LISTAHÁSKÓLI ÍSLANDS
Iceland Academy of the Arts

Department of Design and Architecture
Master of Design



Analysis and Dissemination

Bio/Geo-mimetric Mentoring tool

Creating an empowering Geometric-mentoring tool,
achieving cross-disciplinary knowledge through mimicing nature.

Sinéad McCarron

A document submitted to: The Department of Design and Architecture, Iceland Academy of the Arts, in partial fulfillment of the requirements for the degree of Master of Design, 2016.

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1. Introduction

My goal is to create a Geometric-mentoring tool, which empowers the learner to thrive and map their discoveries, in turn creating tactile outcomes, whilst achieving cross-disciplinary knowledge through nature. As a UX and visual communication designer of previous educational Apps I want to outline the importance of research and design thinking. A 'user experience' designer's job is to enhance the satisfaction of their users improving on usability, accessibility, and pleasure provided in the interaction between the user and the product whether it be digital or physical. I will highlight in my thesis the importance of cross-disciplinary and co-investigative 'learner – mentor' relationships and how we need to move away from 'banking systems' such as the 'teacher student' relationships where students are fed information.[1] The user I will focus on in this case is the 'learner' and hopefully in future create a tool that benefits their relationship with mentors. As a dyslexic I question the tools that are available currently that possibly segregate the users from their peer learners. Are such tools that are designed for 'learners with disabilities necessary'? Going through the educational system as a dyslexic I have been provided with such tools all my life. Whilst some enhanced ability to spell, it in-turn segregated me from my peer learners. I felt oppression throughout my whole education as dyslexic, facing barriers that highlighted my inabilities instead of my abilities. Whilst dyslexia is a writing and reading disorder I felt that my teachers instantly labelled me as creative. Whilst I am a creative person I also believed that I had other abilities in other subjects such as mathematics. The way mathematics was taught to me was hard to understand until one day I had a mathematics teacher who saw me struggle and taught me how to understand Maths through visuals and in particular, shapes. This was a changing point in my life where a mentor understood my way of thinking. Whilst I learned Maths through visualising shapes and my peers learnt through the conventional way, we in turn achieved the same results. I took this empowerment that this teacher provided me with that day through the rest of my education and in turn started to understand subjects such as science. Whilst I have never had the opportunity to go further with Maths and science I believe that we should provide the opportunity for all learners to be empowered to achieve what they want and not feel segregated from their peer learners. I believe as a designer we should design tools that are universal enough to benefit many users and in my case create a tool that is cross-disciplinary and achieve interdisciplinary intelligence enabling for Howard Gardner's theory of multiple intelligence.[2] To achieve this we need to move away from creating learning tools that are focused on singular intelligence or even focusing on one's disabilities and move forward to tools that are focused on one's abilities and across disciplines. I foresee education moving away from traditional classroom environments into cross disciplinary labs of the future. As a parent I question the morals of creating Applications in digital devices and if this is healthy for young users and question are we moving away from understanding our natural environments and forgetting about what we can learn from nature? Whilst I worry about the overuse of digital devices, I am also aware that they can have many benefits. I am looking into how I can create a tool that allows the user to explore nature through the use of their modern technology and how we as designers should make better use of technology and move away from creating careless and pointless applications. One of the aims of my project is to move the learner away from traditional learning environments into the natural world. In a society that is facing increasing ecological threats due to human influence, it is important to create tools that encourage learners to be mindful of their co-inhabitants of the Universe. To achieve this I need to emphasize that as a designer (especially of applications) we need to focus on the design thinking process and understanding of the user before moving into the actual creation of these applications. It is important that we create tools that are inclusive for every user , I will focus on the age group 16-19 year olds. In order for me to create this tool I need to have a wider team of experts from all academic disciplines to achieve the creation of this tool. This has been a 2 years research project and I am currently in the beginning of the implementation. It's an experimental stage of the project focusing on the mathematical sequence of Fibonacci by exploring nature. Looking to achieve an interdisciplinary experience whilst creating tactile outcomes that in turn the user will learn in the process.

1 Paulo Freire, ***Pedagogy of Freedom: Ethics, Democracy and Civic Courage.*** New edition edition. Lanham: Rowman & Littlefield Publishers, 2001. Pg10
2 Howard Gardner, ***Frames of Mind: The Theory of Multiple Intelligences.*** Pg 8

2. Context and background

As outlined in my thesis research I felt the users of this tool are all 'learners', I feel the need to empower those who especially feel labeled and oppressed in our current educational system. Provide them with better opportunities to make use of their skills and abilities. At the same time being conscious of 'learner – mentor' relationships through co-investigative and cross-disciplinary techniques in the hope of achieving multiple intelligent outcomes. I was very much influenced by both Freire and Gardner's theories. Co-investigative is a term coined by Paulo Freire where the teacher is no longer merely the-one-who-teaches, but one who is himself taught in dialogue with the students, who in turn while being taught also teach.[3] I will create a tool that encourages those that have a chance of success and enable problem solving through cross-disciplinary learning moving away from subject based learning similar to the Finnish education system which is one of the top education systems in the world. They announced a reform by dropping subjects in favour of a new method known as "teaching by phenomenon." Phenomenon teaching essentially combines different skills to teach a broad topic. For instance, a single lesson teaching geography, geology and languages might include asking students to identify various countries and discuss their climates all in French.[4] Putting framework of Multiple intelligence into use, a theory coined by Howard Gardner where he suggests that the notion of intelligence, based on I.Q. testing, is far too limited.[5] I place importance upon the learner - being mindful of the process of becoming as an "unfinished character of human beings and the transformational character of reality necessitate that education be an ongoing activity."[6] I am investigating the mathematical sequence of Fibonacci in nature as a metaphor of growth. Like How Freire outlines 'learners' as an unfinished character too is the Fibonacci sequence. Fibonacci is an endless series of numbers where a number is found by adding up the two numbers before it. Just like the growth and progressions of these numbers I believe that learning too is a sequence of endless growth. That learning is the progression from one day to the next improving in the knowledge that you obtained the day previously.

I completed a mentoring course with Innoent Ísland[7] this course has a unique educational approach based around supporting individuals to become the best version of themselves through innovation and entrepreneurship and by observing their techniques I believe that it's universal enough for all ages as learning is a life long journey.
see **Figures 1&2.**

Figure 1&2

3 Paulo Freire and Donaldo P. Macedo. ***Pedagogy of the Oppressed.*** Chapter 2, Pg80
4 ***"Finland Education Does Away With 'Subjects.'"*** Accessed April 4, 2016. http://www.huffingtonpost.ca/2015/04/24/finland-education-subjects_n_7021048.html.
5 Paulo Freire and Donaldo P. Macedo. ***Pedagogy of the Oppressed.*** Chapter 2, Pg80
6 Paulo Freire and Donaldo P. Macedo. P***edagogy of the Oppressed.*** Chapter 2, Pg80
7. Accessed April 4, 2016. http://innoent.is/

In this course I also learned and observed the advantage that learning environments like fab-lab have on learners who typically feel incompetent in traditional classroom environments. Fab-lab is a laboratory with software such as Rhino and devices such as 3d printers and laser printers. As a dyslexic I personally went through an emotional journey of joy doing this course and observing how what I feel will benefit many learners who have limitations. This innovative and entrepreneurial course is the closest course I have seen to my utopian dream of laboratory classrooms. In this course they offer many games and an app where it allows the learner to document their discoveries and exporting these into innovational outcomes. With this exploratory documentation it inspired me to look at bio-mimicry and how I feel learning from nature is important. With the Innoent app they begin the journey of learning outside. Reminding me of Michael Faraday who was one of the founders of modern physics and who discovered the introduction of electricity. He described an environment rich with sensory experiences which allows curiosity and curiosity leads to experimentation. "My education was of the most ordinary description, consisting of little more than the rudiments of Reading, Writing, and Arithmetic at a common day school. My hours outside of school were passed at home and in the streets."[8]

