جـــامـعـــة الـــشـرق الأوسـط
MIDDLE EAST UNIVERSITY
Amman - Jordan

# The functionality of Algorithm-Driven Design Within contemporary Graphic Design Operationalizing Design Process

# توظيف التصميمات لوغاريثمية المبدأ ضمن التصميم الجرافيكي المعاصر في تفعيل عملية التصميم


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Thesis submitted in partial fulfilment for the requirements
of a master's degree in Spatial Planning


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## Authorization

I, **Tawfeeq "Mohammad Eid" Al-Najjar**, authorize the Middle East University for Graduate Studies to provide hard or electronic copies of my thesis to libraries, organizations, or institutions concerned in academic research upon request.

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## Committee Decision

This section is to clarify that thesis entitled "The functionality of Algorithm-Driven Design within contemporary Graphic Design Operationalizing design process" was successfully defended and approved on 17 June 2020.

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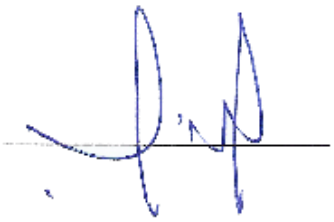
| (Supervisor)<br>**Dr. Wael Waleed Al-Azhari**<br>Professor<br>Dean of Architecture and Graphic Design<br>Middle East University |  |
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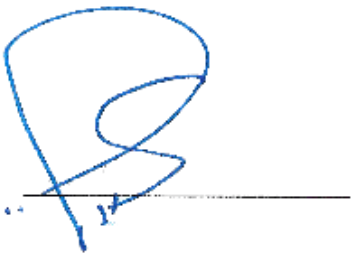
| (External Committee Member)<br>**Dr. Ziyad Haddad**<br>Professor<br>Dean of Architecture and Built Environment<br>German Jordanian University |  |

# Dedication

**"Practice makes perfect."** Anonymous

I dedicate all this effort

To all graphic designers in this world,
To all my friends, who stood there by me,
To my mother, my biggest inspiration, Nada Al-Najjar
To my father, my idol, Mohammad Eid Al-Najjar
To my sisters, Hala, Leen, and Layan Al-Najjar
To my brother, Hamzah Al-Najjar
To my wife, my soulmate, my everything, Waad Badran

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## Abstract

Algorithm-Driven Design is a subject that tackles different design fields; It is a crucial tool for designers, companies, and students to match the rapid transformation in technology. The difference between using conventional design methods and algorithm-driven design methods is the design process that both require to achieve design goals. Moreover, Algorithm-Driven Design is a critical design approach in the medium field of contemporary visual communication design.

Conventional design methodologies no longer provide jobs for designers due to efficiency, speed, and accuracy. Also, Programmers and developers that learn algorithms and achieve Algorithm-Driven Designs do not have a design background. Different design fields require visual communicators to elaborate in the language of our era, concepts such as pattern design, textile design, and User Interface Design (U.I.)

Advancing in knowledge and experimenting through new design technologies invented the Algorithm-Driven design theory. Contemporary Architecture integrated algorithms to interact covalently with spaces and places to serve the function of the spaces as a start. Later on, other design industries consolidated algorithms, such as three-dimensional designs. The researcher elaborated on these goals and explained how the designer could use various kinds such as Parametric and Generative design approaches of Computational algorithm-driven design.

Through this thesis, the researcher examined the effects of algorithms on design process attributes and tested how these attributes relate to graphic design. This research aims to help designers use Algorithm-Driven Design methodologies. This thesis provides a guide that connects algorithms with graphic design approaches.it also sets the action to company supervisors, and educators to pay more attention to the surrounding technologies.

**Keywords**:

Algorithm-Driven Designs, visual communication design, User Interface Design (U.I.), Contemporary Design, Generative Design, Parametric Design, Design Process, Computational Design.

# توظيف التصميمات لوغاريثمية المبدأ ضمن التصميم الجرافيكي المعاصر في تفعيل عملية التصميم

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**الدكتور وائل وليد الأزهري**

## الملخص

التصميمات لوغاريثمية المبدأ تستعرض العديد من المشاكل التي تواجهنا في مختلف مجالات التصميم حيث إنها أداة شديدة الأهمية لمساعدة المصممين، الشركات والطلاب على مواكبة التطورات والتغيرات السريعة في التكنولوجيا الحديثة. تتميز التصميمات لوغاريثمية المبدأ أنها تتطلب طريقة عمل تختلف عن التصميم بالطرق التقليدية للتوصل إلى المنتج النهائي. بالإضافة إلى أن التصميم باستخدام التصميمات لوغاريثمية المبدأ هو أسلوب تصميم ذو أهمية عالية في وسط مجال التصميم المعاصر بالتواصل المرئي.

لم تعد طرق التصميم المعتادة تساعد المصممين وغيرهم من الأفراد في هذا مجال على إيجاد فرص عمل نظرا لأنها لم تعد فعالة أو دقيقة في التصميم وتستهلك وقتا أكثر . وقد أصبح بالإمكان للمبرمجين والمطورين أن يقوموا بتعلم واستخدام طريقة التصميم بالتصميمات لوغاريثمية المبدأ دون وجود خلفية عن التصميم بشكل عام. لقد أصبحت مختلف مجالات التصميم تتطلب من مستخدمين التواصل المرئي بأن يكون معاصرا لحقبتنا من حيث المفهوم مثلا كتصميم القوالب، تصميم الخامات وتصميم واجهة المستخدم.

لقد أثمرت التقدمات والتطورات العلمية بالإضافة إلى التجارب باستخدام تقنيات تصميم مختلفة التي تم تطويرها عبر الزمن بالتوصل إلى نظريات التصميمات لوغاريثمية المبدأ. وساهم التصميم المعاصر في تطوير اللوغاريتمات لدمجها مع مبادئ التصميم المعماري والحضري لتسهيل الاستخدام الوظيفي للمساحات. لاحقا، قامت صناعات أخرى في مجال التصميم بدمج اللوغاريتمات والتوصل إلى مبادئ جديدة مثل التصميم ثلاثي الأبعاد. يقوم الباحث في هذه الرسالة بدراسة وتفصيل هذه الأهداف وشرح كيفية استخدام مختلف مبادئ التصميمات لوغاريثمية مثل إتباع نهج التصميم الباروميتري والتوليدي للتصميمات الحاسوبية المختصة بالمحركات اللوغاريثمية.

من خلال رسالة البحث، قام الباحث بدراسة وفحص تأثير اللوغاريتمات على مختلف نواحي سير عملية التصميم واختبار كيفية ارتباط هذه السمات بالتصميم الجرافيكي. يهدف هذا البحث إلى مساعدة المصممين على استخدام منهجيات التصميم باستخدام لوغاريثمي المبدأ. توفر هذه الرسالة دليلا يربط اللوغاريتمات بأساليب التصميم الجرافيكي، كما أنها تهدف أن يقوم رؤساء ومشرفين الشركات والهيئة التعليمية لإيلاء المزيد من الاهتمام والمواكبة للتكنولوجيا في محيط هذا المجال.

**الكلمات الدالة:**

التصميمات لوغاريثمية المبدأ – التصميم بالتواصل المرئي – اللوغاريتمات – تصميم واجهة المستخدم – التصميم المعاصر – التصميم الباروميتري – التصميم التوليدي – طريقة التصميم – التصميمات الحاسوبية.

# Chapter One:

# Study Background

The first chapter in this research introduces the background of this study and explains the problem. Furthermore, it clarifies the importance of this research, research limitation, and delimitations.

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## 1.1. Introduction

Technology is a process key in the field of design. It is one of the essential rules that every designer needs to process designs in a fast and easy manner. A deep understanding of the relation between design and technology will help convey better, quicker, and with more efficiency. Designers use technology to elaborate, express, and deliver an essential message daily. It is even crucial to mention that technology is the essence of any design output while controlling the efficiency of the design.

Intel, AMD, and Nvidia are three of the most prominent computer parts manufacturers. The triplet competes in producing the best Central Processing Units and Graphics Processing Units. These parts are responsible for the speed and efficiency of our designs. Each one of these chips has unique individual characteristics that can help to make designs in a various wide range of design software, be they two-dimensional or three-dimensional designs.

On the other hand, programming languages also play a significant role in design technologies in a more particular way than the technology itself. It is the communication language that design programs which express their identities through multiple programming technologies embedded inside design programs. The designer now can engage and collaborate more effectively in society since the applications and the data that was programmed by the largest programming industries with the latest technologies that can help the designer work with rapidly and save money, time, and effort.

Autodesk and Adobe are two of the most significant design companies' examples that compete on design software yearly. Both companies are a host of multiple embedded design choices that help the designer identify the visual problem and use a wide variety of tools. The amount of effort given from these companies can control how we think as designers, due to the limitation of this software when there are specific direct and indirect tools to do multiple designs. Using these tools for extended periods affects the designer's mentality and creativity. Therefore, the designer should always engage with the latest design software and trends to meet with the current market requirements resulting in an exhausting process.

Algorithm-Driven Designs are leading designers to use visual script languages, that engage in the design logic and experience rather than brainstorming concepts. Concepts such as User Interface design are one of the examples which consider front end development and decent skills of algorithms to understand the arrangement with the aid of web languages such as HTML, J-Query, and CSS. Designers can use Artificial Intelligence techniques to engage in the designs physically directly toward the users. Furthermore, it is crucial in three-dimensional models to mention that most of the textile, animation, or VFX (Visual Effects) are considered Algorithm based designs.

Animation companies -Disney and Pixar- use programs such as Houdini, which use Algorithm-driven design as the fundamental asset for their work to turn their storyboard sketches into reality. The high collaboration between designers and programmers is essential. It will communicate and innovate in a collaborative work environment to produce advanced design solutions. Gaming companies -Blizzard and Riot Games- are also more involved in algorithms of all kinds to enable players to interact with the three-dimensional spaces through pre-programmed objects. These require the designer to work with a collision system that stops the player from moving outside of the map, this kind of procedural work is done by Artists that work on three-dimensional designs which are of the graphic designer's types.

Several studies have engaged in algorithms as tools for the architectural design but not till now with graphic design or any kind of visual communication design. Parametric design and algorithmic design approaches were introduced before only in structural approaches within architectural designs. Few studies have examined algorithms in graphic design or generative design concerning the design concept and did not still correlate with visual communication designs. In conclusion, different types of designers can design logos, brochures, and multiple batches of product outcomes using algorithms and technology.

Minimal research attention was directed toward the relationship between algorithms and design, even basic programming principles, as object-oriented programming by researchers. New design concepts are required in the market to help the designers from all kinds to find a new job course and descriptions.

Money, time, and effort are three successful vital factors for every designer who works daily, where shorter periods with more money incomes and less effort allow the designers to enhance their life experiences. The designer needs more market credibility, liability which will contribute to the designer's self-esteem.

It is interesting to note that designers who experienced and indulged more through years of designing through the graphic design process have become the innovators and creators of a new system which developed as a knowledge persistently. For example, Textile design has been a default job for every three-dimensional artist or architect where it is a job by itself. The designer requires knowledge on specific details concerning the physical aspect, senses, and shape of each material, looking at the market's local materials and creating them on three-dimensional software. Hiring more Textile Artists that use algorithms as their primary design tool, will satisfy the local market needs for designers, also, will provide more workforce to any design company which is interested in creativity and engaging more designers.

By examining designers' multiple research design methodologies, involving students, the researcher, and the students as participants will understand the concept and misconception designers with algorithm-driven designs. Design administrators and supervisors can plan interventions to engage and innovate behaviors that designers will adopt in the future.

Fundamentally designers and architects think with the same roots when solving a design problem, whether it is a product or a building. In conclusion, the researcher will similarly solve visual communication problems and architectural design ones with the same methodology that Brian Lawson following while experimenting with thirteen different architects. (Lawson, 1980)

**Keywords:** CPU (Central Processing Unit), GPU (Graphical Processing Unit), Algorithm-Driven Design, A.I. (Artificial Intelligence), U.I. (User Interface), VFX (Visual Effects), Graphic Design, Parametric Design, Generative Design

## 1.2. Problem Statement

Design process plays a significant role towards a creative output, as it is considered one of the most challenging steps in maintaining the relationship between the concept and the final product. The massive shift in technology led to the invention of graphic design out of visual art; each year, designers create unique methods with new design principles and elements depending on the generation launched over the different years. Rules change depending on the market's demand and requirements. These problems can be divided into three main issues:

- Time, effort, and money spent through the design process and outcome.
- Textile design, pattern design, game design, and animation require visual programming mechanisms and object-oriented programming techniques.
- The rapid transformation of technology-led the designers to work on an old school set of tools and software, until the generations nowadays reached a completely new approach and methodology in design.

Other sub-Challenges to the current design meta occur, the researcher will engage with some of these challenged as sub categorial problems, and these are:

- Algorithms are the new design language that every designer should at least know about, Architects, Graphic Designers, Three-dimensional Artists, Environmental artists need to understand what these Algorithm-Driven design tools are.

- The subject thesis material can be hard between designers to understand due to programming basics knowledge and logic. On the other hand, it requires the designer's attention to the new organization of shapes and geometry that aspire to the latest trends.

- The program limitations can limit the designer's mind by brainstorming the ideas and focusing on how artists can implement the concept instead; the focus should be on choosing one of the options that programming techniques can provide, which is another pathway in practicing design.

- Graphic design studios were relying on technology rather than designers who should have a programming background—also stereotyping design methodologies where algorithms drive artistic approaches.

- The inadequacy of software mentor's creativity in the field of graphic design, updating software knowledge is the core concept in our generation.

- Graphic design jobs in Jordan are limited. The designer needs a new set of tools to be able to innovate and create differently.

- Design software can limit the designer's mind with the set of tools that are provided for each program by software companies

- The collaboration between the designer and the programmer requires the designer to understand basic programming concepts an order to be able to engage with the project more effectively.

## 1.3. Study Purpose

The main objective of this thesis is to introduce algorithms to graphic designers. The evolution of rapid technology in increasing daily, the necessity of algorithms is also on the rise, which makes the value of algorithmic designers much higher in the community, thus making them unique and individual with this kind of knowledge.

The second main objective is to relate Algorithms to Graphic Design. Algorithms-Driven design is a type of drawing that architects around the world use to functionalize a building based on mathematical equations that can provide the spaces with high efficiency and accurate measurements to serve humans. As Graphic Designers work with different ratios such as the golden ratio, the first grids and patterns can be manipulated by the designers using algorithms.

The researcher summarizes the sub-objectives as below:

- Identify the Algorithm-Driven Designs and study the benefits of using them.
- Associate contemporary Graphic Design with different algorithm-driven design methodologies.
- Build a new workforce in the fields of Graphic Design, designers who would learn and understand that Algorithms would elaborate better in the market.
- Design a new learning plan for University students that are interested in the relation of algorithms and design
- Specify the principles that are necessary to design algorithmically
- Introduce a new design process that includes algorithmic methodologies.

## 1.4. Significance of the Study

From this study, the Researcher enriches and upgrades the knowledge of Algorithmic Design, tackles the contemporary link between Graphic Design and Algorithm-Driven Design, and explore various new design methodologies in using different design software. Moreover, the designer has a variety of solutions to multiple design issues through various design processes.

The study works as a reference for future Designers, Architects, Interior Experts, or any type of design that need to engage with their routine design. It would engage in a new methodology and design process. It helps them reach models within less time and less effort.

The study evokes design companies' on how Algorithmic Design works, and how to even market their ideas, enhance the way on how we could reach customers. Consequently, the research results would help companies and designers understand the technologies used in the design tools, and how they can promote the design marketing growth in the local market.

In this contemporary design world, it is essential to update knowledge efficiently to help develop a strategy that can enhance and contribute to the local market. Algorithm-Driven Designs

add in various areas of designing new aspects of education. Generative adds more options, parametric grants a unique design process, and interaction awards a live experience.

Technology is critical in the design process. Every year there are always updates to the software, hardware, and even new devices that can tackle design in different ways. Such as VR (Virtual Reality), AR (Augmented Reality), and MR (Mixed Reality), or it could be merely new software, such as Unreal Engine, Houdini, and Substance Designer and Painter in the world of 3d design.

Therefore, Designers benefit from this study as a new specialized study of how to use computer sciences in different design approaches. Thus, the limitation of any software can be reachable where every design process or methodology is freedom of will in the designer's mind.

## 1.5. Thesis Questions

The main question that this thesis is going to answer is: How will Algorithm-Driven Design enhance, affect and change the designer's perception and understanding of the design process and methodology in the fields of visual communication design, including architecture, game design, and interior design.

In addition to the critical thesis question, through experiments and research tools, the researcher will answer the following questions:

- How can Algorithm-Driven design be implemented on graphic design as a methodology and a design process?
- In which design fields, Algorithm-Driven Designs can be most efficient?
- How can Algorithm-Driven Designs save time, effort, and money?

Also, through study of the subject matter, the researcher will answer some of the following secondary questions:

- What are the types of Algorithmic Design?
- How can the Designer benefit from using Algorithmic Design, what are the advantages and disadvantages of such use?
- Give some examples of Algorithmic Design that can be usable in the Graphic Design field?

## 1.6. Study Limitations

The research limitations are as follow:

**Place Limits:**

The researcher experimented in Balqa University and Al-Khawarizmi Technical University. Also, the researcher performed a planned pre-test and post-test experimental questionnaire on last year's students from both universities in Jordan. Balqa University in Al-Zarqa City, and Al-Khawarizmi Technical University in Amman city. The research results are not limited to Jordan as the researcher teaches at both universities through online learning methods. Through the lockdown phase of the coronavirus. It is more accessible for the researcher to reach and experiment with students that engage and interact through the quarantine phase daily.

**Time Limits:**

The researcher started the experiments in the second semester of the 2019/2020 academic year.

## 1.7. Subject Limitations

The research will take place in Amman city, Jordan, as this kind of study did not utilize its share of growth in all parts of Jordan, due to teaching restrains. The results of this study do not apply to all Jordan ranks. As to the majority of designers, they do not have the passion for learning

new knowledge or theory accompanied by software supported by technical and theoretical backgrounds.

Any Designer who wishes to take this thesis as an example in finding the solution for similar design problems, the designer should take into consideration their study background of the society, primarily cultural and theoretical backgrounds, due to sensitivity study matter. Many theorists find this study not applicable due to the stereotyped workflow.

The Limited Arabic and English resources are also highly considered as limitations for this study, where the researcher had to apply experiments and knowledge more than researching this study itself to place the hypothesis which may be used.

## 1.8. Definition of Terms

**Algorithm-Driven Design:**

refers to a method or mathematical process for problem-solving and engineering algorithms. The design of algorithms is part of many solution theories of operation research, such as dynamic programming and divide-and-conquer. Techniques for designing and implementing algorithm designs are also called algorithm design patterns, such as the template method pattern and decorator pattern (Knuth, 2010)

**Computer Science:**

is the study of processes that interact with data, and that can be represented as data in the form of programs. It enables the use of algorithms to manipulate, store, and communicate digital information. A computer scientist studies theory of computation and the practice of designing software systems (Parnas, 1998)

**Programming Language:**

is a formal language, which comprises a set of instructions that produce various kinds of output. Programming languages are used in computer programming to implement algorithms (Koetsier, 2001). Most programming languages consist of instructions for computers.

There are programmable machines that use a set of specific instructions, rather than general programming languages. Early ones preceded the invention of the digital computer, the first probably being the automatic flute player described in the 9th century by the brothers Musa in Baghdad, during the Islamic Golden Age (Koetsier, 2001)

**Graphic Design:**

is the process of visual communication and problem-solving through the use of typography, photography, and illustration. The field is considered a subset of visual communication and communication design, but sometimes the term "graphic design" is used synonymously. Graphic designers create and combine symbols, images, and text to form visual representations of ideas and messages (Drucker, Johanna, and McVarish, Emily, 2009).

