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Affordance Theory in XR Design: A Designer’s Perspective

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Abstract

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This thesis explores the application of Affordance Theory in creating virtual learning environments, particularly in the context of the Agile XR project. The author, an experienced spatial designer with a decade and a half of expertise, concentrates on redesigning the user-friendliness and immersion of a virtual world called Dana's Mind. In implementing the Affordance Theory, the author orientates to two significant literatures, The Ecological Approach to Visual Perception (Gibson,1979) and The Design of Everyday Things (Norman, 2013). Affordance Theory can be separated into two views.

Gibson's perspective highlights the significance of environmental clues in indicating potential actions, regarding objects not just as static entities but as invitations for action. Expand upon this concept by introducing the concept of "perceived affordances," highlighting the significance of making these signals clear in design to improve user comprehension without relying on instruction manuals.

This study utilizes a first-person study methodology, where the author actively participates in Dana's Mind, carefully documenting their encounters and findings. The study is enhanced by feedback from teachers who participated in the Agile XR project, which offers significant insights into user interactions. Subsequent redesign

combines theoretical ideas and practical feedback to keep the original design’s style while improving user-centric aspects.

In terms of the study's research participation, this study utilizes a dual-method approach: the author evaluates the revised virtual area, replicating their first experience, while eight other individuals give extra opinions through a survey. Findings emphasize the influence of Affordance Theory on user engagement and highlight its function in establishing a consistent and user-friendly virtual learning environment.

This study suggests that Affordance Theory is a highly effective tool for designers, serving as an advantage in XR design for online education and optimizing the user interface of virtual elements to be intuitive and user-friendly, guaranteeing a smooth and effortless experience for students and teachers. The paper claims that Affordance Theory is crucial for improving XR design, which transforms online learning spaces into settings where navigation is efficient and intuitively simple.

Keywords: Virtual Learning Environment, Affordance Theory, First-Person Study, Agile XR, User Engagement, Online Education.

1 Introduction

American psychologist James J. Gibson introduced affordance theory in his 1979 work, “The Ecological Approach to Visual Perception,” which provides a distinct viewpoint on how humans interact with their surroundings. Gibson argues that the world is not simply a collection of objects but a domain of potential acts. Affordances, which refer to the various activities an environment allows an individual to take, are not fixed and can be modified by the individual’s goals and purposes. These Affordances include physical attributes, cognitive capacities, and cultural factors (Gibson, 1979).

Gibson argues that perception is a dynamic process influenced by an individual’s objectives. The affordance theory field has substantially influenced psychology, design, and robotics (Maier, 2009). The development has produced user-friendly products and advanced robots capable of genuine interactions.

1.1 The Importance of Affordance Theory in XR Design

Affordance theory has significant implications for the design of Extended Reality (XR), including both Virtual Reality (VR) and Augmented Reality (AR). Understanding the potential and advantages of Affordances concerning XR is crucial for creating intuitive, immersive, and user-friendly experiences. Designers utilize the principles of Affordance Theory to create virtual environments that precisely imitate the actual world, guaranteeing an authentic “sense of presence” in virtual reality, which refers to

the subjective experience of feeling physically present in a virtual environment or having a deep connection to digital content.

Affordance Theory is essential in smoothly integrating digital information into the actual surroundings in Augmented Reality (AR). This strategic integration guarantees a seamless merging of the digital and physical domains, amplifying user experiences and increasing security. VR games like Job Simulator demonstrate Affordance Theory, where virtual things imitate real-world alternatives to create an easy user experience.

1.2 The Objective of The Thesis

This thesis explicitly utilizes the Affordance Theory to completely redesign the immersive virtual learning environment, Dana's Mind, as part of the Agile XR project. Dana's Mind is a digital environment built with Autodesk 3dsMax and made accessible on Spatial.io using Spatial io's Unity toolkits designed and created by the researcher. The Agile XR project is a two-year Erasmus+ program integrating agile methodology and XR technologies to revolutionize online educational environments.

The organized virtual world, Dana's Mind, has encountered difficulties identified through user testing and observations in the context of online learning. This thesis aims to overcome these restrictions by employing the Affordance Theory. It seeks to enhance student engagement, provide a more immersive educational environment, personalize learning experiences, and improve accessibility.

The redesign process includes an in-depth evaluation of existing potential and limitations within Dana's Mind. This assessment serves as the basis for strategic interventions to improve the advantages of the virtual learning environment and address identified limitations. The main aim is to synchronize Dana's Mind with the objectives of the Agile XR project, contributing to the progress of online education.

1.3 Research Questions

This thesis explores the potential of Affordance theory to encourage XR designers and improve the usability of XR experiences. The primary investigations driving the study are

- How can the principles of the Affordance theory be utilized in XR projects?
- What are the benefits of integrating Affordance theory into XR design to create user-friendly experiences?

The primary objective of “Affordance Theory in XR Design: A Designer’s Perspective” is to explore the use of Affordance Theory in XR design. This research aims to offer valuable insights to designers and contribute to the advancement of immersive online education.

2 Literature Review

2.1 A Paradigm Shift in Understanding Perception, Action, and Design

James J. Gibson’s groundbreaking work in ecological psychology (Gibson, 1979) has significantly reshaped our comprehension of perception, behavior, and design by introducing the innovative concept of Affordances, marking a substantial departure from the prevailing paradigm. In the eighth section of his influential book, “The Ecological Approach to Visual Perception,” titled “Theory of Affordances,” Gibson (Gibson,1979) delves into the foundational concepts that underpin this transformative framework.

Gibson (1979) initiated his exploration by framing the environment as the physical boundaries demarcating diverse substances, emphasizing its role as a source of opportunities and possibilities for creatures. To Gibson’s argument (1979), Affordances encompass the opportunities and constraints that the environment presents, acting as a crucial link between the characteristics of an entity and its surroundings. Perception of Affordances challenges the traditional notion of values

as purely subjective, demanding a direct understanding of the values and meanings inherent in environmental objects.

Coined by Gibson (1979), the term “Affordance” denotes a specific interaction between the environment and an entity, spotlighting the positive connection between them. Gibson (1979) contends that Affordances are not static, objective attributes or subjective characteristics but dynamic interactions combining physical and psychological elements, transcending the traditional separation of subjective and objective domains.

Gibson (1979) offers various illustrations to demonstrate the functionality of his theory. For instance, support can be provided by a stable surface that is horizontal, flat, extended, and rigid. According to him, support is not a universal trait among all animals but rather an advantage that varies according to size and behavior. Based on shape and structure, solid surfaces can serve various purposes, such as facilitating climbing or enabling sliding. Conceptualization includes external aspects and materials, things, creatures, and even other individuals, each presenting a distinct array of advantages.

Gibson’s theory of affordances (1979) aligns with the ecological concept of a niche, extending beyond habitat to encompass a collection of opportunities and limitations dictating an animal’s interaction with its surroundings. Interaction underscores a mutually beneficial relationship, emphasizing the essential compatibility between animals and their environment.

The ecological perspective on a niche aligns with Gibson’s theory of affordances (1979), extending beyond mere habitat to encompass a collection of opportunities and limitations that define how an animal interacts with its surroundings. Interaction emphasizes a mutually beneficial relationship, highlighting the essential compatibility of the two.

Gibson’s theory (1979) also addresses the informational aspects crucial for visual perception, underscoring the significance of ambient light in revealing surfaces and, consequently, affordances. Perception involves tangible object characteristics and their affordances—the potential opportunities and behaviors they present.

Gibson (1979) observes humans' significant alterations to Earth's landscape over millennia while studying ecosystem development. He argues that these changes stem from a desire to modify environmental opportunities, enhancing accessibility and comfort for humans. He warns that such modifications must be approached carefully to avert potential adverse effects.

Introducing the concept of positive and negative affordances, Gibson (1979) emphasizes that the environment presents both advantageous and detrimental features. Materials, surfaces, objects, and other humans offer various possibilities and hazards, challenging oversimplified classifications between positive and negative aspects.

In summary, Gibson's affordance concept (1979) transcends traditional environmental understandings, providing a conceptual framework for comprehending how animals, including humans, perceive and interact with their surroundings. Paradigm shift carries profound implications for diverse fields, including psychology and design, representing a transition from subjective interpretations to the objective characteristics of the environment and the behaviors they facilitate.

2.2 Don Norman's Insights in The Design of Everyday Things

Years after Gibson (1979), Norman reflects on design concepts articulated in his renowned publication, "The Design of Everyday Things" (Norman, 2013). ideas underscore the enduring relevance of affordances, signifiers, mappings, and restrictions, not only in physical items but also within the evolving landscape of design. Technology advances, and designers increasingly navigate virtual environments, where Norman's (2013) concepts, initially applied to physical objects, seamlessly translate into the digital realm. In the dynamic sphere of XR design, where virtual environments emulate the physical world, integrating these principles becomes paramount, guiding user interactions and ensuring an intuitive user experience.

Norman's (2013) insights transcend traditional physical designs, offering valuable perspectives applicable to various contexts, including cabinet doors. Illuminated by Norman (2013), the tension between aesthetics and usability highlights the need for

explicit design indicators and conspicuous cues to enhance user comprehension and satisfaction.

Norman’s (2013) exploration of switches in diverse contexts is a valuable reference for designers, especially when incorporating these concepts into XR design. The application proves pivotal in addressing challenges related to discoverability and feedback, critical components in crafting immersive and user-friendly XR experiences.

Norman’s (2013) perspectives form the foundation for delving into the potential of Affordance Theory to inspire XR designers and enhance the usability of XR experiences. Alignment with the central research questions of the thesis emphasizes the transformative nature of Affordance Theory in shaping immersive and user-friendly experiences within Extended Reality (XR) applications.

Norman’s nuanced understanding of affordances as the possible actions perceivable in a specific context (2013) serves as a guiding principle for designers. Adopting these ideas, designers gain profound insights into how users engage with virtual environments, akin to Norman’s (2013) adept handling of technical intricacies in his examples.

Norman’s (2013) pragmatic problem-solving approach, advocating for various tactics, including subtle movements and physical strength, underscores the flexibility required in navigating the complexities of XR design. Interact with dynamic and ever-changing virtual environments, necessitating adaptability in design considerations.

Norman’s (2013) exploration of the Gulfs of Execution and Evaluation offers crucial insights into user challenges within interactive systems, especially relevant in XR design. Gulfs underscore the need to minimize disparities between user intents and system reactions, emphasizing the importance of explicit feedback mechanisms and robust conceptual models.

Norman (2013) introduced seven action stages, including goal formulation, planning, specifying an action, executing the action, perceiving the system state, interpreting the system state, assessing the outcome, and presenting designers with a

comprehensive framework. This structured approach enables designers to identify challenges at each level and develop solutions, ensuring a holistic improvement in the user experience in extended reality (XR) apps. Leveraging Norman's (2013) concepts, XR designers can create virtual experiences centered on the user, making a significant impact while meeting user expectations and bridging the gaps between task execution and outcome evaluation.