Are learners today spending enough time away from the classrooms? I feel that digital devices take up a lot of this spare time. I want to achieve a tool where the user explores bio-mimicry through the use of these devices in outside environments. Later I will outline the importance of Bio-mimicry in my tool and transferring this into Geo-mimicry. I will continue to outline who the user is in relation to nature. When do we lose touch with nature? "As adults, we need to put down our books about nature and actually get into a rainstorm, be startled by the deer we startle, climb a tree like chameleon."[9] This is where I question again age limitations. I don't feel it's good to put an age limit on this tool being influenced by Freire to move away from labelling and making it more inclusive. But I have an intuitive attraction to learners who are between the age of 16-19 years old and where does their interest in nature lie? This is the age where they have just completed their transfer test. Many learners in Iceland for example lose interest in the subject such as mathematics and are not doing so well in the Pisa results.[10&11]

This is the age where personal hobbies and interests become a priority. With many being interested in modern music and creative projects I want to look into how cross-disciplinary learning is key to this age group. This is also the age that can get very addicted to digital technology and their interests may be away from the classroom. I am experimenting with ways to influence this age group to explore natural environments by taking advantage of their devices. This will be outlined later. Whilst this is a key age group for me I want to have this tool to be universal enough for all learners. I am keen to create something that will show these mid-teen learners that Maths can be fun in music and music can be found in nature? Or being able to explore science via art or art via science, through cross-disciplinary techniques. One of the goals of the tool would be to have these learners be aware of their equal stance to living systems in this world "we need to look at life that preceded us for tips on how to be better neighbours."[12] Is it up to educators and guardians to bring learners out into nature? I believe a digital device can spark this interest and where the learner will feel ownership of their discoveries. I want to achieve a tool where the users can take interest in their hobbies such as music and showing them that music can be found in organisms or energy in places where green things grow. Having learners being interested in mathematics and life sciences, by looking at species and their ways and talents of survival as an example. Where the learners can enjoy looking for sustainable approaches by examining molecular biology and how the knowledge of our natural world will be passed on. How to do that? I will be using the Fibonacci sequences as outlined above.

8 - Ivan Illich, ***Deschooling Society*** Accessed April 19, 2016.
9 Janine Benyus, ***Bio mimicry: Innovation Inspired by Nature***. New York: William Morrow, 1997. Pg288
10 "Pisa Tests: Top 40 for Maths and Reading." BBC News. Accessed March 30, 2016. http://www.bbc.com/news/business-26249042.
11 "Vísir - Tæpur Helmingur Nemenda Fellaskóla Nær Ekki Grunnstigi." Visir.is. Accessed March 30, 2016. http://www.visir.is/taepur-helmingur-nemenda-fellaskola-naer-ekki-grunnstigi/article/2014140629189.
12 Janine Benyus, ***Bio mimicry: Innovation Inspired by Nature***. New York: William Morrow, 1997.Pg288

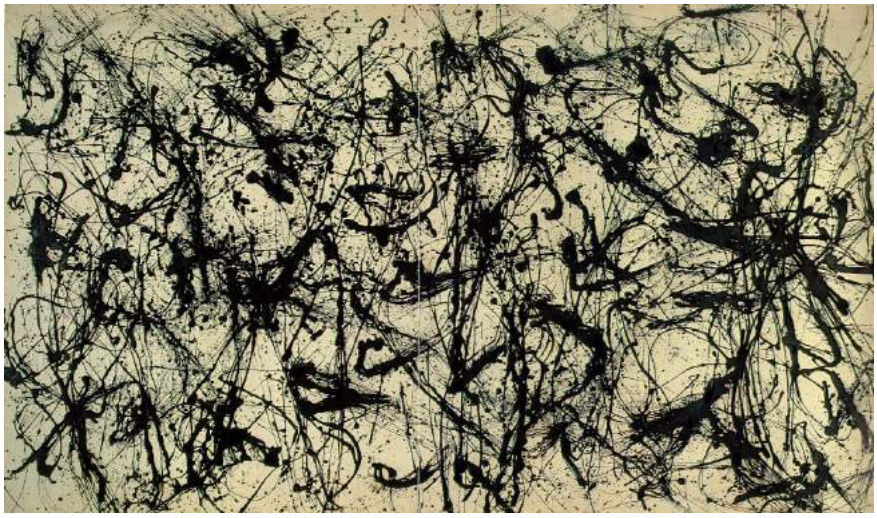
3. So why mathematics?

In my introduction I outlined the way I learned mathematics through the exploration of shapes and how it empowered me throughout my learning process. I often think about how those of us who are labeled in the education system affects their ability to succeed. How we all think differently for example, in my case with shapes. This idea led me to looking at the mathematical sequences of Pi, Phi and Fibonacci. How do people of multiple intelligence as outlined by Gardner see this algorithm? **see chapter 3.1 figure 1 in my thesis.** For example music smart people might see Fibonacci patterns in notes. body smart people might relate it to body movements. Word smart people might discover how language is an invention from this sequence. Self smart people might connect to the sequence and relate to living systems. Where nature smart people might find the sequences in our universe and possibly finding new mathematics sequences related. Ideally for cross-disciplinary knowledge we would have a team of these multiple learners resulting in new findings. Joi Ito, the director of the MIT Media Lab announced that "Connecting science and design is the future of the Media Lab," In Ito's statement he says "that the world is quickly changing. Science, design, art, and engineering, long considered their own areas of focus, are no longer domains to be explored in isolation, but together, in the hopes of expediting progress and discovery."13 I believe that we should explore interdisciplinary groups at the ages of 16-19 years old. Pre-preparation for University level where cross-disciplines should work and be able to work together.

Many artists and musicians actually have a very keen interest in mathematical sequences such as Fibonnacci, or it has been claimed they have. Such as Salvador Dali - The sacrament of the last supper dodecahedron **Figure3**, Jackson Pollock: number 32 **Figure4**, Dali interested in the 4th dimension **Figure5**, Jorge Luis Borges writer, interested in infinity and paradox **Figure6**, Chorographerlist Rudolf Laban **Figure7**, Musician Béla Bartók, At the Sources of Folk Music (1925) to name a few. In 1955, the Hungarian musical analyst Ernö Lendvai started to publish works of Béla Bartók claiming the existence of the Fibonacci number and the golden ratio in many of Bartók's pieces. Bartók himself describes the relationship of his music to nature. "We follow nature in composition ... folk music is a phenomenon of nature. Its formations developed as spontaneously as other living natural organisms: the flowers, animals, etc." — Bartók, At the Sources of Folk Music (1925).[14]

The sacrament of the last supper dodecahedron **Figure 3**

14 "The Bartók Controversy - Bartok-Web.pdf." Accessed April 4, 2016.