**Visual Programming Language:**

is any programming language that lets users create programs by manipulating program elements graphically rather than by specifying them textually. A VPL allows programming with visual expressions, spatial arrangements of text and graphic symbols, used either as elements of syntax or secondary notation. For example, many VPLs (known as dataflow or diagrammatic programming) is based on the idea of "boxes and arrows," where boxes or other screen objects are treated as entities, connected by arrows, lines or arcs which represent relations. (Roberta IEEE, 2001)

**Design Process:**

is a plan or specification for the construction of an object or system or the implementation of an activity or process, or the result of that plan or specification in the form of a prototype, product, or process. The verb to design expresses the process of developing a design. In some cases, the direct construction of an object without an explicit prior plan (such as in craftwork, some engineering, coding, and graphic design) may also be a design activity (Cross,2006).

**Contemporary Graphic Design:**

Graphic designers are expected to be proficient in software programs for image-making, typography, and layout. Nearly all of the popular and "industry standard" software programs used by graphic designers since the early 1990s are products of Adobe Systems Incorporated. Adobe Photoshop (a raster-based program for photo editing) and Adobe Illustrator (a vector-based program for drawing) are often used in the final stage. Designers often use pre-designed raster images and vector graphics in their work from online design databases. (Pollard and Little, 2001).

# Chapter Two:

# Literature Review and Case Studies

The researcher depends on literature review analysis in building a reliable database for understanding the subject. In this part, the researcher is going to demonstrate all literature on every aspect of the thesis subject.

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## 2.1. The Mind of the Designer

Creative outputs vary from one form to another, while creativity is considered one of the significant characteristics that control the evolution and prosperity of the design. Moreover, music, art, and science, engineering math is within the creative level. According to Brian Lawson, creativity is divided into two major parts; inventions such as Einstein's theories are one kind. Brian elaborates this kind of creativity as H-Creativity, which stands for high creativity. On the other hand, L-creativity, which stands for low creativity, which consists of developing an existing idea then add details to the design according to the study. (Lawson, 1980)

Creative intelligence is interrelated with patience, motivation, and confidence, according to Lawson. (Lawson, 1980). Rational design thoughts come out of the experience, and the more years are spent in the field of design, the more developed the ideas and solutions will be. (Al-Azhari, 2008). In this study, creativity will combine both mathematical and computational logic orders to define the boundaries of the design output.

Design methodology to reach the design output varies according to Robert Curedale. Fifty selected design methods divided into either mapping or ideation methods to achieve design solutions. The combination of analytical thinking of the problem or brainstorming methodologies makes every designer unique. The ability also to work as a team within the disciplinary design work area is also an important skill to develop. (Curedale, 2017)

Design thinking approaches are mainly three, convergent, divergent, and design thinkers. Convergent thinker responds to numerous steps of a unique solution to one design problem; this kind of thinking is highly applied in the fields of science, engineering, math, and technology. (Curedale, 2017). In the case of this study, the convergent thinker applies to algorithms that use different multiple coded solutions to one answer.

On the other hand, divergent thinking sets alternative solutions and several choices for one design problem. Divergent thinking is used when the answer is hideous, or the next step is hard to reveal. (Curedale, 2017). The combination of both schools of thought is vital, while the algorithmic

approach uses both convergent when having a mathematical problem and divergent when using computational logics, which are unpredictable.

Design thinking is an approach that reaches out to the innovation skills of the designer. Empathy, passion, and love are emotions that motivate the design thinking process. The combination of heart, soul, and brain predicts outstanding design results. Analytical, emotional, creative characteristics are required through the design process. (Curedale, 2017). The different toolkit of methods is applied to different styles of problems by different types of people same applies to algorithmic approaches where different computational approaches are used to different logical solutions.

Diverse design methods that include biomimicry, brainstorming, card sorting, crown funding, empathy map, mind mapping objective trees, personas, and scenarios. (Curedale, 2017) Design requirements are the criteria of choice to the multiple design methods ahead where the designer choose the way that is most applicable with mind, heart, and soul.

## 2.2. The Design Process

Several studies suggest that conventional design methodology follow the process below:

**Example sequence of stages**

Typical stages which consist of with the rational model include the following:

**Pre-production Design**

1) Design brief or Parti pris – an early (often the beginning) statement of design goals.

2) Analysis – Analysis of current design goals.

3) Research – Investigating similar design solutions in the field or related topics

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4) Specification – specifying requirements of a design solution for a product (product design specification) or service.

5) Problem-solving – conceptualizing and documenting design solutions

6) Presentation – Presenting the design solutions

**Design During Production**

1) Development – continuation, and improvement of a designed solution

2) Testing – In situ testing of a designed solution

**Post-production design feedback for future designs**

1) Implementation – introducing the designed solution into the environment

2) Evaluation and conclusion – Summary of process and results, including constructive criticism and suggestions for future improvements.

**Redesign**

Any or all stages repeated in the design process (with corrections made) at any time before, during, or after production. (Cross,2006).

The routes in following different design processes include mixed emotions. Panic, enthusiasm, and disillusionment are involved feelings while designing either for the first or last time. The exciting part about the design process that it has never changed whether creating a refinery oil or construction of a mosque. (Lawson, 2003). Excitement generates the continuous urge feeling to design more efficiently during the same design process.

According to studies, mapping can differ from one designer to another. Different personal creative skills are included and defines the person's mapping ideology. Affiliation, customer user experience, observing the surrounding, criticizing, and developing are different ideologies to ideation mapping. Connections and relationships that the designer makes between design entities define the designer's personality in solving the problem. (Curedale, 2013)

The balance between heart and brain throughout the design process is essential. The algorithm methodology requires the designer to balance creative and logical methods to succeed in the field of visual communication design. Although mapping and relationships can differ between different valid reasons instead of analytical ones, the heart should embed feelings into the project through mathematical and logical processes. Algorithm-Driven design phases implement the designer's characteristics that are divided into different emotional, consistent, coherent, and creative perceptions. The designer needs to collaborate between these bits of intelligence.

## 2.3. What is Algorithm-Driven Design

Algorithm-Driven Design is considered one of the contemporary design methodologies (School of Thought); it is the tool the designer uses to deliver multiple pre-functioned coded steps to achieve a design solution. Therefore, it is essential for utilizing time and effort when doing numerous designs with one functioned ready to use visually scripted.

Patterns are the most challenging to design, for its various applications on backgrounds, designs, even in nature. Creating patterns with an algorithmic design is merely knowing what exactly to code and setting the right variables for the output that makes an elegant design. The idea of using algorithm-driven models is more applicable in this situation where the designer can achieve multiple design iterations within one big pre-coded set of algorithms.

On the other hand, Algorithmic Design is also a tool for any repetitive task. A creative designer would create a code or a system such does that routine task. The designer always had to manipulate random generation for these tasks, not to be a complete replica. The designer can use algorithm-driven design methodologies to achieve that task uniquely.

The simulating design can also be hard to achieve with the current design meta; It is one of the challenges of every designer when there is a geometry in mind, the models should manipulate in a precise grid or pattern based on the designer's mind. These kinds of interactive designs are hard to obtain with the current design software stereotyped kit. Also, it provides direct feedback for the designer to observe and watch the desired model without the urge for complete remodeling.

Algorithmic design is the process of design thinking, when the designer thinks visually by visual scripting nods which lead to solutions, using multiple programming logic and object-oriented programming techniques. It creates in the designer's mind a new mindset where the designer creates codes and nodes rather than grabbing the move or rotate the tool; therefore, the designer's mind becomes more transparent and free and thinks in a more logical understanding (new design process).

Algorithm-Driven Design as a design process explores and inspire new design options and iterations. While logically thinking in a solution, the designer's mind operates in inputs, outputs, and intermediate methods—the design approach in this methodology is centered around exploring and inspiring to finalize the right product.

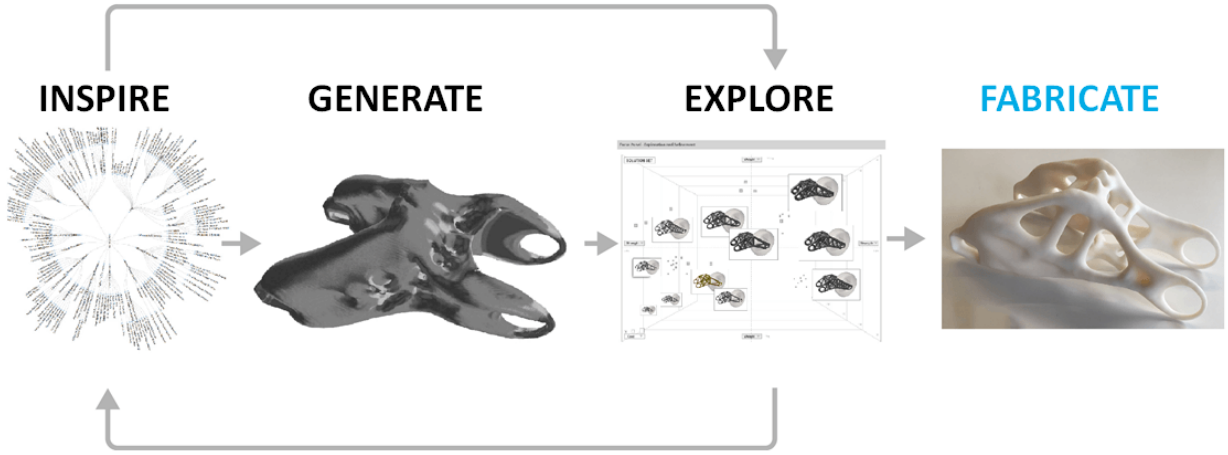


Figure 1: the Algorithm-Driven Design Process

Source: https://autodeskresearch.com/projects/dreamcatcher

The conventional design process operates differently. At the point where the designer finishes collecting information from the client, the designer starts sketching and prototyping. Then the mind works in an old-fashioned way, where the solution depends on developing the sketch rather than exploring the problem. And here, Algorithm-Driven Design comes in handy through exploring multiple options in less time and less effort.

The final output is also affected by the Algorithm-Driven Design methodology. Productions are more interactive, variant, and convenient to the client, as the researcher will show later in the methods of the experiment. For example, modeling a bracelet that has multiple sizes of pearls would take hours to calculate in the conventional methodology, plus aligning them all in the same line would also take more time. But using a set of mathematical equations accompanied by Algorithm-Driven Design, which would make this task take lesser time to accomplish and achieve.

The follow-up example demonstrates the steps of doing pearl necklace algorithmically by the researcher; the researcher starts with a standard curve then divides that curve mathematically into small segments and then calculates the radius of the sphere and the distance that each sphere needs to fit into the same trajectory - Curve. Through **Visual Scripting**, the demonstration is much easier than text scripting, where the designer needs to know in that case every single line of data and how to analyze it like a programmer.

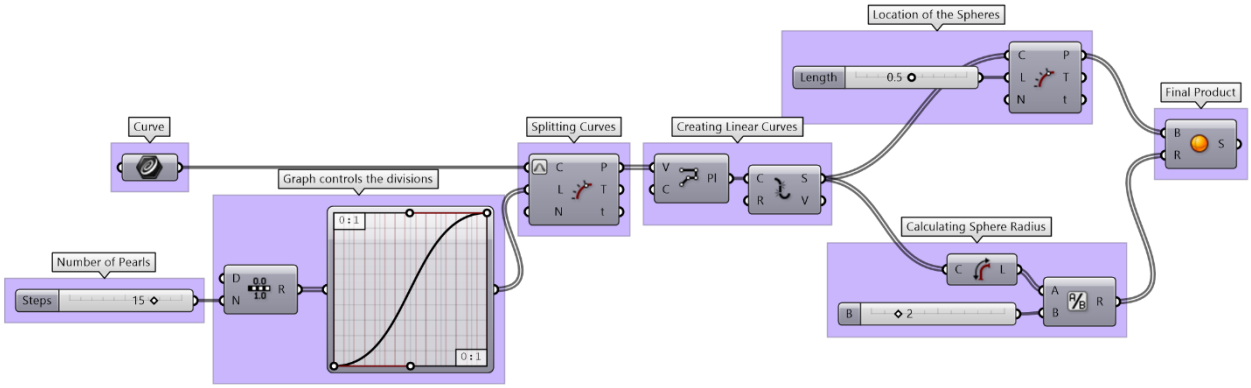


Figure 2: The Process of doing pearl through Algorithms

Source: The Researcher, 2020

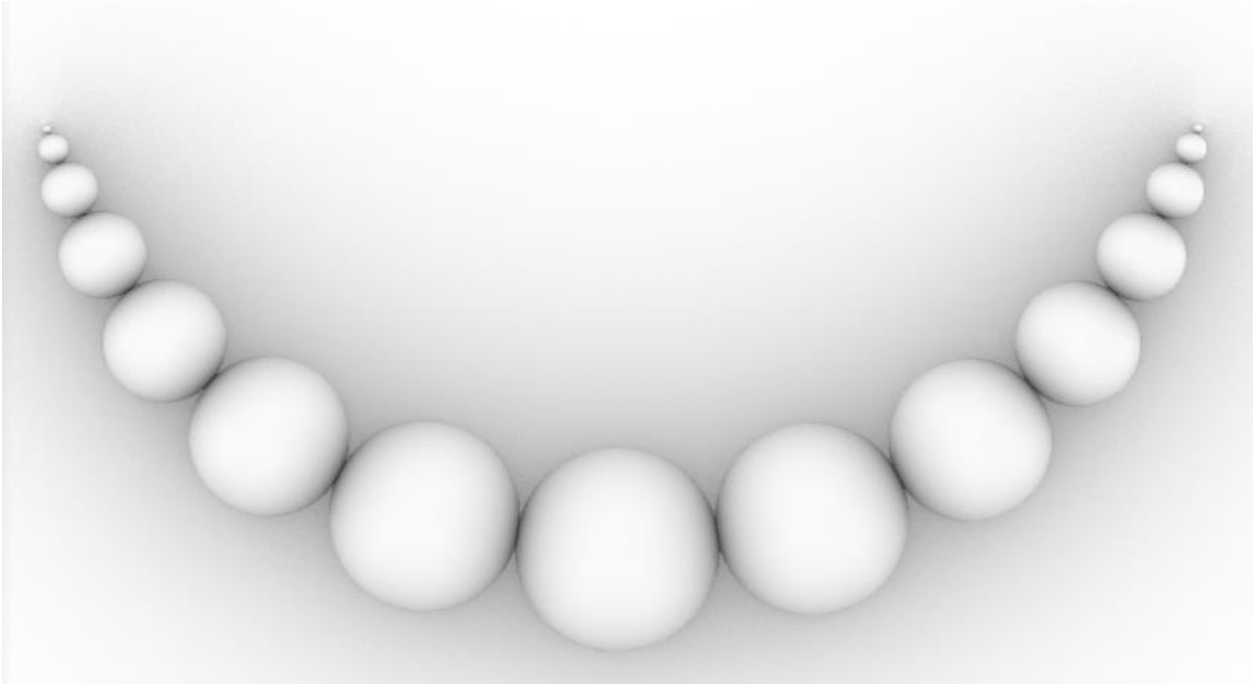

Figure 3: The Final Product for the pearl

Source: The Researcher, 2020

The main difference between conventional and algorithm-driven design is the intermediate process where the algorithmic designer thinks through logical operations, and the traditional designer thinks through sketching and developing. Identifying the client's problem, gathering information around the problem remains the same in both design processes, Developing, and having feedback for the problem also varies for every designer. On the one hand, the algorithmic designer will search for more plug-ins or codes to elaborate on the solution. On the other hand, the conventional will operate differently through sketching a new design model that concludes the feedback information which is received.

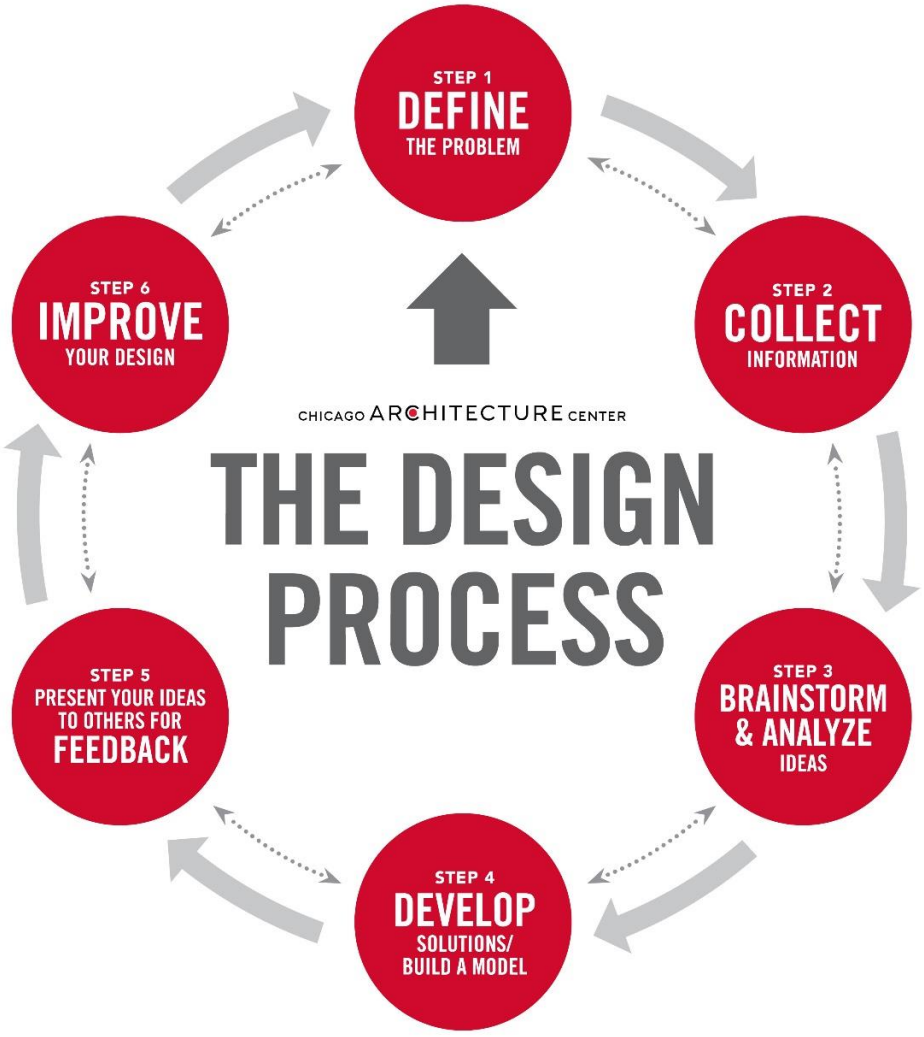


Figure 4 shows the conventional-traditional design process

Source: https://discoverdesign.org/handbook

There are two approaches to Algorithm-Driven Designs. **Visual scripting** is a universal approach due to learning procedures, where it is faster and easier through graphical interfaces; the other one is **Direct Scripting.** In this broader approach**,** the designer has no boundaries in creating any desired outputs, although it consumes much more time.

The researcher will elaborate and explain different visual scripting approaches, to be able to explain and demonstrate more straightforward concepts. In contrast, direct scripting requires the knowledge of computer science bachelors and much more complicated theories that involve different programming languages.

