Hexostasis: A Transdisciplinary Approach Towards Educational Gaming and Game Design

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Background

I have always been fascinated with video games. When I was little, we didn't have a computer in our house; so, I would ask my best friend to play together on their computer. I used to ask them so often that they eventually prohibited me from asking. On my 8th birthday, a wonderful thing happened: my great aunt gifted me a computer. I could not believe how lucky I was. Following that, my mom took me to buy my very first video game. I selected *Barbie Super Sports* (1999) where the players embody *Barbie*, or one of her other friends, and learn how to snowboard or skate. As time passed, I and my mom added more games to my collection. She became one of my first video game friends. We solved mysteries as detective *Barbie* in *Detective Barbie 2* (2000), saved animals as veterinary *Barbie* in *Barbie Pet Rescue* (2000), built homes in *The Sims* (2003), and fought *Draco Malfoy* in *Harry Potter and The Philosopher's Stone* (2001).

Years later, I started studying Interior Architecture and Environmental Design. I got fascinated with design and the possibilities that virtual spaces offer. Following that, I decided to pursue an M.Sc. Degree in Industrial Design

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where I studied virtual environments further through the subcultural interactions of gamers, and designed products that enable these interactions. This transition and connection with game studies didn't surprise anyone who knew me and my passion for battling virtual zombies and having adventures in alternative worlds ever since I was little. During my Master's studies, I observed that there is a strong bond in the gaming community where people teach other players and even create in-game events for systematic training to improve each other as players. Furthermore, I found that there are many gathering spaces exist outside of the games, where players leave tips, answer each other's questions, and share their experiences. This was the first time I saw the incredible educational potentials that the games provide; not just as designed products and pieces of art, but also as tools of creating community spaces for gathering. Naturally, I decided to pursue this newfound passion through a Ph.D. in Art Education. Shortly after I started, I noticed that due to my multidisciplinary background, which I acquired through my past training, I have learned to think in different ways. After noticing the positive impacts of this situation, as a maker and designer, my passion for video games as pedagogical tools expanded into creating spaces where people can learn how to think using multiple disciplines together. I also wanted to showcase the possibilities that diverse disciplines can create when combined. From fighting *Draco Malfoy* with my mom to becoming an art and design educator, all my past encounters with games and academia amalgamated in this study where I practice and invite for a similar mix to my background.

For this study, I designed a puzzle video game called *Hexostasis*. Through *Hexostasis,* I propose a transdisciplinary method towards problem-solving strategies to showcase the potential of fusing conventionally siloed disciplines. I curated a set of discipline-associated thinking strategies from art education, design, and computer science. While *Hexostasis* is a product of this study, the study is not limited to this game. *Hexostasis*, the first prototype of this approach I propose, is a cornerstone for future research on games as informal, transdisciplinary learning spaces.

Problem Statement and Research Questions

With the ever-evolving technology and raising levels of access to a variety of devices, gaming is one of the fastest growing industries. With that growth, different types of games emerge with varying promises which include education.

Unfortunately, despite these promises, the growth does not always benefit the players in terms of providing the best possible content. For this reason, there are two premises I focus on:

1. When education and video games are put together, this connotes K-12 or pre-school education. Therefore, most educational games are tried to be fitted within the formal education and its goals, which overlooks the other areas of games' potential for both adult and child learners. This approach also diminishes the visibility of important outcomes such *as learning thinking strategies and problem-solving skills in a holistic, not disciplinarily siloed manner*.
2. Even if a game is not labeled as educational, it might still teach. Between the games that claim to teach and the games that only offer fun, selecting and delivering the right content requires *criticality and expertise from educators and/ or designers.*

With these premises in mind, using thinking strategies from computer science and art and design education, this research inquires *how my self-designed video game can elicit a transdisciplinary approach towards problem-solving*? With that overarching question, I also look at these disciplinary practices separately and question *how a video game and a game narrative can affect players' design-based problem-solving skills, understanding and utilization of the concepts of decomposition and abstraction, and their criticality in play*.

One of the challenges of this research is that I was observing my process of creating *Hexostasis* while also using it as a pedagogical tool. This created a lengthy and intertwined process. To reflect *Hexostasis* the best, in this paper I specifically focus on how I designed the game, and the research and thinking behind it. For this purpose, I first present the game itself, then the literature behind it, and finally the methods I used during this process.

What is Hexostasis?