Jackson Pollock: number 32

Figure 4

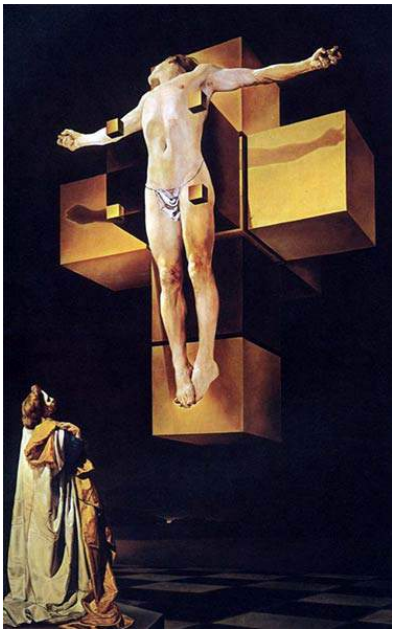


Figure 5

Dali interested in the 4th dimension

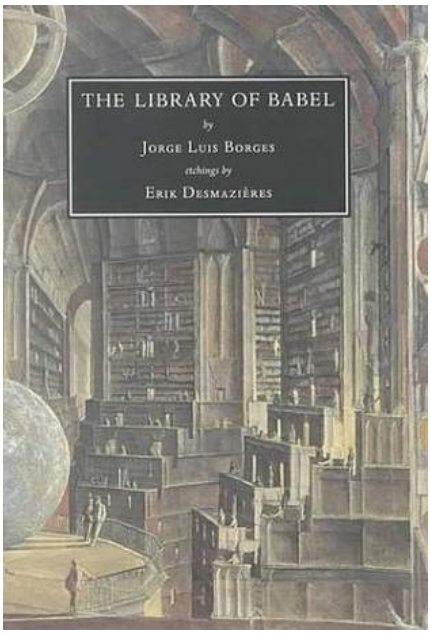


Figure 6

Jorge Luis Borges - Book The Library of Babel

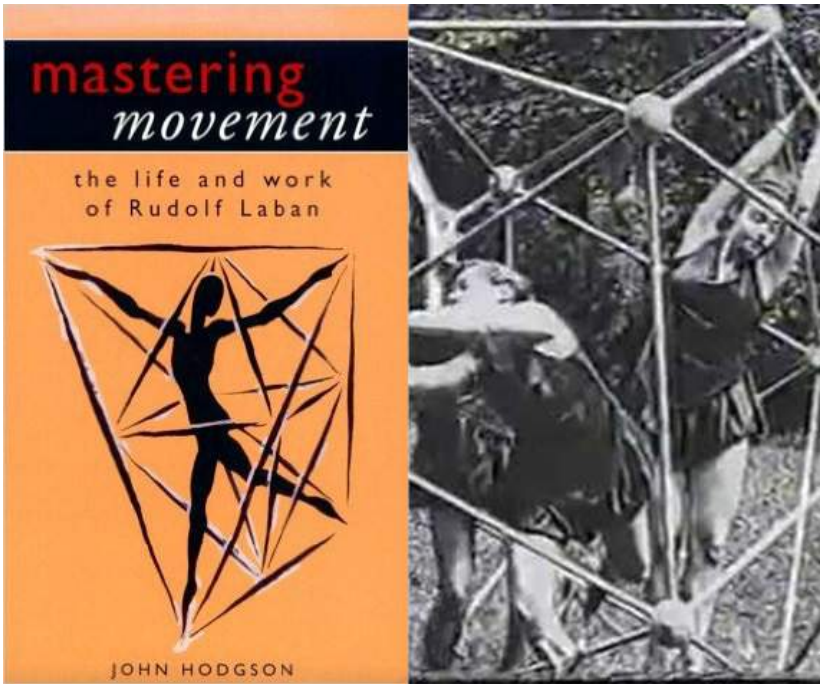
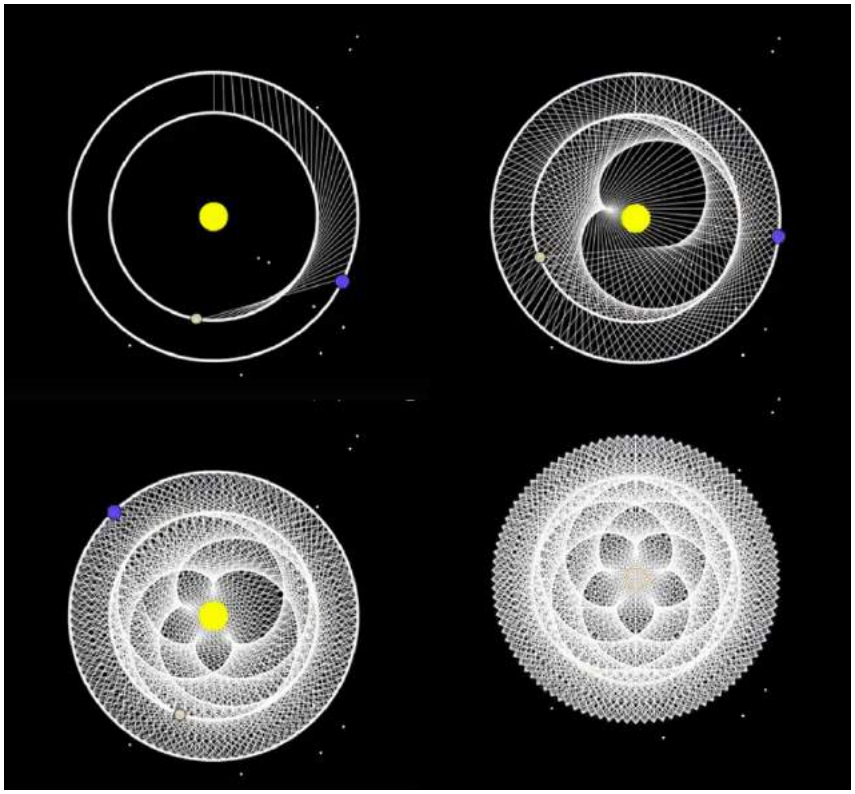


Figure 7

Chorographerlist Rudolf Laban

I am inspired that artists explore mathematical sequences in nature such as Fibonacci, and I feel that geometry and mathematics is the language of the universe and is an inherent part of nature. I also want to outline that mathematics is also the language of science. Is maths the key that leads to innovation or is innovation and discovery the key to learning maths? Maths has been effective through science, technology and engineering. Engineers work on the domain of the approximate in mathematics where it's close enough to take you to mars.[15] Neptune was the first planet to be discovered by using mathematics and gravitational pull.[16] Geometric shapes can be found in activity in the universe. Such as when Venus orbits the Sun 13 times for every 8 Earth orbits. If you track the relative positions of Earth and Venus, this is the resulting pattern in figure 8.[17] Which resembles the flower of life pattern known in Sacred Geometry.



Venus orbits the Sun 13 times for every 8 Earth orbits **Figure 8**

In my experiments with geometry of Fibonacci for this master project I feel like this is a good framework or at least of a stepping-stone to a cross disciplinary tool. Many artists and scientists from across-disciplines have been interested in this sequence as outlined above. I must also add that It is a sequence that is being taught in Mathematics in Iceland between the ages 14 - 19 years old.[18] see **Figure 9**

14 "The Bartók Controversy - Bartok-Web.pdf." Accessed April 4, 2016. http://mathcs.holycross.edu/~groberts/Courses/Mont2/Handouts/Lectures/Bartok-web.pdf.
15 "The Great Math Mystery." Accessed April 2, 2016. /wgbh/nova/physics/great-math-mystery.html.
16 "Ask an Astronomer." Cool Cosmos. Accessed April 2, 2016. http://coolcosmos.ipac.caltech.edu/ask/146--When-was-Neptune-discovered-.
17 "Ensign Software - ESPL: Dances of the Planets." Accessed April 4, 2016. http://ensign.editme.com/t43dances.
18 "Stæ 103, Jón Þorvarðar** - A4." Accessed April 4, 2016. http://a4.is/product/stae-103-jon-thorvardar-ny-2012.

