assist in enhancing or limiting a user’s focus potential. Research shows that students with ADHD have difficulty with executive functions which can limit organizing their ideas and resources during a project (Alloway et al. 2009; Gathercole et al. 2008; Langberg et al. 2008). Langberg explored physical organization using backpacks, binders and lockers and found that ADHD students who were given methods to better their organizational skills showed an increase in organization when the guides were excluded.

Figure 32 (Below)

Methods of importing assets into VR.



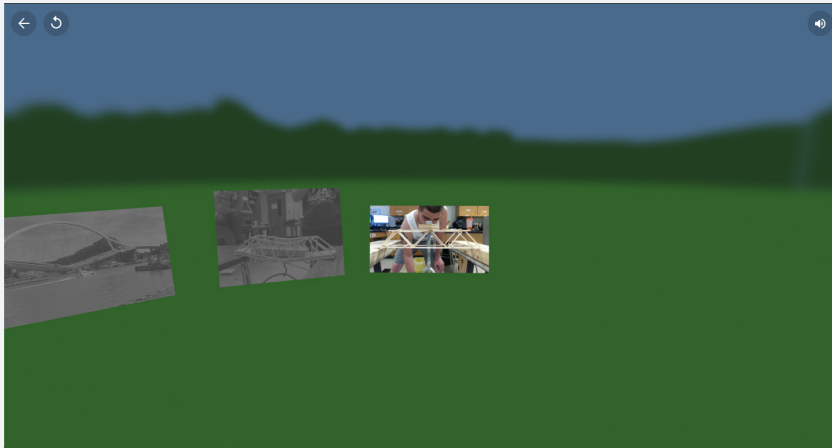


Figure 33 (Above)

Opacity Tool to reduce visual stimuli around focus point.

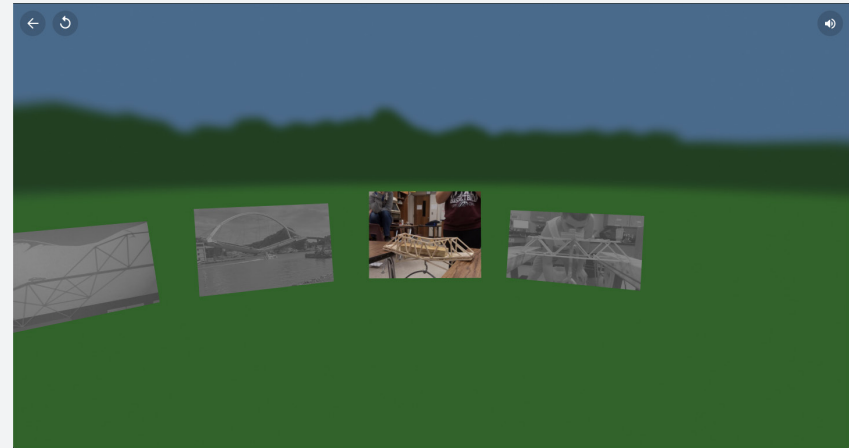
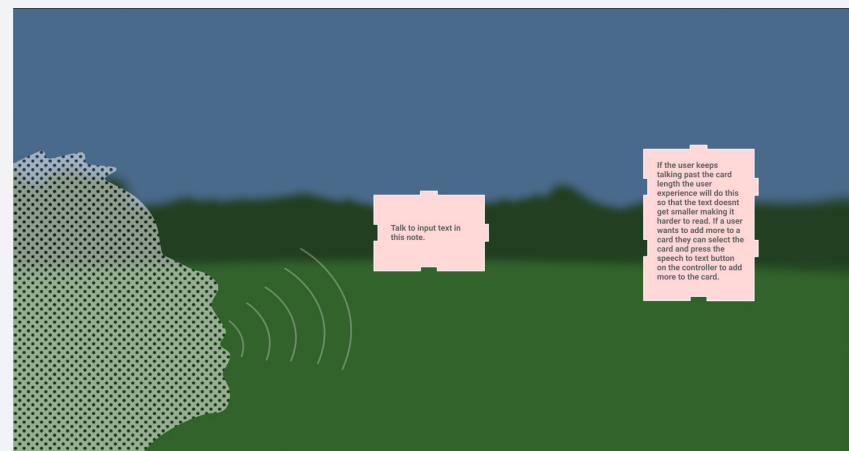


Figure 34 (Right)

Speech Tool to increase legibility of written material within VR.



SUBQUESTION 02

AUTOMATIC INTERACTIONS

When assets are added to the scene, the cognitive load of the user starts to get heavier. Users can experience a lack of control during these moments. The following tools are selected by the teacher and paired to a user depending on the severity of their ADHD. Through feedback from the user, the teacher can change what tools are turned on and off.

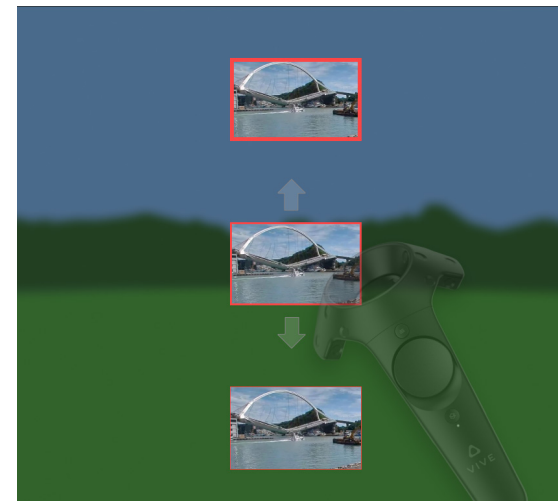
Hierarchy Tool. This tool gives users the control to create a border around an asset or a part in the kit of parts. When they grab an object, they can press a button on the controller to turn on the border tool. While still holding the object, the user can raise or lower the object in the air to adjust the size of the border to increase or decrease hierarchy of the asset (Figure 35).

Opacity Tool. VR has the functionality to track users' eyes and head movement. This can open up a wide range of possibilities to control what users see and don't see in their peripherals allowing for the focus to stay on the desired object. This tool changes the opacity of everything outside of the user's focus (Figure 33).

Speech to Text Tool. Writing in air can be challenging for a user who struggles with dexterity. From experience, virtual writing can often lead to legibility issues and takes more time than speaking out loud. To alleviate frustrations, this thesis explores speech to text when writing on a component in the kit of parts. Once a user selects a component, they can press a button and talk out loud for dictation (Figure 34).

Figure 35 (Below)

Hierarchy Tool to allow a user to change how distracting a visual stimuli is to being awareness to importance. This tool could be too novel, leading to frustration or distraction.



SUBQUESTION 02

KIT OF PARTS

A kit of parts is composed of pre-made components that live within a virtual reality scene. In the engineering field, a kit of parts should be modular (ability to replace), extensive (ability to reuse), scalable (ability to connect), and reconfigurable (ability to move). They are introduced to the user once they enter VR and provide a starting place to explore the problem. The components that were selected for this exploration are simple shapes like cubes and flat planes to limit both the load on the program and the complexity of the scene, resulting in a reduction in a user's cognitive load. With simple shapes, users can build up complexity at their own pace and keep assets organized.

Thought Block. When a user starts the process of connecting different assets to form ideas, they can use a thought block to place assets in a linear sequence to form a thought (Figure 36). They can add assets by dropping an image on the plus icon, placing it at the end of the sequence. When a user is done with a particular thought, they can easily turn the block one quarter turn and start again until all four sides are filled. Sequencing assets can help users stay focused on one thought and limit distractions by positioning other assets away from the user's field of view.

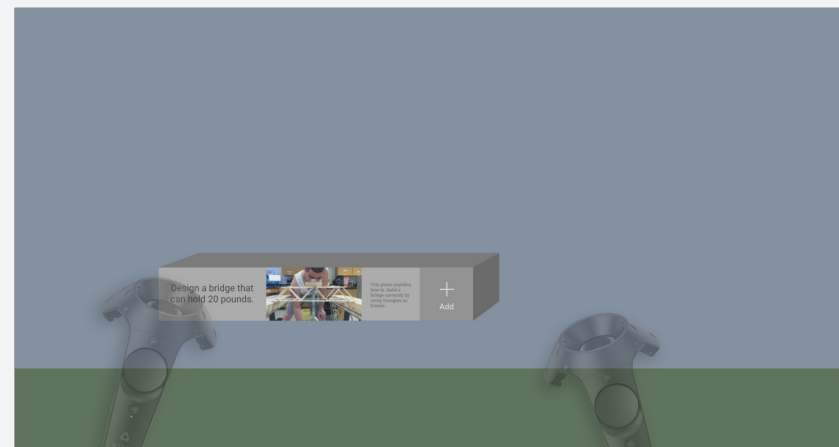
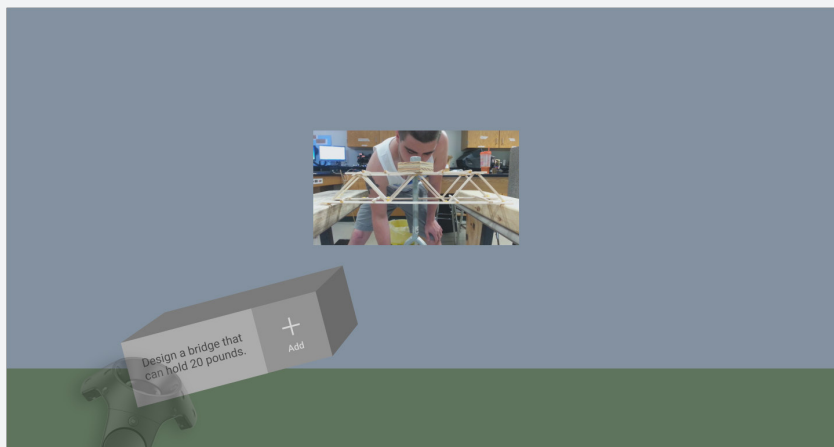


Figure 36 (Above)
 Thought block to combine ideas in the form of images and text as a linear string of thoughts.

Modular Thought Block. Unlike the thought block, these components are separated into individual containers that can house visual assets, or text. Each component can link to one another forming a box that can be stacked on one another. The inspiration for this design comes from puzzles, an activity that some 5th graders can be familiar with. The puzzle piece shaped component can provide the user with functionality without being so novel that it distracts from the rest of the scene (Figure 37).

Framing Tool. After a user is nearing completion of a problem, assets can build up in the scene, exposing opportunities for distraction. This tool can be used as a way to bring awareness to a section of the problem or as a way to block out visual stimuli. Once the frame is set into position, a user can peer into the frame and view the smaller portion of content (Figure 38). On the front face of the frame a user can place images or add text using the text to speech tool.

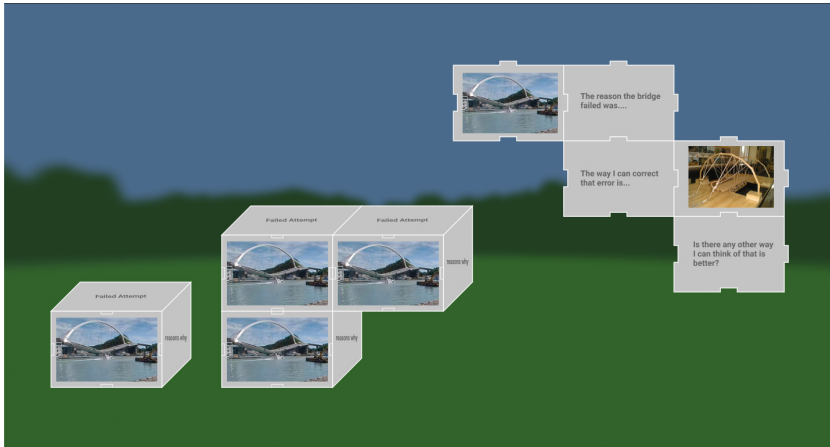
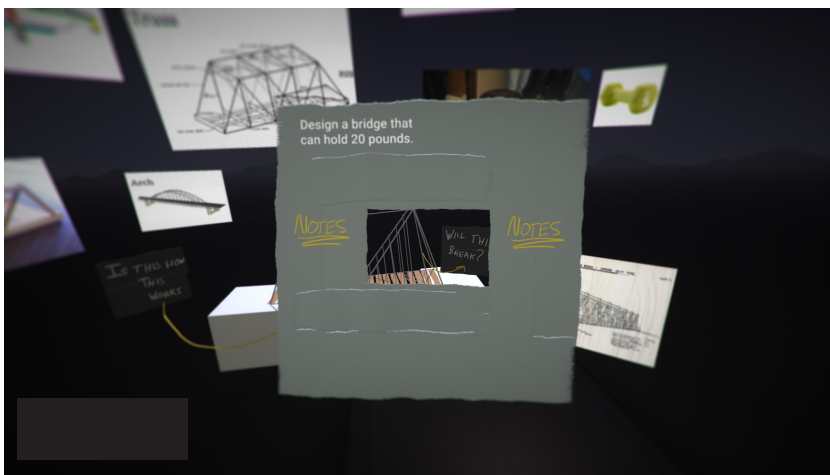