Hexostasis is a single-player puzzle game in which the players take on the role of a world builder and are introduced to various challenges on different planets. Each planet consists of three maps that correspond to different levels of the game. There are three connected systems in the game: environmental balance, moving to the next level, and the habitants.

Figure 1: Menu Screen

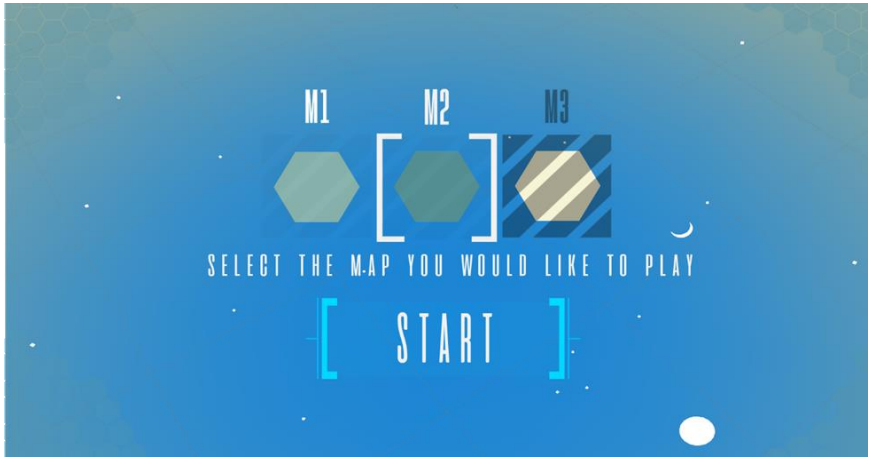

Figure 2: Selection Screen

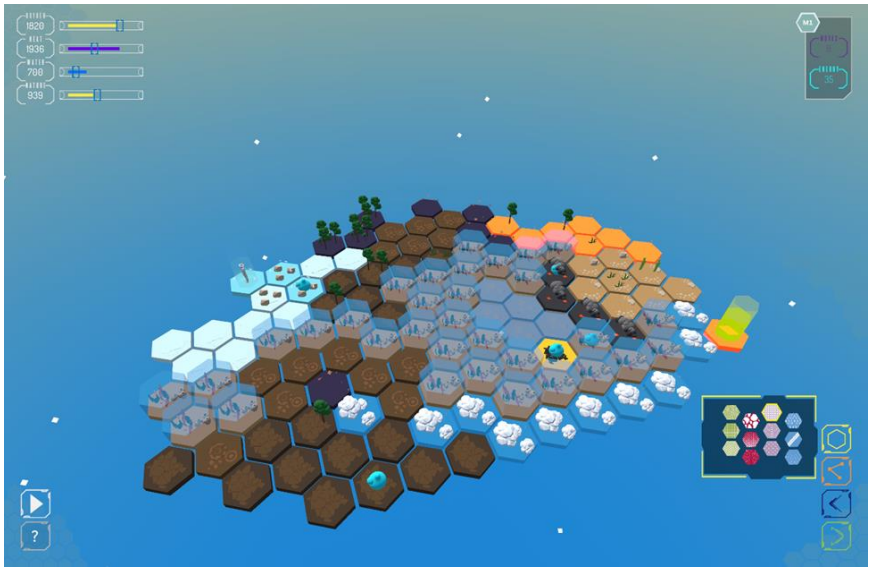

FIGURE 3: GAMEPLAY I

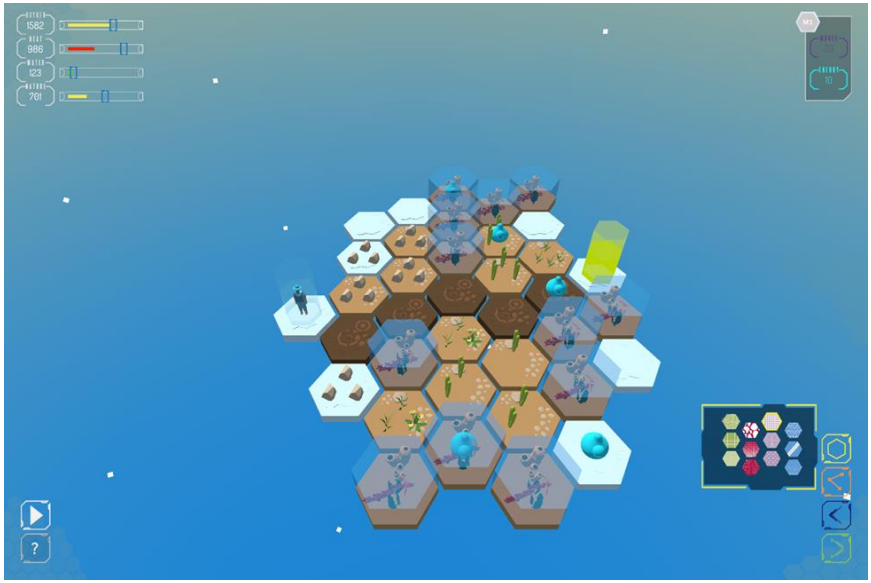

FIGURE 4: GAMEPLAY II

Environmental balance

Finding the environmental balance is the main, overarching goal. Each planet has ideal values for oxygen, nature, heat, and water. This balance is a combination of all three maps for a planet. Thus, this balance needs to be considered as a combination of all three maps. The players influence these values by changing the tiles that constitute the maps or by placing objects on existing tiles. There are four tile categories representing the four basic elements: fire, water, earth, and air. For each category, there are three tile types that create different effects. For the fire category, there is fire, lava, and heat wave. For water, there is water, vapor, and ice. For air, there is wind, air bubble, and cold wave. Finally, for earth there is sand, mud, and earth. For example, if a player places a vapor tile, the oxygen decreases as the heat and water increase. Additionally, since the only way to add a tile is to change an existing one, the players need to consider what to remove as well. To illustrate, if a player changes a vapor tile to an ice tile, this action does not only add the properties of the ice tile (decreasing the heat), but also removes the properties of the vapor tile (increasing the heat) as it is no longer there. As a result, the heat would decrease significantly since the player replaced a tile that was increasing the heat with a tile that decreases it.

Similarly, there are tile objects which consist of rock, plant, tree, and grass. These can be placed on certain tile types and players can impact the balance without removing an existing tile. However, these objects have a smaller impact compared to changing a tile and they cannot be placed everywhere. For example, on a lava tile, only rocks can be placed as objects. Hence, these objects add an additional set of tools that should be considered carefully.

Finally, players are also limited by the number of changes/moves they can perform. For example, if they have 15 moves, they can either change a tile or put an object on an existing tile for 15 times only. However, they can use the undo and redo buttons to test different solutions.

Moving to the next level

Each planet consists of three levels/maps. On every level, there is a starting tile and a teleportation tile; the player needs to select a path between these two tiles to advance to the next level. However, traveling between each tile costs an amount of energy which is determined both by the tile type that the character

traverses and the number of objects on them. Similar to the tile types, builders/characters have four types, fire, earth, air, and water. For instance, if a character's type is water, it costs them less energy to traverse water tiles (vapor, ice, and water), compared to the builders of other types. Additionally, as the number of objects on a tile increases, the required energy to pass them also increases proportionally. Therefore, finding a path should be considered simultaneously with impacting the environmental balance.