2.3 Examples of Affordance Theory in Extended Reality (XR) Design

Virtual reality (VR) games tend to use the affordance theory to create objects and interactions that are easily comprehensible and user-friendly. For instance, a virtual reality sword may possess a substantial and authentic weight, creating the illusion of being physically present in the user's hand.

In the VR game Job Simulator, players can engage with various virtual objects through various interactive means. As an illustration, users can grasp a simulated item, position it on a surface, and move it into the air. The virtual things possess affordances that closely resemble real-world objects, resulting in a game experience that feels real and intuitive. The game employs realistic physics and collision detection algorithms, ensuring that objects behave consistently with their real-world counterparts. For instance, when a player propels a simulated object, it will follow a curving path in the atmosphere until ultimately making contact with the ground, producing an audible effect that improves the game's immersion by creating a sense of genuine interaction between the player and real-life objects.

Here are a few concrete instances illustrating the comparable affordances between the virtual reality game Job Simulator and real-life experiences:

Movement: Users can navigate their digital surroundings using the same basic movements in the real world. For instance, they can move, run, and bend, facilitating players' learning of locomotion skills in VR while simultaneously creating a natural feeling.

Gesture: Players can manipulate virtual items using their hands through various actions. As an illustration, they can grasp items, apply force, and push them through

the air, which allows players to carry out a variety of actions in virtual reality, consequently increasing the immersive aspect of the experience.

Physics: Virtual reality (VR) games employ realistic physics and collision detection algorithms to ensure that objects behave in a manner consistent with the laws of the physical world. For instance, when a player pushes a virtual object, it will follow a curved trajectory in the air and subsequently make contact with the ground, producing an audible sound. This feature improves the game's realism and enables players to interact with items differently.

AR navigation apps frequently employ affordance theory to display digital directions over the physical environment in a user-friendly manner. For instance, a simulated arrow may guide the user toward the correct path, while a simulated sign could highlight the upcoming change in direction.

In the AR app Pokémon GO, users can catch virtual Pokémon creatures visible inside the physical environment. This game's unique gaming mechanism has captivated many players worldwide, and its success can be partially attributed to its intuitive and natural affordances. The affordance of catching a Pokémon in Pokémon GO involves swiping the screen using the user's finger, imitating the action of throwing a Poké Ball in the Pokémon video games. This straightforward yet efficient action effortlessly integrates the digital environment of Pokémon with the physical world, facilitating players' comprehension and interaction with the game's dynamics.

The effectiveness of swiping to catch a Pokémon is improved by its grounding in real-world interactions. When we push an object, we instinctively extend our arm and make a smooth, sweeping action. The movement of swiping on a touchscreen replicates this physical motion, enabling players to intuitively understand the process of throwing a Poké Ball in the virtual world. The game's visual feedback further strengthens the connection between the physical and virtual worlds. When a player performs a swiping motion to capture a Pokémon, the Poké Ball materializes on the screen. It follows a curving path toward the Pokémon, mimicking the behavior seen in the video games. This visual stimulus enhances the perception of the action of swiping and facilitates players' comprehension of the outcomes resulting from their actions.

The inherent and instinctive capability of capturing a Pokémon is a crucial element in the success of Pokémon GO. The game effortlessly combines the virtual and physical worlds, enabling players from all ages and backgrounds to readily comprehend and actively participate in its principles. The simplicity of access to Pokémon GO has played a significant role in its extensive popularity, and it remains a vital aspect of the game's attraction.

Augmented reality (AR) training simulations frequently employ affordance theory to construct realistic and believable settings that accurately represent the physical world. This resource facilitates users' gaining the knowledge and skills necessary to do jobs safely and efficiently in real-life scenarios.

VR training simulators such as STRIVR have changed our skill development and training approach entirely. STRIVR creates lifelike virtual worlds that mimic real-world conditions, providing learners with more effective and captivating training experiences.

Spatial Affordances: STRIVR's virtual surroundings accurately represent real-world locations' precise physical dimensions and arrangements. Trainees can move and interact with objects in virtual space in a manner that closely matches real-world experiences.

Visual Affordances: STRIVR's virtual surroundings are visually immersive and intricate, precisely reproducing the textures, colors, and lighting of real-life environments. The high quality of the visuals improves the sense of being fully engaged and helps trainees form accurate mental representations of the surroundings.

Interactive Affordances: STRIVR's virtual environments offer extensive interactivity, enabling trainees to modify things actively, interact with characters, and promptly respond to stimulation presented within the simulation. This interactive experience mimics the genuine encounters that learners may encounter on their real-life tasks.

Affordance theory is a powerful tool for designers working in extended reality (XR). Designers may enhance the intuitiveness, user-friendliness, and immersion of

encounters in XR environments by comprehending their affordances, resulting in engaging and reliable outcomes.

3 Research Approach

3.1 Personal Investigation of Dana's Mind

This research was centered around using a first-person study approach, where the researcher took on the role of a solo explorer within the virtual environment of Dana's Mind. The data-gathering strategy consisted mainly of taking personal notes, enabling detailed documentation of observations and interactions within the virtual environment. Intentional choice was made to enhance the user's comprehension of the complex information incorporated in the layout and features of the virtual environment. Assuming the role of the sole user, the researcher aimed to establish a close relationship with Dana's Mind, exploring its capabilities and constraints through direct engagement.

The Affordance Theory served as the guiding foundation for this individual exploration. In cognitive psychology, Affordance theory centers on the natural capacity for interaction between users and their surroundings. The study attempted to analyze how the design characteristics of Dana's Mind influenced user interactions and experiences using this theoretical lens. The solo trip was not only a navigational exercise but a thorough exploration aimed at revealing the details that influence user involvement in this digital world.

3.2 Affordance Theory Framework

The study's methodological approach was greatly influenced by Affordance Theory, which served as a fundamental framework that refers to the inherent possibilities for action in a situation and was used as a conceptual framework to evaluate Dana's Mind. Theoretical framework led to analyzing users' perception and interaction with items in virtual space, providing essential insights into the user experience.

The study attempted to analyze the affordances provided by Dana's Mind using Affordance Theory, distinguishing between aspects that effectively guided user activities and those that caused difficulties. The analysis is centered on the relationship between design components and user reactions, which improves our detailed understanding of the virtual environment's influence on user engagement and satisfaction.

3.3 Personal Documentation of Highs and Lows

The sole investigation of Dana's Mind was an active and analytical effort. In this solitary journey, the study relied heavily on a careful recording. The author recorded personal reflections, documenting their views on the aspects of the virtual environment that functioned smoothly, the minor errors they noticed, and an overall study of the complete user experience.

This documentation provided a comprehensive collection of qualitative data, capturing the subjective intricacies of the virtual experience. Comprehensive notes covered the technical factors and the emotional and cognitive reactions produced by Dana's Mind. Personal documentation aims to offer a complete and detailed record of the successes and challenges faced during the individual investigation, focusing on capturing the complex details of the experience.

3.4 External Input: Feedback from teachers on the Agile XR Project

The research's approach went beyond individual investigation by including external feedback. On October 3, 2023, a group of teachers actively participating in the Agile XR initiative traveled to Helsinki, where they jointly interacted with Dana's Mind. The purpose of this collaborative testing session was carefully planned to enhance the understanding gained from the individual investigation.

The Agile XR project teachers contributed a wide variety of diverse expertise and viewpoints to the testing procedure. Views, thoughts, and suggestions helped shape the research by providing further insights and enriching the comprehension of Dana's Mind. Incorporating external feedback into the evaluation process can enhance its

overall quality by taking into consideration different perspectives beyond those of the researcher.

3.5 Harmony of Individual and Group Viewpoints

The research methodology intentionally combines individual exploration and group testing sessions to understand Dana's Mind processes in-depth. The objective is to provide a comprehensive and complex assessment of the virtual environment by combining the personal observations from the first-person study with the varied viewpoints of the Agile XR project instructors.

This integration involves more than just combining individual and collective perspectives. It is a deliberate attempt to interconnect many viewpoints, resulting in a story that effectively represents the essence of user experiences within Dana's Mind. The study aims to reveal patterns, variances, and overarching themes contributing to a sophisticated understanding of the virtual environment by combining individual comments with collective insights.

The following chapters will explore the numerous data obtained from this comprehensive research method, thoroughly examining the multiple factors that influence user interaction in the virtual world of Dana's Mind.

4 Analysis

On the specified date, the researcher investigated the virtual world of Dana's Mind, emphasizing its original conception. The study aimed to fully evaluate the virtual environment by employing the First-Person Study approach, which offers an immersive and individualized viewpoint of the user's experience.

4.1 Testing and Analyzing Dana's Mind's Early Design

Study Date: November 27, 2023

Point of entry and initial observations

Upon entering Dana's Mind, the visitor faced a brightly illuminated and spacious environment decorated with significant writings that said, "Welcome to Dana's." The words were positioned above large wooden boxes, emphasizing the place's name. View from the entryway was limited, making it difficult to grasp the surrounding area quickly.

Image 1. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Wayfinding and signage

After taking a few steps, the user came across three bright red arrows indicating separate destinations, labeled "Auditorium," "Rooms," and "Biology." These arrows seem to serve as initial indicators for some areas of the space. The user was curious about a radio that included a "play/pause" symbol and an F button, even though the act of playing music seemed unrelated to the intended function of the surroundings.

Image 2. A snapshot taken inside the virtual world of Dana’s Mind, generated using Spatial.io.

Image 3. A snapshot taken inside the virtual world of Dana’s Mind, generated using Spatial.io.

The researcher noticed an extra sign labeled “Point of interest,” which offers crucial information. Item produced a mystery. The intended purpose of it remained unclear.

Cooperative Environments

As the researcher approached the “Collaborative 1” and “Collaborative 2” cylinders, she observed that these cylinders served as entrances to separate rooms. 1 included a tiny space with chairs and small tables, lit boxes placed on the floor (whose significance remained unclear), and frames hung on the wall encouraging the user to “Upload Art.” The lack of clear instructions left this room’s purpose uncertain, yet its arrangement suggested a conducive environment for collaborative activities.

Image 4. A snapshot taken inside the virtual world of Dana’s Mind, generated using Spatial.io.

Image 5. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

There is a ladder in the collaborative area that, although attractive, gives a misleading appearance of participation. It is an escape portal that will transport users to the main area. There is ambiguity in the presence of both a ladder and an exit text. The ladder is just a decorative element and cannot be used for climbing.

Image 6. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Image 7. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Lower-Level Lecture Area

Upon reaching a lower level in the central space, a lecture area was found, which included a curved arrangement of seats facing a large screen. The lower position suggests that this area is specifically designed for giving lectures and presentations. Visually appealing ladders are present, but their usefulness is questionable, leaving the possibility of teleportation uncertain.