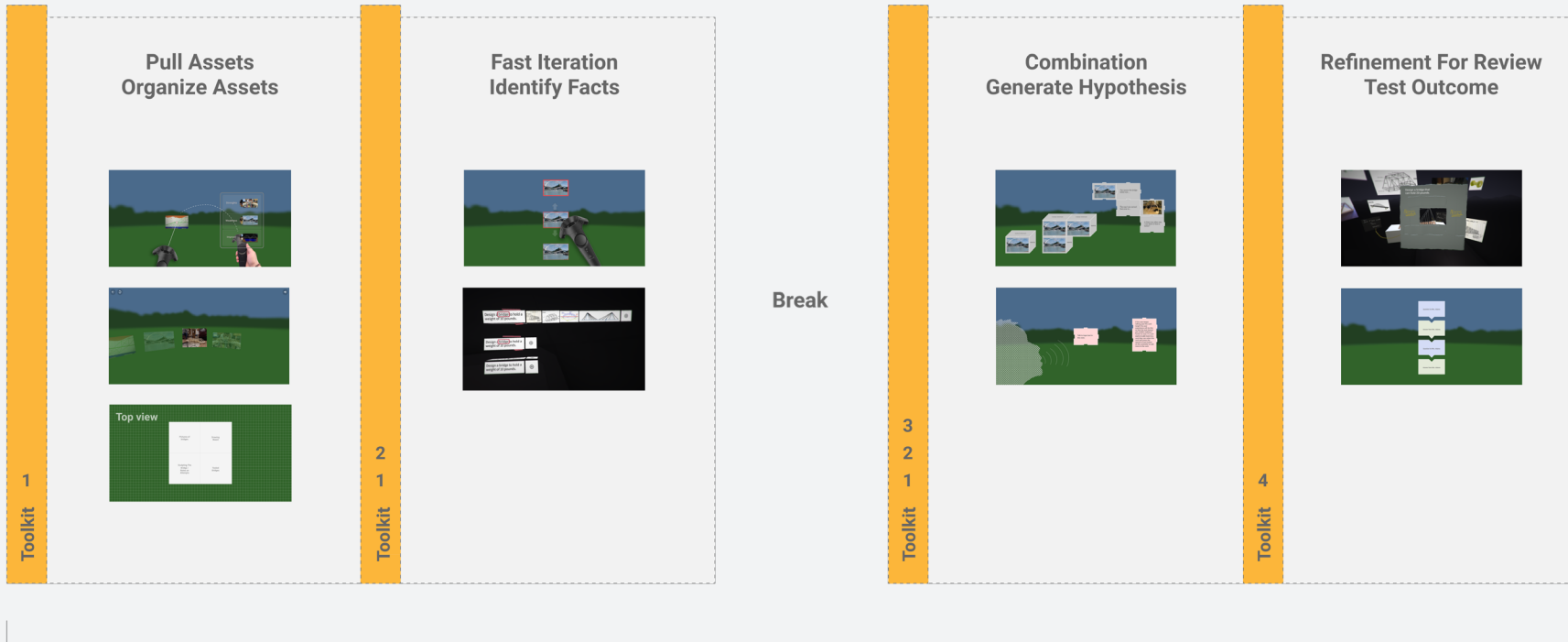
Figure 37 (Left)

Modular Thought Block to connect single ideas into a complex form. Visualized as puzzle pieces.

Figure 38 (Below)

Frame Tool to block out stimuli and act as a note taking device..





Virtual Reality

SUBQUESTION 02

RESULTS OF THE STUDY

Designing within the same medium that a persona interacts with can help a designer understand the user and the problems they might face. Beginning stages in this exploration involved the iteration of possible tools using Google's Tilt Brush. Exposing limitations within the program helped understand possible pain points of the user and the creation of these tools. Along with research, designers should make a point to use the medium they are designing for to understand the problem space further.

This exploration centered around a toolkit, composed of a kit of parts and part interactions. The kit of parts consisted of modular components that can guide users through the PBL process (Figure 39). When a user interacts with a particular part, options to block out visual stimuli or increase the importance of an asset were made available. The design of this toolkit was focused to avoid novel experience and leverage interactions that 5th graders are used to, speeding up the onboarding process. Time estimations of user onboarding depends on the teacher's familiarity with VR and the quality of an onboarding tutorial that was not explored in this thesis. Due to the familiar interactions and limited number of tools provided, an assumption is that onboarding would take less time than Tiltbrush.

Figure 39 (On Left Page)

Kit of parts within the problem based learning process.

Virtual Reality Background

A non-interactive image that provides boundaries to a virtual experience.

How can the design of a **virtual reality background** assist a student who has attention fatigue?

SUBQUESTION 03

VIRTUAL BACKGROUNDS

Within a VR environment, non-interactive elements like the background or sky can take up considerable room in your field of view, potentially impacting concentration and attention. Research has determined that contrast between important and unimportant objects are pivotal to the attention span of someone who has ADHD-I (Kim, Chen, and Tannock 2013). A study by Zeynep Oktem explored the change of attention level in a classroom if the white board was framed by a red wall (Öktem, 2019). The findings uncovered that students with ADHD-I made far less errors when the wall was a different color than the board. Although the study was only tested with the color red, other research has explored color and its relationship to ADHD-I (Lee, 2014; Zentall, 1985). A study by Dr. Lee in 2014 discovered that students' attention improved when looking at a grass covered surface rather than a gray covered surface (Lee, 2014). The conclusion to this study indicated colors with low wavelengths like blue and green are good for concentration and attention restoration (Lee, 2014). Conversely, other research indicates that colors at the bottom of the spectrum, like unsaturated blue, can be harmful to eyes due to wavelength penetration in the sensitive parts of the retina (Zhao, 2018). This project explores how the background of a scene can affect a student's concentration level while remaining safe to the user's vision and how it can be incorporated as a tool to assist the user when they lose focus.

Similar to the tools in the browser window, these nuances can be selected and adjusted by the teacher before and during class. Over time, the teacher can find the right combination to decrease attention limitations.

WHAT ARE THE DEPENDENCIES?

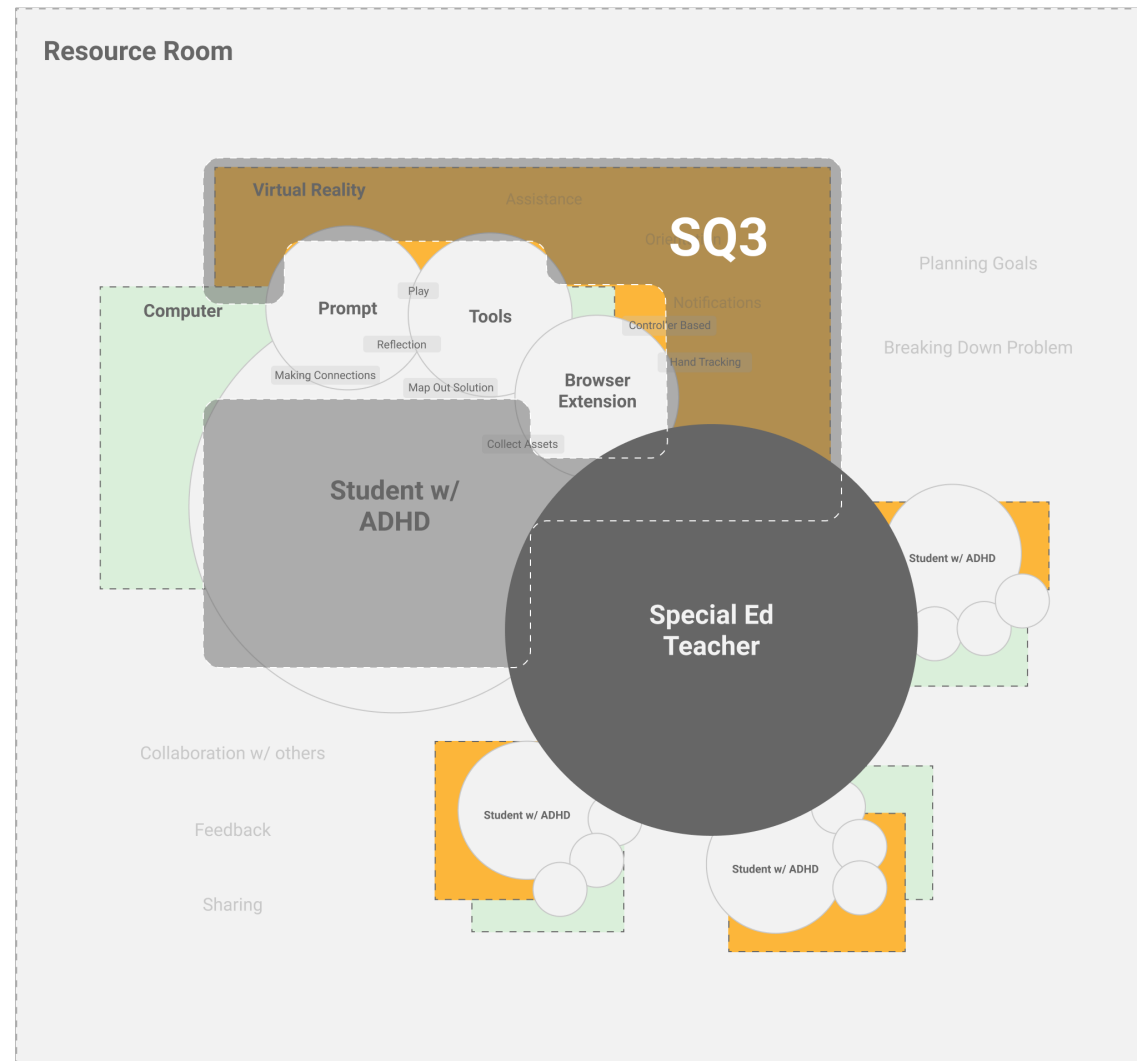


Figure 40 (Right)

Dependencies of a virtual reality background in the design system.

**Grey sections indicate unexplored work.*

WHAT PARTS OF PBL IS THIS INCORPORATED?

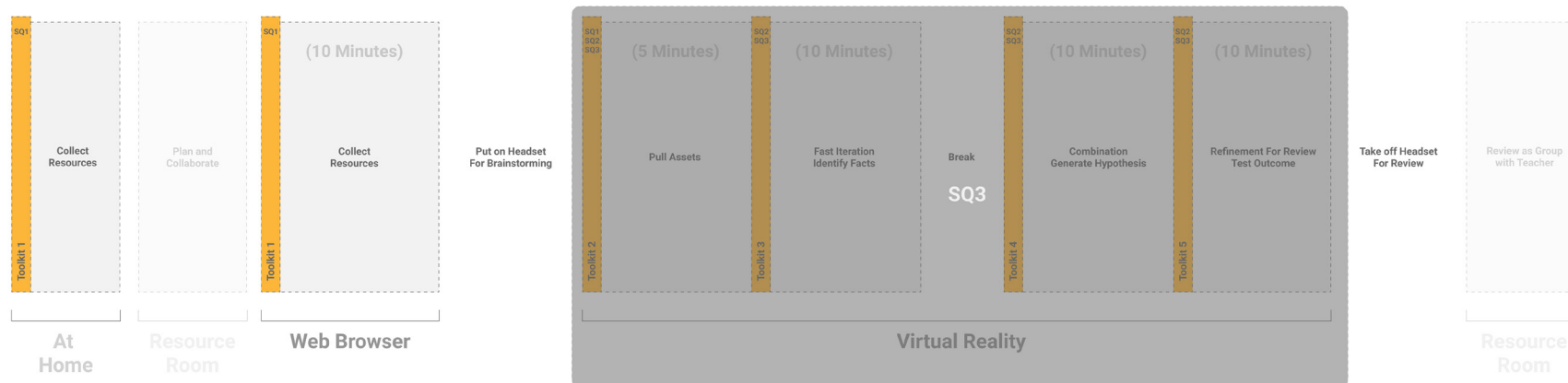


Figure 41 (Above)

Parts of PBL where a user will experience a virtual reality background.