Mathematics book in Iceland Stæ 103, Jón Þorvarðar **Figure 9**

As outlined above learners today seem to be struggling with math and many learners only learn in adulthood what importance math has in our adult lives. So how do I accomplish an interest in finding geometric shapes in nature with my users? Also transforming these discoveries into 3d tactile outcomes. Whilst having the users learn the mathematical algorithm unconsciously. In the hope that the user explores across disciplines. This has me move onto nature and what can be learned from it and the concept of bio-mimicry in the next chapter. How I can take this concept and transfer it into Geo-mimic outcomes?

4. Nature as a mentor – Bio-mimicry

The Pi, Phi and Fibanacci numbers appear repeatedly in nature. From atoms, to sunflower seeds to the spirals in the universe. **See Figure 10.**

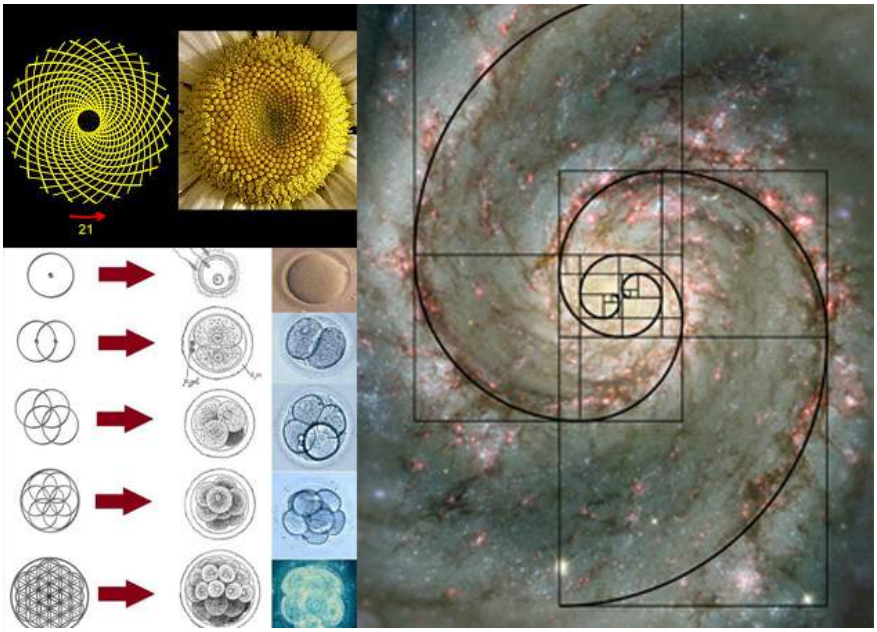


Figure 10

So how do we have learners explore and discover back into nature again? Many mathematicians actually believe that math is discovered and not invented.[19] I believe that learning is also a discovery and experiences should be away from the classroom. Allowing learner's to discover their connection to the natural world. During my design process I examined if possibly bio-mimicry in education might be a good framework for Howard Gardner's Theory of Multiple intelligence that I outlined in my thesis in **chapter 3.1.** I could see so many possible benefits that learners can receive from nature with co-investigative relationships. Janine Benyus describes similar views of mine. She describes nature as a Mentor "Biomimicry is a new way of viewing and valuing nature. It introduces an era based not on what we can extract from the natural world, but on what we can learn from it."[20]

Learning from nature is a question I have been reflecting on since the beginning of my research and studies. In my design exploration I look into how to use modern technology to have learners explore outside of their classrooms. Getting in touch with plants, animals and microbes who we share this planet with. Moving away from the thinking of "what we can extract from nature, but what we can learn from her."[21] I believe that we can take advantage of technology to have learners be at one with nature instead of driving them away by addictive social sites and apps. We need to change our motives in creating applications, our motivation should not be for financial gain and market values which are less focused on their users. Our designs should be more human centered, and focused. Human centered design is coined by IDEO;

> Its a process that starts with the people you're designing for and ends with new solutions that are tailor made to suit their needs. Human-centered design is all about building a deep empathy with the people you're designing for; generating tons of ideas; building a bunch of prototypes; sharing what you've made with the people you're designing for; and eventually putting your innovative new solution out in the world.[22]

19 "The Great Math Mystery." Accessed April 2, 2016. /wgbh/nova/physics/great-math-mystery.html.
20 Janine Benyus, ***Bio mimicry: Innovation Inspired by Nature***. New York: William Morrow, 1997.
21 anine Benyus, ***Bio mimicry: Innovation Inspired by Nature***. New York: William Morrow, 1997. Pg 2
22 "Design Kit." Accessed April 4, 2016. http://www.designkit.org/human-centered-design.

I am hoping that I can use technology to endorse Janine Benyus' idea and have it user focused where nature is the teacher. Are mentors and educational systems forgetting what we can extract from nature? "Was anyone in this day and age, who regarded organisms and natural systems as the ultimate teacher?"[23] Benyus shares my views in having cross-disciplinary learning as I outlined in **chapter 3** above, she talks about this in connection to those in the working environment whilst I discuss it in the learning environment . She points out that people working at the edge of their disciplines, where ecology meets agriculture, medicine, material science, energy, computing, and commerce are learning that there is more to discover than to invent.[24] I foresee my tool creating tactile outcomes but not necessarily innovations or designs. I see these outcomes as scientific and mathematical discovery tools. I also believe that we have a lot to discover before we invent. I believe the interdisciplinary departments would benefit from not necessarily final outcomes but research results. Where it's not actually necessary to design and invent something but more importantly to understand what is needed.

Do learners get the opportunity to forage for pinecones, leaves, feathers and rocks, treasures? In my design process I experimented with how I can use these principles of bio-mimicry to find geometry creating innovation, mathematical and scientific discoveries and outcomes. Benyus foresees an education similar to what Joi Ito, the director of the MIT Media Lab describes in **chapter 3** above.

> The trick is to show this hidden likeness to engineers and biologists before they put on their blinders. It takes educating in the estuary - the place where two or more disciplines flow together to make a fertile idea-bed. Throughout their degree work and even in their continuing education, biologists and technologists should take courses in one another's fields. At think tanks, task forces, joint forums, conferences, and professional societies, they should get to know one another on a personal basis, rubbing minds and getting a little creative friction going. Sparks fly from these mixed unions in a way that just doesn't happen within bureaucracies of like minded people.[25]

With all my influences outlined in my thesis and in chapters above, Freire, Gardner, Sternberg and Innoent Education. I foresee this tool being a cross-disciplinary, cross-investigative discovery tool through nature with geometric tactile outcomes. I think it is only rational to actually have a team of cross knowledge to create this tool. It might even be a case of a larger project of a few related tools. At this initial stage of research and implementation this is the first step before I create a bigger team. I believe that learners should be interdisciplinary so in turn I too should understand it. I need to understand how the interdisciplinary process should work. I want to engage a team of experts to help achieve this tool to its full potential. With the interest in looking at music I have already engaged a music expert with a back-ground in science theory who has already agreed to join me in creating this tool. She too is interested in education and will graduate this term with a masters in education. We have already discussed programmers as part of the team. I would also need a professional scientist, and a mathematician to create this.