Image 8, A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Image 9. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Challenges in the field of exploration

After reaching the main floor, many empty boxes created uncertainty on the next steps. A hole in one box indicated a specific function, although it was challenging to

distinguish it from other boxes due to its like material. The hole led to Collaborative 2, which mirrored “Collaborative 1 “regarding clarity and purpose issues.

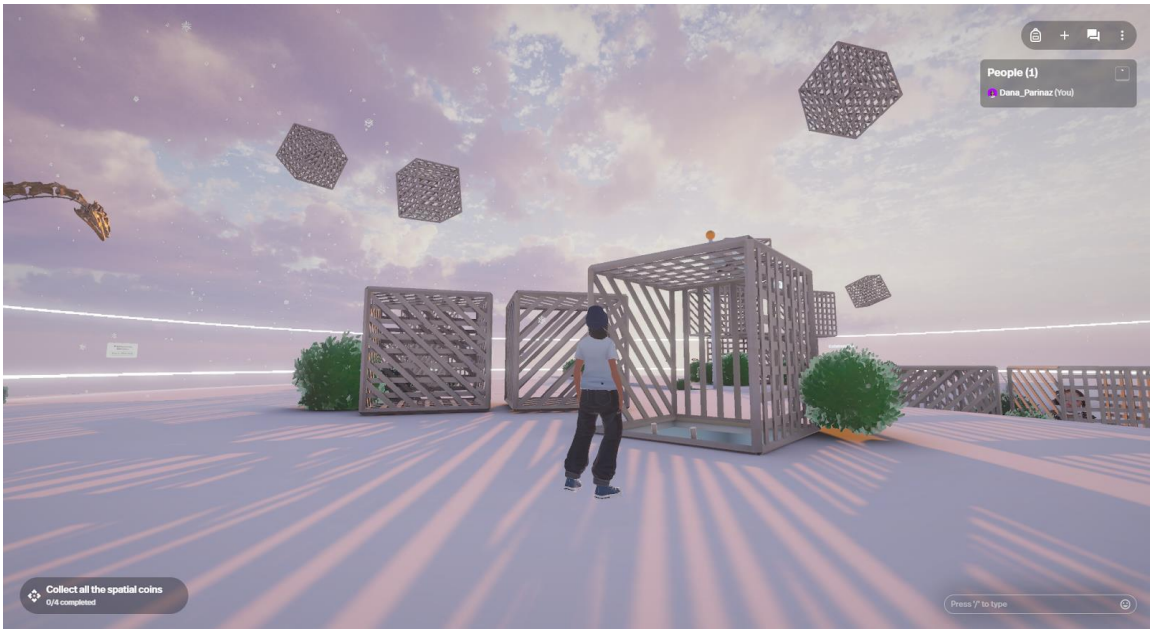


Image 10. A snapshot taken inside the virtual world of Dana’s Mind, generated using Spatial.io.

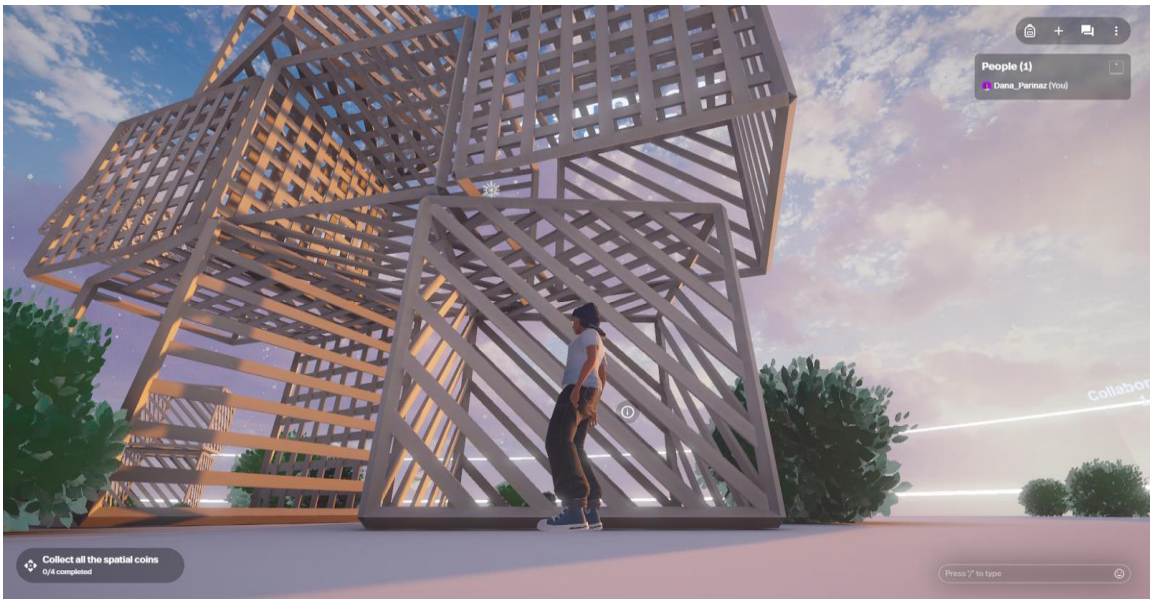


Image 11. A snapshot taken inside the virtual world of Dana’s Mind, generated using Spatial.io.

Furthermore, during this research trip, the researcher encountered giant spheres displayed with writings that indicated: “Journey to.” This function was initially developed to navigate multiple worlds within Dana’s Mind.

Image 12. A snapshot taken inside the virtual world of Dana’s Mind, generated using Spatial.io.

Concluding Thoughts

The calm and bright ambiance of the environment was highly appreciated, enhanced by playful elements like a flag pattern with a picture of a teacher, which contributed a lovely flavor. User experience was improved by snowflakes, bright sunny weather, and visually appealing design components.

Dana’s Mind introduces an immersive virtual environment that has the potential to facilitate collaborative activities. User research indicated the need for more transparent navigational information, purposeful interaction elements, and more precise indications of the utility of the environment. These areas would optimize user engagement and comprehension within the educational setting of the Agile XR Project.

4.2 Evaluation of Dana's Mind First Design

After conducting a comprehensive analysis of Dana's Mind during its initial development phase, some significant discoveries and insights were discovered, revealing its advantages and areas needing improvement. This evaluation aims to thoroughly assess Dana's Mind's initial design, utilizing the researcher's direct investigation and observations.

The positive aspects

Immersive Ambiance: Dana's Mind is distinguished by its immersive ambiance, defined by a calm and luminous atmosphere. Including flag patterns and visually appealing elements adds a playful touch and improves the user experience by providing a welcome ambiance.

Potential for Collaborative Activities: The design of Dana's Mind exhibits encouraging prospects for aiding collaborative activities. The presence of collaborative spaces furnished with seats and small tables, as well as the inclusion of a lower-level lecture room, clearly demonstrates an intentional effort to facilitate group interactions and presentations within the virtual environment.

Visual Appeal: The pleasing appearance of Dana's Mind is visually captivating, with careful consideration of detail in features like snowflakes and sunny weather effects. These visual improvements help create an immersive and visually appealing virtual environment.

Areas that need improvement

Navigational Clarity: Insufficient navigational clarity emerged as a critical problem encountered while exploring Dana's Mind. Users experienced challenges in promptly comprehending the arrangement of the environment, resulting in confusion and uncertainty regarding further actions.

Purposeful Interaction features: The observation of interactive features, such as buttons and signs, within Dana's Mind, was made. However, their intended purpose

and usefulness were not consistently obvious. Enhancing user comprehension and engagement would be facilitated by providing more explicit instructions on interacting with these aspects and what effects will be expected.

Functionality Indications Precision: The significance of specific components in Dana's Mind, such as the radio including a "play/pause" icon and an F button, lacked clarity about the entire context. Enhancing the user's comprehension and utilization of the virtual area could be achieved by providing more explicit signals of the usefulness of these aspects.

Optimization for User Engagement: Dana's Mind would greatly benefit from implementing tactics focused on enhancing user engagement and comprehension in the educational context of the Agile XR Project that could involve improving navigational cues, optimizing interface features, and offering more accurate capability indications across the virtual world.

Suggestions

Enhanced Navigation Support: Incorporating more explicit navigational indicators, such as prominent signage or interactive maps, will enhance users' ability to explore Dana's Mind with greater efficiency and self-assurance.

The discovery of Interactive Components: Enhancing user comprehension and promoting active participation in the virtual world can be achieved by offering explicit instructions or tools for interactive items.

Enhancement of Intentional Design: To enhance the purposeful design, it is essential to conduct user testing and feedback sessions to optimize the functioning and design of elements like radios and signage, which will guarantee that they effectively serve meaningful functions within Dana's Mind.

Iterative Design Process: By implementing an iterative design process, Dana's Mind may continuously enhance its functionality and adapt to user requirements and expectations. This technique incorporates user feedback and evaluation to make updates and adjustments, resulting in a refined user experience.

To summarize, Dana's Mind exhibits various strengths in its initial design, such as its captivating atmosphere and capacity for collaborative tasks. However, some areas also require enhancement, specifically regarding navigational clarity, purposeful interactive components, and user engagement optimization. By focusing on these areas and implementing suggested improvements, Dana's Mind can transform into a very efficient and user-friendly virtual environment under the Agile XR Project.

4.3 Applying Affordance Theory to Redesign Dana's Mind:

The motivations for redesign come from the identified restrictions that have formed, emphasizing the need to update Dana's Mind despite its original potential. Using affordance theory, which analyzes the relationship between an environment and the actions it allows or inhibits for individuals, it is possible to apply a strategic approach to dealing with these limitations.

Boosting student engagement and encouraging active participation:

Current state: Dana's Mind aims to improve student engagement, yet the existing design may only partially fulfill this objective.

An approach using Affordance Theory: Identify and address obstacles that limit student engagement, such as a lack of opportunities for cooperation or appropriate components for interaction.

Creating a learning environment that promotes active participation and involvement:
Current state: There is a potential need for more immersion in the virtual environment.

An approach using Affordance Theory: Apply the affordance theory approach to comprehend how users perceive and interact with a virtual environment, ensuring that it meets their expectations and aligns with their experiences.

Tailoring the Learning Experience:

Current state: It may be necessary to fully customize Dana's Mind to cater to each learner's specific needs and preferences.

An approach using Affordance Theory: Apply the affordance theory method to customize the learning experience by understanding and adapting to individual needs, providing a variety of challenges, and including different activities.

Encouraging diversity for all students:
Current state: Certain obstacles in usability for learners with diverse needs.

An approach based on Affordance Theory: Apply affordance theory to ensure diversity by considering learners' diverse physical and cognitive abilities and incorporating features like alternative input methods and audio explanations.