SUBQUESTION 03

TYPES OF BACKGROUNDS

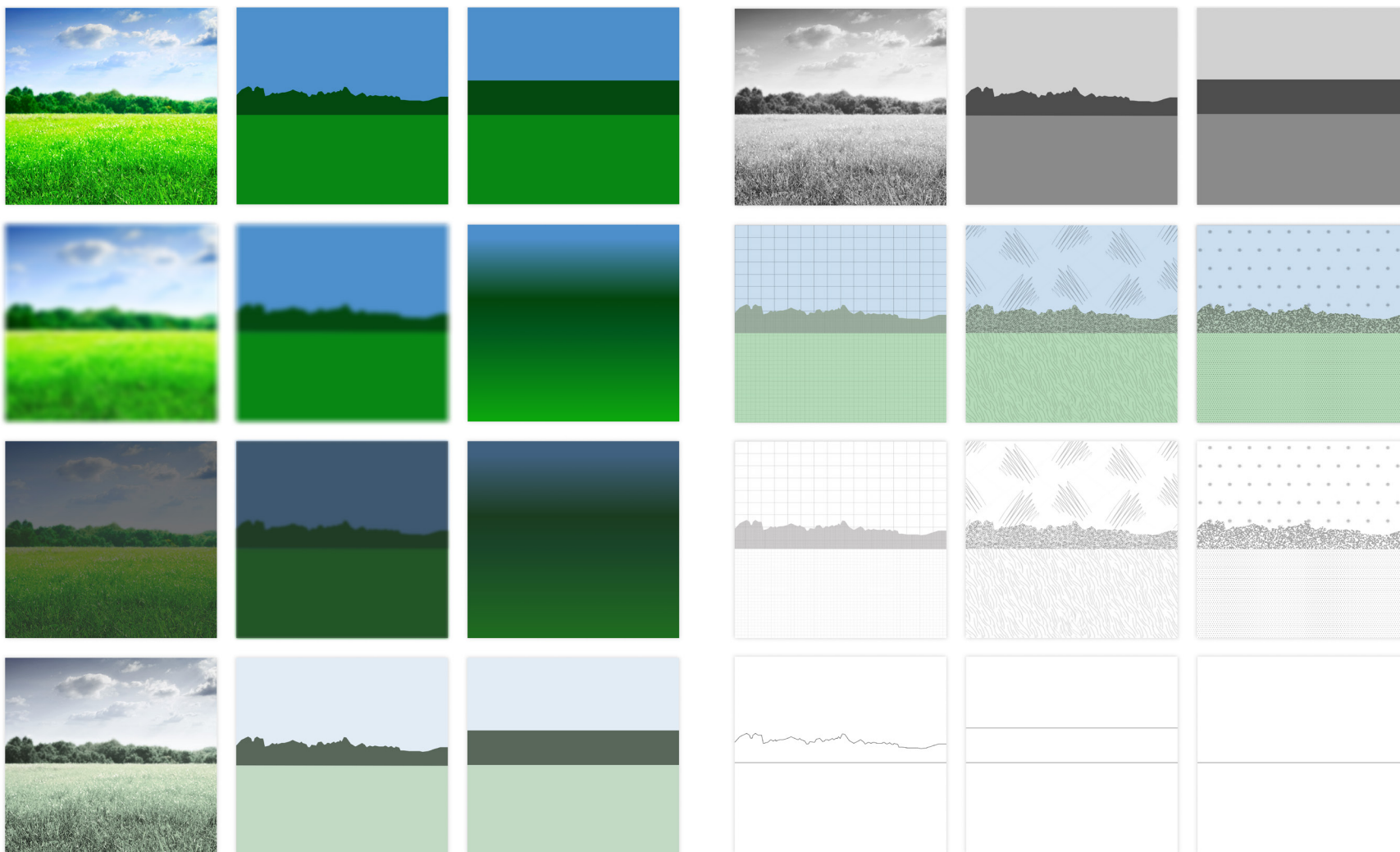
To create structure in this exploration I created visuals based on context and intensity. Context was driven by Scott McCloud's triangle of representation, creating a range of high contextual content (concrete) to low contextual content (abstract) visuals (McCloud, 1993). Intensity was driven by color, saturation, and visual texture (Zentall, 1985).

VR Backgrounds as a Tool. In the beginning of this exploration I questioned how these backgrounds could be used. Are they static? Do they change automatically over time? Do they change appearance based on each phase of PBL? Are they controlled by the student or the teacher?

Static Backgrounds. This thesis explored how the background can be impacted by context and intensity (Figure 42). Leveraging the study by Kate Lee, the primary visual used is a grass field to be viewed when a user's attention is fatigued but also a visual that is not distracting. When the visual was placed into A-Frame, a virtual reality builder, the visual was calming however the texture and brightness of the visual became distracting to the task at hand. Visuals that range from concrete to abstract, giving the user a presence of a field and sky without the distracting elements like grass texture or clouds could be a solution to assist attention fatigue and limit distractions. Textures, gradients, lines, and solid blocks of color can resemble identifying features of an image yet limit the distractions that can be created by complex scenes.

Figure 42 (On Right Page)

Static backgrounds ranging from abstract to concrete.





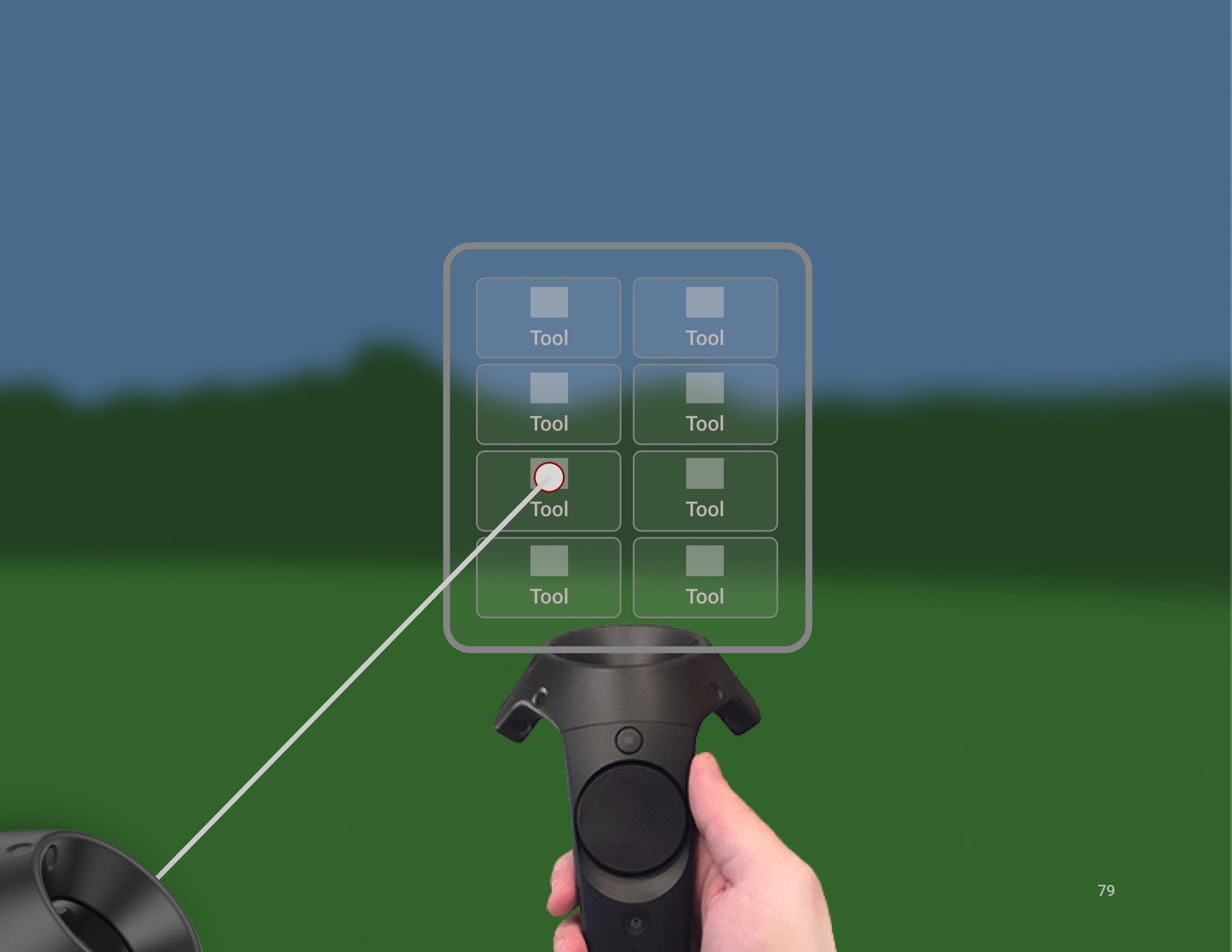




Figure 43 (Right)
Animated VR backgrounds

Throughout Session

Animated Backgrounds. This investigation explored how the background can subtly change based on time left in a session, attention level of a student, or topic that is being explored (Figure 43). Throughout the session, colors can shift from unsaturated when the user has high attention to saturated when the attention level is lower, needing attention restoration. The same interaction can be applied to context. In addition, color can increase urgency if a session is coming to an end.

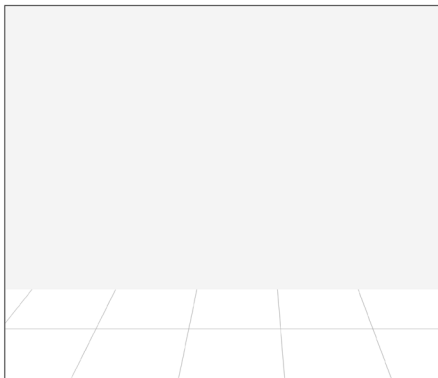
SUBQUESTION 03

TEACHER STUDENT INTERACTION

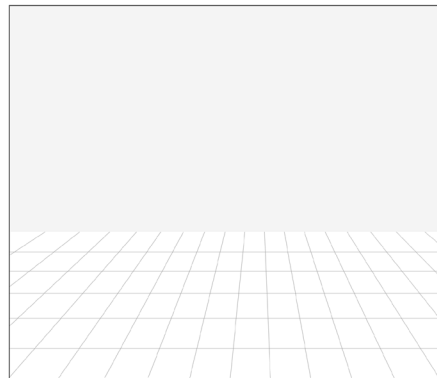
VR backgrounds can be used as a tool by the teacher to let students know when it is time to reflect on the current project or by the user in an active and/or passive manner. Relying on their peripherals, students can view the background while focusing on their work or when their attention fatigues, they can go into a state of reflection by hiding their work, viewing only the background. These interactions can be controlled by the teacher with the use of an external monitor, providing the ability to observe a student in VR and change the background based on an attention assessment. Along with the ability to change the context and intensity level of a background, the teacher can limit the visual distance of the background depending on what phase of PBL the student is working in (Figure 44). For instance, if a student is creating ideas rapidly, they could experience a background that shortens the perceptual distance of their creation space to promote quicker making. If a student is in the refinement stage of PBL, they could experience a larger perceptual distance so they can focus without pressure.

Figure 44 (On Right Page)

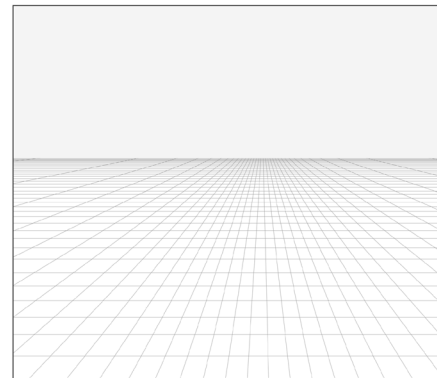
Changing perceptual distance for a VR background to change users perception of workable space.