As part of my graduate design outcome I experimented with possible outcomes that can be achieved in the knowledge that I already have but was aware of the possiblities of better outcomes with a bigger team. I felt in this process that my experiments would of benefited with more knowledge from experts and actually found it quiet a lonely process. I felt that there was a need for more understanding for this tool for example possibilities of collaborating with experts from other disciplines in other universities. I envisage a dynamic team for this project with myself as project leader but in a critical co-investigative relationship with my team similar to Freire[26] belief how education should be. My experiments are outlined as follows and this will explain my thoughts of possible geo-mimetic outcomes in 3D printing

I look at as follows:
The role of digital devices
Music to tactile outcomes
Design Science revolution (Buckminster Fuller)
Sustainable 3D printing.
User interfaces and living systems (Scott Snibbe)

23 Janine Benyus, ***Bio mimicry: Innovation Inspired by Nature***. New York: William Morrow, 1997.. Pg4
24 Janine Benyus, ***Bio mimicry: Innovation Inspired by Nature***. New York: William Morrow, 1997.Pg285
25 Janine Benyus, ***Bio mimicry: Innovation Inspired by Nature***. New York: William Morrow, 1997. Pg290-291
26 Freire, Paulo, and Donaldo P. Macedo. ***Pedagogy of the Oppressed.*** Chapter 2, Pg72

5. Exposition

The role of digital devices and the journey of exploration

In my first journey of analysis for this design process I instantly went on my own journey of discovery outside to search in living systems to find synergy through the mathematical sequences such as Pi, Phi and Fibonacci. How can I engage users into their own exploration as I believe we are all Geo-metricians. Resulting in exposing learners to alternative ways of thinking starting with the exploration of nature. Removing constraints, allowing for freedom, curiosity which will stimulate their capacity for risk, for adventure whilst creating agents of change. I must note that January is winter in Iceland and temperature levels were between -1 to -8 as you can see in **Figure 11&12.**

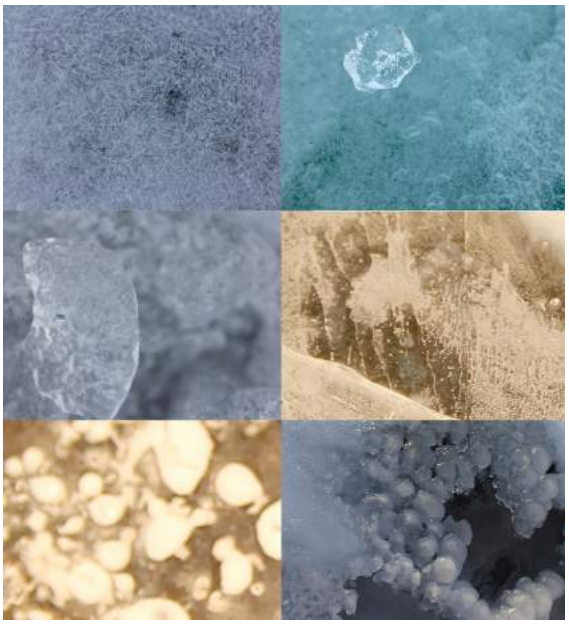


Figure 11

Figure 12

There is not a lot of vegetation at this time of year but plenty to discover. I instantly wanted to explore finding the geometry in snowflakes, which lead me to experiment **Figure 13**. With this I had microscope slides and I froze the slides along with a clean paintbrush and super glue over night so I could find possible geometric shapes in the micro lens. The brush and glue needed to be cold after I discovered in my first attempt where the glue was warm and instantly melted the flakes. After numerous attempts I managed to capture snow but the density of it wasn't right. So I left this experiment then, but being conscious to keep trying this in the future when the weather is right. Through this experiment (because of the weather conditions) I realised that I should narrow my exploration. I decided to stay with the Icelandic black beach as there is not as much snow as other places and it doesn't affect seaweed which was of interest to me. It also holds a symbolic meaning to me of a place of discovery dreaming of futures where we can enter the coral reefs. We often discuss what other planets we can discover and forget what we have one on our door step. The coral reefs are vulnerable to global ocean temperatures that are threatening some of our most cherished underwater ecosystems.[27] We have an ocean full of discovery where patterns of Fibonacci can be found. Whilst we can't dive in without expensive equipment we will soon be able to enter via virtual glasses and explore for ourselves.

27 Accessed April 4, 2016. http://mashable.com/2015/09/26/coral-bleaching-underwater-photos/?utm_cid=mash-com-fb-main-link#hKcnlinzWSqQ.

Figure 13

This brought to mind that it would help my users to have microscope in their digital device. I created a mini low-tech microscope for my mobile devices where users can look into microphotography without paying high prices.
See Figure14&15

Figure 14 **Figure 15**

I created this by cutting some plexiglass and I took apart a laser pen and removed the lenses within the pen and used it for this low-tech magnifying glass where you can discover more geometric shapes that are not visible to the naked eye. Making me think beyond future technology and how technology is advancing that learners can see further into the universe and micro universe with Nasa using lenses to reach beyond what we can imagine. Some technology is not yet in the classroom such as micro lenses and 3d scanners, which would help with the digital device, I am hoping to achieve. But it certainly will only be a matter of time.

In the next phase I think about finding the 2d geometric shapes and how it can be drawn digitally with the thought of how to measure Geometrics, and questions in my device if I should use pre-existing Geometric shapes, where the user can create shapes over images and videos with a similar effect that I created in **Figure 16.**

Figure 16

Knowing from previous experiences in UX design I know this is achievable. As a designer I needed to have an understanding how Fibonacci is measured as I am not a mathematician so I created Fibonacci tools in rhino such as the golden gauge **Figure 17** and rulers in **Figure 18**. I experimented in how to extend the gauge see **Figure 19** and whilst doing that I felt that I learnt the mathematical sequence even more - something that I would hope for my users to experience.