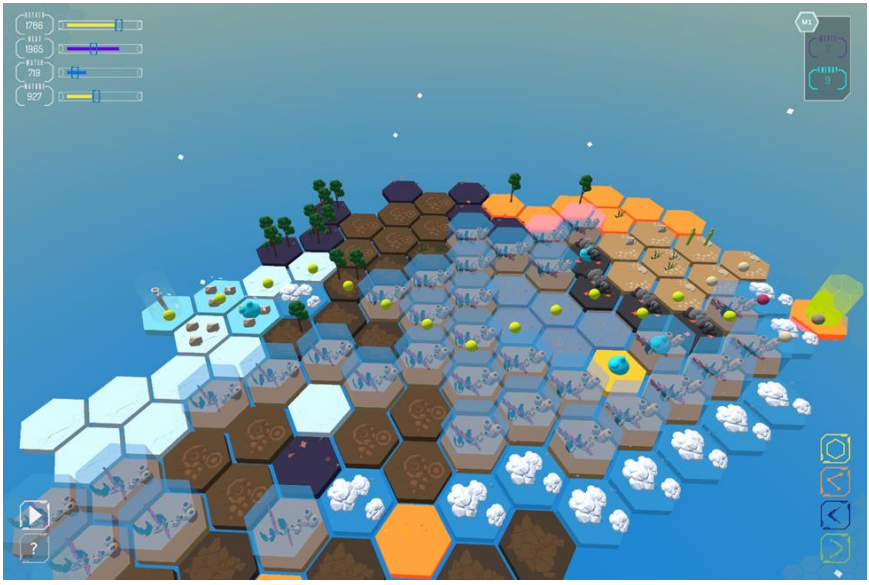

FIGURE 5: PATH

Habitants

According to the game narrative, habitants are the bodies of a hive-minded creature that show up on unchanged tiles. They are the customers who asked the builders to balance their world. However, this information is hidden until the players start interacting with the habitants. If clicked on, one of their bodies dies and gives one energy. With this first click, the game explains the true nature of the habitants, how they are living on this planet, and the fact that their extinction would cause a catastrophe. After this point, if players continue to eliminate them, they also continue gaining energy. Yet, the game starts to punish them by starting to take away their moves, their ability to rewind, etc. Finally, if

they end up eliminating all the habitants, the players automatically lose the game since there is no one left on the planet.

Following this introduction of *Hexostasis*, I introduce a brief literature review where I highlight the theories and literature behind the game while also pointing to the related design decisions.

A Brief Literature Review

When referring to disciplinary multiplicity, it is not always easy to differentiate the diverse ways disciplines might come together. However, for this study, it is important to underline what transdisciplinarity means and how it is different from the other ways disciplines might be brought together. In their meta-analysis, Marshall (2014) makes this separation clearly,

> Multidisciplinarity is associative; it indicates collaboration or correlation without integrating disciplines. Interdisciplinarity is defined as connective, implying deeper connections and correlation with varying levels of integration of disciplinary concepts, theories, methods, and findings in which disciplines remain discrete (Klein, 2000; Leavy, 2011). In other words, connections are made without fusion (p.106).

In the light of this definition, I refer to transdisciplinarity as a fusion of disciplines. Similar to this approach, one of the earlier definitions of transdisciplinarity points to a more system-like approach where Piaget (1972) defines transdisciplinarity as a "superior stage…which will not be limited to recognize the interactions and/or reciprocities between the specialized researches, but which will locate these links inside a total system without stable boundaries between the disciplines" (p.144). Likewise, Steger's (2019) definition also refers to transdisciplinarity as "the systemic and holistic integration of diverse forms of knowledge by cutting across existing disciplinary boundaries and paradigms in ways that reach beyond each individual discipline" (pp. 765-766). This highlights that the way transdisciplinarity is defined is consistent and points to an approach that creates more complicated, system-like relationships compared to multidisciplinarity and interdisciplinarity.

According to the game studies scholars Salen et al. (2011), a system is "an entity designed by humans or by nature that maintains its existence and functions as a whole through the dynamic interaction of its parts" (p. 37). This aligns with the structure of video games. In fact, games are already defined as

large complex systems by many scholars (Akcaoglu & Green, 2018; Squire, 2011; Gee, 2008). Hence, it can be argued that this approach makes video games favorable for creating transdisciplinary learning experiences. Mirroring this perspective, in *Hexostasis* the disciplinary practices are fused into one another where they are encouraged all at once as a part of the overall game system. One game mechanic can serve multiple areas at once, and one practice can be encouraged through multiple game elements. In the next section, I present these practices that I am combining in a transdisciplinary way, which is followed by the structure of games and how I weave these together in *Hexostasis*.

Design Problem and Activity-centered Design (ACD)

There are many ways of approaching a design problem, using a variety of tools including the different design methods. However, these approaches cannot be forced into prescribed techniques as each design problem is unique. Thus, in this study, I first looked at the concept of a "design problem". Buchnan (1992), explains that anything can be positioned as a design problem and uses Rittel and Webber's (1973) "wicked problem" approach as an alternative for the step-by-step design processes which dismiss the designer's identity. According to Rittel (1992), this design problem approach avoids any definite solution to a problem and is more flexible (pp. 15-16). This indicates that every design problem is unique, and for a more concrete and well-thought solution, they should be approached as such. With that understanding, I decided that activity-centered design (ACD) would be a good fit for this approach towards a problem.

Norman (1988) is well known for his famous book, *Design of Everyday Things* where he introduces human-centered design (HCD). Today, HCD is a buzzword, alongside design thinking, as the ideal way of approaching a design problem. However, echoing the previous concerns that I highlighted about the lack of flexibility and dismissal of identity, no design approach or method should be seen as a universal solution to every design problem. In fact, years later, Norman (2005) challenges how HCD is used and proposes another approach in his paper *Human-Centered Design Considered Harmful*. While not dismissing HCD's value, he highlights a more critical approach through activity-centered design (ACD) for an approach focusing on innovation.