Fast Iteration



Exploration & Research



Final Solution

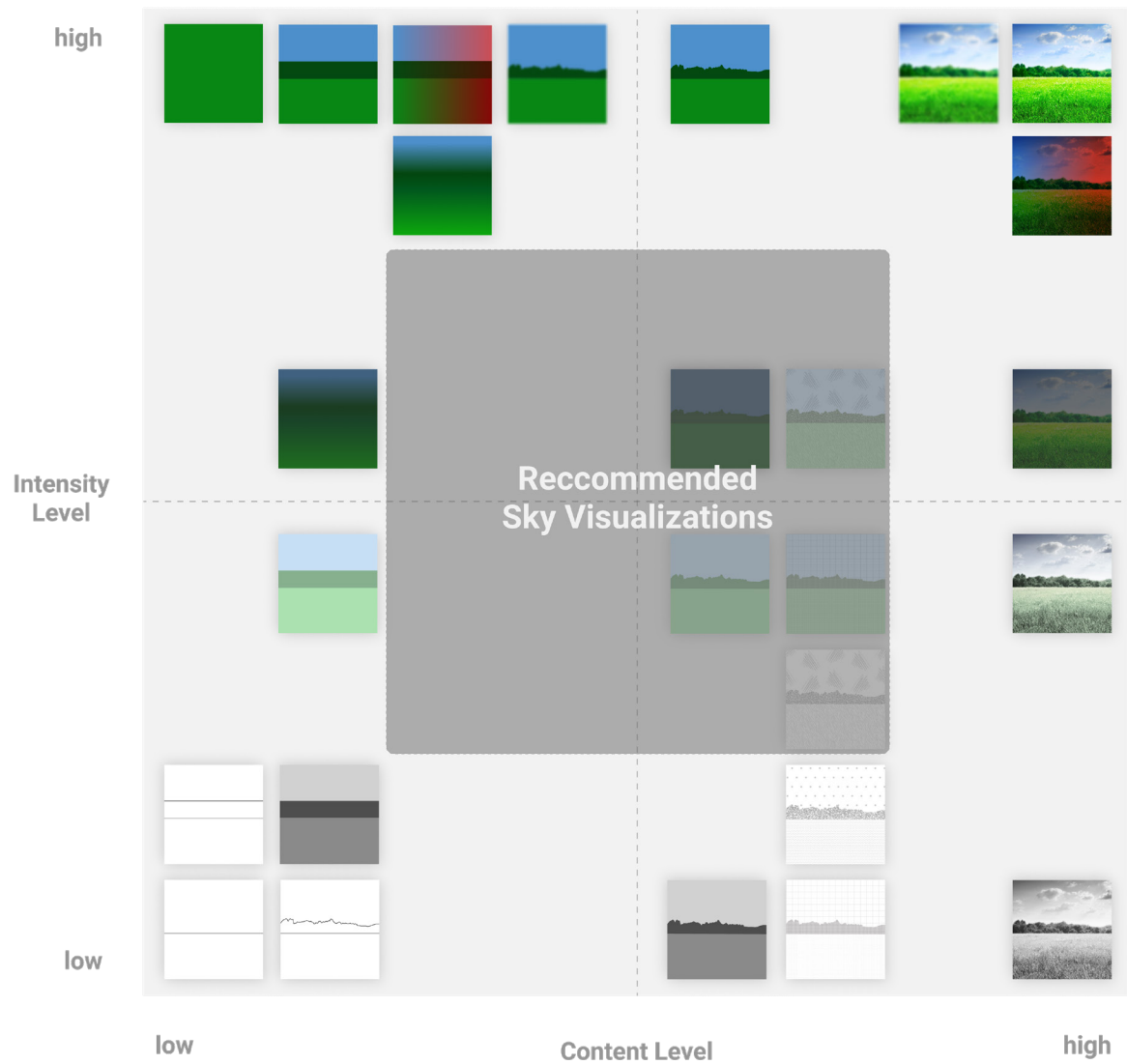


Figure 45 (Right)
*Grid of backgrounds on a scale of
 context to intensity.*

SUBQUESTION 03

RESULTS OF STUDY

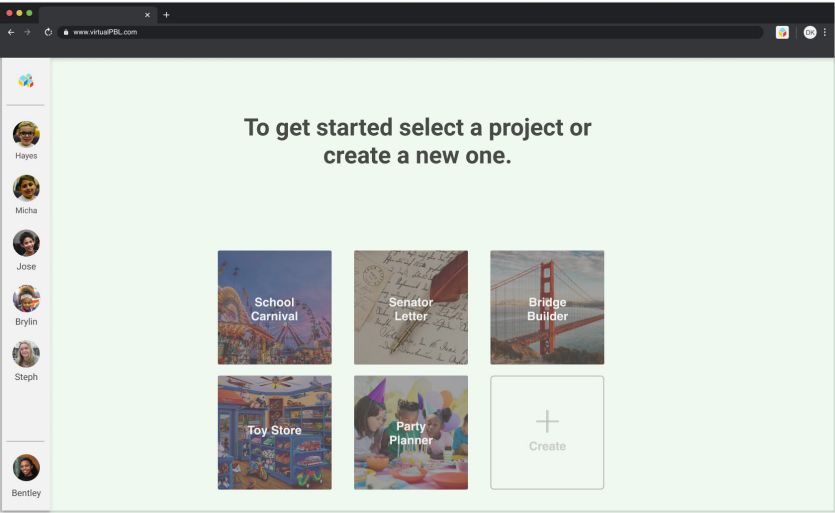
The results of this study (Figure 45), were represented on a grid that organized backgrounds based on their content and intensity level. Observation noted that as the intensity or contrast increased, approaching realism, the background started to distract from the task at hand. On the other hand, as the context approaches abstract the benefits from the context become ineffective. In addition, in a recent survey from students with ADHD-I Kim, Chen and Tannock discovered that bright light can deter their focus from the task at hand (Kim, Chen, and Tannock 2013). As a result, a possible starting place for testing could be the center of this grid. In regard to intensity, the saturated backgrounds could be perceived as non-distracting however they can hold their color for context. For context, the semi-abstract backgrounds could be perceived as non-distracting however the context is real enough to maintain the benefits of attention restoration. Although this is not the limit as to what can be visualized, the results provide a framework that can be applied to other elements in the scene, such as 3D models and other experiences, that require attention-based tasks.

SCENARIO

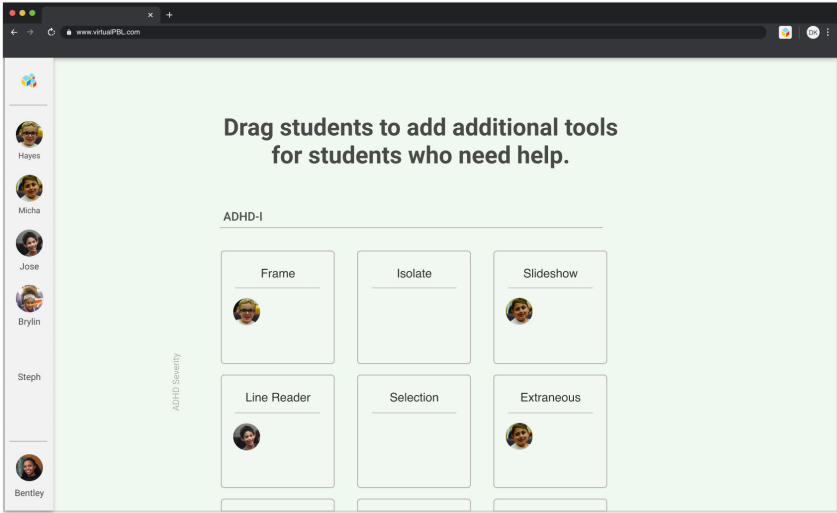
THE SCENARIO

This scenario maps out the journeys of each personas, Jose, Hayes, and Micha. The level of ADHD-I increases in each scenario and different pain points are addressed with the implementation of this system. Some scenarios require the assistance of the teacher Mrs. Adams to help the student through the problem.

THE SETUP AND ASSIGNING OF TOOLS



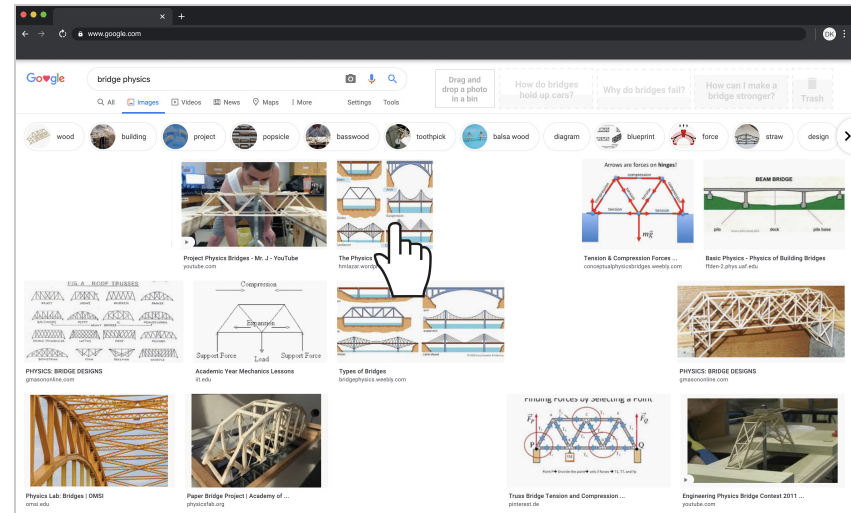
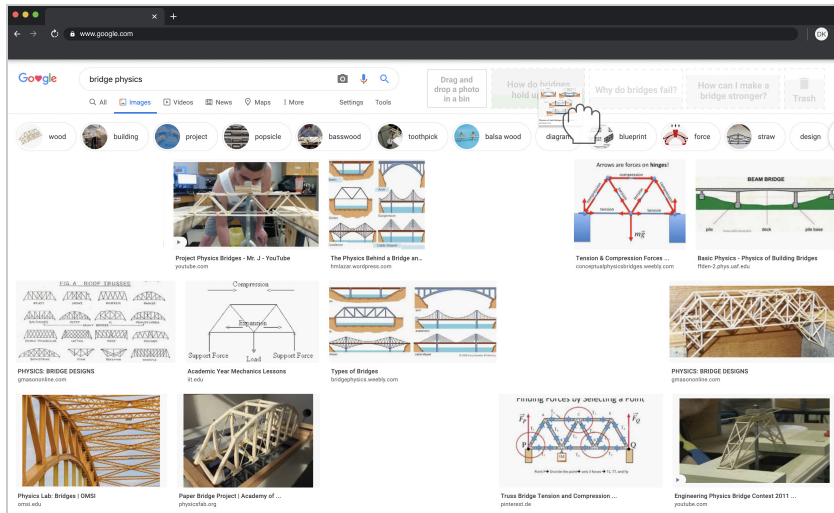
Jacob, the primary teacher and Bentley, the special education teacher have been using Virtual PBL for a couple of years and now the children have been responding well to it. It is now the first day of school and they have to choose a project to teach.



The teachers receive their new class and were notified that there were four students who have special needs. Bentley discovers that Hayes experiences attention fatigue with large amounts of pictures, Micha has severe attention limitations, and Jose has difficulties focusing during reading. Bentley assigns additional tools for the four students and starts the class.

A student can only be assigned to one tool in each row allowing the ability to assign multiple tools to an individual user depending on their needs.

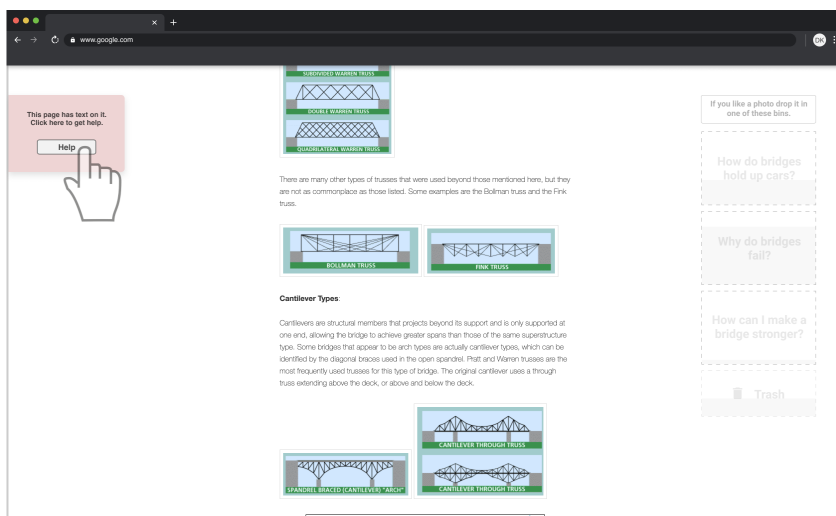
JOSE COLLECTING ASSETS



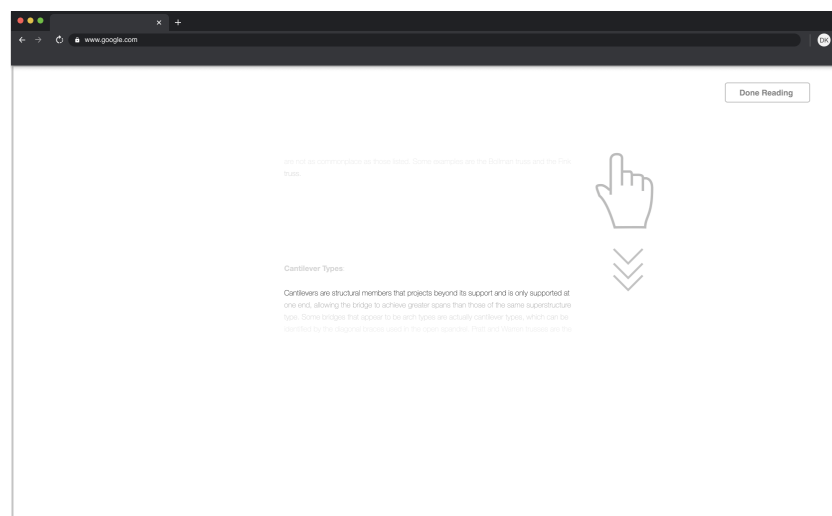
Jose goes into the resource room awaiting to be instructed by Mrs. Adams. She gives the instructions for this week's problem and Jose goes to his computer to get to work.