Figure 17

One of my Golden Gauge created in laser printer

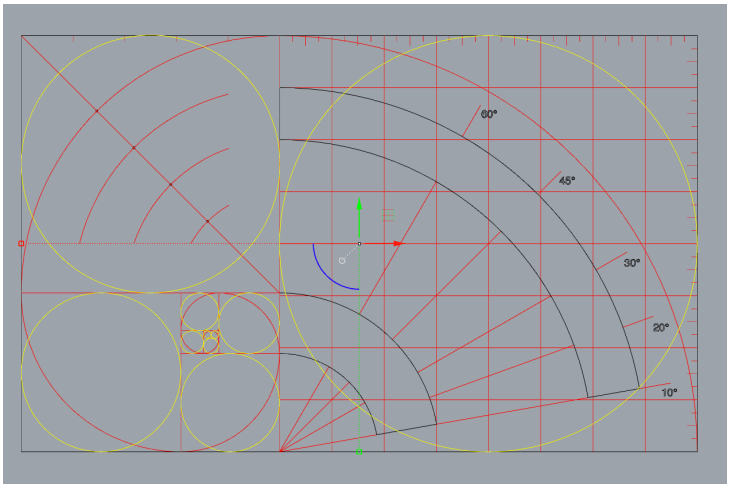


Figure 18 Fibonnacci measurement

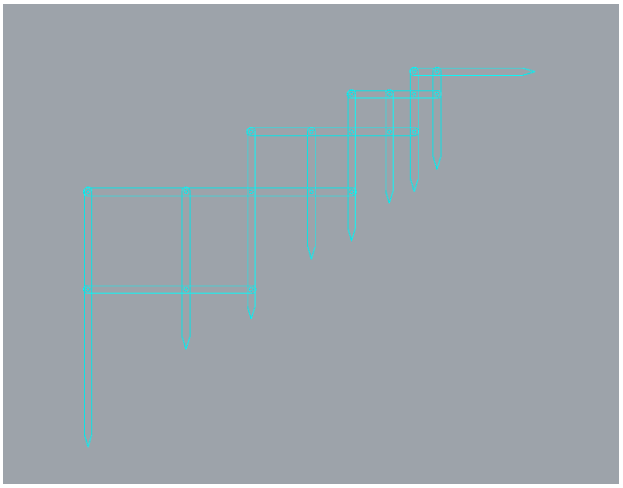


Figure 19 My extended gauge create in Rhino

I think that the initial stage of discovery and creating 2d geometrics shapes is no problem technically to create. I believe that transforming it into 3d would be challenging and need an extension of my knowledge from another expert possible in my future team. As I envision 'learners' possibilities creating musical sounds with these geometrical shapes that are discovered in nature creating these 3d outcomes for example. This is where I moved on to my next analysis and most tedious part of my exploration. This was the resonance experiment which is an experiment using frequency and vibration that visualise geometric patterns. Nikola Tesla said "if you want to find the secrets of the universe, think in terms of energy, frequency, and vibration."[28] This was tedious as whilst I had a sound engineer helping me I would have needed to have the expert knowledge of a music theorist or a master's graduate engaged in the process to assist me. Whilst I already have an expert that I can defer to, we can not colaborate on this until she completes her graduate project.
I most certainly would also have needed the expertise of a scientist. Just as I mentioned about how I would need a cross-discipline of knowledge in this project. I was proved right I believe whilst experimenting with this as I outline next.

28 "Astropixie: Frequency and Vibration Visualized." Accessed April 4, 2016.

6. Music to tactile outcomes

Mathematics and music have been linked since the days of Pythagoras. For example the measuring the length of vibrating strings are related to math for example an Octave is 2:1 Fifth 3:2 and a fourth 4:3 See figure 20.29 **Figure 20**

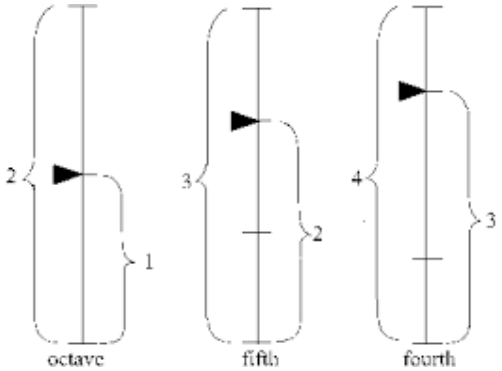


Figure 20

Whilst I would like to look more into what nature's sounds look like in geometrical shapes I started at looking at what sounds look like in 3d as an experiment. Looking at how my tool could reach this achievement. I started with simply looking at what exactly does Beethoven's 5th symphony and the sol·fège Do, Re, Mi, Fa, So, La, Ti look like in geometric shapes by exploring sacred geometry and seeing if there is a connection **Figure 21.**

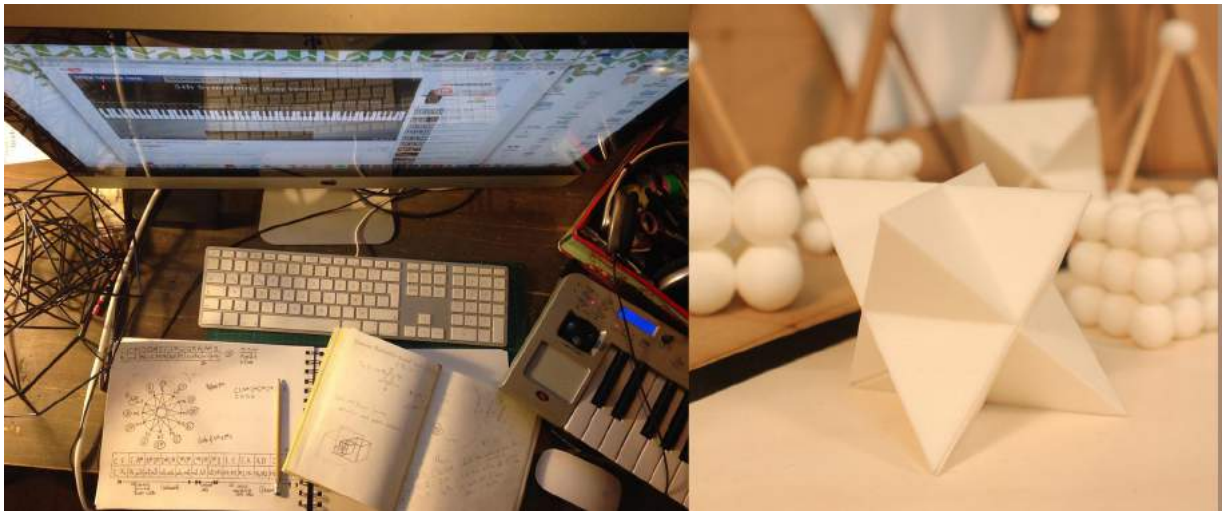


Figure 21 - Sol·fège in a 3d

29 "The Great Math Mystery." Accessed April 2, 2016.

Sacred geometry ascribes symbolic and sacred meanings to certain geometric shapes and proportions. I am not sure if the sacred geometric shapes and the connections people place with music is fabricated. I definitely believe that there is a connection that Pythagoras discovered in the sounds of strings so I looked at these patterns on the piano see **Figure 22**. I learned that many musical instruments are made using the Fibonacci sequence such as the keys on the piano and strings on the violin.

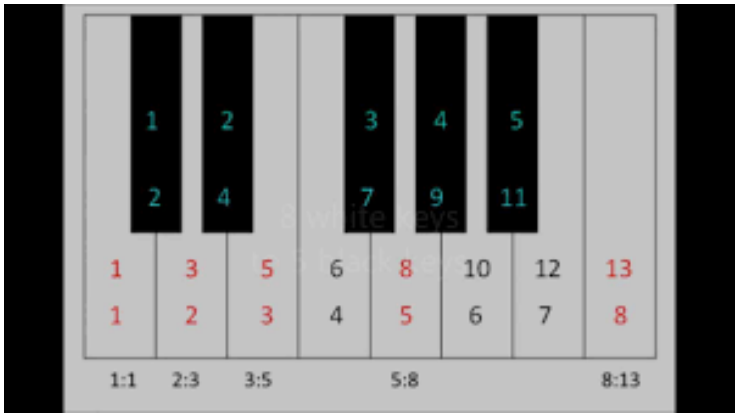


Figure 22 - Fibonacci piano

Again looking at these patterns in musical instruments I achieve a little more understanding of the mathematical sequence of Fibonacci, just as I hope will happen to the users of my tool. I thought about the universe in relation to the language of mathematics and Nikola Tesla's quote on thinking in terms of energy, frequency, and vibration and how it is the secret of the universe. This allowed me to continue with my experiments with music and looked closer at frequencies and vibrations through the resonance experiment. After gravitational waves was discovered through vibration and frequencies.[30]

My first experiment with resonance was a successful one and had instant results. I obtained a speaker and pulled it apart to get to the vibrational part of the speaker I used just salt and placed water on top of the speaker to examine the waves in the water. This was a home experiment. Then I decided to move this experiment into a studio space which allowed me to play with high frequencies. Also to play with different material for the platform above the speaker. As you can see in see **Figure 23.**