## 2.4. Visual Scripting:

In this method, the designer chooses from a set of pre-coded library divided based on their functionality. From each, the designer tries to find a solution for the desired final output by connecting these visual nodes. The designer does not have to know how to code, therefore its more comfortable for them to use ready nodes to recall the premade scripts through **Visual Nodes**.

One of the significant software used for that particular example is Grasshopper3d; Grasshopper offers a friendly, easy graphical interface, with all the Visual Nodes pre-coded at the top of the interface, which makes it easier for any designer to learn and approach Algorithmic Design through Grasshopper.

Grasshopper is a visual programming editor developed by David Rutten at Robert McNeel and Associates. As a plug-in for Rhino3D, Grasshopper is integrated with the robust and versatile modeling environment used by creative professionals across a diverse range of fields, including architecture, engineering, product design, and more. In tandem, Grasshopper and Rhino offer us the opportunity to define precise parametric control over models, the capability to explore generative design workflows, and a platform to develop higher-level programming logic – all within an intuitive, graphical interface. (Primer, 2014)

The researcher explains how we can recall the data inside Grasshopper3d from the library within the Scripts category, for that visual node to compute. There should be input and output parameters to be able to achieve a task—using a variety of tools that are categorized based on function and placed in menus on the upper side of the software. The small icons in the visual nodes explain the purpose of that node. For example, a small spherical icon indicates that there will be a sphere operation that will process.

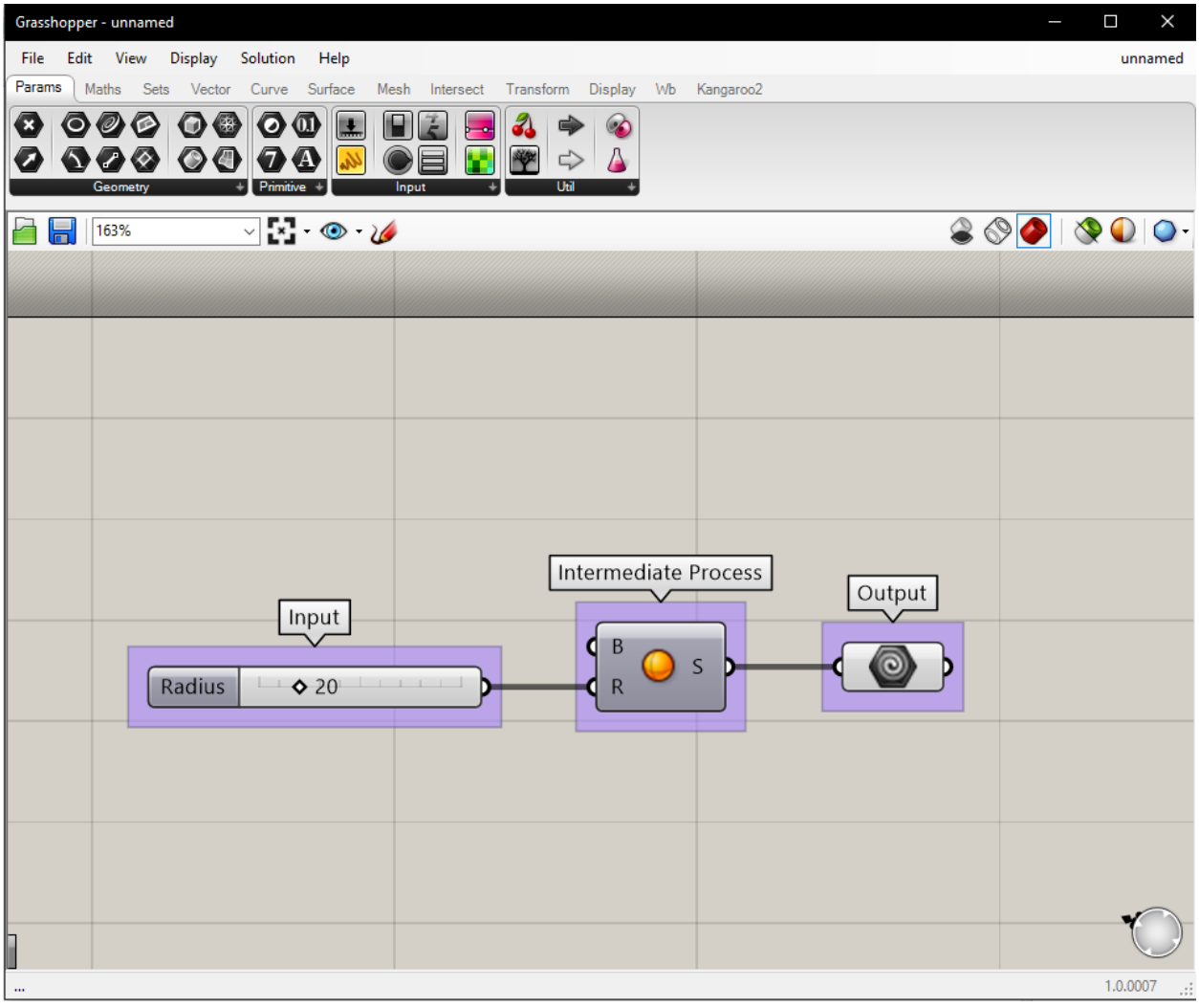


Figure 5: Grasshopper3d Interface, visual nodes explained inside Grasshopper3d

Source: The Researcher, 2020

## 2.5. Types of Algorithmic Design

There are various types of Algorithm-Driven Design, which can be achievable in a variety of types and methodologies. The researcher divides these types into:

### 2.5.1. Generative Design

**Generative Design** is an iterative design process that involves a program that will generate a certain number of outputs that meet certain constraints. and a designer that will fine-tune the feasible region by changing minimal and maximal values of an interval in which a variable of the program meets the set of constraints, to reduce or augment the number of outputs to choose. (Krish,2011)

This type of algorithm-driven design anticipates multiple options as an output, the design process in this methodology depends on the selection criteria of the final product, where the program analyses these different outputs and based on the designer's taste or selection set the prototype published.

Generative Design involves multiple industries such as logo variations, product design, and even color selections. Design companies should include this type of design to help negotiate with the client the variety of output that can be made within the same conventional methodology that outputs one final product instead of multiple ones.

**Pattern Design**, it is always a challenge designing in a pattern or a grid-based on the mathematical or artistic point of view, that can challenge the designer to learn computational skills. Pattern Design consists of one or two basic shapes in a specific order to create various two-dimensional geometries. Due to the sophisticated client's requests, it can be hard to manipulate such shapes. Generative design gives the ability and capability for the designer to work under various outputs for the design with the aid of Algorithms that help achieve the goal with multiple design iterations—one way of reaching pattern design in a generative design approach. Patterns exist in many posters or poster backgrounds; they can also be three-dimensional designs for graphic designers and architects. Thus, patterns, formulate shapes, charts, and geometries. It is crucial to mention that it is also considered one of the major design principles through proportion.

**Data Structure** is the knowledge that consists of data management, organization, and storage that empowers the designer to control the outputs of the design through manipulating this data using precise, systematic order. For example, using odd or even numbers from each intersecting resulting shape can help the generative approach design. With the aid of data structure knowledge, it becomes more eligible to edit any geometry using the right set on a mathematical or logical order.


Figure 6: Data set menus in Grasshopper3d

Source: The Researcher, 2020

Grasshopper3d demonstrates some of the tools that can be handy to arrange the right set of data to output specific geometries. The first menu lists manipulate the order of that data by shifting or listing one of the components or even randomizing individual outputs. The second list of data demonstrates the sequence or interval numeration of data. The third menu shows scrolls that can also help get outputs in the shape of a grid. The last menu, which is named Tree, will demonstrate the relationship between two groups of data where the designer controls the connection, for example relating every odd number from group "A" with even number from group "B."

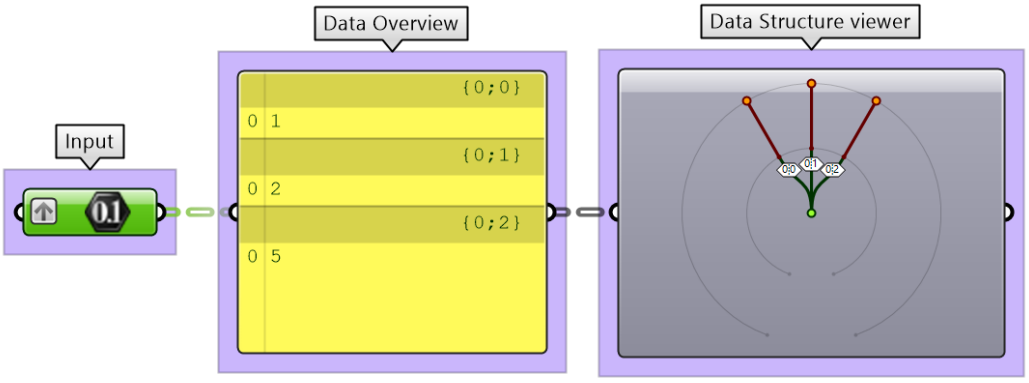


Figure 7: Data Structure visual nodes in Grasshopper3d

Source: The Researcher, 2020

The researcher will demonstrate multiple examples to explain how we can use the algorithm-driven design. In the following figures, the researcher created a variety of pattern designs using Grasshopper3d and Generative Design approach.

The researcher used basic grid shapes accompanied by choosing a systematic data structure to output the upcoming shapes and figures. The black fill shows the numbering system used to illustrate the pattern designs.

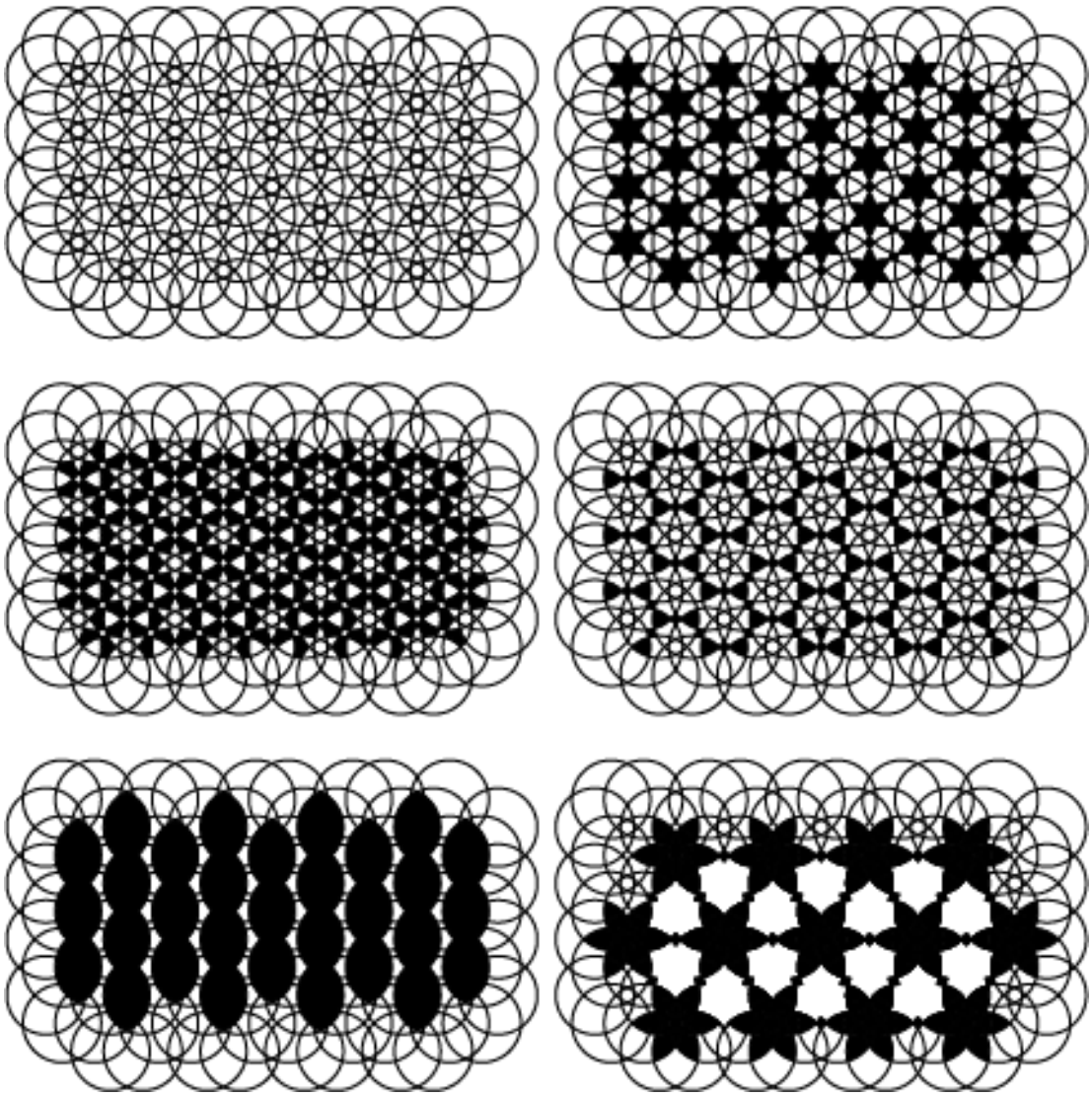

Figure 8: Circular Patterns, Rectangular Grid, Created using Generative Design approach

Source: The Researcher, 2020

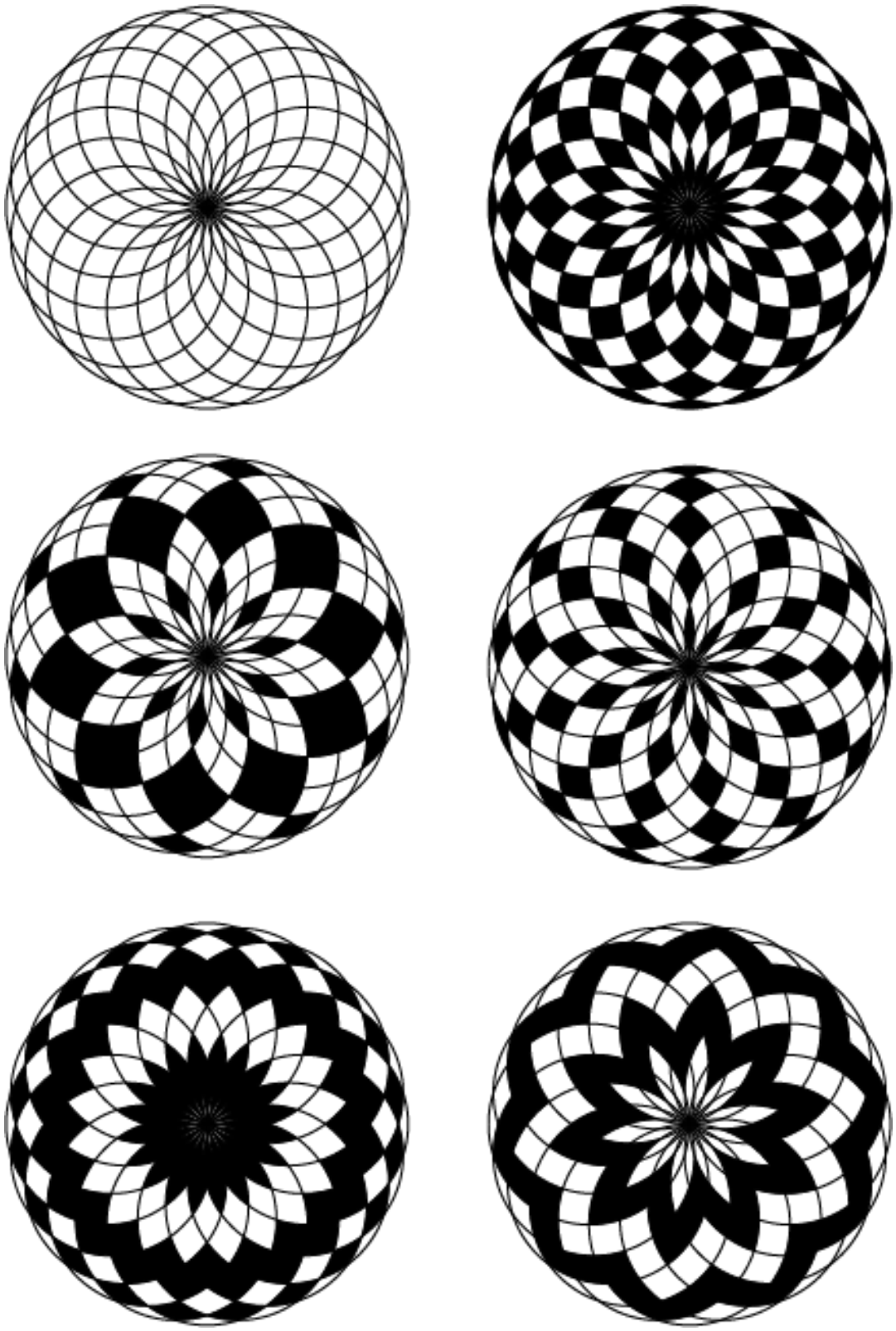

Figure 9: Circular Patterns, Created using Generative Design approach

Source: The Researcher, 2020

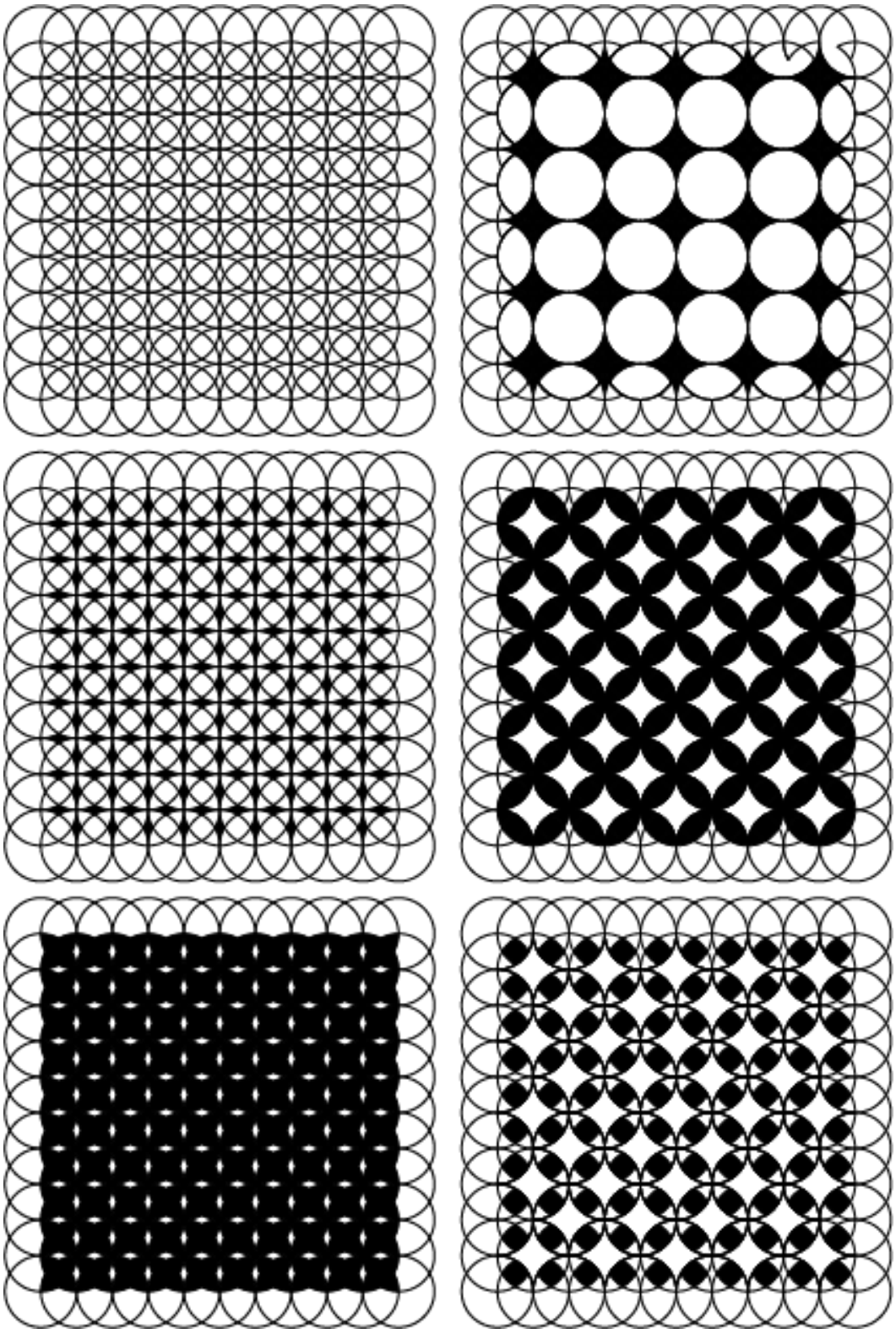

Figure 10: Circular Patterns based on square grid, Created using Generative Design approach