Jose google searches bridges and starts by deleting some images he doesn't have interest in and saving some images for later.

He sees a photo that he wants to learn more about. Jose clicks on the image.

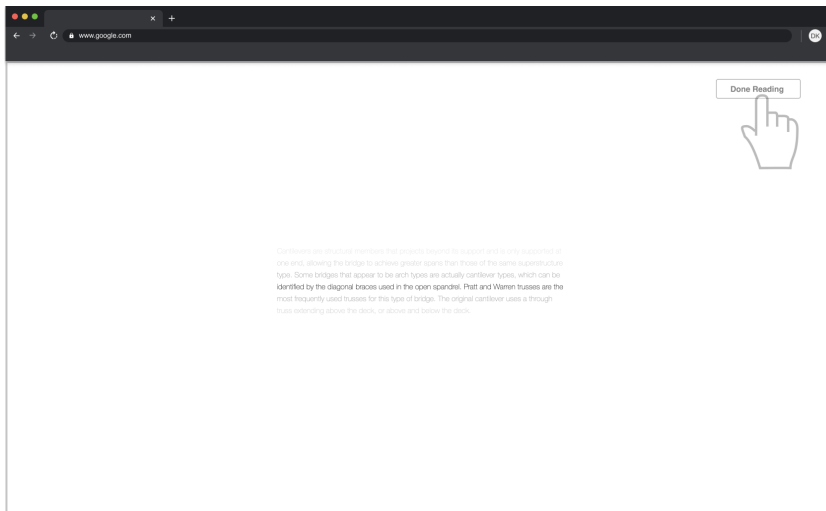


Jose reaches a page that has text on it and Virtual PBL sends him a notification to use the line reader tool. Jose attempts reading to no avail, so he decides to get assistance and clicks the help button.

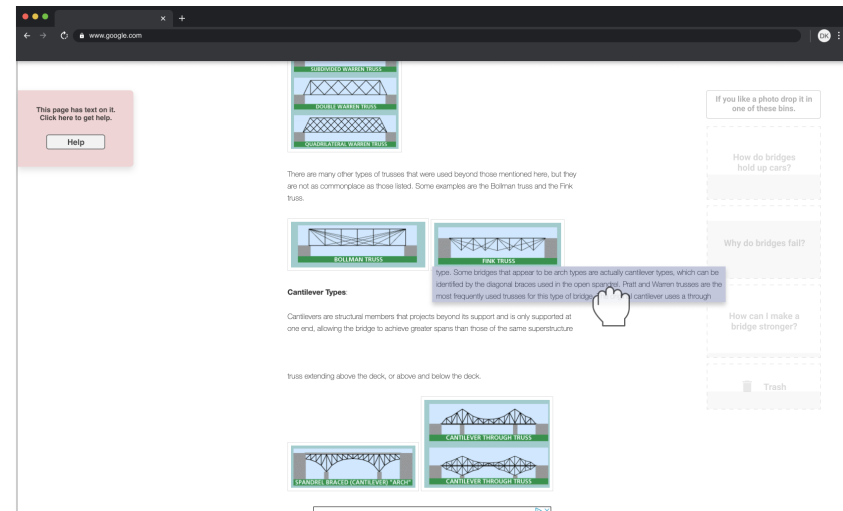


Jose uses the scroll bar on his computer to move to each line.

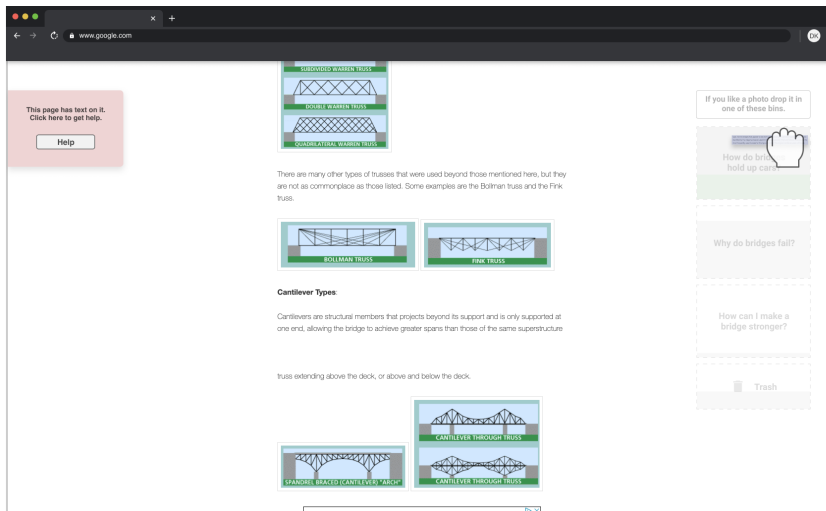
JOSE COLLECTING ASSETS (CONT.)



Jose sees a line that is useful to his project, so he decides to end reading.



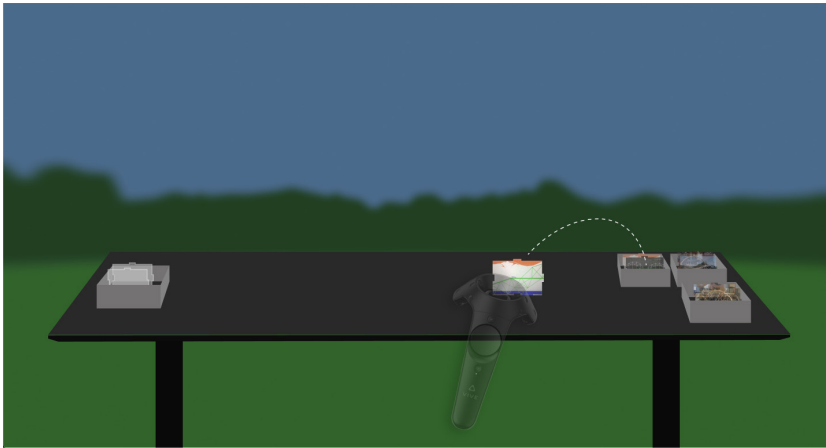
Jose arrives back to the default view with the last line and two surrounding lines highlighted. (two surrounding lines gives Jose context later) Jose drags the highlighted text to its corresponding virtual bin.



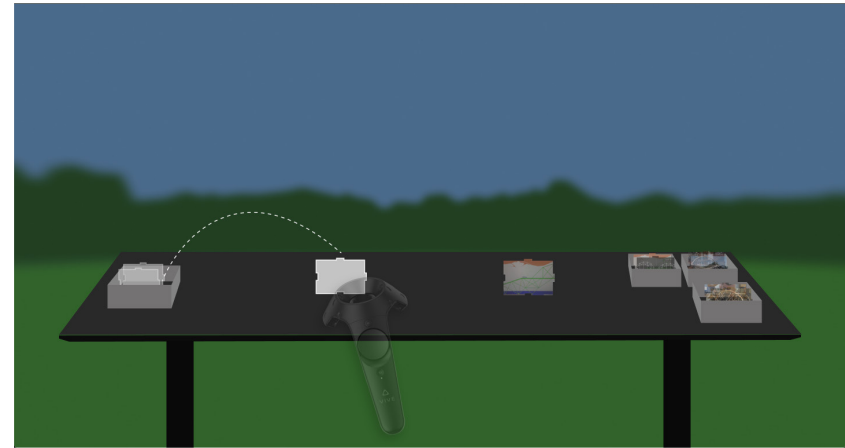
Jose drops the text in the bin to use later in the problem-based learning process.

Jose collects all of his resources and picks up his VR headset.

JOSE PULLING ASSETS AND MAKING CONNECTIONS



Jose enters his virtual environment and sees a table with storage bins. He sees that each bin represents the bins he had on his web browser. Jose takes a picture out of the bin and places it on the table.



On the other side of the table Jose sees a bin that contains blank cards. He takes one out and notices that the other picture changes opacity.

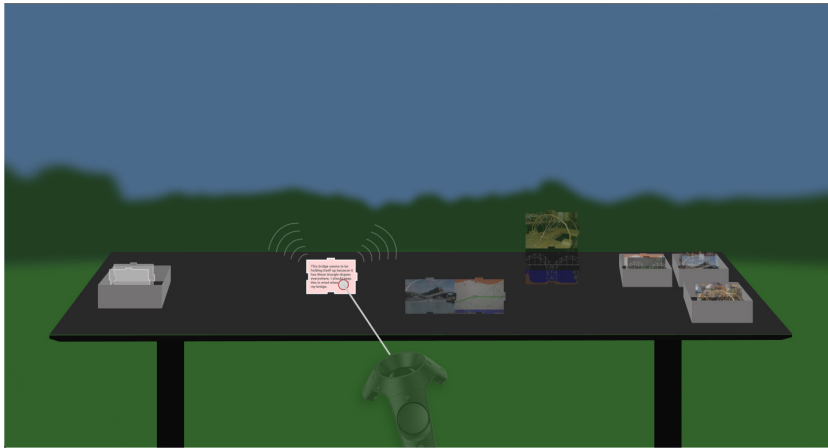


Jose decides to activate the speech to text tool while holding the blank card and starts talking out his idea. Jose is happy that he doesn't have to write the idea down physically.



Jose places the card down and continues pulling out cards and makes a couple connections. Jose noticed that when he connected two images together, they both are now the same opacity. Once he goes to a different asset the opacity for both assets become diminished again.

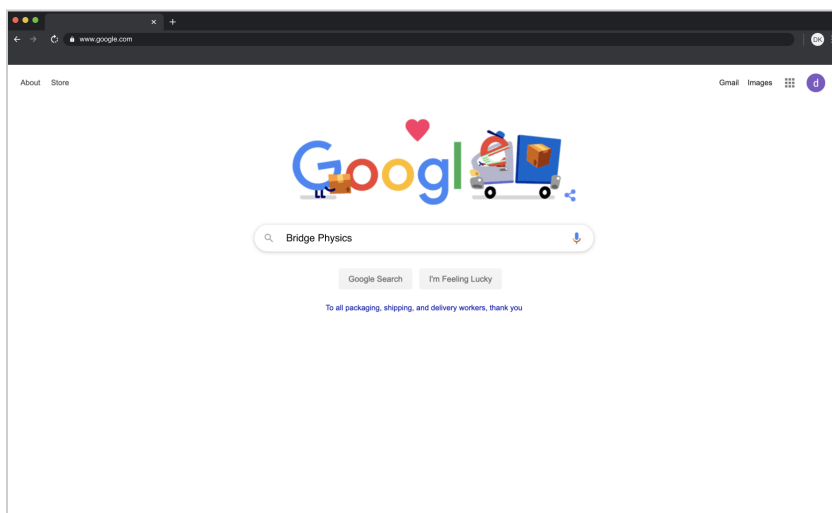
JOSE PULLING ASSETS AND MAKING CONNECTIONS (CONT.)



Jose forgot what he had said on the card that he placed down before so he pointed at the card and pressed the speech to text button. A voice started reading what was written on the card.