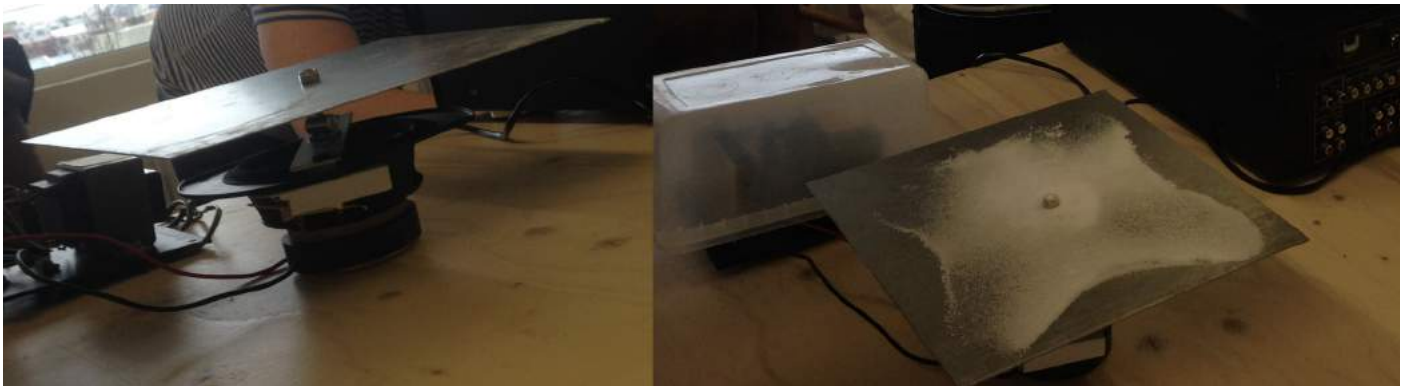


Figure 23

30 Dennis Overbye, "Gravitational Waves Detected, Confirming Einstein's Theory." The New York Times, February 11, 2016.

When I recorded and experimented with higher frequencies in the studio my first speaker blew. With my second speaker it would only achieve geometry in lower frequencies and I started to use sand instead of salt which I believe is what was affecting my results. I experimented with many materials as a platform and will continue with this experiment. Experimenting around with this enabled me to foresee future experiments where I can use a room full of speakers to create 3d shapes moving up the 3rd dimension in the Y axes. Possibly creating Ephemeralization dMass results. Ephemeralization is a term coined by R.Buckminster Fuller, which is the ability of technological advancement to do "more and more with less and less until eventually you can do everything with nothing". Which makes me explore the vision of Buckminster Fuller before I expected to. I expected to explore his work later in my experiments process.31 dMass is a principle of learning to apply these principles of mimicking the way nature solves problems and applying them to all aspects of our lives in order to reduce the total amount of Mass that is invested in the wealth and progress in order to take care of earth in a more sustainable bases.[31] Buckminster foresaw that we can continue to do more with less until sometimes we won't need wires.

For example the moon and earth are in a perfect tension balance that has an invisible tether and they don't need a mass of materials. This is where I thought about using vibration as a mimic of the tension of the moon and earth. I want to keeping working on this experiment after graduation with a group of experts and how these how geometric shapes created by frequencies can convert into tactile educational outcomes. All of my experiments of frequencies are on video and will be available on my project web-page[32] see Figure 24 for a still. I will continue using the black beach sand that I used keeping in mind the possiblities of bio-material's used for 3d printing.

Figure 24

32 "Designead." Accessed April 4, 2016. http://cargocollective.com/Designead.

Looking at the principle of dMass had me move into looking at my next part of the project of transegrity. Transegrity is a structural principle based on the use of isolated components in compression inside a net of continuous tension, in such a way that the compressed members (usually bars or struts) do not touch each other and the pre-stressed tensioned members (usually cables or tendons) delineate the system spatially. The tensegrity was coined by Buckminster Fuller in the 1960s as a portmanteau of "tensional integrity".[33]

7. Design Science Revolution

Ephemeralization, as outlined above moved me onto tensegrity also outlined above. Buckminster Fuller liked the idea of doing more with less for example in his discovery of the arch and what he experimented with and what made better arches. Iron tubes formed into triangular shapes. So creating the arch into a truss, discovering that all we needed were wire cables.
The principle of dMass, the principle of using much more benefit with less resources is evident in the bridge industry and the computer industry. Computers are getting smaller but we are still using too many materials. DMass is about learning to apply these principles of mimicking the way nature solves problems and applying them to all aspects of our lives in order to reduce the total amount of Mass that is invested in the wealth and progress, in order to take care of earth in a more sustainable way. This is where I thought it was neccessary for me to understand the principle of dMass by experimenting with transegrity see **Figure 25**.

Figure 25 Tensegrity

33 "Tensegrity - The Geometry of Thinking | The Buckminster Fuller Institute." Accessed April 4, 2016.

I believe that an understanding of dMass and it is the geometry of thinking is again something that I should continue experimenting with for my educational tool possibly with user tests in an off-line user experience. I also believe that this understanding will benefit 3d printing which is where I move on to my next chapter on 3d printing. Before I move on I think about the
Buckminster Fuller's main premise that nature's existing and omnipotent order must be allowed to guide designs made by man, if they are to survive and thrive as a species. Buckminster Fuller coined the concept Design science making people question the distinction between scientific method and design method.[34&35] Did Fuller dream of cross-disciplinary knowledge in designs? I am not sure but I am certainly thinking about scientific and Mathematic outcomes whilst experimenting with his principles. Something again that I want my user to also experience.

8. Sustainable 3D printing.

3D printing is the first technology that has the potential to enable a more biomimetric production model by aligning with one of nature's fundamental tenets: the tendency to manufacture locally. (These and other deep design principles from nature are collectively known as the practice of biomimicry.) Traditional manufacturing methods focus on milling a starting blank — that is, removing material until you've achieved the desired shape — or injecting material into a mold. This is where I believe the benefits of dMass understand would benefit learners using my tool.

In an additively manufactured product, in contrast, the product is printed layer by layer, with each cross section stacked on top of the one below it. Because this operation can be performed without huge, high-throughout machinery, it can be performed at hundreds or thousands of remote location or millions, if you consider the potential of a 3D printer in every classroom — with near-zero waste.

When I first used the 3d printer I questioned the sustainability of the material and made me think about materials I found on the beach and what I could use for the creation of the 3d shapes. I started to experiment with materials whilst I was experimenting with the Vibrations. This is a side distraction. But believe that my tool should encourage users to be side tracked into their own experiments. Creating possible new scientific outcomes or new designs in the process.
See **Figure 26**

But It's also worth highlighting the materials most common used for the printing polylactic acid (PLA). PLA is actually a sugar-derived polymer, so it can be made from plants; most commonly, it's made from corn.

Figure 26

34 "Design Science." Wikipedia, the Free Encyclopedia, February 29, 2016.
35 "Fuller on Design Science | The Buckminster Fuller Institute." Accessed April 4, 2016.

User interfaces and living systems

I plan in my project to encourage learners to explore the world beneath their fingertips but very conscious of virtual and authentic environments. For learners to make genuine outcomes through their exploration in the virtual dimensions. With passionate interests turned into active learning inspired by Scott Snibbe outlined in my theoretical paper. Snibbe inspired me as UX designer as to how he looks closely at the link between users, actions and technology. I liked his complicated structures, constructed of geometric interactive puzzles. How Snibbe looks at the relationships across natural and human disciplines excites me. For this part I hope to experiment with mimicking the nature of the geometrics and vibrations into grid tearing, a technique used in grasshopper using curve paths and heights which influence point allocation to resemble tearing of a grid. Which I think would work well in reflection of the experimentation of the vibrations. For this I would need a professional programmer so for at this stage I will create the effects in animated artwork **See Figure 27** for my interactive experiment. Like Buckminster Fuller, Snibbe is very much inspired by living systems and nature, transferring into his interfaces. Like Snibbe I hope to link between users actions and technology. As the designer of this project I explore how I transfer these virtual dimensions learned from nature into 3d outcomes. Using software such as Rhino to have a better understanding of 3d dimensional learning and exploring Fibonacci patterns and transforming them into 3d creation.**See Figure 27 &28.**