The application of affordance theory in the redesign of Dana's Mind aims to transform it into a virtual learning environment that is more effective, engaging, and easily accessible. Outcomes may include

- increased student engagement and active participation
- improved engagement and immersion in the teaching environment
- enhanced customization of the learning experience
- improved accessibility for a wide range of learners.

Future efforts should involve the use of iterative testing, integration of user feedback, and the construction of continuous improvement cycles. The redesign method follows the concepts of affordance theory to ensure a seamless and user-centered interaction between individuals and their digital learning environment.

4.4 User Testing and Observations of Dana's Mind Redesign

The researcher tested the modified version of Dana's Mind utilizing the First-Person Study approach on the scheduled day. The researcher aimed to provide an in-depth personal viewpoint on the user's experience inside the virtual environment.

Study Date: December 9, 2023

Entrance

Upon arrival, the user is greeted by an arrow pointing towards a tunnel, inviting them to immerse themselves in the captivating world of Dana's Mind. The user's movement was limited by an invisible obstacle, driving them to climb over a seemingly round, gray ground. This action would transform the circular surface's color, shifting it from gray to blue. An auditory notification would also be activated, audibly providing the note's content. Including explicit instructions and smooth color, gradients have enhanced the user experience by making it easier to navigate and minimizing potential confusion.

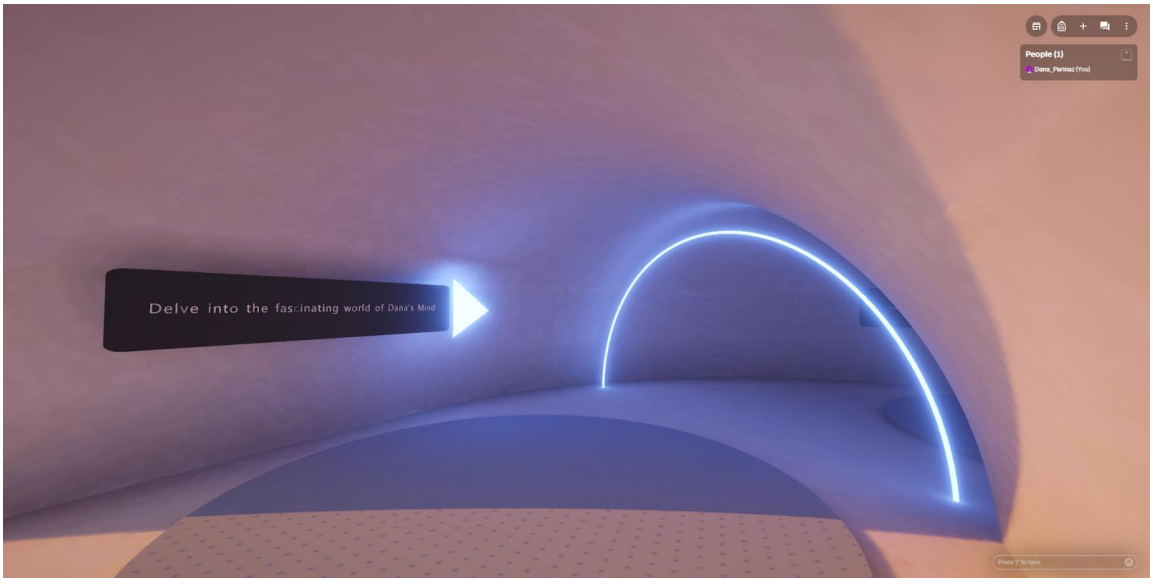


Image 13. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

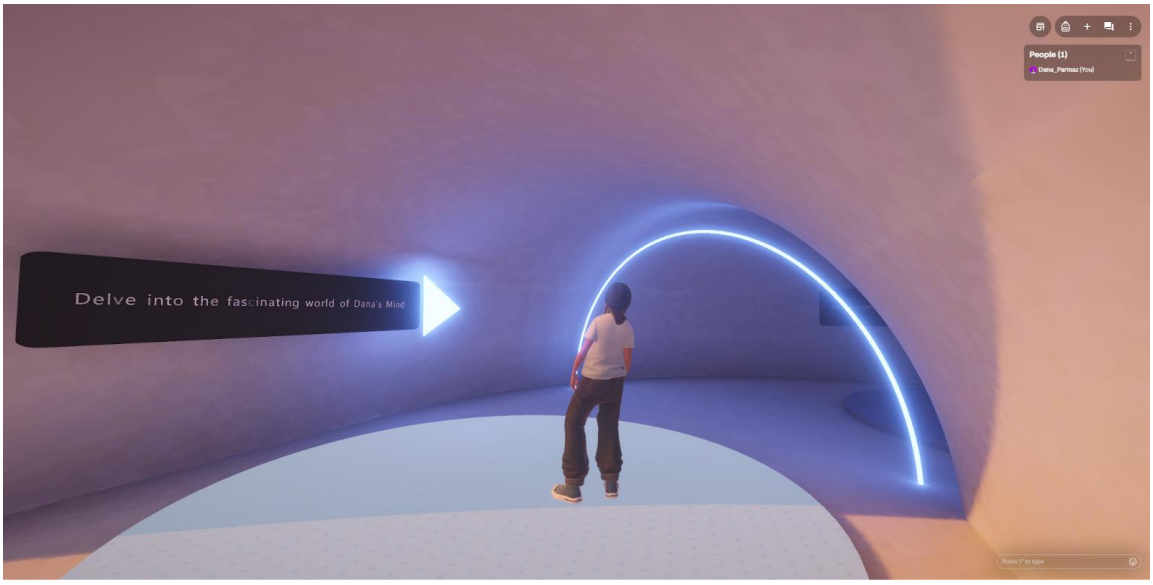


Image 14. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

As the user continued, progress and additional knowledge began to integrate smoothly. The initial objective of interactive flooring was to integrate auditory and visual stimuli for learning.

Image 15. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

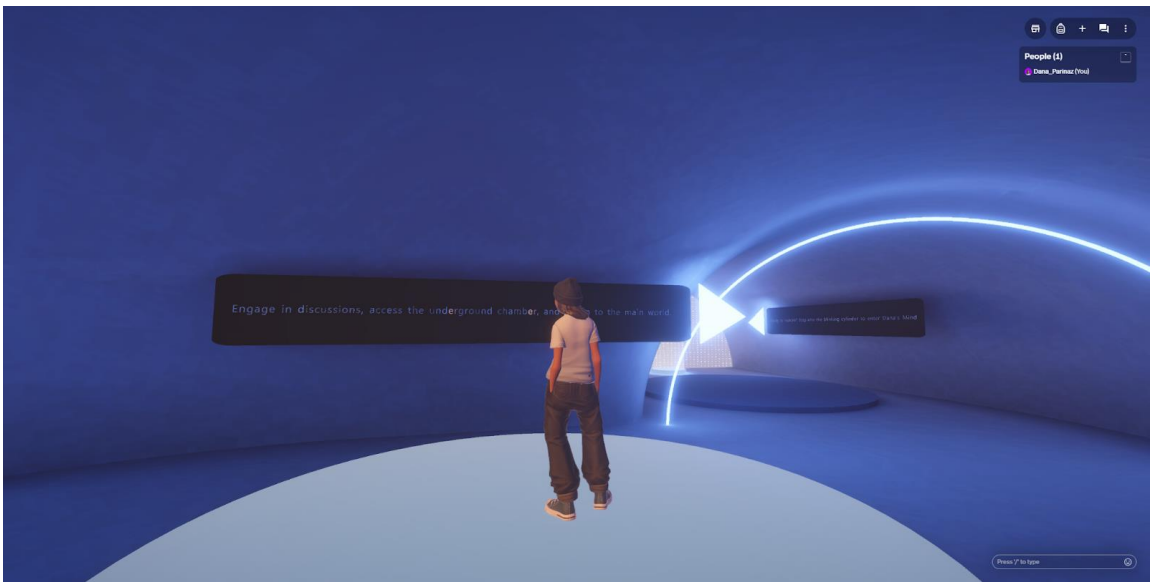


Image 16. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

These information boards provide users with comprehensive information about the various sections of Dana's Mind, such as a lecture hall, private meeting rooms, and discussion spaces. The seamless integration of visual and audio elements successfully communicated information. Upon leaving, the floors transitioned from active to non-active gray states, signaling a change from interactive to non-interactive modes.

Image 17. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Transition to Main Lounge

At the end of the tunnel, the player meets a luminous spherical cylinder that transfers them from the tunnel to the central lounge area of Dana's Mind. The primary lounge has an elevated viewpoint, offering a clear and comprehensive view of the entire area. There is a distinctive information desk that stimulates curiosity, encouraging users to explore its purpose. Significant directional signage is present, indicating the location of the steps and enabling participants to descend to the lower level safely.

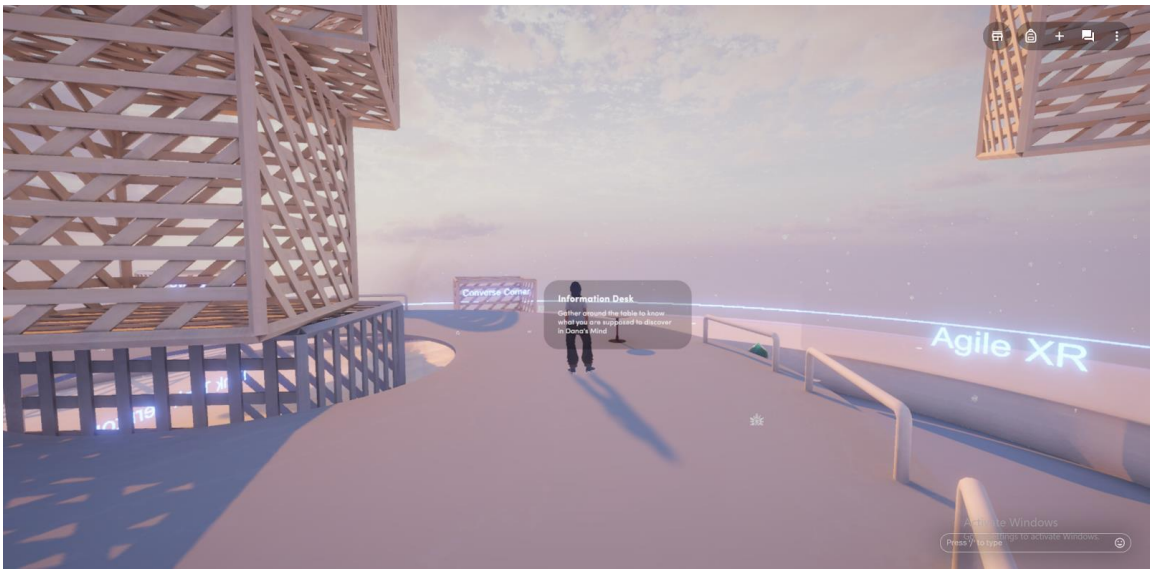


Image 18. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Image 19. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Image 20. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Image 21. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Dedicated Lecture Place

Down the stairs, the user reaches the ground floor and arrives at the bottommost area of the space. The space seems specifically designated for lectures, highlighted by a curving arrangement of seats oriented towards a translucent screen. Pathways, represented by ladders, enable users to access awareness and offer an avenue for departure from this lowest level.