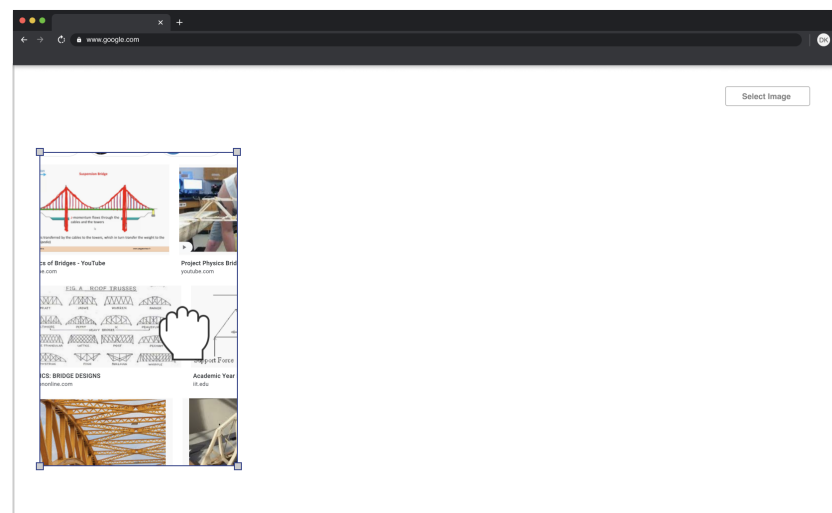
Jose continues making connections and it is now time for the class to take a break.

HAYES COLLECTING ASSETS



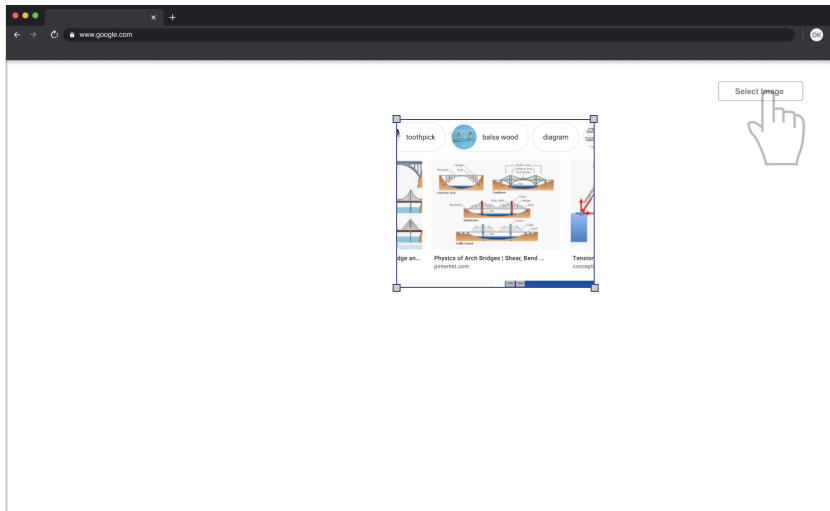
Hayes goes into the resource room awaiting to be instructed by Mrs. Adams. She gives the instructions for this week's problem and Hayes goes to his computer to get to work.

Hayes google searches bridges.

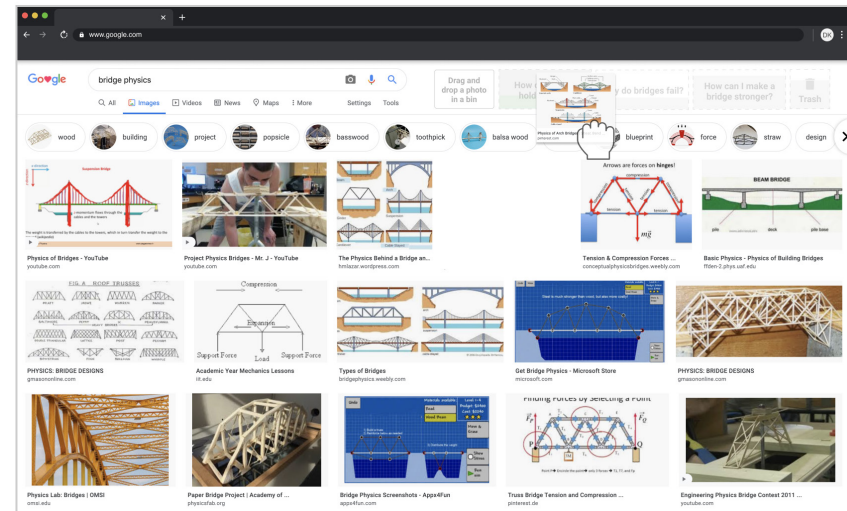


Instead of going to a view of all images Virtual PBL starts Hayes with a frame that he can make smaller or bigger to see fewer or more assets.

HAYES COLLECTING ASSETS (CONT.)

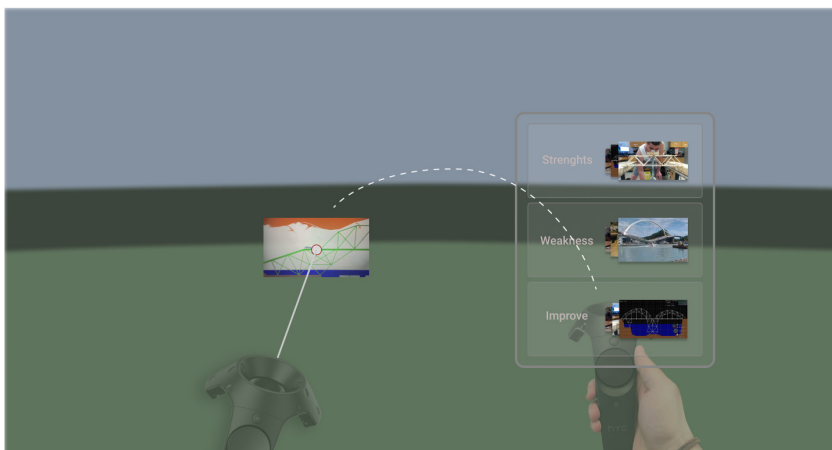


Hayes identifies an image that is useful to his project and clicks select image to drop it into a bin.

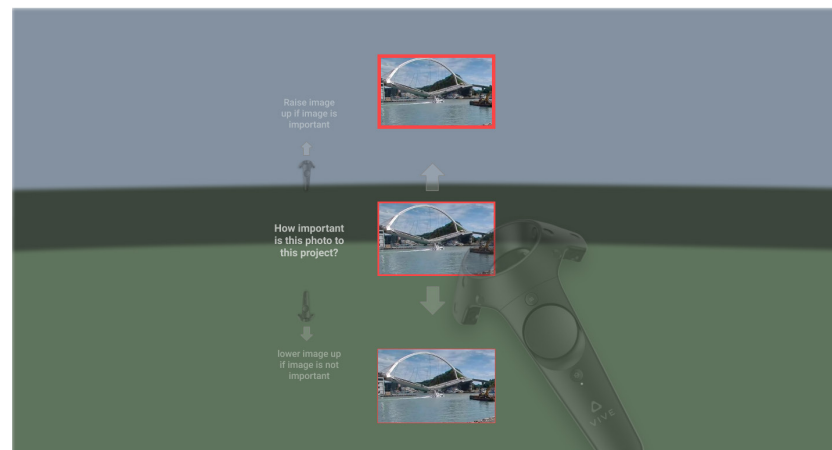


Hayes identifies an image that is useful to his project and clicks select image to drop it into a bin.

HAYES PULLING ASSETS AND MAKING CONNECTIONS

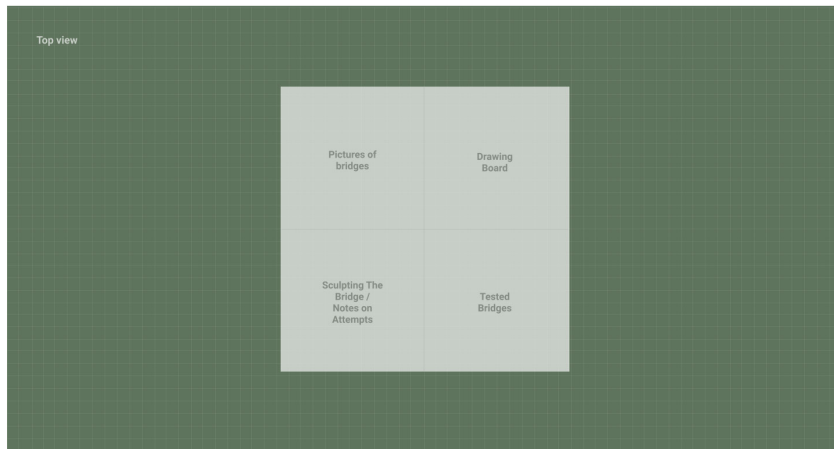


Hayes enters his virtual environment and has access to a virtual panel with three types of assets to choose from. He selects one and holds the image in his hand.



Hayes presses the border button on his controller and a border appears. The Image prompts Hayes, asking what level of importance is this image? He sees this image as highly important, so he lifts the image up increasing the border.

HAYES PULLING ASSETS AND MAKING CONNECTIONS (CONT.)

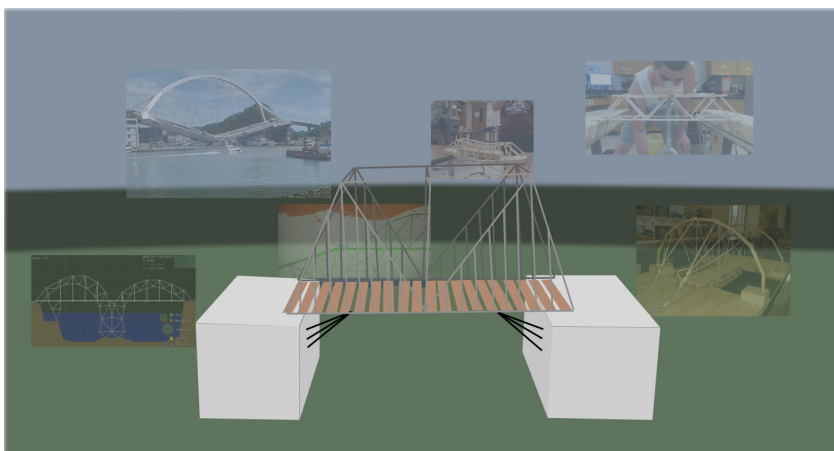


Hayes looks down at the floor and notices that there is an area designated for pictures of bridges. He places the image in that quadrant. Hayes continues pulling assets into his scene and starts making connections.



Hayes's scene is beginning to become very complex however Hayes is still able to see what assets were more important than others and continues making connections until break.

MRS. ADAMS FOCUSING HAYES



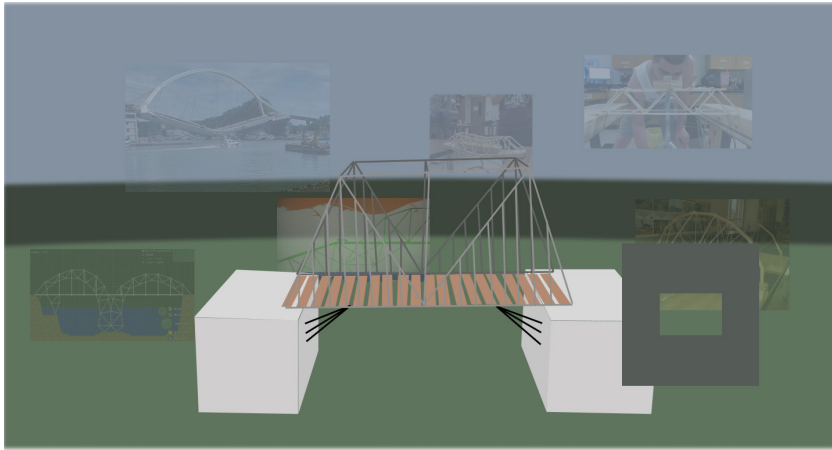
Hayes is doing great on his bridge however because of the visual stimuli he is starting to lose focus. Hayes notices a problem with his bridge but can't seem to make progress because of the distractions.

Hayes sits in VR for a few minutes and Mrs. Adams intervenes.

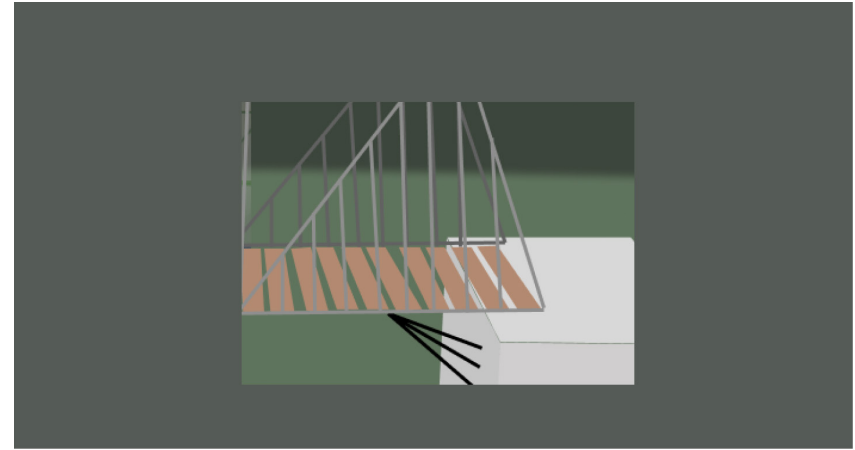


Mrs. Adams starts by giving Hayes some time to reflect on his project, internally, without seeing any visual stimuli.