Source: The Researcher, 2020

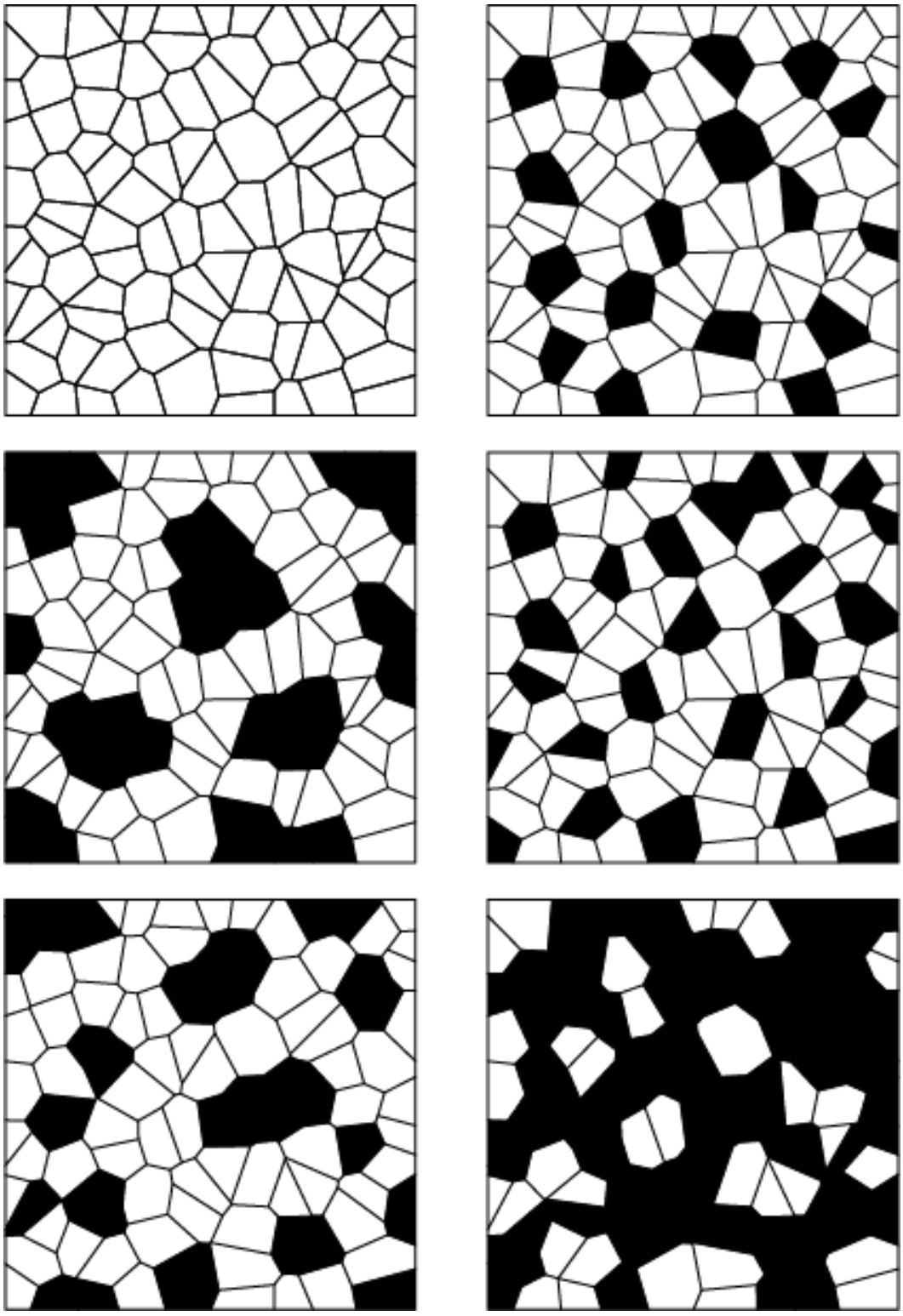

Figure 11: Voronoi grid, Created using Generative Design approach

Source: The Researcher, 2020

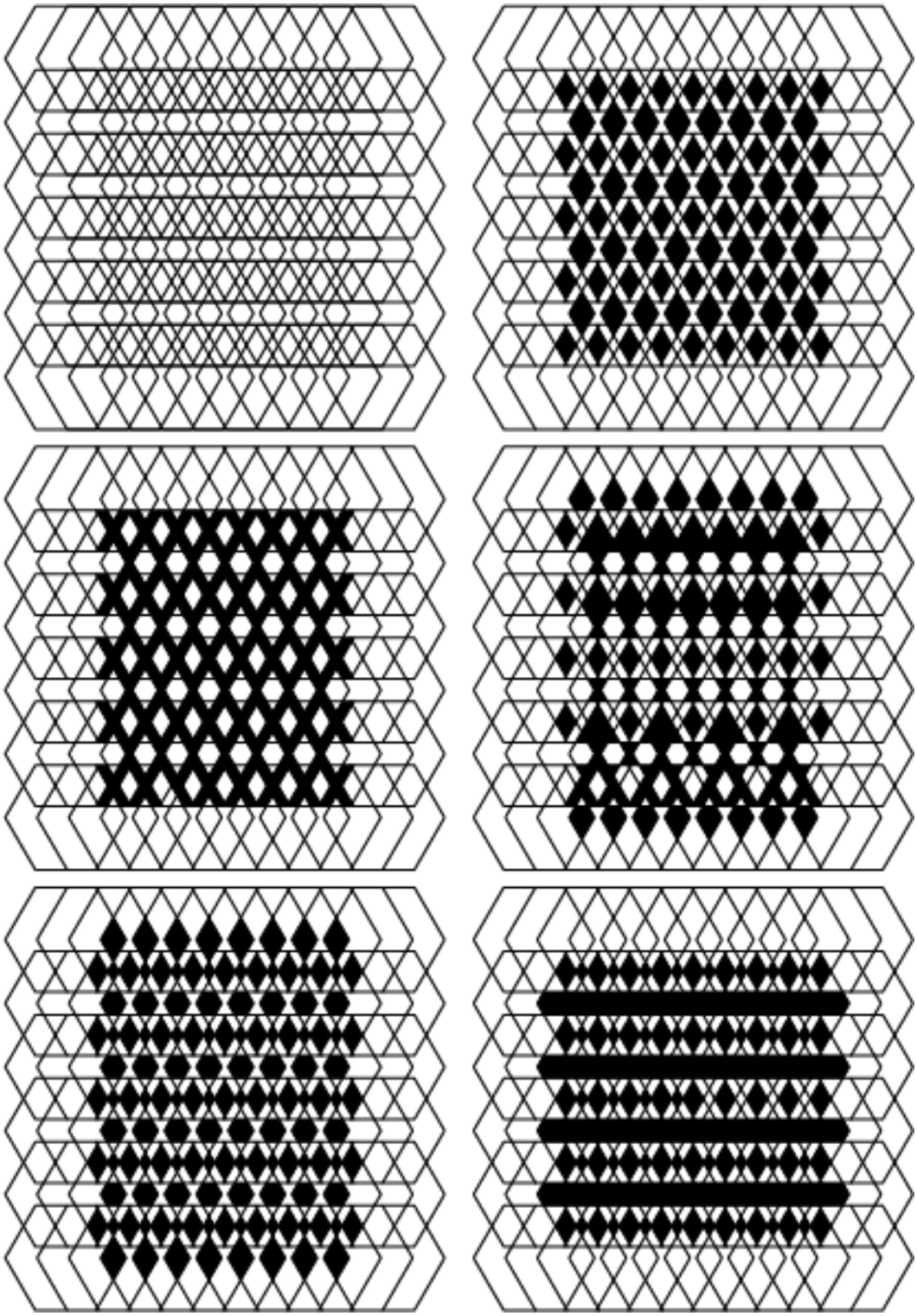

Figure 12: Triangle grid, Created using Generative Design approach

Source: The Researcher, 2020

### 2.5.2. Parametric Design

**Parametric Design** is considered one of the main types of algorithm-driven design which qualify the use of necessary parameters to define, clarify, and encode the relationship between design inputs and outputs. It also establishes the relationship between intents and design responses. Parametric design help deliver the design of complicated structures and geometries.

**Form-finding** is one of the strategies that parametric design follows to find the appropriate desired shape based on the propagation system where the designer computes from known inputs to unknown output data flow models. Parametric modeling also consists of a constraint system that bounds the processes into a set of solutions that is constrained and discredited by constraints. The data structure distribution either bound the processes or predicts unique final design goals. The designer here optimizes solutions based on numeric statistics that help the selection criteria of the final choice with the client.

Both generative design and parametric design are used together as concepts to manipulate and generate unique design ideas that elaborate on the era of contemporary graphic design. Combining both design definitions can operate algorithms and utilize the work of everyday work better by constraint variables that work as parameters for the design projects—generating. Also, collective design sensitizes the designer's mind making it easier to innovate and creatively create better.

The researcher explains how designers can create various designs by importing any picture and applying scripts on that picture; this method is called image trace. Image Trace is a technology used by different Adobe software such as Adobe Illustrator and Adobe Photoshop. This kind of technology computes the data given as pixels; either they were black and white or colored, and based on any colorization method, the designer can create unique designs out of pixel colorization, due to the readability utilization in grasshopper3d, image tracing technology gives conglomerate design options combining it with divergent patterns and grids. The image trace approach depends on the pixel variable and the percentage value of black in each pixel square. Also, Hue, Saturation, Luminosity, and pixel ratio can be parameters.

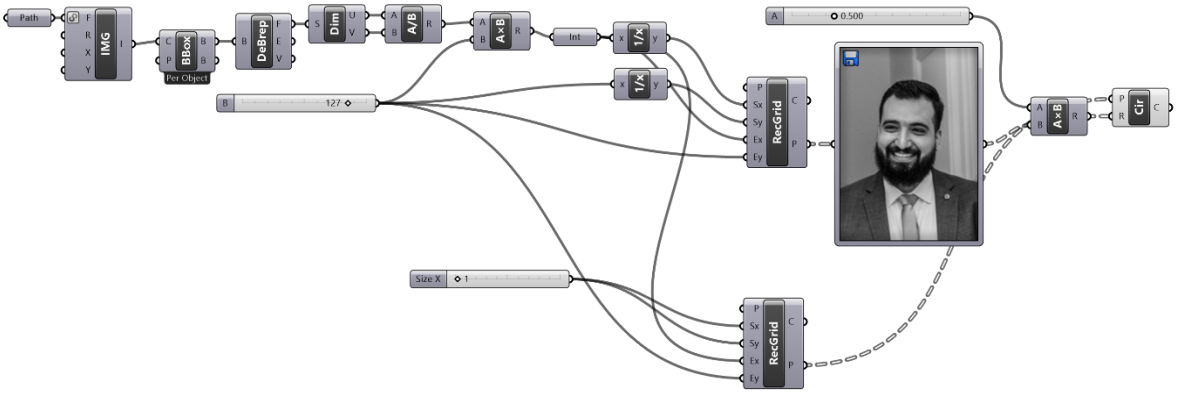


Figure 13: The process of integrating image trace through parametric design approach

Source: The Researcher, 2020

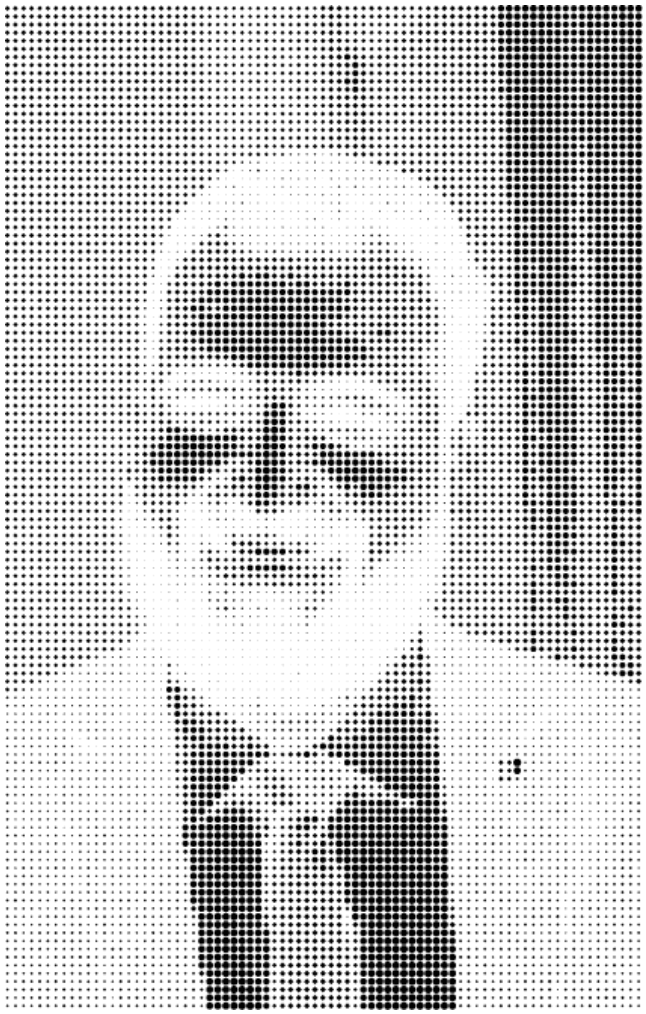

Figure 14: Design response as circular shapes

Source: The Researcher, 2020

Attraction points design approach is one of the algorithm-driven design approaches that tackle parametric design. The parameters of the output pattern are the distance between the attraction point and grid points. Also, the circular shapes are constraint by the length of the attraction points. The researcher combined both generative and parametric design in this example; the researcher was able to iterate various design options pre-coding the process and constraining variables to criticize the final shape model.

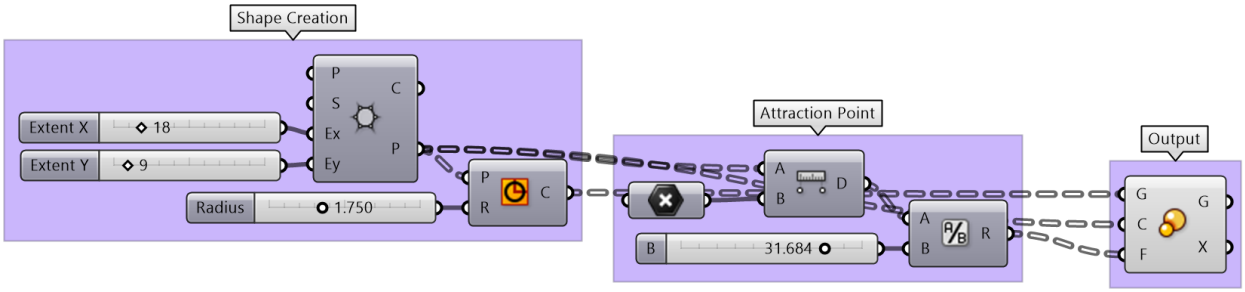


Figure 15: Grasshopper3d visual nodes demonstrates the process of attraction points

Source: The Researcher, 2020

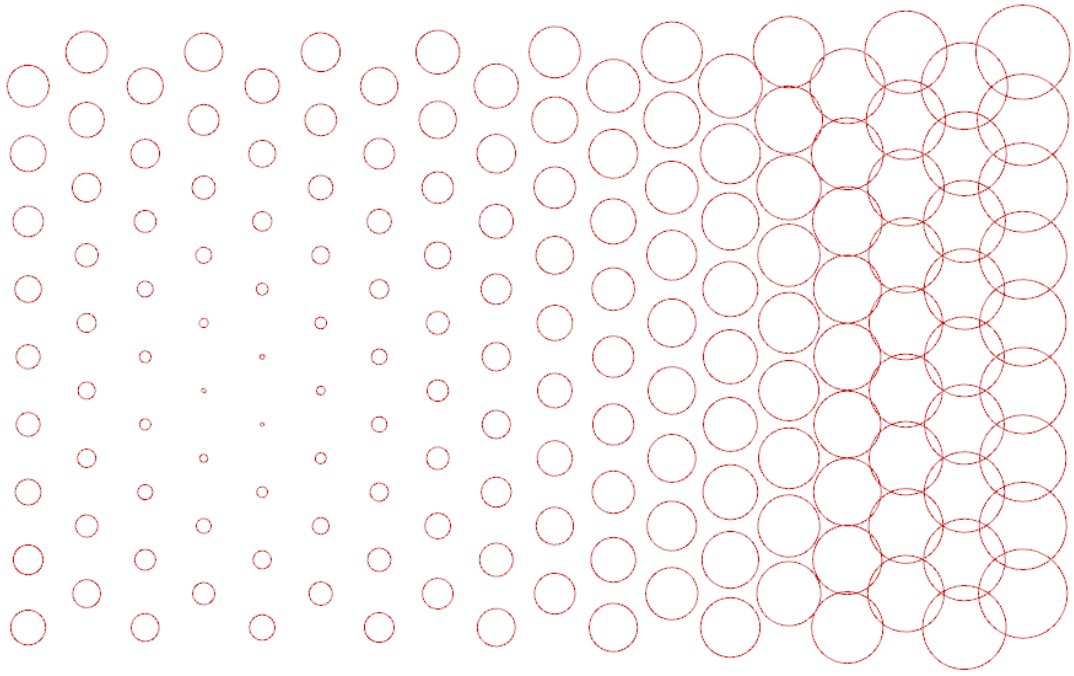

Figure 16: Pattern Design using Parametric design and attraction point approach

Source: The Researcher, 2020

### 2.5.3. Interactive Design

Interactive Design is defined as a user-oriented field of study that focuses on meaningful communication of media through cyclical and collaborative processes between people and technology. Successful interactive designs have simple, clearly defined goals, a definite purpose, and an intuitive screen interface. (Lisa, 1998)

In this method, the designer has the opportunity to create a design where it interacts with the user or client, using Algorithmic Design thinking process helps the designer meet the requirements of the client through directly observing the changes on the shapes and choosing at any moment the required design.

One of the significant software used in this methodology is Unreal Engine, where it can help the designer through a three-dimensional pre-coded environment, and help the designer through these sets of tools achieve a close visual look to how it will appear stimulating real-life actions, making the client see rather than imagine how the design will be.

One of the approaches of interactive design is simulative design. Simulations are opposed to helping demonstrate real physics or simulate specific mechanics in the field of mechatronics engineering. With the aid of Algorithm-Driven design, the interaction parameters can be observable through algorithms and mathematics that exemplify the model.