Image 22. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

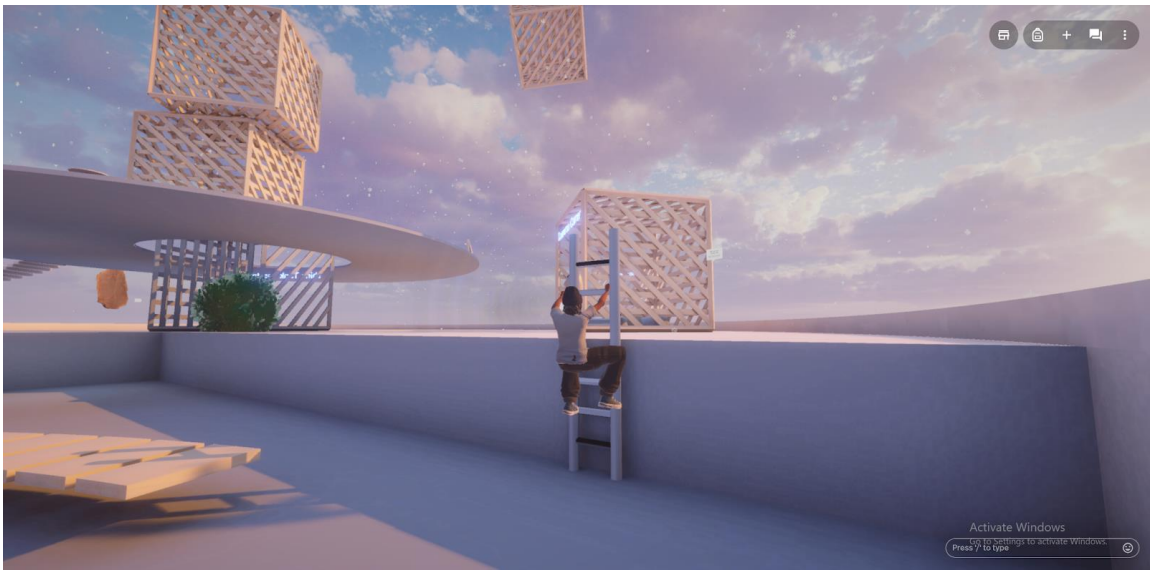


Image 23. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

After careful examination, the user has identified three distinct regions enclosed in boxes, each possessing individual labels: Converse Corner, Synergy Square, and Think Tank Territory. The design decisions were purposeful and carefully planned. Goals were communicated through precise terminology and visual cues, such as diverse materials and color schemes. Think Tank Territory stood out due to its distinct color, underscoring its singular objective. Corner and Synergy Square have

seating arrangements that consist of seats and a table. Spaces are specifically created to enhance dialogue and accommodate small gatherings.

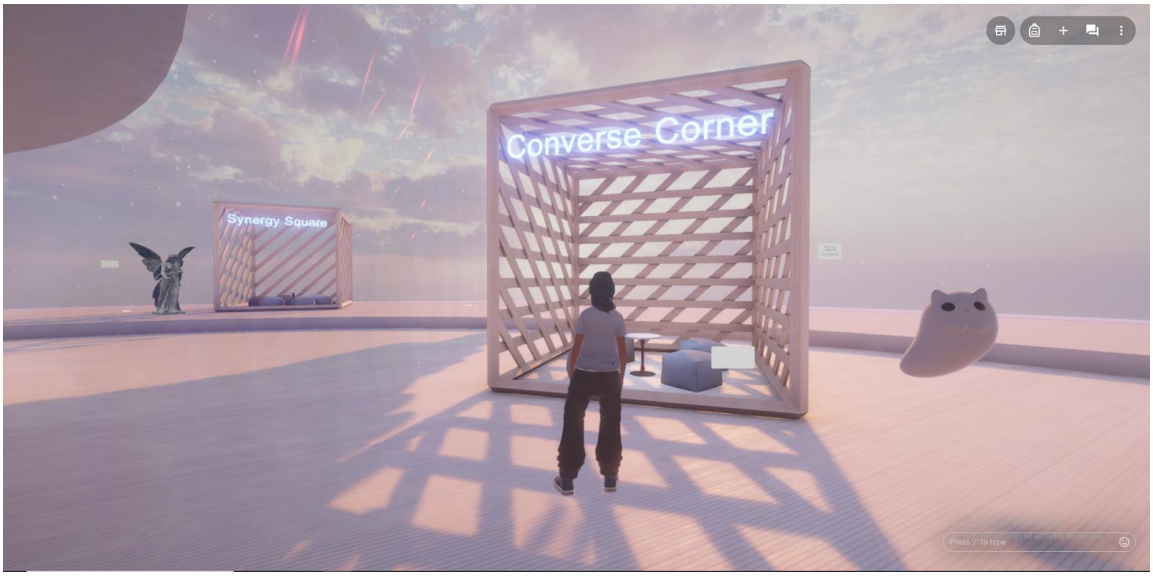


Image 24. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

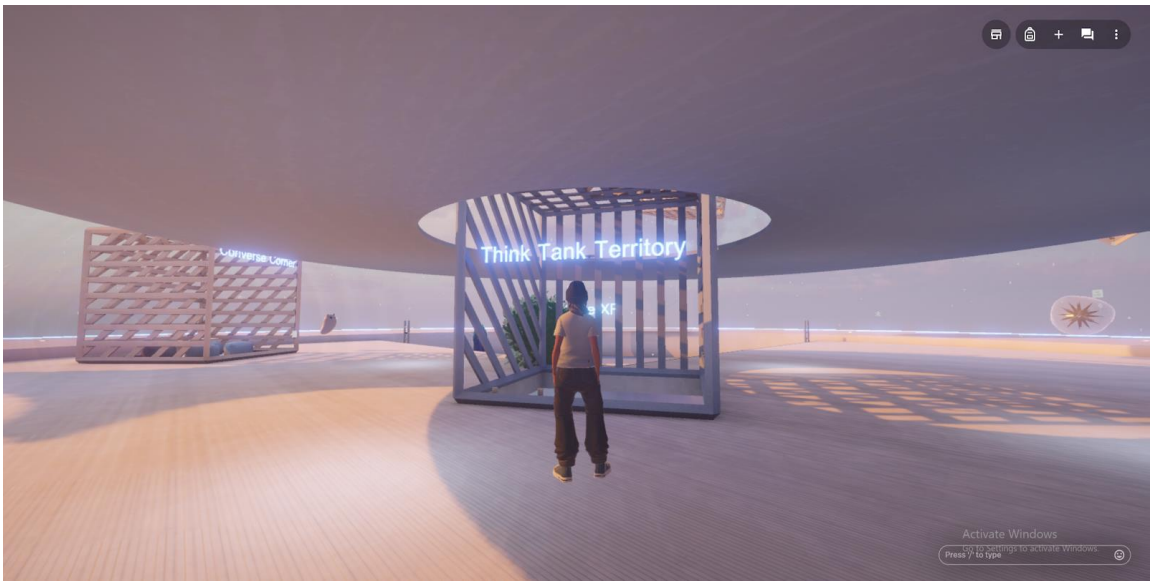


Image 25. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Collaboration and Interaction

Upon entering the Think Tank Territory, the user encounters a small, round space separated into two sections. Every part has comfortable seating and a table, indicating small-group communication. The presence of a spacious circular table, surrounded by several chairs, indicates it can accommodate numerous participants for discussions. The presentation space is located adjacent to this spacious table. The significant table can identify its exclusive purpose. The user's conversational and interactive skills were demonstrated by their engagement with the well-appointed sitting arrangements in specified areas. The Think Tank Territory has a circular table design that emphasizes collaborative efforts, reduces interruptions, and improves concentration. Users in this specific environment are unable to perceive any exterior disturbances. Furthermore, the room has a ladder, suggesting the user can climb up and leave.

Image 26. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Image 27. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

Conclusion

The updated iteration of Dana's Mind employed the First-Person Study methodology to conduct an in-depth investigation. The research unveiled an environment with enhanced transparency, less ambiguity, and well-defined limits between functions. Implementing the First-Person Study approach, which integrates audio and visual cues along with carefully designed elements, significantly improved the overall user experience.

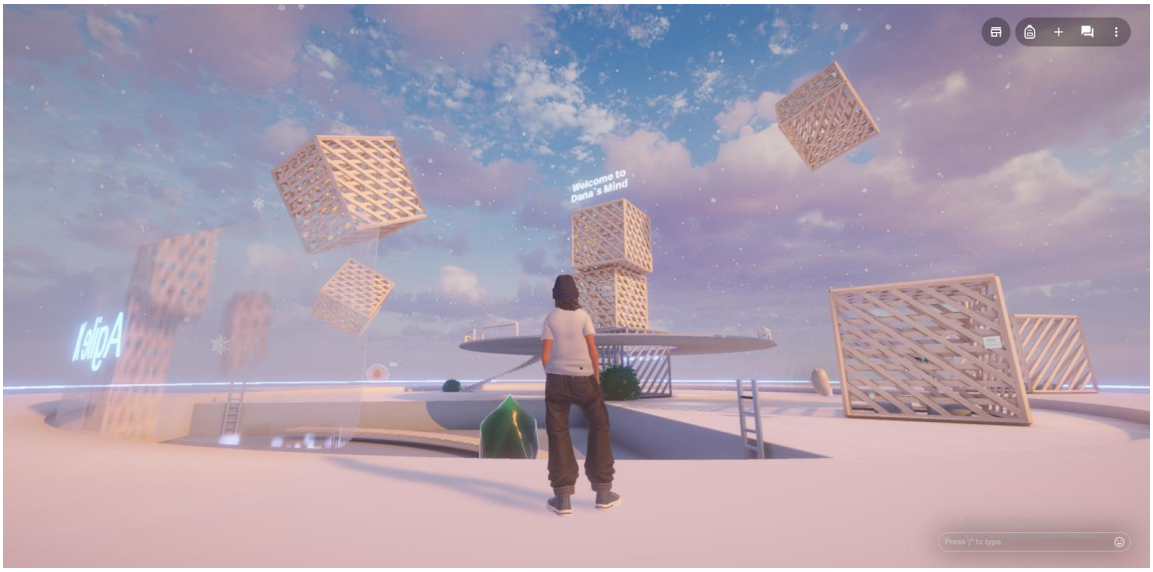


Image 28. A snapshot taken inside the virtual world of Dana's Mind, generated using Spatial.io.