Hayes spends a couple minutes and is ready to return back to his creation scene.

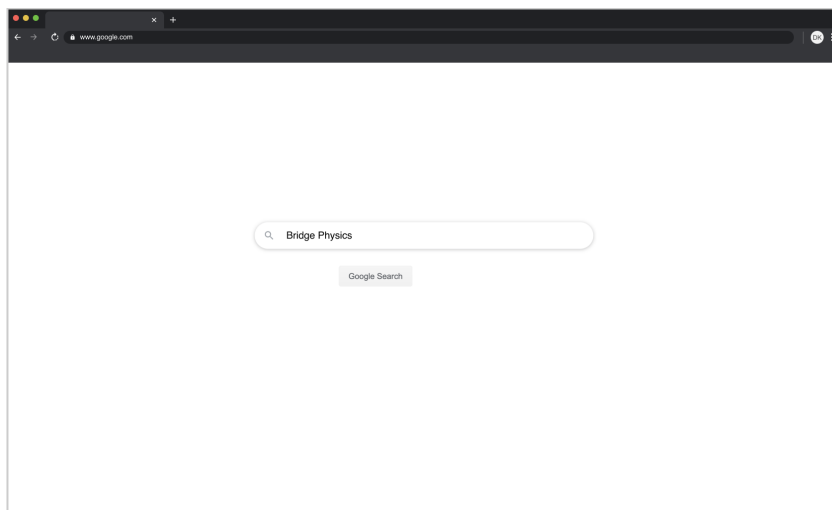
MRS. ADAMS FOCUSING HAYES (CONT.)

To help Hayes, Mrs. Adams adjusts his scene settings, lowering the opacity of his images, and activates the framing tool to help him focus on his scene.



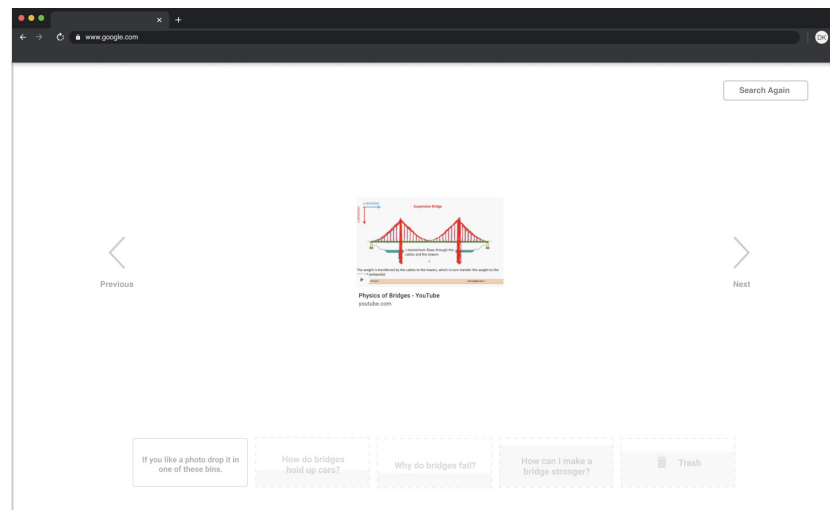
Hayes picks up the frame tool and looks through it at his bridge and notices an issue with one of the supports. Hayes fixes the problem and continues to work on his bridge with the frame tool.

MICHA COLLECTING ASSETS



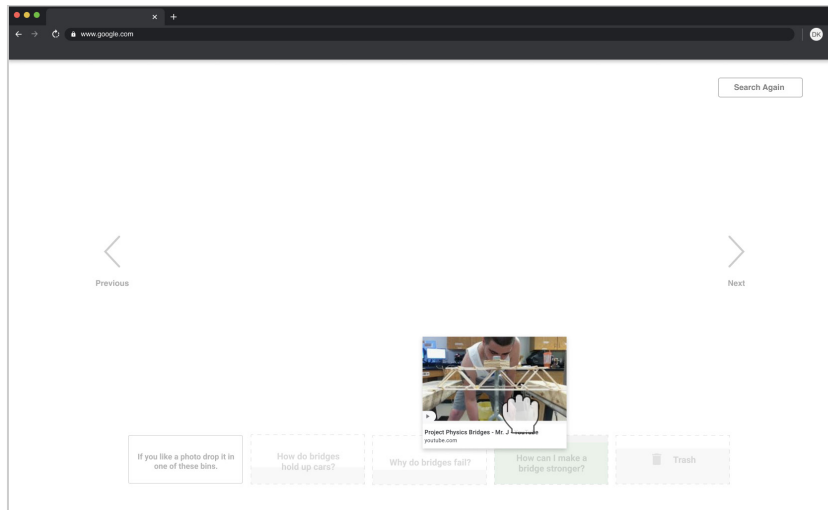
Micha goes into the resource room awaiting to be instructed by Mrs. Adams. She gives the instructions for this week's problem and Micha goes to his computer to get to work.

Micha google searches bridges. Any extraneous information is blocked out by the Virtual PBL program.



Instead of going to a view of all images Virtual PBL takes each image and puts it in a slideshow view, allowing Micha to look at each picture one by one.

MICHA COLLECTING ASSETS (CONT.)



Micha sees a photo he likes and drops it into the corresponding bin.

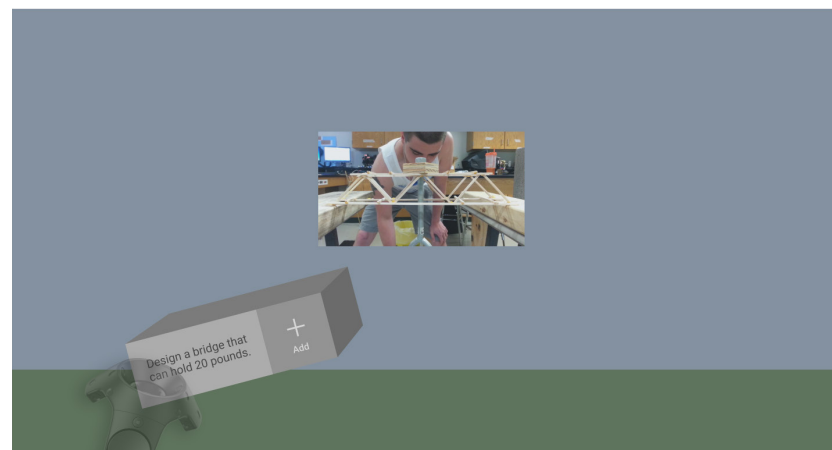
Micha collects all of his resources and picks up his VR headset.

MICHA EXPLORING WITH THOUGHT BLOCKS



Before entering Micha's virtual scene, Mrs. Adams explains to Micha that he is going to be using thought blocks to explore one of his ideas at a time. Once completed he will have a period of reflection and start again with a blank thought block.

After he completes three thought blocks Mrs. Adams and Micha will have a conversation about potential ideas before he starts his bridge.

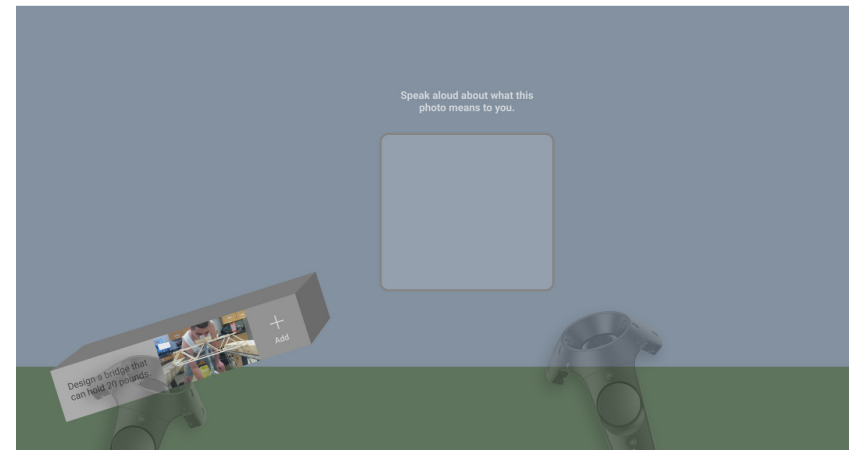


Micha goes into his virtual environment and images start appearing one by one for him to add to his thought block. Mrs. Adams choose a background that gives the perception of limited space to make Micha work quicker.

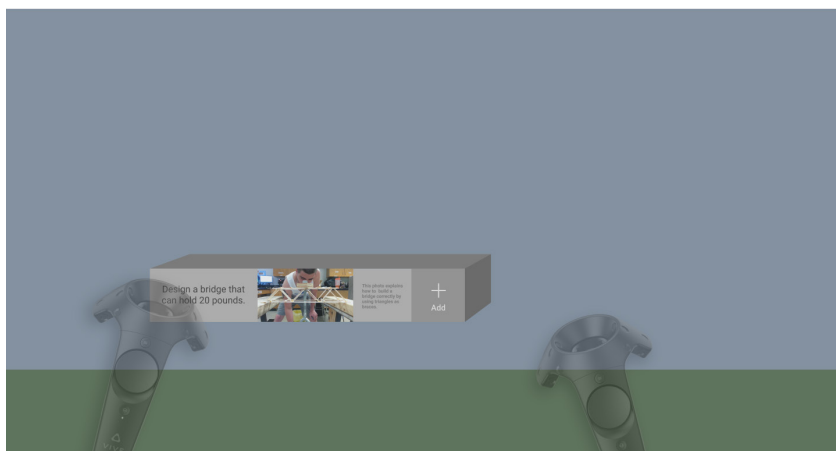
MICHA EXPLORING WITH THOUGHT BLOCKS (CONT.)



Micha picks up the asset and adds it to block.



When Micha places the object a prompt signals him to talk about how the image can help with his project.



Micha completes the prompt and a text component attaches to the photo that was talked about.



Some time goes by and Micha has gone through three images and three speech prompts.

MICHA REFLECTING



After Micha completes this side of the block his environment is cleared, and it is time for reflection before returning to his thought block for the next sequence.

Micha finishes three thought blocks and has finishes with a discussion with Mrs. Adams

CONCLUSION

DESIGN PRINCIPLES

This thesis explored a set of VR and web-based tools that can assist ADHD-I when they have attention, concentration and organization limitations in a PBL environment. Although these tools were specifically designed for ADHD-I users, they have exposed design principles that can be transferable and scalable to situations outside of students learning through VR in a PBL environment. The following conclusions were aggregated from extensive research, technological observations, and research through design.

Toolkit Interchangeable Functionality. Regarding accessibility, there is not a shoe that fits all. This exploration concludes that for ADHD-I, a toolkit that leverages interchangeable parts can assist a persona that changes from user to user due to their unique interests, ability for recollection, and their definition of novelty. Designers should consider the how simple interchangeable parts can be cross compatible across different edge cases.

Signaling and Segmenting. A virtual toolkit can be used when users have limitations with attention and organization during the creativity process. For example, a thought block can organize a user's thoughts into a linear progression and provide an idea track instead of bouncing from one idea to another. Providing a user with prefabricated components can help offload working memory by signaling the start of a task and segmenting the tasks that they must complete.

Coherence. Even though a VR headset blocks out all external stimuli including audio, a user's cognitive load can still become affected based on the complexity of the virtual environment. Designers should consider the cognitive load of users when creating environments inside and outside of VR.

Pretraining. Creativity is a process that requires technological knowledge and speed to materialize an idea. This thesis explored how outside technology, in this case a web browser, can pair with virtual reality to speed up the creativity process within PBL. This thesis explored how both technologies could share the same user experience resulting in a reduction in distractions novelty and less reliance on working memory to understand how each program works. When designing for cross platform functionality, designers should explore a universal user experience from one digital product to another.

Automatic VS User Enabled Tools. In some cases, users are not capable of managing their limitations on their own. This thesis explored how to assist a student with inattention who does not have the cognitive capability to recognize they need help with the task at hand. When designing for accessibility, designers should consider limiting or automating a user's control of a feature if that user's limitation prevents the design from functioning.