**Simulation Design:**

A simulation is a close imitation of the operation of a process or system; the act of simulating first requires the development of the model. This model is a well-defined description of the simulated subject and represents its key characteristics, such as its behavior, functions, and abstract or physical properties. The model represents the system itself, whereas the simulation represents its operation over time. (Nicol, 2001)

Simulation design consists of frames and animation, where the map is animated to show an inevitable result if a force or an attraction point existed. The designer's community use

simulation to simulate real-life situations and examine how things will react if this happened. It only can be described as computational physics, where physical theories are applied and stimulated.

The Designers simply use processing software while it provides a variety of simulation nodes that can be recalled by a programming language called Java; the output result is called JQuery. This method stimulates real-life physics and provides an essential graphical and visual image to the eyes of the designer. Yet, it also provides a stronger message to the end-user.

**Processing** is a flexible software sketchbook and a language for learning how to code within the context of the visual arts. Since 2001, Processing has promoted software literacy within the visual arts and visual literacy within technology. There are tens of thousands of students, artists, designers, researchers, and hobbyists who use Processing for learning and prototyping. (Reas, 2001)

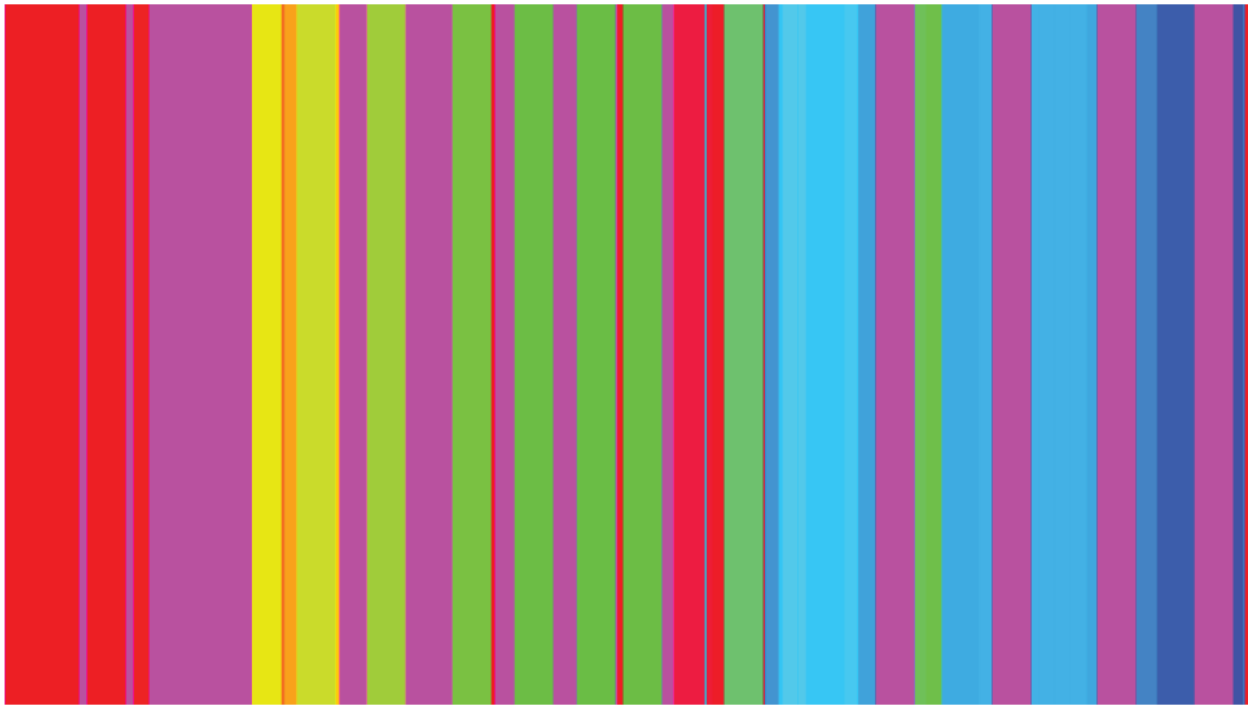

Figure 17: Processing output window

Source: The Researcher, 2020

Hue is the color reflected in this image, hovering the mouse over this image will alter the tone based on the times moved vertically over this image resulting in multiple designs, this methodology is considered a simulation design. This method uses a text coding approach -Java- to obtain simulative results for visual designers and architects who would like to interact with different kinds of design.

```
int barWidth = 20;
int lastBar = -1;

void setup()
{
  size(640, 360);
  colorMode(HSB, height, height, height);
  noStroke();
  background(0);
}

void draw()
{
  int whichBar = mouseX / barWidth;
  if (whichBar != lastBar) {
    int barX = whichBar * barWidth;
    fill(mouseY, height, height);
    rect(barX, 0, barWidth, height);
    lastBar = whichBar;
  }
}
```

Figure 18: Processing code and output

Source: The Researcher, 2020

The researcher demonstrates a cloth simulation design through Autodesk 3ds max software. Cloth simulation commonly used with blankets, pillows, and tissues in three-dimensional configurations. The polygons, which consist of four edges, interact with faces from the other model simulating how a cloth body interacts with real-physics and mathematical orders that are based on algorithms which the designer place.

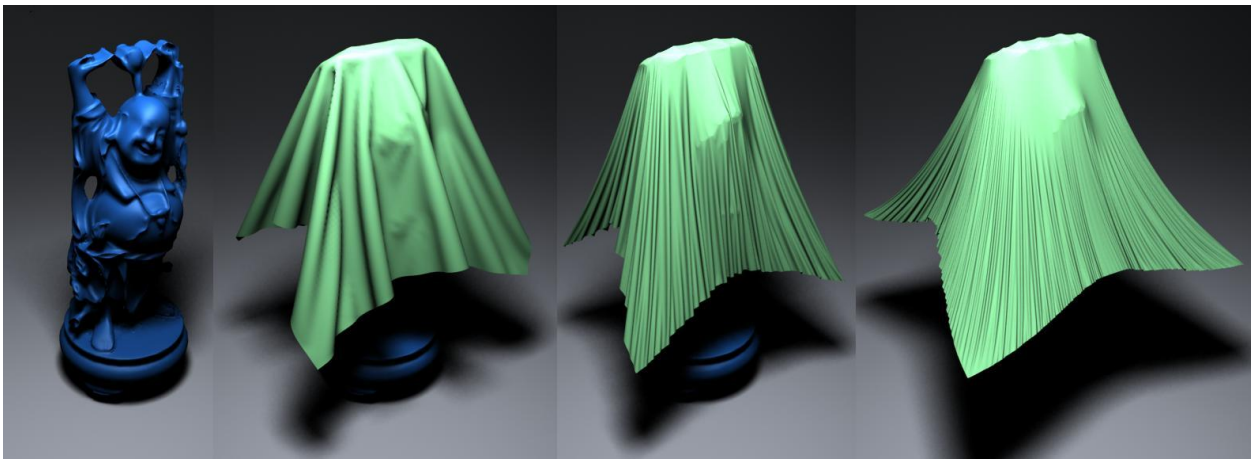

Figure 19: Cloth Simulation using 3ds Max 2020

Source: https://gamma.cs.unc.edu/gcloth/

## 2.6. Algorithm-Driven Design Fields

The researcher explores different field majors that work with Algorithm-Driven Designs, and these majors can be classified as:

### 2.6.1. Algorithmic Design in Architecture

Architecture is the researcher's primary inspiration as the history of contemporary design significantly shows algorithm-driven approaches that functionalized spaces with algorithms. Function as the primary parameter approach is the main reason why architects use parametric design methodology.

Architects design elevations based on sun or shadow parameters that help analyze sunlight annually, and then calculate the possible ratio of energy heat transmitting into the building space. This kind of calculation needs the algorithm-driven design to help identify which of the building elements precisely need sunlight and which does not if the case was shadow or sun parameter. Architects also use algorithms to shape canopies and rooftops in an organic matter that might parametrize based on systematic order that might resemble music.

Architects also analyze urban fabrics through algorithms that predict the best pedestrian roads, connection hubs, circulation, and even land-use distribution.

Unreal Engine's Blueprint means there is a space with an inevitable collision that interacts with the user when that user approaches that space the interface changes to be interactive and the user can start interacting with the area like real-life actions.

The following figure is an execution for an interior design done for one of the architectural offices; The interface guides the client to point and choose different furniture using two joysticks. The client can change the interior colors of the room by creating Algorithmic formulas using visual nodes that can control the hue, saturation, and value of any selected element inside this room and

be able to change the camera angles or use VR -Virtual Reality. These are called Unreal Blueprints.


Figure 20: Unreal Engine Interactive Design output using Virtual Reality -V.R.

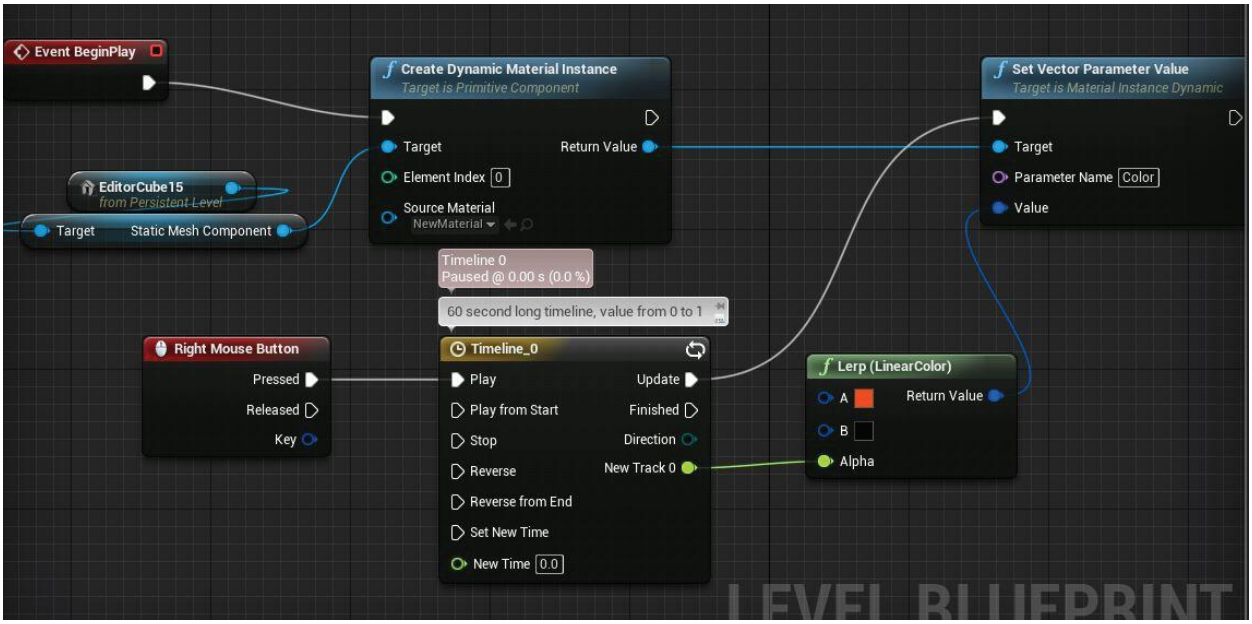


Figure 21: Unreal Engine Blueprint – Visual coding process.

Source: The Researcher, 2020

## 2.7. Previous Studies

In this section, the researcher presents the previous thesis that resembles similar objectives for the study.

On the one hand, all studied cases are constructive for my research goals and have some similarities. They describe how algorithmic design could distribute in the design process, architecturally, graphically, or at any shape of the design.

On the other hand, what makes this thesis stand out is that there was not any case study that explored those effects of algorithmic design as only in architecture or only an unusual design type.

Following is some of the previous case studies that helped strengthen the literature for this study, explaining the intersections and differences in each:

**-Mathematical concepts in Arabic Calligraphy: The proportions of the ‘Alif By Mohammad Yaghan, 2020**

The starting point of every study on the proportions of Arabic calligraphy is the letter ʾAlif. It is considered the reference for all other letters. Usually, it is measured in dots. This paper is an attempt to study the mathematical concepts upon which the historical theory of the ʾAlif proportions was based, though not mathematically stated. To achieve this, the terms and components of the method were clearly defined and analyzed in their textual and visual context, historically, and logically according to our present time. Despite the frequent use of these terms throughout time, their meanings were not always precise and can accept different interpretations. Some words, even, indicated different purposes and were loosely used to satisfy different functions, for example, the term “Nuqṭah” (dot). Relating the components of the theory was, also, opened for opinions and interpretations, for instance, the number of dots for the ʾAlif was never agreed upon. This paper starts with historical research and analysis. Then, it presents the mathematical expressions of the ʾAlif proportions, both numerically and visually. Later, it discusses how they do apply, how other modern interpretations can fit, and how historical

misunderstandings can be understood. Finally, it presents the historical account of how to relate other letters to the ʾAlif recommending analyzing their mathematical aspects in future studies.

**-Integrated Algorithmic Design by Renata Alves Castelo Branco (Technico Lisboa), 2018**

Many great architectural endeavors today engage in a multi-software approach, as each party develops its part of the project in different software. Moreover, the architectural plan itself covers many tasks, including 3D modeling, analysis, and rendering, which benefit from the use of different tools. Combining them in the same project involves the sharing and crossing of the various information systems, which is not always a successful process. A mechanism is needed that connects all the different tools used more effectively - a portability mechanism. Algorithmic Design (A.D.) presents itself as a potential solution.

A.D. is an algorithmic approach to architectural design that allows architects to transcend factory-set limitations of the currently used 3D software. As mathematical descriptions are oblivious to any software, the algorithmic descriptions of the models become independent from the software.

The researcher's thesis aims to explore the advantages, and algorithmic approach can bring to the design process, and investigate, at the same time, how to bridge the gap between the different tools with which architecture currently operates. We propose a methodology based on an algorithmic approach to design, where a single program can describe not only the intended model but also additional tasks, such as model analysis. We call this approach, Integrated Algorithmic Design (IAD), and using it. The architect can take advantage of various CAD, BIM, and analysis tools, with little effort when it comes to the transition between them.

Through Optimization, Environmental Performance, the researcher can benefit from these methodologies through practice and design.

**- Algorithmic Approach Functions in Digital Architecture and its Effect on Architectural Design Process by Meysam Kazemi, Behnaz Borjian (University of Tehran), 2015**

Algorithmic systems act based on algorithmic rules that an algorithm is a finite set of instructions to achieve a specific goal. An algorithm is a value or set of values as its input, shows some of the measurable stages that convert or changes the information, and finally produces one or some benefits as output. The power of algorithms in solving multiple is measurable problems including but not limited to categorizing and searching, an operation associated with the information configuration, solving combinatorial and numerical problems, such as producing random numbers and measurable geometry (Cormen, 2001 ).

The main three instructions that perform basic operations are as follows (Chang, 2003):

- Sorting (displaying instructions respectively);
- Choosing (choosing instructions for the user and then displaying explanations);
- Repetition (repeating instructions in the form of linear or return).

Algorithmic thinking and algorithm design are highly associated with design production. According to Terzidis, deductive and inductive algorithms provide guidelines by which complex issues are simulated. Algorithms can be used as an inspiration for the human mind to develop and expand it and facilitate to achieve unpredictable potential applied to the human brain (El-Khaldi, 2007).

# Chapter Three:

# Methodology

This chapter carries out the procedures that were followed to achieve the application of the study. It explains the method of the study, the tools, and the studied population sample.

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## 3.1. Methodology / Research Design

This research design is **Action Research** combining both **Experimental quantitative** research and **Grounded-Theory qualitative** research methodologies.

The researcher has chosen to adopt the experimental method, to explore the different answers for the research questions, and to confirm or refute the thesis hypotheses. The thesis topic is not local only, and the researcher will apply some of the algorithmically computational thoughts on last year's students from selected universities.

The researcher has experimented in the literature review, creating generative and parametric design approaches to help confirm thoughts around the hypotheses of the study.

The experiment variables manipulations are supported with data collection of literature review and analysis from the researcher's literature review, previous studies, and gathered data.

The experiments are followed with analysis and questionnaire, that studied the effects of changing covariates that affect dependent variables on the independent variable. The **Quantitative** approach is conducted to assure the best statistical analysis for the results from the questionnaire data collection. The **Qualitative** approach is undertaken to empower statistical analysis from quantitative design results and support the researcher's hypotheses. The researcher will follow Brian Lawson’s methodology, experimenting with ten different designers to reach out to experimental conclusions. (Lawson, 2003).

## 3.2. Study Society

The researcher, along with designers, cooperated in designing and producing the experiment tools. The experiments, analysis, and questionnaire are performed on the selected audience from two universities (Multi-media and Graphics students in Al-Khwarizmi University, Animation, and Computer Graphics students in Al-Balqa University) in Amman, Jordan.

## 3.3. Study Sample

First, the researcher together with university graphic designers from both universities (Al-Balqa, Al-Khwarizmi Technical University) Amman Jordan. Students experimented with pre-tests and post-tests to produce the first experiment tool, which is integrating Algorithmic Design within graphic design.

Secondly, some experiments were collected from previous designs of architectural algorithmic design methodologies and computational design, all kinds that are associated with design, all with Algorithmic design applied to them are used for the survey and analysis to ensure satisfactory results.

A total of four exercises were designed by the researcher and reviewed by local designers, and the exercises include pattern design since it is the easiest to achieve and experiment.

Thirdly, professionals in the field, such as design professors, local designers, and architects, helped in evaluating the adequacy of the preliminary questions to guarantee authentic results.

Finally, experiments are performed on selected groups in Amman city, Jordan. Targeted groups are limited based on their interests (Digital Illustration, Logo Design, Interactive Design, Game Design, Web Design, Multi-Media Production, different artistic majors).

## 3.4. Study Tools

The researcher used two main tools in this research. First, the pre-test experiment tools, which are pattern design exercises that students must accomplish without algorithmic school of thought designed by the researcher.

The second tool is a post-test -after the lecture- that analyzes the relationship and need for algorithmic design in design types. The questionnaire was performed on selected groups in Amman.

## 3.5. Validity

The validity of the experimental questions is assured by interviewing and cooperating with a total of four experienced academicians and professionals in the field of Design.

## 3.6. Reliability

The reliability of the tool is accomplished by doing multiple pre-questionnaire results to other groups to ensure the adequacy of the instrument and after precisely measuring. Doing three different statistical groups will ensure the capability of the tests. The statistics refer to a close-ended question with one answer choice for each to assure a reliable outcome.

## 3.7. Study Variables

**This research contains two variables**

**Independent Variable:** Contemporary Graphic Design, Algorithm-Driven Design.

The researcher will change and experiment with the effect of each independent variable on the dependent variable. Independent variables chosen in this study are four pattern designs that have a group of selected attributes that were conducted and analyzed based on literature review and professional assessments. Independent variables are coded later in the analysis chapter as following; (Simple and Complex)

**Dependent Variable:** Design Process

The design process is the dependent variable that is tested and evaluated in this study. The researcher measured which of the independent variables would affect the design process. The changes in the previously mentioned pattern designs have been tested by the researcher, which have been adopted by the researcher based on the literature review. The final dependent variables are named as following; (Task Time, Effort by design process steps, and Design Iterations).

**Covariates:** Time, Effort, and Design Options.

## 3.8. Study Procedures

The procedures of the research have been handled in the following sequence:

1) The researcher has reviewed previous case studies and books to learn about Algorithmic Design, Design Process, and Conventional design. In addition to Algorithm approaches such as generative and parametric to be able to classify and assign which of Algorithmic Design attributes to relate Graphic Design attributes.