4.5 Evaluation of Dana's Mind Redesign

Examining Dana's Mind's improved design from the perspective of Affordance Theory highlights numerous notable enhancements that align with the theory's fundamental principles. Affordance Theory, developed by James J. Gibson (1979), highlights the correlation between the characteristics of an environment and the possible behaviors it presents to users. In this analysis, the researcher assesses the revised edition of Dana's Mind by examining its features and the resulting impact on user interaction and experience.

Clear Signals for Navigation and Interaction

The revised layout of Dana's Mind showcases an intentional effort to offer distinct cues for navigation and interaction, improving user engagement and understanding. For example, directional arrows towards the tunnel entrance and the glowing spherical cylinder serve as explicit invites for users to explore various sections of the virtual environment. These visual signals act as features or indicate the potential activities that users can perform, such as entering the tunnel or moving to the main lounge area.

Seamless Integration of Audio-Visual Features without interruption

Dana's Mind's redesigned design stands out because it seamlessly incorporates audio-visual features, effectively communicating information. Information boards employ visual and audio cues to provide complete details about many aspects of the environment, facilitating effortless learning of knowledge about Dana's Mind for users. The change in flooring between active and non-active stages provides distinct options, signaling the transition from interactive to non-interactive modes that effectively direct user behavior and establish expectations within the virtual environment.

Intentional Design Choices

The upgraded version of Dana's Mind demonstrates purposeful design choices that emphasize the development of features. Explicitly categorizing areas enclosed in boxes, such as Converse Corner, Synergy Square, and Think Tank Territory, effectively conveys specialized opportunities for particular activities and interactions. Utilizing various materials, color palettes, and seating configurations strengthens these advantages, directing users towards desired actions and promoting cooperation and contact inside specified areas.

Facilitation of Cooperative Activities

The new design of Dana's Mind successfully enables collaborative activities by providing spaces that offer a wide range of possibilities and are specifically designed to promote discussion and active participation. The layout of facilities like Think Tank Territory, characterized by a circular table arrangement and comfortable seats, promotes collaborative efforts while reducing disruptions. The existence of a ladder implies the potential for multiple levels of involvement, improving the spatial opportunities for diverse interactions and exploration within the digital setting.

Summary

Overall, the assessment of Dana's Mind's redesigned layout, analyzed through the lens of Affordance Theory, reveals notable progress in offering explicit, intentional,

and captivating opportunities for user interaction and involvement. Dana's Mind optimizes the user experience by successfully utilizing audio-visual signals, enabling navigation, and promoting collaborative activities, thus taking advantage of affordances. To further enhance user engagement and pleasure in the virtual world, it is crucial to focus on design concepts that indicate how users might interact with the system.

4.6 Dana's Mind Redesign User Feedback - December 5, 2023

On December 5, 2023, nine students and teachers from different backgrounds conducted an assessment and testing session in a virtual environment, particularly in the modified iteration of Dana's Mind. That program assessed user experience, functionality, and overall effectiveness through a methodical examination. Participants were given access to the upgraded virtual environment and instructed to investigate and engage with its diverse components. After the investigation, all participants were instructed to fill out a questionnaire designed using Google Forms. The purpose of the questionnaire was to gather the participants' perspectives, suggestions, and evaluations regarding the updated layout of Dana's Mind, including the user interface, navigation features, clarity of information, and overall ease of use.

The landing area's visibility: 66.7% of the participants rated it 4, while 33.3% ranked it 5. Additionally, an average of 66.7% of the participants said it provided enough information.

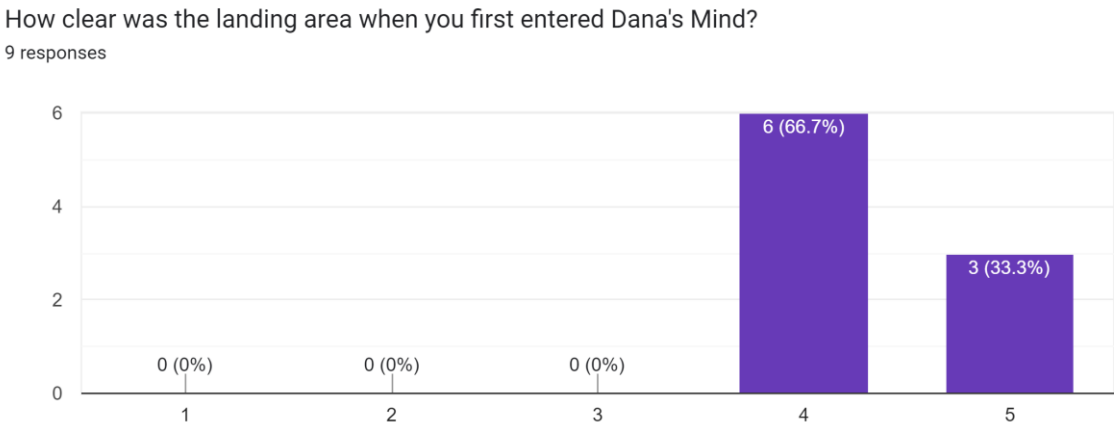


Figure 1. Screenshot of Google Forms survey interface.

Objective of Landing Zone: Approximately 77.8% of users grasped the intended goal, with a significant majority. 22.2% remains unclear.

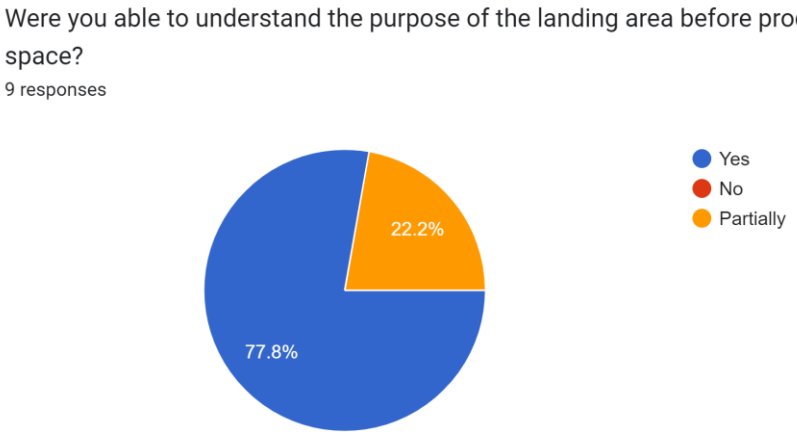


Figure 2. Screenshot of Google Forms survey interface.

Efficacy of directional arrows: 88.9% of the participants reported that the guiding arrows produced successful results.

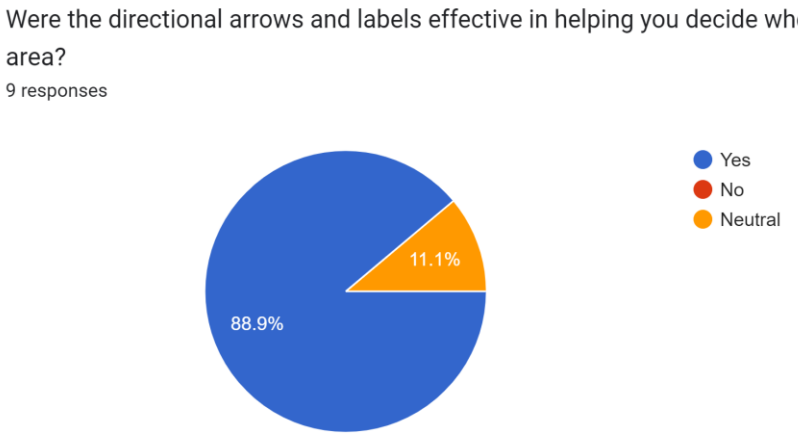


Figure 3. Screenshot of Google Forms survey interface.

Changing the color tones of the floor: Approximately 77.8% of people agreed that this was informative.

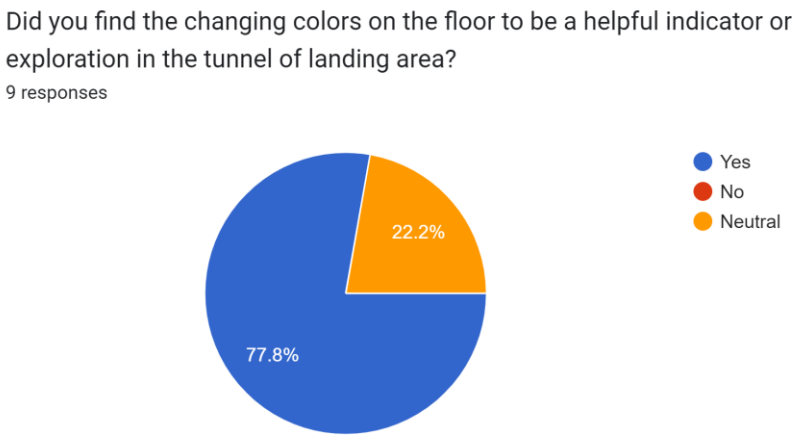


Figure 4. Screenshot of Google Forms survey interface.

Uncertainties regarding the landing zone: Different ideas for improvement. Other issues regarding the text's comprehension and understanding of spoken instructions exist.

Overall Assessment: Most respondents, precisely 88.9%, gave a good rating.

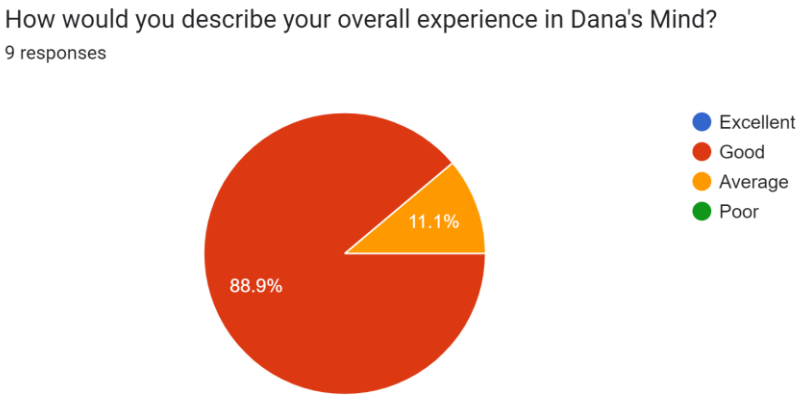


Figure 5. Screenshot of Google Forms survey interface.

Significant Features: 44.4% of the emphasis is on Visual Design, with an additional 44.4% on Collaborative Spaces.