> The historical record contains numerous examples of successful devices that required people to adapt to and learn the devices. People were expected to acquire a good understanding of the activities to be

> performed and of the operation of the technology. None of this "tools adapt to the people" nonsense— "people adapt to the tools." (p. 15)

Through this perspective, he highlights that there are different design approaches for different needs, and associates ACD with innovation, where the designed activities lead the design process instead of being limited to what people can imagine. I find this approach to be especially fruitful for game design as it can help designers evaluate the actions and activities that are defined in their games while also creating space for innovation and unexpected outcomes. Thus, ACD is instrumental for the way I approach *Hexostasis,* as my design process started with thinking about the activities and actions that I encourage for a transdisciplinary approach. It also helped me question what these in-game actions communicate to my players.

Critical Play

While criticality in play is not a new concept, Flanagan (2013) looks at it from an art education perspective and theorizes it in her book, *Critical Play*. For this study, her theory plays a crucial role for all stages, including game design, research design, and user studies. Hence, while criticality has many meanings in academia, I use Flanagan's (2013) approach where she defines critical play as "to create or occupy play environments and activities that represent one or more questions about aspects of human life" (p. 6). She also explains that "games ultimately create cognitive and epistemological environments that position the player or participants with the experiences previously described in meaningful ways" (2013, p.6). In addition to Flanagan, according to Gee (2003), one of the ways of learning is "to be critical as well as active", the learner should be able to recognize and produce meaning not "in a particular semiotic domain that is recognizable to those affiliated with the domain, but, in addition, how to think about the domain at a "meta" level as a complex system of interrelated parts" (p.23). Based on these approaches, in a video game, the game elements such as the narrative, mechanics, visual elements, and in-game activities are related and they present and transform the past activities in a new, meaningful way. In connection with ACD, these approaches mean thinking about all the game elements and the way players interact with them while reflecting on how these interactions and activities position the player's past experiences. Hence, while designing a game and its activities, designers are not only concerned if the game is fun but also with the significance of the activities and what these

communicate as a whole. Finally, Flanagan (2013) highlights games as "safe spaces" where "critical play is not about making experts, but about designing spaces where diverse minds feel comfortable enough to take part in the discovery of solutions" (p.261). With that approach in mind, one of my goals for *Hexostasis* was to make it into a space where my players can explore and reflect on their solutions, activities, and interactions from a critical lens.

Abstraction and Decomposition

In this research, I am using abstraction and decomposition from computer science. Echoing the arguments around design thinking, computational thinking is also still explored and cannot be limited to a single predetermined approach (Denning, 2017). However, in this research, I focused on versions that are specifically defined for pedagogical purposes. These versions mainly focus on the concepts of decomposition, abstraction, pattern recognition, and algorithms (Barr & Stephenson, 2011). Decomposition refers to breaking a large problem into more manageable, smaller pieces and tackling it that way. Abstraction involves taking out unnecessary information while finding and transferring common solutions. Pattern recognition includes identifying recurring elements. Lastly, an algorithm is the design of a sequence of instructions (Wing, 2006; Yadav et al., 2016; Barr and Stephenson, 2011). As I previously underlined, in *Hexostasis,* I specifically focused on abstraction and decomposition out of these four concepts.

When I was thinking about ways to fuse these practices and disciplines together, I started to find commonalities that I could merge through the game elements. For instance, I felt like I was already practicing decomposition as a designer whenever I was approaching a design problem, and I was already using abstraction in my iterative cycles of problem-solving. This encouraged me to look closely into the game elements and leverage them to create a coherent game system that incorporates them well. In the next section, I focus on these elements that compose a video game.

Game elements

There are different ways of approaching games and their structure. According to McGonigal (2011) there are "four defining traits" of video games (p.20). These

include *the goal, the rules, the feedback system, and voluntary participation*. In this study, I used this framework with one addition: *failure*.

Video games have a *hierarchy of goals*. These are:

1. First-level goals: They are necessary but smaller-scaled achievements that are important for navigating and enabling interaction with the game

2. Second-level goals: These are goals to raise confidence and slowly ease into the bigger challenges. They help with gaining skills and building a positive self-image without putting a lot of stress into achieving the main goal.