2) The researcher has explored different Design tools that have algorithmic thinking on them, and analyzed their effects on Designs, to use them as data for the experimental questionnaires

3) Design students from Al-Khawarizmi and Al-Balqa are to collaborate with the researcher to produce different design processes with the conventional and algorithmic way of thinking through pre-tests and post-tests. Experiments were used in the analysis and questionnaire to relate the designs to calculate the ratio of effort, time, and design options.

4) The researcher has designed a questionnaire that tests the effects of algorithmic designs on selected students. All of which were applied to algorithmic design as a process as it is the case study of this research.
5) Interviews are to be made with professional academics and designers in the fields of Design to assure the credibility and efficiency of the experimental tests in examining the functionality of Algorithmic Design attributes on Graphic Design.

6) Conclusions and solutions were conducted through the analysis of the survey results. In this step, the researcher answered all the research questions and hypotheses. A recommendation was made to suggest solutions for designers, architects, and companies for using Algorithmic design to convey messages in different design fields.

## 3.9. Study Hypothesis

The researcher will refute the following Hypotheses:

1) **Hypothesis"1":** Products and Designs takes less time and less effort using algorithmic approaches than conventional approaches

2) **Hypothesis"2":** Generating multiple design options and diverse design iterations when using algorithmic approaches than in the conventional method.

The researcher will consider measuring **effort as the number of steps** the designer will take doing any design task. Also, the researcher will consider measuring the **design process as the time, effort, and countability of design options** that the designer can make through the same amount of time

The researcher will also consider **measuring multiple design options as design iteration** by measuring how diverse the options are and how many will determine the designer outcome while experimenting with pre- and post- tests.

# Chapter Four:

# Implementation

In this chapter, the researcher implements the study in two steps. First, the experiments and data collecting. Second, the questionnaire, which answered the thesis questions and hypothesis.

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## 4.1. Group "A" Experiment Results

### 4.1.1. Introductory Questionnaire Results

As a start, the first experiments done by the researcher at Al-Khawarizmi Technical University based on the student's educational degree are classified as group "A." The researcher chose last year's students to control the variables of the sample and to assure the reliability of the study sample; some of the students may vary in age since some of them took a community college degree before taking a bachelor's study plan. The first experiments concluded nine students, five females and four males. The researcher started with introductory questions that identify general information about the candidates. One of the questions introduced age. Age gives insights on the candidates whether they attended community college at Al-Khawarizmi or not.

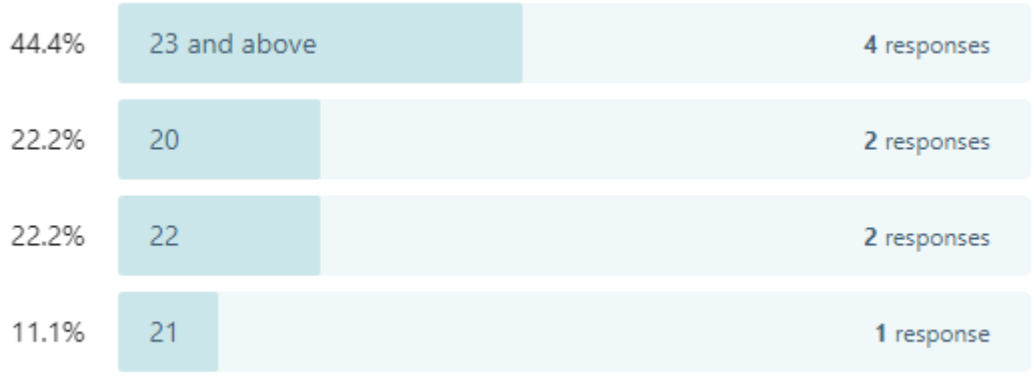


Figure 22: Age statistics at Al-Khawarizmi Technical University

Source: The Researcher, 2020

The charts indicate that four candidates took community college at Al-Khawarizmi collage study plan out of nine, and the rest started directly with the bachelor's degree.

The second attribute of the questions introduced the design interest of the candidates. Multiple options were provided for the students to choose which design fields students will contribute to algorithms. This question indicates the study on areas that algorithm-driven design that will be most effective. The most preferred choice will orient future designers with the aid of algorithms.

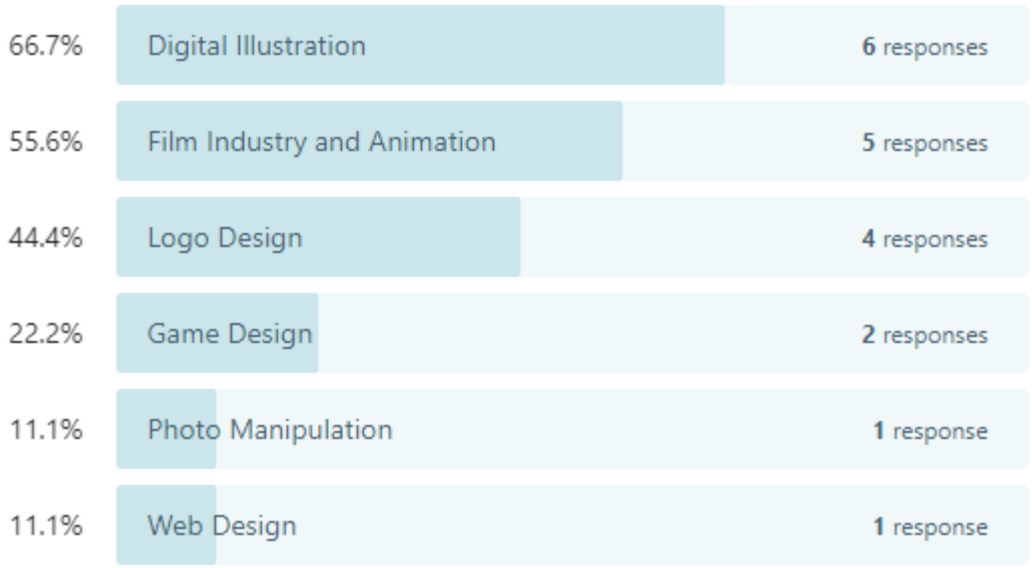


Figure 23: Design Interests at Al-Khawarizmi Technical University

Source: The Researcher, 2020

The chart indicates that each six out of nine students will use algorithms with digital illustrations since it's their primary interests. Also, five of each nine students will use algorithms in Film Industry and Animation; other interests took low rates in percentage. Game Design, Photo Manipulation, and Web Design are nearly rare in importance and usage. One or two of each nine students have interests in these the previous fields of design.

The participants took courses in Adobe Illustrator at the al-Khawarizmi technical university. This course controls the variables of the experiment's equation. Participants that did not take Adobe Illustrator were not eligible to receive this experimental test

The third attribute of the questions asks the candidates on the most usable program daily. The question in this section indicates which software can be accompanied or compatible with algorithm-driven design programs. Grasshopper3d has a plug-in called DoodleBug that directly synchronizes shapes into Adobe Illustrator, which gives the researcher a milestone for program usage.

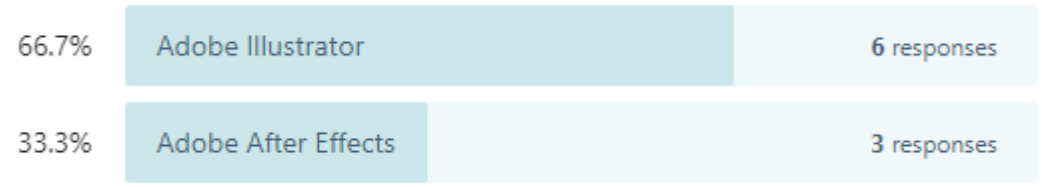


Figure 24: Most usable program at Al-Khawarizmi Technical University

Source: The Researcher, 2020

Six of the respondents preferred Adobe Illustrator, and three of the respondents preferred Adobe After Effects. The researcher indicates that most of the users will be using Grasshopper3d since its more compatible with Adobe Illustrator. Others can use Newton plug-in that simulates real physics into animation.

Newton is a plug-in on Adobe After Effects that simulate gravity, collisions, and joints. Tasks such as a bouncing ball or letter joints can only be simulated using only Newton plug-in.

The fourth attribution of the introductory questions, the respondents on their knowledge in Adobe Illustrator, Since the conventional methodology of design consists of using Adobe Illustrator or Coral Draw. Due to no curriculum on Coral Draw. The researcher only asked on Adobe Illustrator skills.

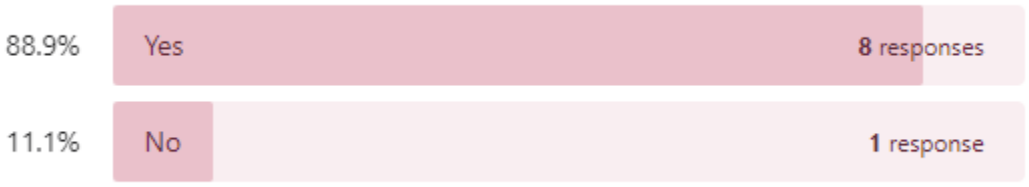


Figure 25: Candidates using Adobe Illustrator professionally at Al-Khawarizmi Technical University

Source: The Researcher, 2020

Eight out of nine participants know how to use illustrator at a professional level.

The researcher conveyed the knowledge in Adobe Illustrator by knowing how many years did the candidates work on the program. Also, the researcher asked the candidates to give scalar attributes on how good the participants are in illustrator within short periods.

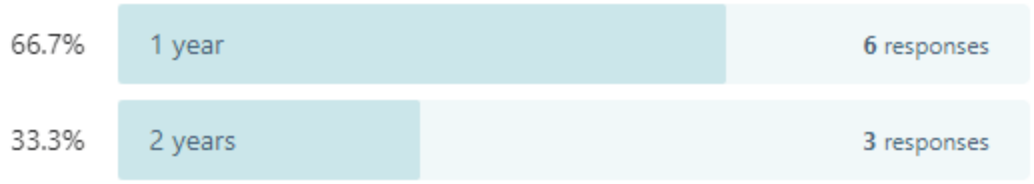


Figure 26: Number of years using Adobe Illustrator professionally at Al-Khawarizmi Technical University

Source: The Researcher, 2020

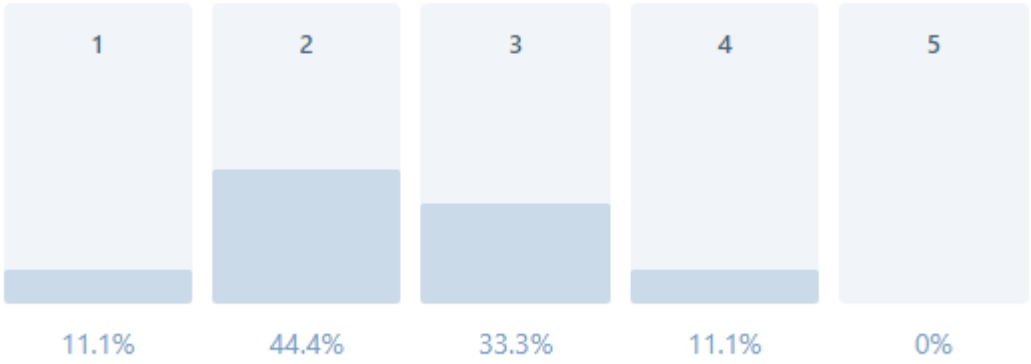


Figure 27: Experty level on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

Six out of nine respondents had only one-year experience or even less, and three of the respondents had more than two years of experience. The indicator shows that most of the participants know the essential tools of Adobe Illustrator. Seven respondents from scale two to three out of five know how to use adobe illustrator. Since the pre-test requires the candidates to know vital knowledge in a vector-based program, these indicators show that candidates can easily participate in this study's experimental tests.

### 4.1.2. Pre-Test Results

The second section of the experiment required the candidates on -task one- to draw a hexagonal grid on adobe illustrator and then report through a questionnaire that was created by the researcher to measure the time consumed doing the task. Also, measure the effort needed to do the task through the number of steps necessary to finish the task. And finally, estimate how many design options the candidates can make from the grid they created.

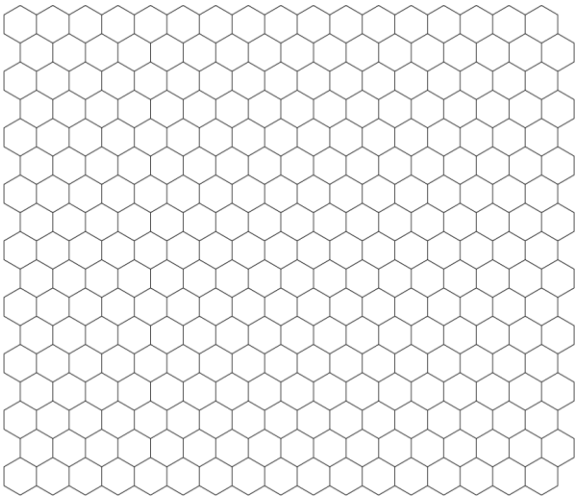

Figure 28: Pre-test, task one, hexagonal grid done on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

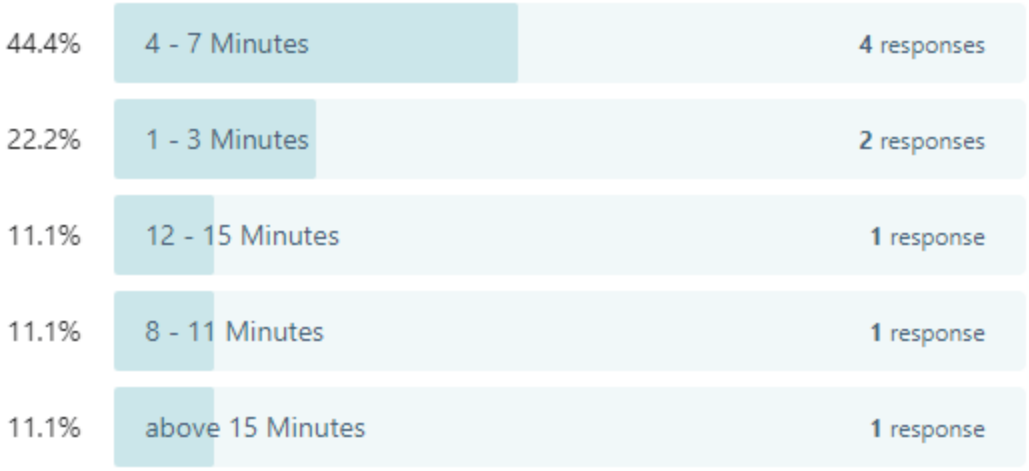


Figure 29: Pre-test, task one, time consumed doing the task on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

Seven out of nine candidates finished the task in more than four minutes. Candidates that completed the task didn't have the hexagonal grid perfectly aligned.

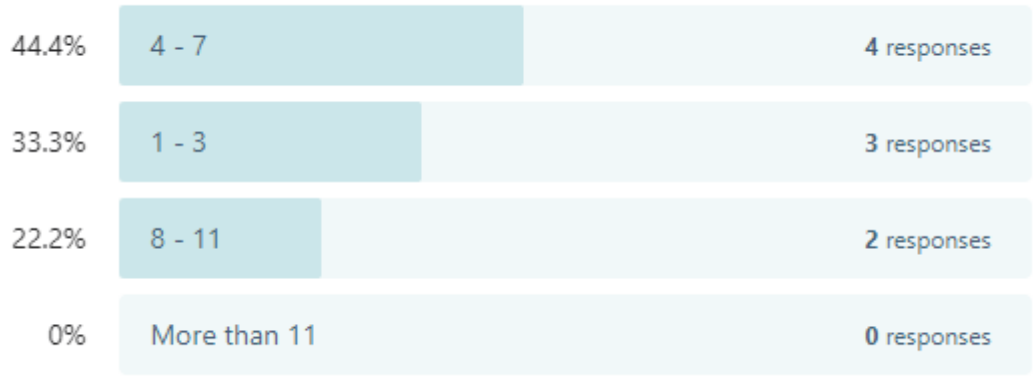


Figure 30: Pre-test, task one, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

Seven out of nine candidates finished the task using more than four different tools. Candidates that completed the task used one of the tools multiple times. The researcher observed the amount of copied shapes. On average, the count reached duplicating more than eleven times for this particular task.

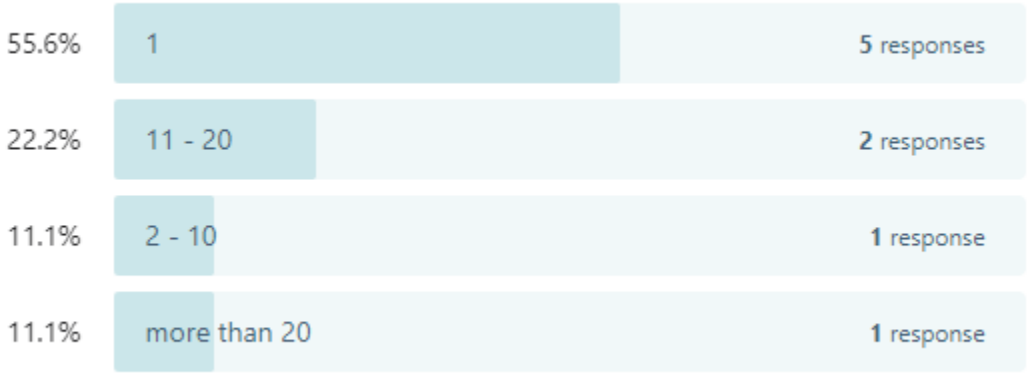


Figure 31: Pre-test, task one, design iterations - possibilities on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

Five out of nine respondents believed that they could do only one option out of the hexagonal grid. Four of the candidates thought they could do more than two options. The researcher observed the variety of these multiple options; shapes cannot be hardly manipulated due to fixed two-dimensional creation that the software provides.

The Second Segment of the Pre-test is doing this shape using a hexagonal grid as guidelines to initiate the circles at the corners. Snapping to anchor points can be hard with mouse hovering but creating it algorithmically with Grasshopper3d with mathematically correct angles by inputting it as visual nodes. The researcher asked the participants to do the following shape using Adobe Illustrator. Task two should be more complex to be able to observe notes precisely.

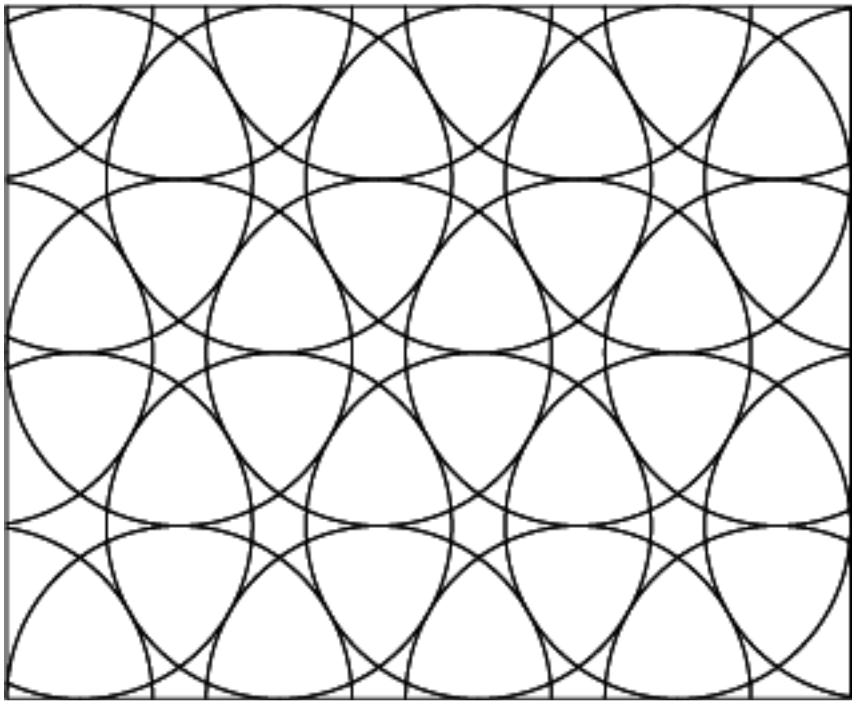

Figure 32: Pre-test, task two, Circlular patterns based on hexagonal grid done on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

The participants found this task much harder to do due to its complex nature. They could not precisely analyze the shapes and required assistance from the researcher. The researcher also noticed that circles are not being aligned perfectly by the participants. Seven out of nine candidates had alignment issues.