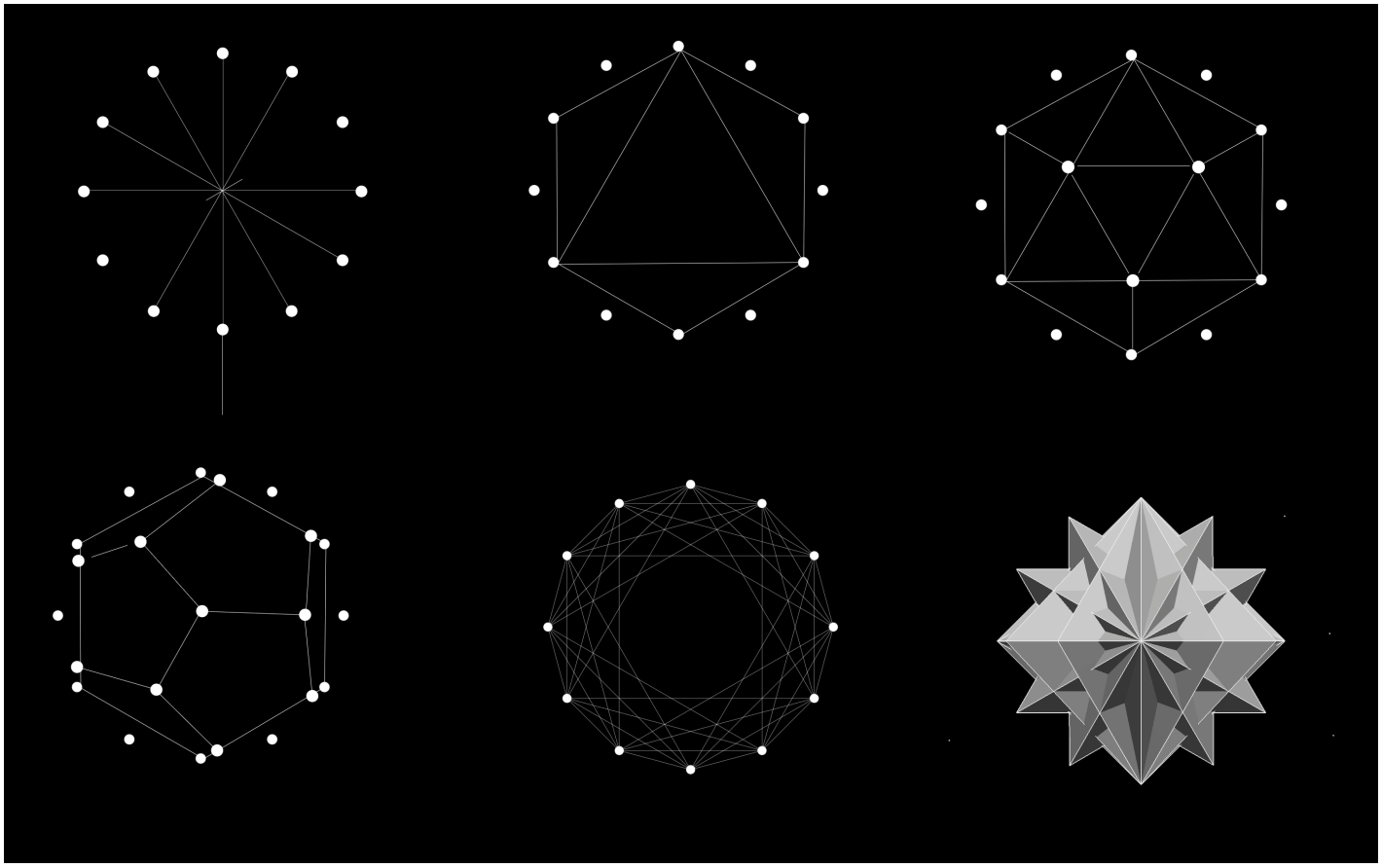


Figure 27

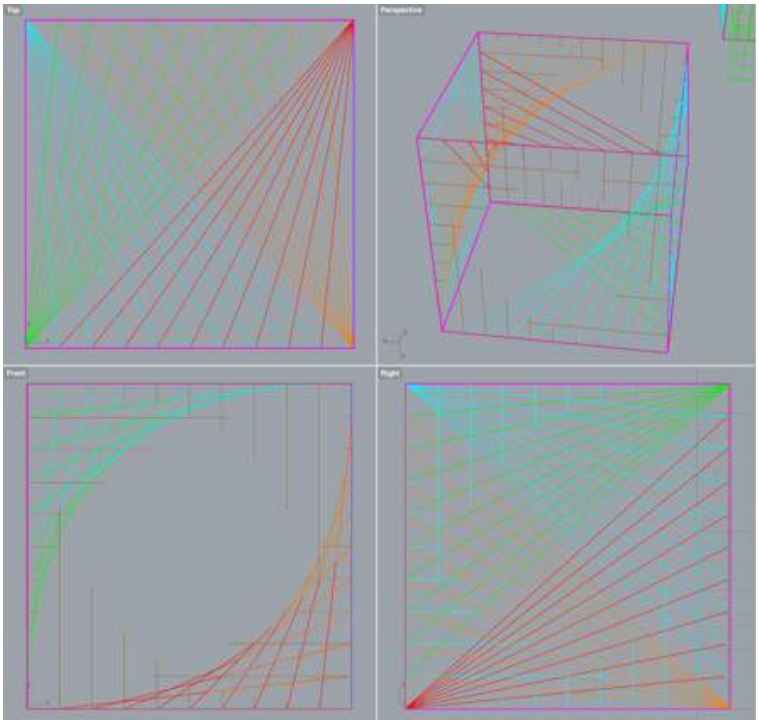


Figure 28

Conclusion

I have been investigating if learners will have a better understanding of cross disciplinary subjects by exploring and mimicking nature in geometric outcomes. Not just to achieve tactile outcomes but also to be cautious of possibly implementing interdisciplinary academic outcomes- exploring negative and positive effects. In order for me to create a tool that encourages cross disciplinary, cross-investigative technigues. I need to, in turn, have a team of experts who are from cross-disciplines. By being a critical co-investigative, collaborative team we can take this project into the next stages. This tool should have learners advancing into a new future where jobs are also cross disciplinary and allowing scientists for example to explore art and music as well to achieve a brighter future. As discussed above not all of my experiments were successful, but I do believe that this is just the beginning and I am excited to explore these experiments more with professionals such as scientists, musicians and mathematicians. I believe that bio-mimicry and geo-mimicry are good frameworks to have users experience, and make discoveries away from the classroom to strengthen their connections to the natural world, with a taste for adventure becoming the focus. As a UX designer going through these investigative experiments made me understand more how the experience of the user should be. Of course in the user test of the project in the future this will help me clarify this more. At my final exhibition I will display possibilities and create an offline user experience to show my initial stage of creation and implementation. I hope to observe and learn from possible users. A tool that is inclusive and learner focused creating future 'agents of change' and better inhabitants of this universe and empowering learners to embrace their cross-disciplinary knowledge excites me. I foresee a tool that makes 'design scientists' / 'agents of change' of the future, whilst learning mathematical sequences in the process. "Art and Maths are different languages but it's really the one culture"[36] Moving learners away from the conveyor belt, and towards a more responsible and encouraging tool for every learners and all will have access's to the same opportunities. This tool will invest in the well being of future generations.

36 Marcus du. Sautoy, "The Hidden Maths in Great Art." Accessed April 2, 2016.

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