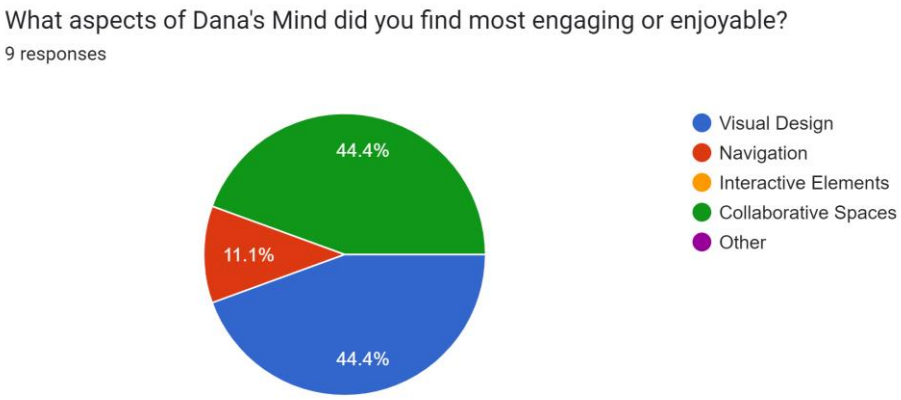


Figure 6. Screenshot of Google Forms survey interface.

Unclear Components: The ratio of the user interface components is 11.1% for navigation, 22.2% for interactive elements, and 11.1% for collaboration areas.

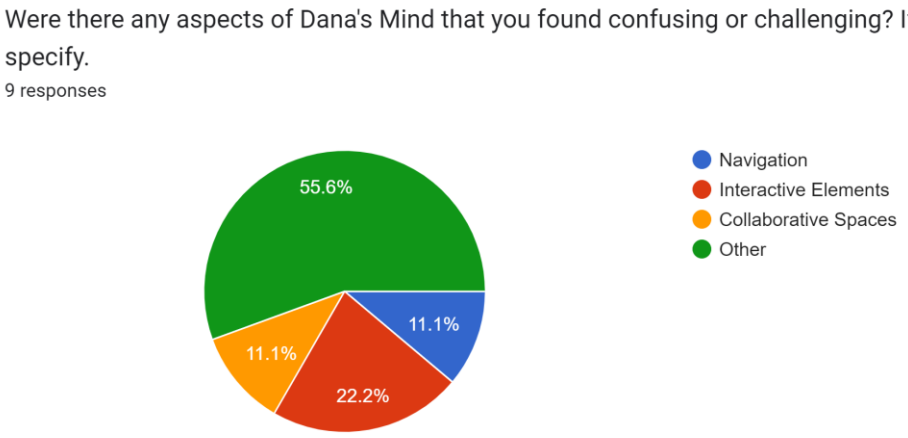
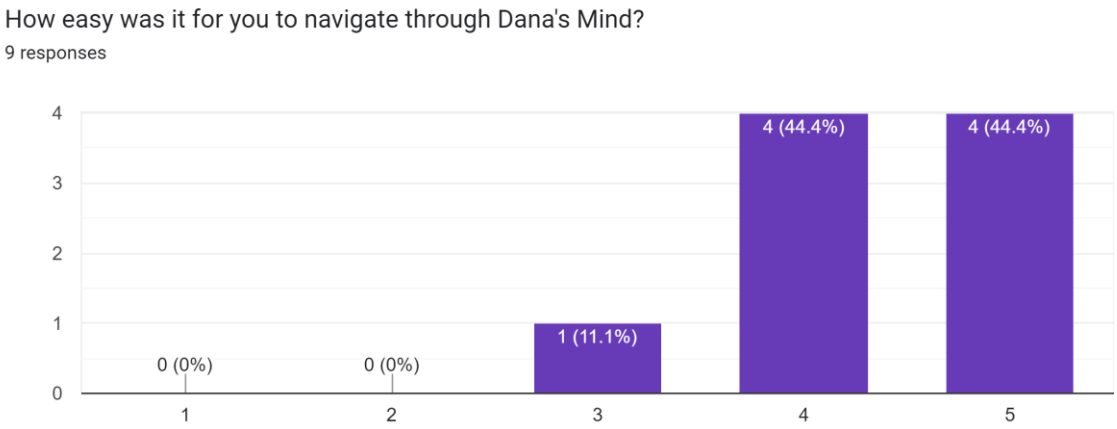


Figure 7. Screenshot of Google Forms survey interface.

Navigation usability: The outcomes were varied, as 44.4% of participants rated it as 4, and another 44.4% rated it as 5.



Helpful Navigation Features: The text labels and overall design were commended for their clarity and efficacy. Multiple issues have been identified regarding ladders. 77.8% of participants thought that interactive seats and frames improved engagement.

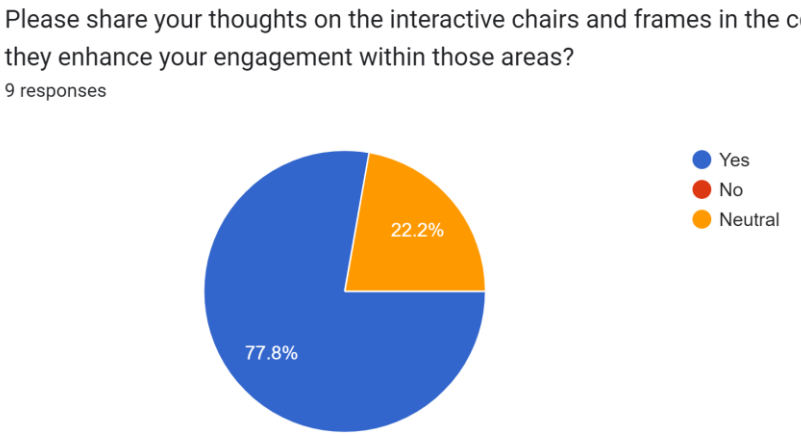


Figure 8. Screenshot of Google Forms survey interface.

Interactivity Expectations: A significant number of users, including 44.4%, reported discovering elements that lacked suitable interactivity.

Feedback on the Collaborative setting Experience was varied, with 55.6% of respondents having no opinion and 44.4% finding the setting suitable for collaboration.

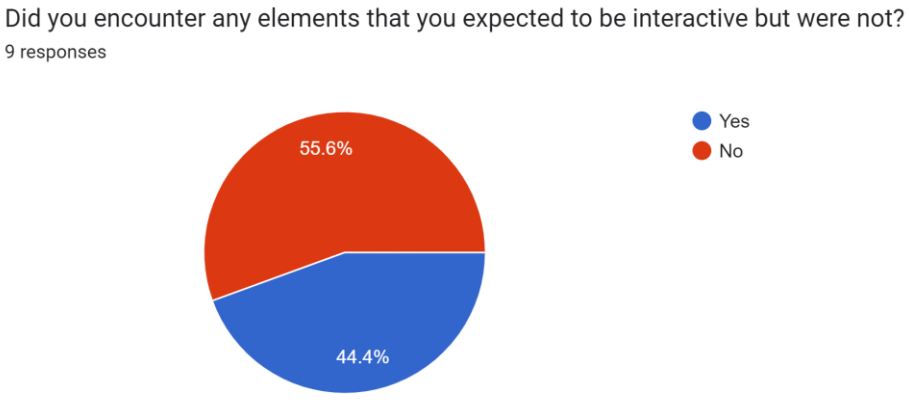


Figure 9. Screenshot of Google Forms survey interface.

Figure 10. Screenshot of Google Forms survey interface.

Lower-Level Lecture Area: A majority of 55.6% of respondents considered it a functional environment for presenting lectures. Concerning the view of large empty containers, 44.4% of individuals clearly understood their purpose, while 33.3% found them confusing.

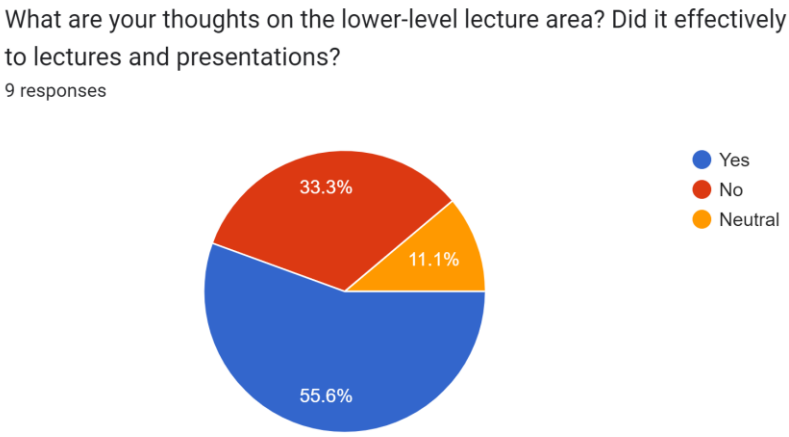


Figure 11. Screenshot of Google Forms survey interface.

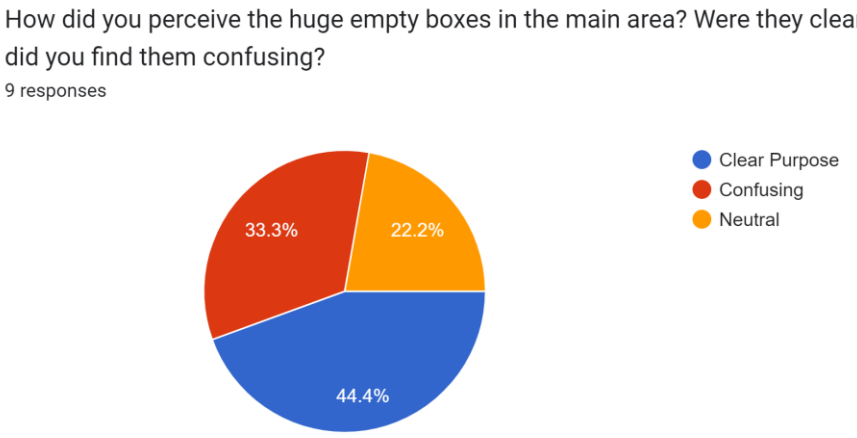


Figure 12. Screenshot of Google Forms survey interface.

Proposed Enhancements: There are recommendations for better signage and labeling, more engagement, and more activities.

User Experience Improvements: A significant majority of users, precisely 55.6%, have expressed a need for extra educational content.