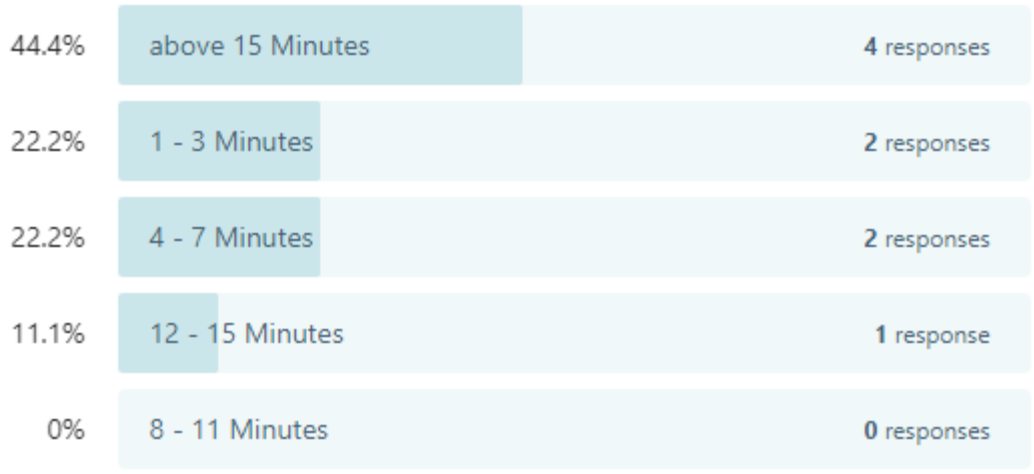


Figure 33: Pre-test, task two, time consumed doing the task on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

Five of the participants out of nine did the task with more than twelve minutes. The indicator of this chart results in longer times when patterns are more complex. When adding more sophisticated shapes, participants took longer hours to figure out through form-finding techniques that their brain function and, based on the limitation of the program in adobe illustrator what are the origin of these shapes.

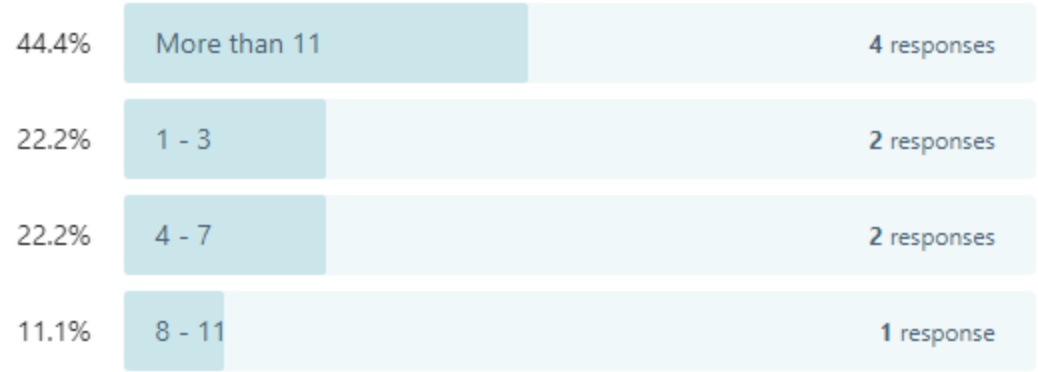


Figure 34: Pre-test, task two, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

Seven out of nine participants took more than four steps doing the second task, while also consuming a lot of time and effort. While four participants did the task within more than eleven steps, they also took more than fifteen minutes.

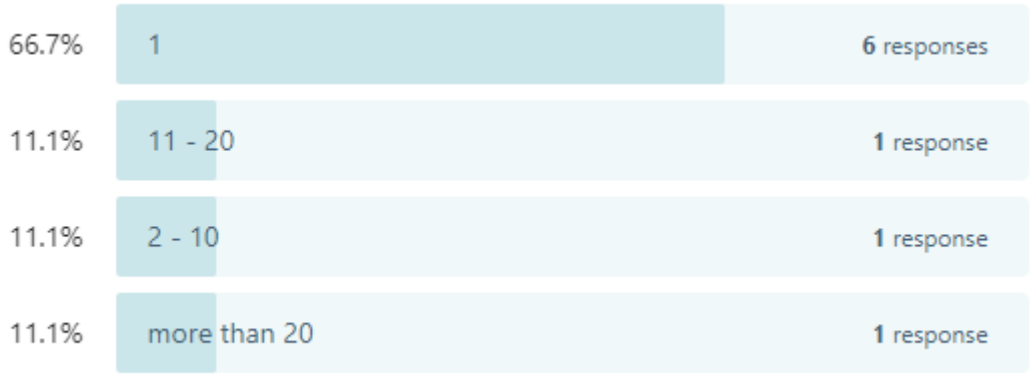


Figure 35: Pre-test, task two, design iterations - possibilities on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

Six out of nine participants believed that they could only do one design iterations. The researcher also observed participants who did more than one iteration and noticed that they needed more time doing each iteration. The researcher estimates the time necessary to do each iteration to be around three minutes.

The participants asked the researcher continuously for help during the test. The researcher solved the test after the experimental analysis has occurred. Some of the participants did the task using a tool called Pattern generator. This tool does not give the flexibility for the designer to choose parts of the shapes and recolor intersecting shapes. The researcher observed this problem and tried manipulating the second method that the students approach. Most of the participants used copy and paste methodology to solve both tests. Eight out of nine students used duplicate methods to manipulate the required shape.

### 4.1.3. Post-Test Results

The researcher explained a full lecture and included most of Grasshopper3d tools. The researcher also explained algorithm-driven design methodologies within two hours lecture. Furthermore, participants were asked to download grasshopper3d before the lecture started; the researcher solved all technical issues before beginning the experiment. The researcher asked the participants to do task one in grasshopper3d from the pre-test phase to create a diversion between both results and compare them. The researcher asked the students to re-create the hexagonal grid using Grasshopper3d.

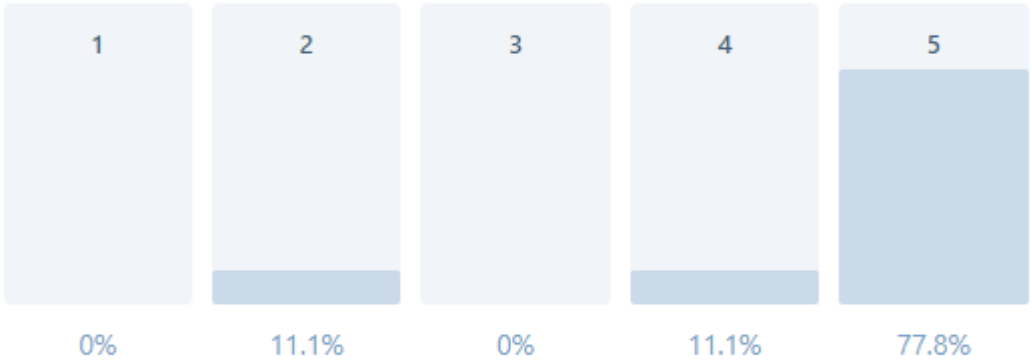


Figure 36: Post-test, task three, Participants lecture satisfaction at Al-Khawarizmi Technical University

Source: The Researcher, 2020

The researcher measured the candidates' satisfaction through a scalar degree from one to five. Eight out of nine students understood the lecture entirely by assigning four or five out of five. The indicator in this exercise enables the researcher the acceptance of algorithms within the designers' community.

The candidates felt excited about the topic due to them achieving and understanding the materials quickly. The candidates asked for a full course in algorithms involving graphic design and felt this would solve a lot of their problems as the candidates commented. The researcher showed the implementation of algorithms after the lecture was done. Students explored the urge to learn more about this knowledge. Also, five out of nine participants believed that design supervisors in companies should learn more about algorithms.

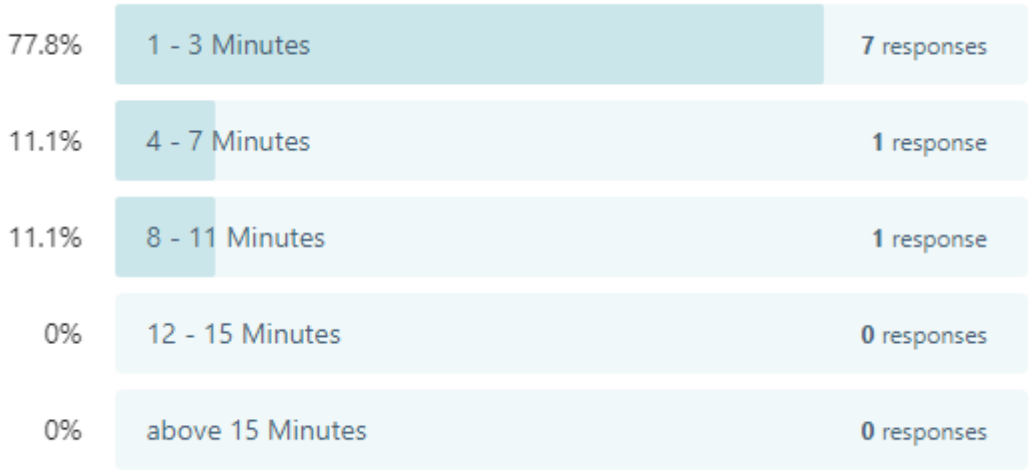


Figure 37: Post-test, task three, time consumed doing the task on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

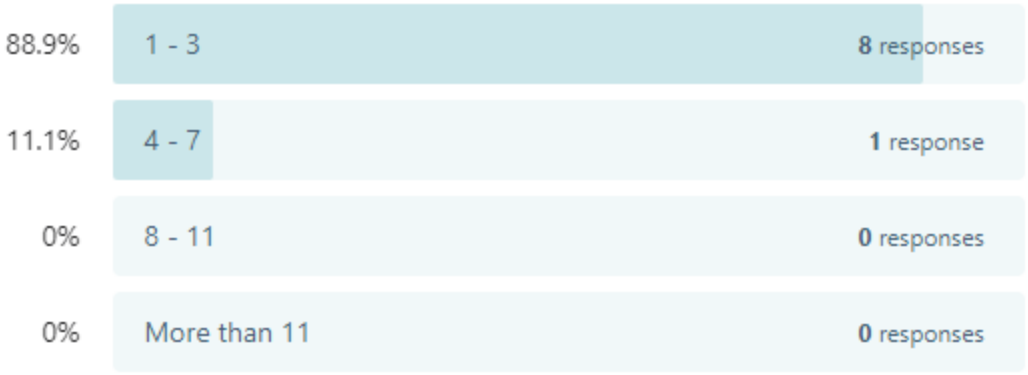


Figure 38: Post-test, task three, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

Eight out of nine participants did task three shorter than three minutes using less than three tools, which tremendously reduced time and effort. The participants felt excited and proud of the effort and time consumed doing this task.

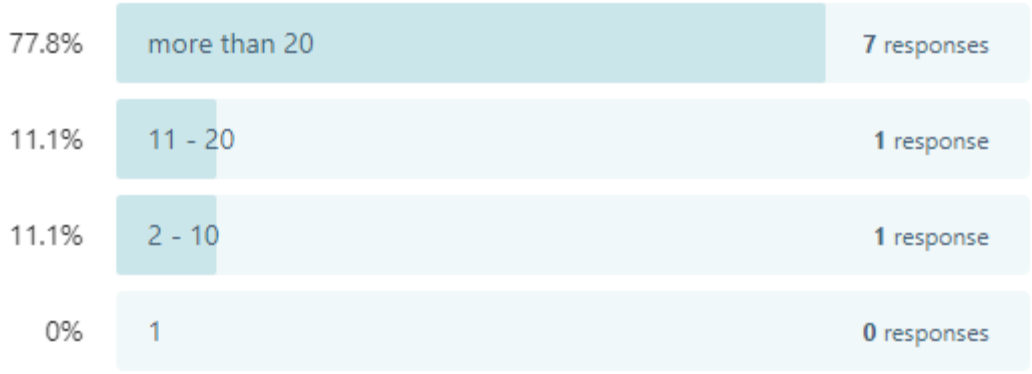


Figure 39: Pre-test, task three, design iterations - possibilities on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

Seven out of nine students believed they could do more than twenty design possibilities, which allowed students to elaborate and try more design possibilities. The researcher noticed that the students got more interested in designing the tool and asked the researcher for further tasks.

Comparing task three results and task one results in, it is noticeably to conclude that five of the students could do the design faster within one to three minutes out of eight to eleven minutes. Also, seven out of nine participants could do more than twenty possibilities when at task one, six out of nine candidates believed they could do the task with only one iteration. The design possibilities increased as well. Finally, the number of steps required to reach the final design has been reduced, while five out of nine candidates believed they could do it in less than three visual nodes. At task one, only one participant could elaborate on the task within three steps.

Participants were asked to redo task three, which is intersection circular shapes that integrated from the hexagonal grid. As task four started, the participants had a more precise idea of how to manipulate shapes algorithmically.

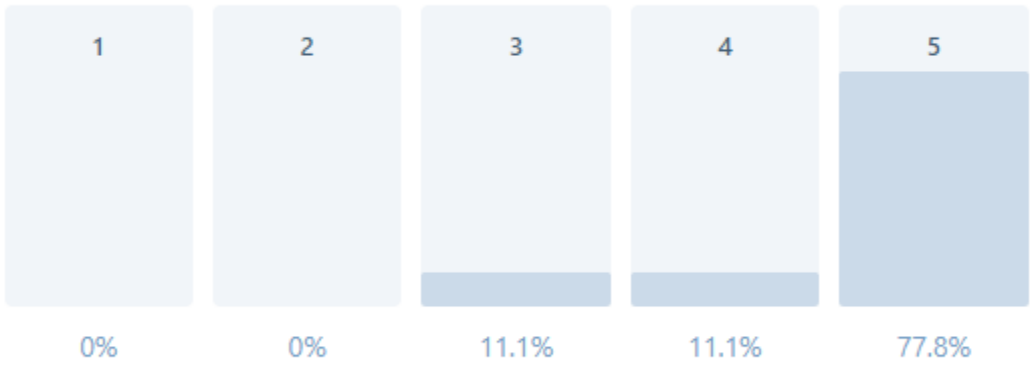


Figure 40: Post-test, task four, Participants lecture satisfaction at Al-Khawarizmi Technical University

Source: The Researcher, 2020

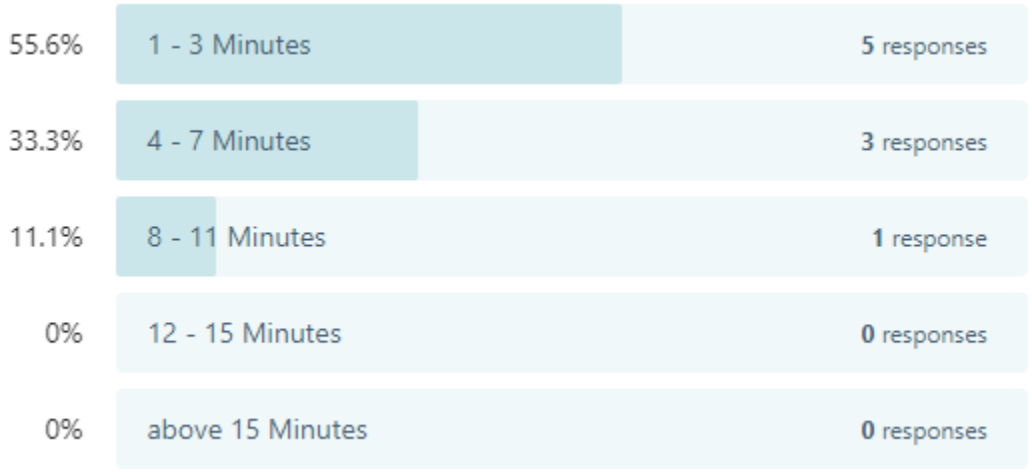


Figure 41: Post-test, task four, time consumed doing the task on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

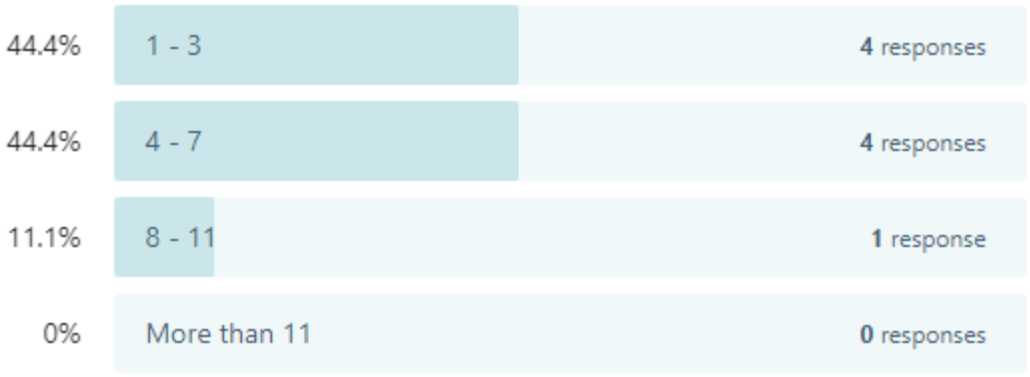


Figure 42: Post-test, task four, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

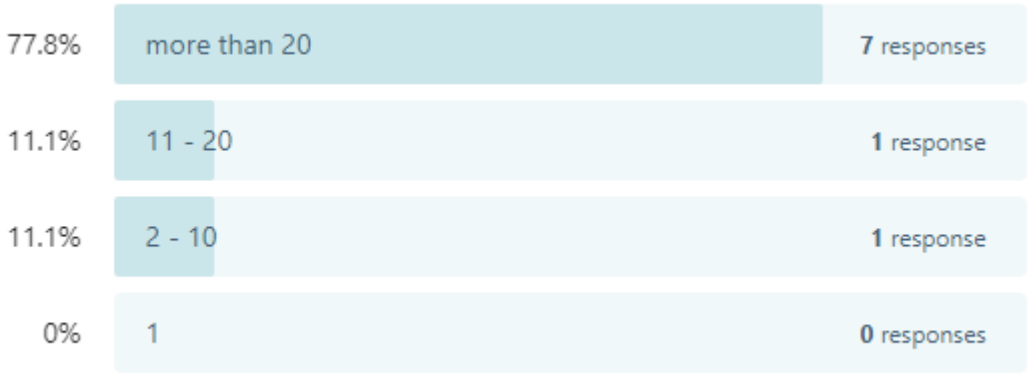


Figure 43: Pre-test, task four, design iterations - possibilities on Adobe Illustrator at Al-Khawarizmi Technical University

Source: The Researcher, 2020

## 4.2. Group "B" Experiment Results

### 4.2.1. Introductory Questionnaire Results

The second experiment done by the researcher at Al-Balqa University based on the student's educational degree is classified as group "B." The researcher chose last year's students to control the variables of the sample and to assure the reliability of the study sample. The first experiments concluded eleven students, four females and seven males. The researcher started with introductory questions that identify general information about the candidates. One of the questions introduced age. Age gives insights into the results and assures the quality of the tool.