3. The Main Goal: This is the main solution to the problem; what is wished to be achieved through the whole narrative structure and challenges. (Yolac, 2019, p.261)

This hierarchy considers a game as a system of relationships that is structured to keep the player engaged while learning and advancing within the game.

A video game has *rules/ mechanics*. These rules and mechanics "define the space, the timing, the objects, the actions, the consequences of the actions, the constraints on the actions, and the goals" (Schell, 2014, p.174). Therefore, these rules are closely connected with the gaming environment and the other elements within it. In relation to that approach, Anthropy (2014) looks at the in-game activities as a grammar and highlights the verbs that we define through our design. This approach is especially valuable for the transdisciplinary system that I created since essentially it focuses on the activities that are defined for the players. Thus, it acknowledges that any activity a game allows or encourages has an impact and must be considered carefully beyond what it offers in terms of fun.

A video game has a *feedback* system. While this feedback might change according to the goals and the genre of the game, all games inform their players. Even simpler and more casual games allow their players to know how they are doing at any given time. When a player tries to jump and falls in a game, or, when they press a button and hear a sound effect with a negative connotation, this can be considered as a simple type of feedback. A more complex example would be the feedback provided through the game interface. For example, when playing a massively multiplayer online game, the game can provide feedback on how much damage a character dealt after a fight, or showcase how many times they used their abilities, which are more statistics-oriented. Hence, there is a

range of ways that games provide feedback. However, in good games, players are always made aware of their current status.

Voluntary involvement is one of the most attractive aspects of video games for educators. Considering Csikszentmihalyi's (1990) well-known flow theory, a well-designed game has the potential of keeping its players in the flow as long as it can balance skills and challenges. Therefore, if a game can create a proportional raise between its difficulty and its player's skills, it is more likely to keep the player motivated and engaged. While Csikszentmihalyi's (1990) theory is originally created addressing the happiness in life, it is used in game studies and educational technologies in theories like "game flow" where it is branched out to be applied for games specifically (Sweetser & Wyeth, 2005).

Finally, games have *failure* and no matter how many times a player fails, they still feel successful when they complete a game. Juul (2013) explains that failure is not a pleasant feeling. While games can create and nurture this feeling, they also create opportunities to improve ourselves. In a way, we know that a game is meant to be played, a level is meant to be passed. In Juul's (2013) words "Games promise us a fair chance of redeeming ourselves. This distinguishes games' failure from failure in our regular lives: (good) games are designed such that they give us a fair chance, whereas the regular world makes no such promises" (p.7). Hence, games create a "safe space" (Flanagan, 2013) and allow us to try until we become better and successful.

In conclusion, I would like to reiterate that video games are large complex systems that consist of multiple elements. When designing *Hexostasis*, my main goal was to echo this structure through the game elements and, by creating a space where practices from computer science, design, and art education come together. In the next section, I dissect *Hexostasis* and showcase how everything that I argued so far comes together in the game.

How does Hexostasis bring everything together?

As I previously mentioned, understanding the structure of video games and the elements they are composed of is important to fully leverage them. Following the same order from the previous section, first, *Hexostasis* has a hierarchy of goals. While balancing the environment is the main goal, it is followed by the goals of moving to the next level and keeping the habitants alive. Second, these goals and systems are defined by the rules that construe the activities and how

players can interact with the game. Third, *Hexostasis* has multiple ways of providing feedback such as sound effects, dynamic narrative, information screens, and success conditions. Fourth, through its gradually rising difficulty and flexibility for error, *Hexostasis* enables players to remain interested and engaged. Finally, while it allows for failure, it also promises a solution through its game elements that allows for iteration and experimentation. As a system, the way these game elements are designed allow disciplinary practices to be encouraged throughout the playing experience.

Due to the nature of transdisciplinarity, multiple game elements of *Hexostasis* can serve different disciplines. Hence, while categorizing each element according to these practices does not fully express this fusion, I present the main design elements and their connections to certain disciplinary practices.

- Because of the existence of multiple levels, and the information that is provided on them, in order to succeed in *Hexostasis* players learn to create a tactic and solution of their own. They also apply it to the next levels while also eliminating unnecessary information that isn't related to their solution. This aligns with the definition of *abstraction*.
- Planets have three connected levels. These levels consist of tiles and objects on them which requires using *decomposition* and solving the problem by considering it in small, connected pieces.
- The entire game fits the way I previously defined a design problem approach where the game allows multiple iterations and experimentation.
- The game encourages its players to think about their in-game activities, as it is in ACD, and how these contribute to the solution while also thinking about these solutions critically all through the habitants, game narrative, and the overall environmental balance.