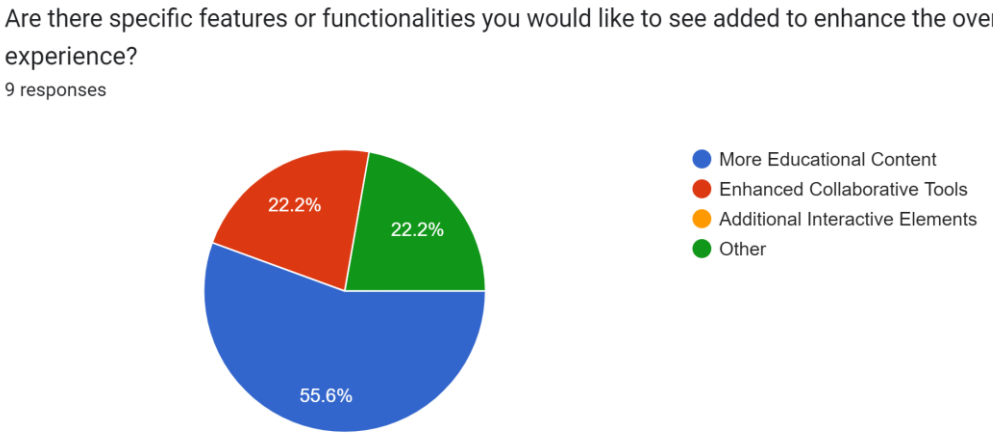


Figure 13. Screenshot of Google Forms survey interface.

Purpose Clarity: A majority of 66.7% of respondents judged it to be transparent.

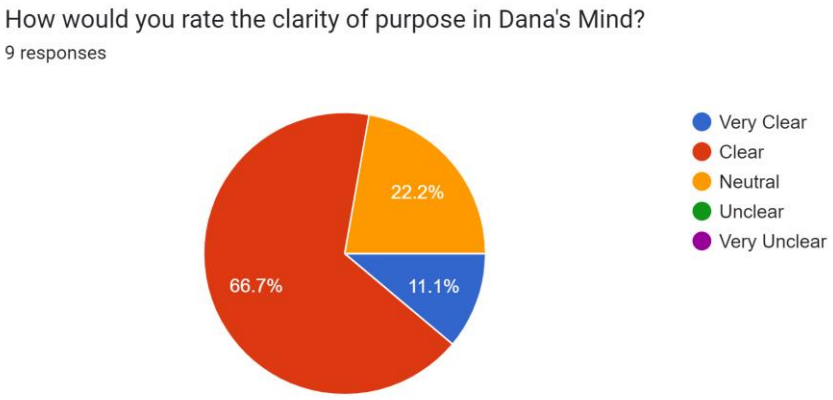


Figure 14. Screenshot of Google Forms survey interface.

The efficacy of the communication: The rating was 4 out of 5, with 66.7% of respondents giving this value.

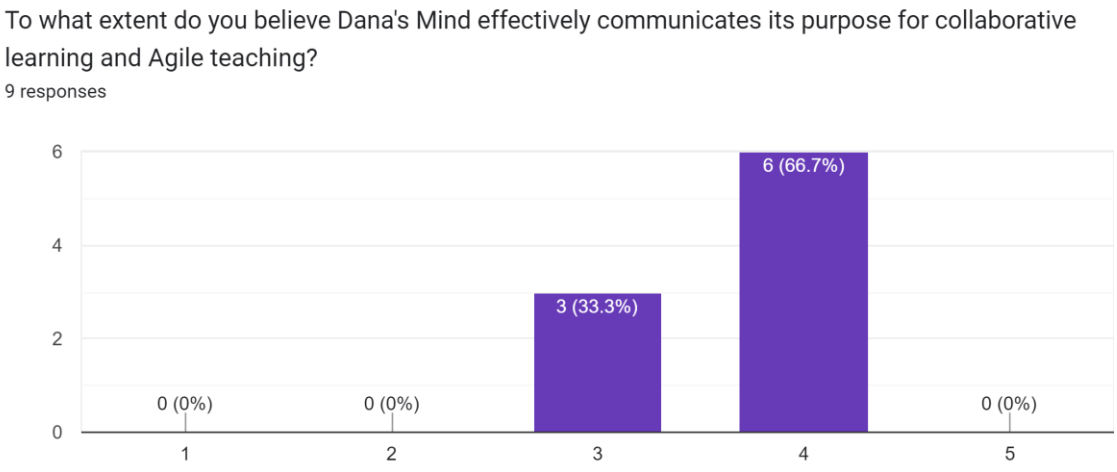


Figure 15. Screenshot of Google Forms survey interface.

Signifier Clarity: The participants' responses varied, with 33.3% perceiving the signifiers as transparent.

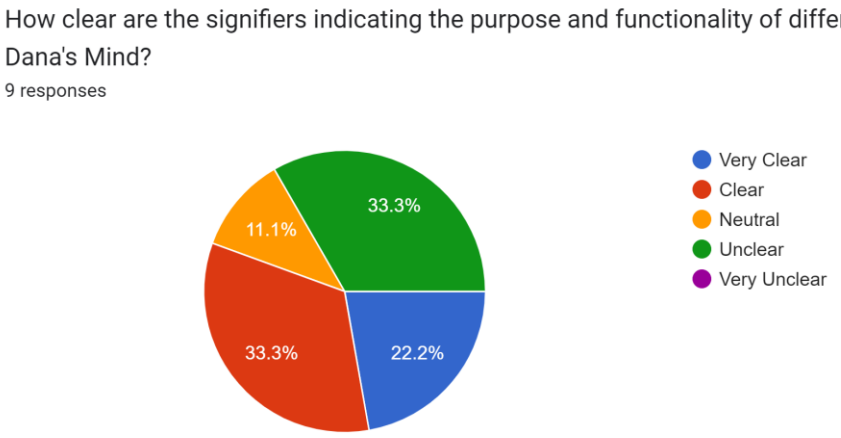


Figure 16. Screenshot of Google Forms survey interface.

Error Prevention: A significant majority of respondents, precisely 66.7%, rated it as a four on a scale ranging from one to five.

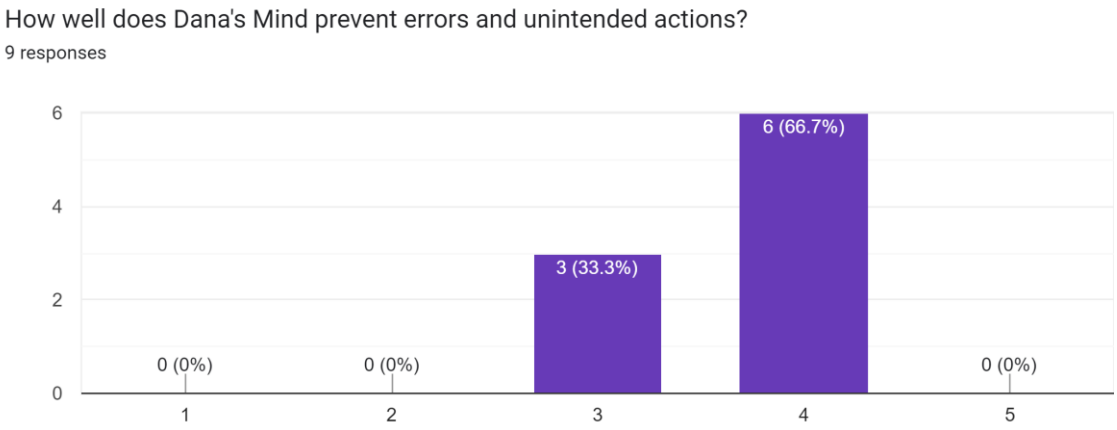


Figure 17. Screenshot of Google Forms survey interface.

Further remarks: The researcher has received much feedback, including suggestions for increasing the breakout rooms and expanding the study areas.

The participants vigorously participated in Dana's Mind, commending its visual layout and interactive capabilities. However, specific elements, such as navigation and interactive features, were challenges. Suggestions were given to improve the overall

user experience by incorporating additional clear indicators, polished guidelines, and extra interactive components. The findings offer essential perspectives to optimize the ongoing development of Dana's Mind.

5 Conclusion and Future Outlook

The last stage of the research dives into a comprehensive analysis of Dana's Mind, including its initial creation, upcoming enhancements, user assessment, and feedback that leads to a collection of findings that highlight the main idea of this thesis. This process involves applying the Affordance Theory in the XR design environment to address challenges and introduce new strategies.

5.1 Important Discoveries Summary

The adventure started with an in-depth review of texts, focusing on the transition from Gibson's (1979) Affordance Theory to Norman's (2013) design principles and the valuable insights gained from them. The theory laid the foundation for the following examination, assessment, and restructuring of Dana's Mind.

5.2 Testing and Assessment

Dana's Mind has been evaluated to identify its strengths and weaknesses, focusing on navigation, collaborative spaces, and the overall user experience. It utilized Affordance Theory based on Norman's (2013) concepts identified areas needing enhancement, emphasizing the significance of clear indications, deliberate interactive elements, and precise navigational instructions.

5.3 Redesign and Integration of Affordances

The following phase in the development process was an intentional redesign of Dana's Mind, guided by the results of the analysis and evaluation phases. We conducted an in-depth examination of the initial design, finding critical areas for improvement based on user feedback and Affordance Theory principles. The redesigned Dana's Mind received significant user testing to enhance engagement,

clarity, and usability. The testing revealed significant improvements in clarity, leading to reduced user confusion and more accurate differentiation between various functions. This iterative approach demonstrates our dedication to creating an engaging and easy-to-use XR learning environment that includes ongoing modifications depending on user feedback.

5.4 User Feedback and Iterative Improvement

User feedback offered valuable insights into the advantages and constraints of Dana's Mind following its update. Beneficial feedback was obtained for incorporating clear directional markers, audio and visual cues, and purposeful interaction components. However, challenges related to navigation, interactive features, and collaborative settings were identified, leading to continuous improvements.

5.5 Potential for the Future

The thesis provides possibilities for additional research and progress in XR design. Dana's Mind may be continuously developed by including iterative testing, user feedback loops, and integrating new technologies. Features like haptic feedback, speech recognition, and AI-based customization could enhance the immersive and customized XR learning experience.

5.6 Conclusion

In conclusion, Dana's Mind has experienced a notable change influenced by the concepts of Affordance Theory, which played a vital role in its redesign. Affordance Theory was essential in guiding decisions on incorporating clear indicators, intuitive interactive components, and a user-centered approach throughout the process. The thesis utilized Affordance Theory insights to enhance XR design principles, creating a more engaging and understandable virtual environment. The collaborative and iterative design methodology guaranteed that Dana's Mind stayed dynamic and sensitive to user needs during the redesign process.

5.7 Final Reflection

This study highlights the flexible nature of XR design, showcasing its capacity to adjust to changing user requirements and preferences. The case study of Dana's Mind demonstrates the success of an iterative and user-centered approach to developing XR learning environments. However, it is vital to recognize the study's limitations. Future studies should investigate more aspects of XR design, such as incorporating new technologies like artificial intelligence or haptic feedback, to improve user engagement and learning results. Studying the socio-cultural effects of XR adoption in educational contexts could offer valuable insights into its long-term effectiveness and influence. Researchers, designers, and educators may progress XR design by combining theoretical knowledge, practical implementation, and user-focused strategies that will push the boundaries of virtual learning and improve educational experiences.

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