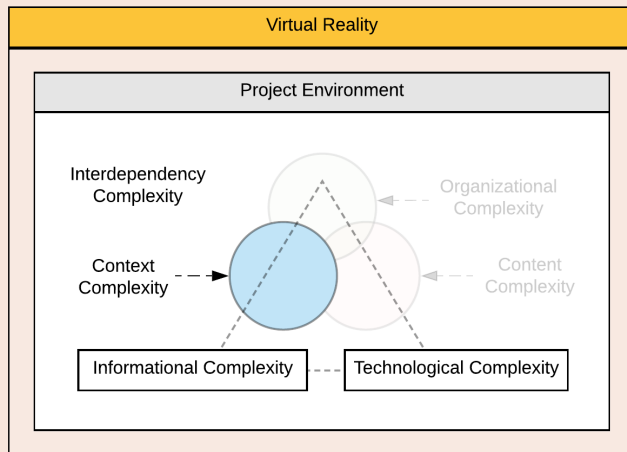


Figure 46 (Above)

Project Complexities not covered in this thesis.

CONCLUSION

FUTURE WORK

Project Complexity. In regard to the complexity of a VR environment, this thesis explored organizational complexity and content complexity (Figure 46). Future research can include design explorations for simplifying the technological complexity of VR when designing gestures, controller button layout, and hand tracking functionality.

Dexterity Based Tasks. Students with ADHD can have limitations with dexterity-based tasks. Research has not indicated how design can assist controller or hand tracking interactions within VR when the user has difficulties with dexterity.

Machine Learning. Incorporating machine learning and eye tracking software within VR can bring even more control over the user's attention span. Current virtual creation experiences have a static environment that changes only when an update is pushed. This poses the question; how can the design of a responsive VR environment manage the cognitive load of a user but not limit a user's potential to solve a problem?

Social Constructivist. Constructivist methodologies have indicated that PBL works best when collaborative. Though this exploration focused primarily on single user interactions and distraction management, future research should explore collaboration within a virtual PBL environment (Abdullah et al., 2019; Silver, 2004).

Prompts. Onboarding users with ADHD to new workflows and interactions within VR have not been explored in this thesis. During onboarding, cues can remind users of function capabilities within VR and can help offload working memory for students with ADHD however the design of these cues should be subtle enough to not distract from the rest of the scene.

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WORKS CITED

AUTHOR CONTRIBUTIONS

Abdullah, J., Mohd-Isa, W. N., & Samsudin, M. A. (2019). Virtual reality to improve group work skill and self-directed learning in problem-based learning narratives. *Virtual Reality*, 23(4), 461-471. doi:10.1007/s10055-019-00381-1

Adams, R., Finn, P., Moes, E., Flannery, K., & Rizzo, A. ". (2009). Distractibility in Attention/Deficit/ Hyperactivity Disorder (ADHD): The Virtual Reality Classroom. *Child Neuropsychology*, 15(2), 120-135. doi:10.1080/09297040802169077

Alloway, T. P., Gathercole, S. E., Kirkwood, H., & Elliott, J. (2009). The Cognitive and Behavioral Characteristics of Children With Low Working Memory. *Child Development*, 80(2), 606-621. doi:10.1111/j.1467-8624.2009.01282.x

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). <https://doi.org/10.1176/appi.books.9780890425596>

Bakhshi, J., Ireland, V., & Gorod, A. (2016). Clarifying the project complexity construct: Past, present and future. *International Journal of Project Management*, 34(7), 1199-1213. doi:10.1016/j.ijproman.2016.06.002

- Brown, T. (2019).** Brown Rating Scales: Brown ADHD Clinic: United States. Retrieved April 17, 2020, from <https://www.browнадhd-clinic.com/brown-rating-scales>
- Capelo, D. C., Sánchez, M. E., Hurtado, J. S., & Chicaiza, D. B. (2018).** Multisensory Virtual Game with Use of the Device Leap Motion to Improve the Lack of Attention in Children of 7–12 Years with ADHD. Proceedings of the International Conference on Information Technology & Systems (ICITS 2018) Advances in Intelligent Systems and Computing, 897-906. doi:10.1007/978-3-319-73450-7_85
- Chen, J. F., Warden, C. A., Tai, D. W., Chen, F., & Chao, C. (2011).** Level of abstraction and feelings of presence in virtual space: Business English negotiation in Open Wonderland. Computers & Education, 57(3), 2126-2134. doi:10.1016/j.compedu.2011.05.017
- Chun, M. M., Golomb, J. D., & Turk-Browne, N. B. (2011).** A Taxonomy of External and Internal Attention. Annual Review of Psychology, 62(1), 73-101. doi:10.1146/annurev.psych.093008.100427
- Chun, M., & Johnson, M. (2011).** Memory: Enduring Traces of Perceptual and Reflective Attention. Neuron, 72(4), 520-535. doi:10.1016/j.neuron.2011.10.026

- Danielson, M. L., Bitsko, R. H., Ghandour, R. M., Holbrook, J. R., Kogan, M. D., & Blumberg, S. J. (2018).** Prevalence of Parent-Reported ADHD Diagnosis and Associated Treatment Among U.S. Children and Adolescents, 2016. *Journal of Clinical Child & Adolescent Psychology*, 47(2), 199-212. doi:10.1080/15374416.2017.1417860
- Dupaul, G. J., Weyandt, L. L., & Janusis, G. M. (2011).** ADHD in the Classroom: Effective Intervention Strategies. *Theory Into Practice*, 50(1), 35-42. doi:10.1080/00405841.2011.534935
- Gathercole, S. E., Alloway, T. P., Kirkwood, H. J., Elliott, J. G., Holmes, J., & Hilton, K. A. (2008).** Attentional and executive function behaviors in children with poor working memory. *Learning and Individual Differences*, 18(2), 214-223. doi:10.1016/j.lindif.2007.10.003
- Gerjets, P., Walter, C., Rosenstiel, W., Bogdan, M., & Zander, T. O. (2014).** Cognitive state monitoring and the design of adaptive instruction in digital environments: Lessons learned from cognitive workload assessment using a passive brain-computer interface approach. *Frontiers in Neuroscience*, 8. doi:10.3389/fnins.2014.00385
- Haverkamp, M. (1958).** *Synesthetic Design : Handbook for a Multi-Sensory Approach*. Birkhäuser, Basel, 2012.
- Hmelo-Silver, C. E. (2004).** Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, 16(3), 235-266. doi:10.1023/b:edpr.0000034022.16470.f3

- Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007).** Scaffolding and Achievement in Problem-Based and Inquiry Learning: A Response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, 42(2), 99-107. doi:10.1080/00461520701263368
- Ip, H. H., & Li, C. (2015).** Virtual Reality-Based Learning Environments: Recent Developments and Ongoing Challenges. *Lecture Notes in Computer Science Hybrid Learning: Innovation in Educational Practices*, 3-14. doi:10.1007/978-3-319-20621-9_1
- Jerald, J. (2016).** *The Vr book: human-centered design for virtual reality*. New York: Association for Computing Machinery.
- Kim, S., Chen, S., & Tannock, R. (2014).** Visual function and color vision in adults with Attention-Deficit/Hyperactivity Disorder. *Journal of Optometry*, 7(1), 22-36. doi:10.1016/j.optom.2013.07.001
- Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. (2014).** Experiential Learning Theory: Previous Research and New Directions. *Perspectives on Thinking, Learning, and Cognitive Styles*, 227–248. doi:10.4324/9781410605986-9
- Langberg, J. M., Epstein, J. N., Urbanowicz, C. M., Simon, J. O., & Graham, A. J. (2008).** Efficacy of an organization skills intervention to improve the academic functioning of students with attention-deficit/hyperactivity disorder. *School Psychology Quarterly*, 23(3), 407-417. doi:10.1037/1045-3830.23.3.407

- Lee, H., Li, Y., Yeh, S., Huang, Y., Wu, Z., & Du, Z. (2017).** ADHD assessment and testing system design based on virtual reality. 2017 2nd International Conference on Information Technology (INCIT). doi:10.1109/incit.2017.8257860
- Lee, K. E., Williams, K. J., Sargent, L. D., Williams, N. S., & Johnson, K. A. (2015).** 40-second green roof views sustain attention: The role of micro-breaks in attention restoration. *Journal of Environmental Psychology*, 42, 182-189. doi:10.1016/j.jenvp.2015.04.003
- Loe, I. M., & Feldman, H. M. (2007).** Academic and Educational Outcomes of Children With ADHD. *Ambulatory Pediatrics*, 7(1), 82-90. doi:10.1016/j.ambp.2006.05.005
- Martinussen, R., Tannock, R., & Chaban, P. (2010).** Teachers' Reported Use of Instructional and Behavior Management Practices for Students with Behavior Problems: Relationship to Role and Level of Training in ADHD. *Child & Youth Care Forum*, 40(3), 193-210. doi:10.1007/s10566-010-9130-6
- Mayer, R. E., & Moreno, R. (2003).** Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, 38(1), 43-52.
- Mayer, R. E. (2014).** Incorporating motivation into multimedia learning. *Learning and Instruction*, 29, 171-173. doi:10.1016/j.learninstruc.2013.04.003
- McCloud, S. (1993).** *Understanding comics: The invisible art*. New York, NY: Harper Collins.

- Moreno, R., & Mayer, R. (2007).** Interactive Multimodal Learning Environments. *Educational Psychology Review*, 19(3), 309-326. doi:10.1007/s10648-007-9047-2
- Moreno, R., & Mayer, R. E. (2004).** Personalized Messages That Promote Science Learning in Virtual Environments. *Journal of Educational Psychology*, 96(1), 165-173. doi:10.1037/0022-0663.96.1.165
- Narayan, R., Rodriguez, C., Araujo, J., Shaqlaih, A., & Moss, G. (2013).** Constructivism—Constructivist learning theory. In B. J. Irby, G. Brown, R. Lara-Alecio, & S. Jackson (Eds.), *The handbook of educational theories* (p. 169–183). IAP Information Age Publishing.
- Nelson, B. C., & Erlandson, B. E. (2007).** Managing cognitive load in educational multi-user virtual environments: Reflection on design practice. *Educational Technology Research and Development*, 56(5-6), 619-641. doi:10.1007/s11423-007-9082-1
- Paas, F., Gog, T. V., & Sweller, J. (2010).** Cognitive Load Theory: New Conceptualizations, Specifications, and Integrated Research Perspectives. *Educational Psychology Review*, 22(2), 115-121. doi:10.1007/s10648-010-9133-8
- Parsons, T. D., Bowerly, T., Buckwalter, J. G., & Rizzo, A. A. (2007).** A Controlled Clinical Comparison of Attention Performance in Children with ADHD in a Virtual Reality Classroom Compared to Standard Neuropsychological Methods. *Child Neuropsychology*, 13(4), 363-381. doi:10.1080/13825580600943473

- Rapp, D. N. (2006).** The value of attention aware systems in educational settings. *Computers in Human Behavior*, 22(4), 603-614. doi:10.1016/j.chb.2005.12.004
- Resnick, M., & Robinson, K. (2018).** Lifelong kindergarten: Cultivating creativity through projects, passion, peers, and play. Cambridge, MA: The MIT Press.
- Sajadi, S., & Khan, M. (2011).** An Evaluation Of Constructivism For Learners With ADHD: Development Of A Constructivist Pedagogy For Special Needs. European, Mediterranean & Middle Eastern Conference on Information Systems (EMOIS 2011)
- Shalev, L., Tsai, Y., & Mevorach, C. (2007).** Computerized Progressive Attentional Training (CPAT) Program: Effective Direct Intervention for Children with ADHD. *Child Neuropsychology*, 13(4), 382-388. doi:10.1080/09297040600770787
- Wilens, T. E., & Spencer, T. J. (2010).** Understanding Attention-Deficit/Hyperactivity Disorder from Childhood to Adulthood. *Postgraduate Medicine*, 122(5), 97–109. doi: 10.3810/pgm.2010.09.2206
- Zentall, S. S., Falkenberg, S. D., & Smith, L. B. (1985).** Effects of color stimulation and information on the copying performance of attention-problem adolescents. *Journal of Abnormal Child Psychology*, 13(4), 501-511. doi:10.1007/bf00923137
- Zhao, Z. (2018).** Research progress about the effect and prevention of blue light on eyes. *International Journal of Ophthalmology*. doi:10.18240/ijo.2018.12.20

Öktem, Z., & Olguntürk, N. (2019). Effects of Framing and the Color Red on In-Class Performances of Children with Attention Deficit Hyperactivity Disorder. *Ted Eğitim Ve Bilim*. doi:10.15390/eb.2019.8169