Following this short summary, it is important to highlight that, naturally, *Hexostasis* has more complicated relationships which will continue to evolve with each iteration.

Past, Present, and the Future of Hexostasis

While the main focus of this paper is to introduce *Hexostasis* and how it was designed, as a design-based research project (DBR), the game is consistently

maintained and updated. Therefore, I find it important to introduce my research methods, as they are not just used after the game design is completed, but they are a part of the continuing design process. Hence, these methods are a part of the past, present, and future work around *Hexostasis*.

Methods

First, as a designer who aims to adopt and evoke a critical approach, it was crucial for me to use Flanagan's (2013) design method which I weaved my research design into. Flanagan improves the popular iterative game design method and proposes her 'critical play' game design model. Initially, she adds values and goals to create a meaningful experience. She, then, adds the step of designing for diverse play styles. Next, she underlines playtesting with a diverse audience and is follows this with verifying values and revising goals.

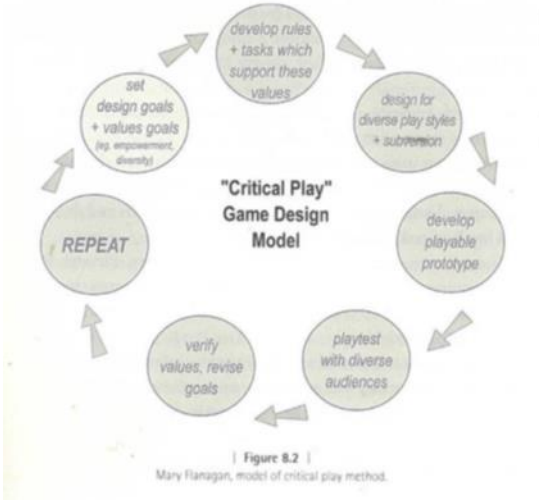

FIGURE 6: CRITICAL PLAY MODEL (FLANAGAN, 2013, P. 257)

When designing *Hexostasis* I followed this model at every step of the process. I first used a DBR methodology where the research conditions and experiments are designed by the researchers. These serve as a form of intervention in which the way the learning environment and tools are designed is included in the research inquiry. This causes the designed tools and conditions to be revisited and updated periodically as the experiments go on (Barab &

Squire, 2004; Sandoval, 2014; The Design-Based Research Collective, 2003). *Hexostasis* played the role of the "designed tool" which I created iterations of following Flanagan's (2013) model. To collect and analyze data, I adopted a mixed methods approach which involves, "the planned use of two or more different kinds of data gathering and analysis techniques" (Greene et al., 2011, p.259). I conducted study sessions with a total of 15 participants for both phases of the first two iterations so far. First, I asked participants to fill a pre-survey, then they played the game while thinking aloud, which was followed by a post-survey and an open-ended interview. I recorded both the gameplay and the interview sessions which I later transcribed. Finally, using the data from the main study, I coded the interviews using Saldana's (2009) coding method where I created main themes and concepts as a result of multiple cycles. I mainly used this research design to inform the second and third iterations of the game which I will continue working on.

Future of Hexostasis

In this paper, I focus on the design of *Hexostasis* and depict my journey of creating this tool as an artist and a designer. However, I find it important to illustrate this journey through the methods and methodologies that I used as it is intertwined with the entire design process. I am planning to use a similar research design for the later iterations. In that sense, this paper represents a section of a long research journey.

To conclude, in this paper I presented *Hexostasis*. First, I briefly talked about my background and the circumstances that led to this research. Next, I introduced my problem statement and research questions. Then, I explained how *Hexostasis* works. This was followed by a brief literature review and a showcase of the way theories and concepts got weaved into the game. Finally, I discussed the research methods, which are not only the past but also the future of *Hexostasis*. *Hexostasis* is not limited to my Ph.D. studies; its complexity and potential can't be fitted into a single paper or a dissertation. Therefore, I will continue working on it, create more iterations in addition to the new games I will produce with this same transdisciplinary design approach that I presented in this paper. Hence, *Hexostasis* is a cornerstone for a new way of approaching art, design, and education from a transdisciplinary lens.

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