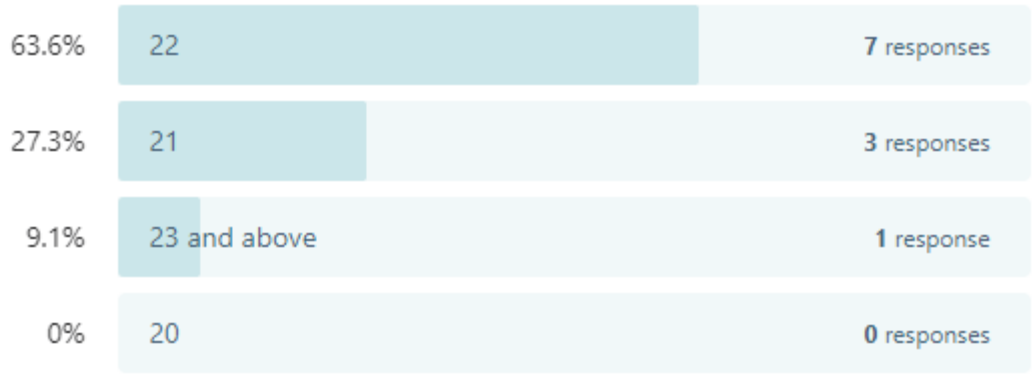


Figure 44: Age statistics at Al-Balqa University - Group B

Source: The Researcher, 2020

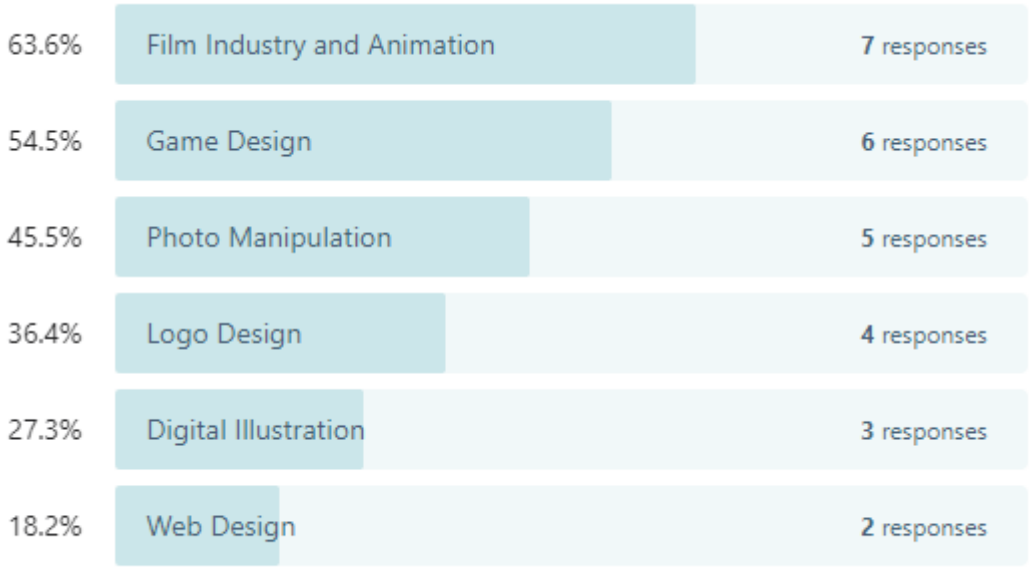


Figure 45: Design Interests at Al-Balqa University - Group B

Source: The Researcher, 2020

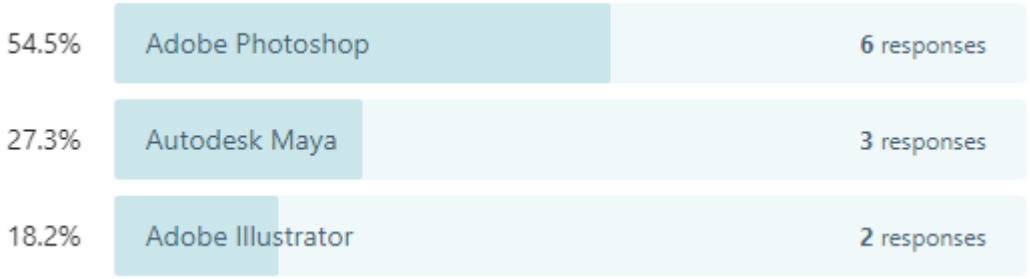


Figure 46: Most usable program at Al-Balqa University - Group B

Source: The Researcher, 2020


Figure 47: Candidates using Adobe Illustrator professionally at Al-Balqa University - Group B

Source: The Researcher, 2020

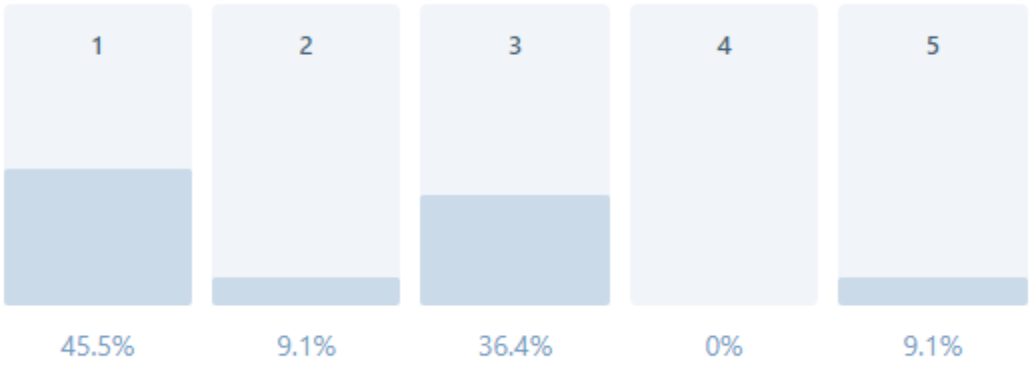


Figure 48: Experty level on Adobe Illustrator at Al-Balqa University - Group B

Source: The Researcher, 2020

### 4.2.2. Pre-Test Results

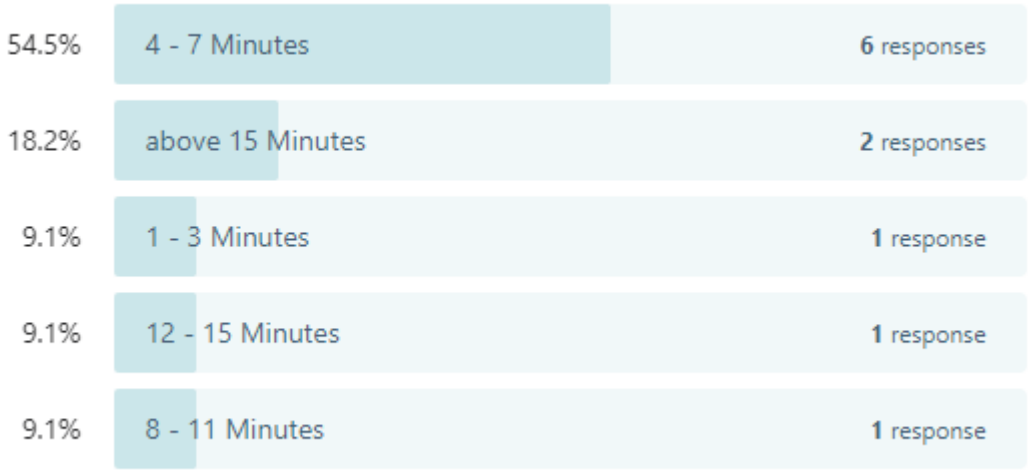


Figure 49: Pre-test, task one, time consumed doing the task on Adobe Illustrator at Al-Balqa University - Group B

Source: The Researcher, 2020

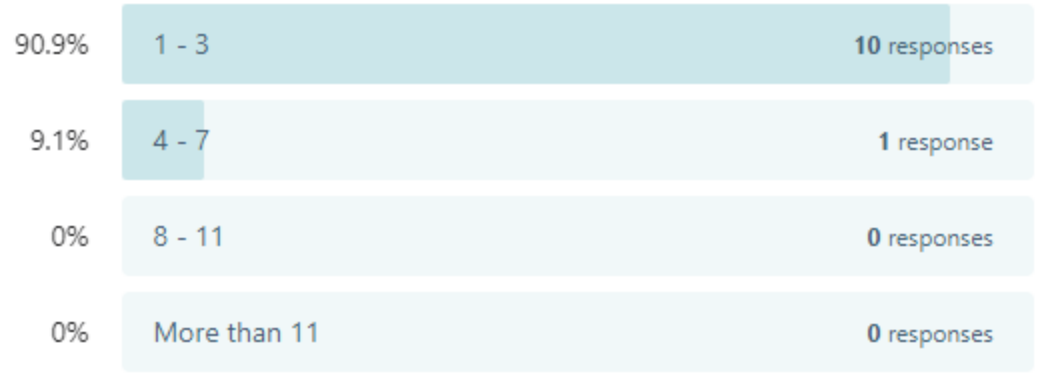


Figure 50: Pre-test, task one, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Balqa University - Group B

Source: The Researcher, 2020

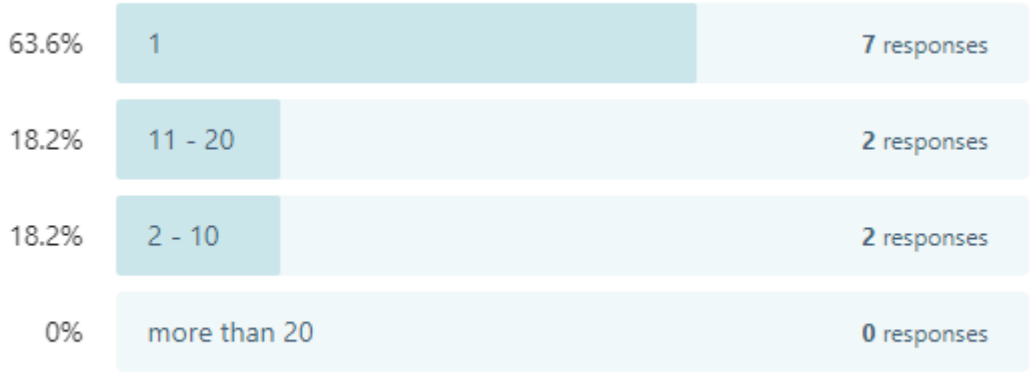


Figure 51: Pre-test, task one, design iterations - possibilities on Adobe Illustrator at Al-Balqa University - Group B

Source: The Researcher, 2020

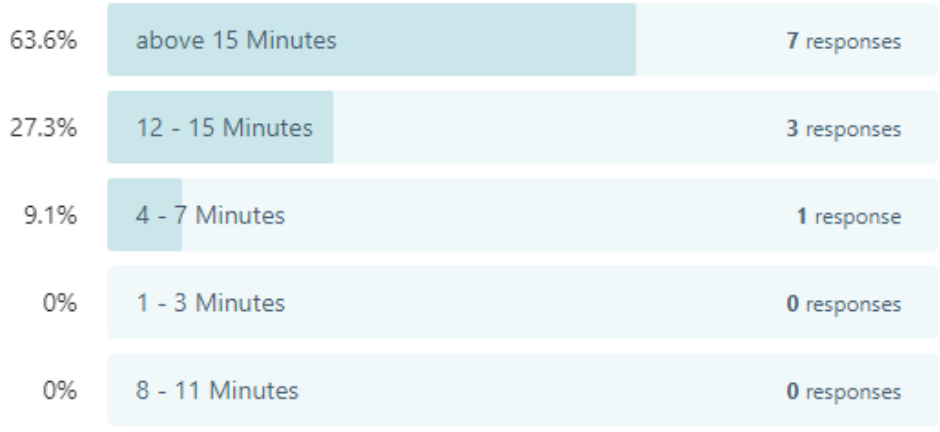


Figure 52: Pre-test, task two, time consumed doing the task on Adobe Illustrator at Al-Balqa University - Group B

Source: The Researcher, 2020

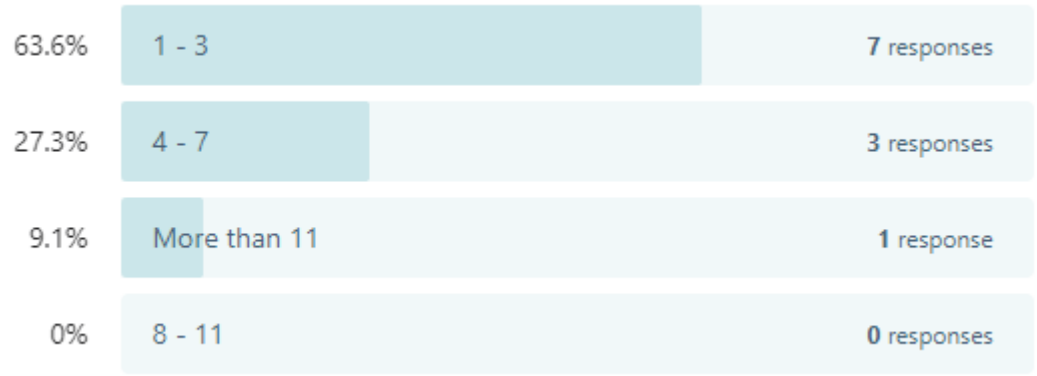


Figure 53: Pre-test, task two, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Balqa University - Group B

Source: The Researcher, 2020

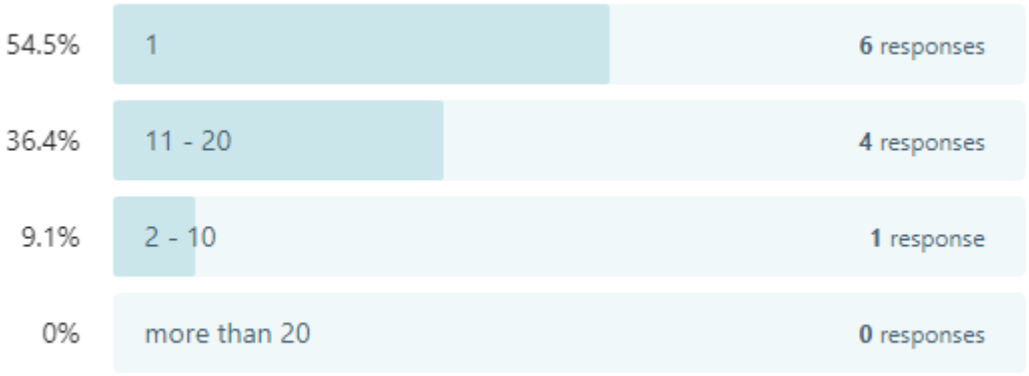


Figure 54: Pre-test, task two, design iterations - possibilities on Adobe Illustrator at Al-Balqa University - Group B

Source: The Researcher, 2020

### 4.2.3. Post-Test Results

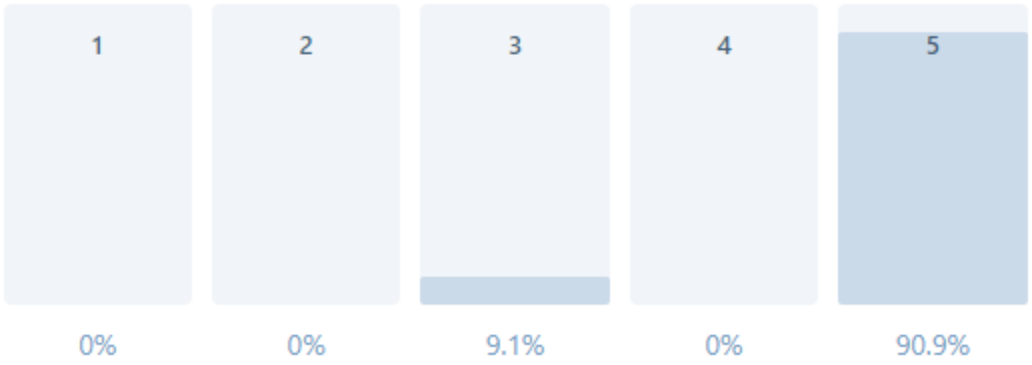


Figure 55: Post-test, task three, Participants lecture satisfaction at Al-Balqa University - Group B

Source: The Researcher, 2020

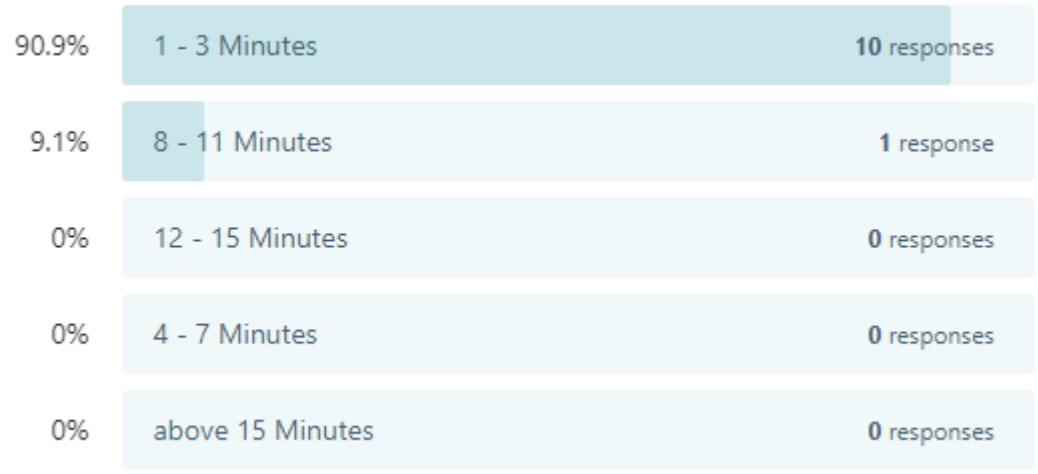


Figure 56: Post-test, task three, time consumed doing the task on Adobe Illustrator at Al-Balqa University - Group B

Source: The Researcher, 2020

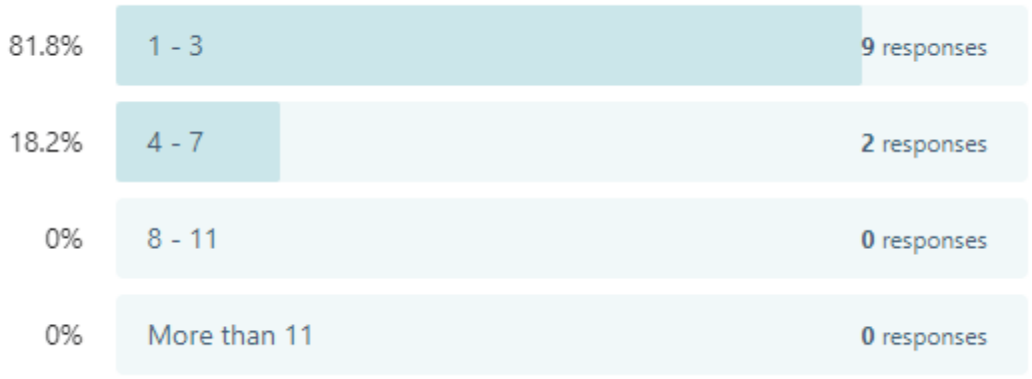


Figure 57: Post-test, task three, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Balqa University - Group B

Source: The Researcher, 2020

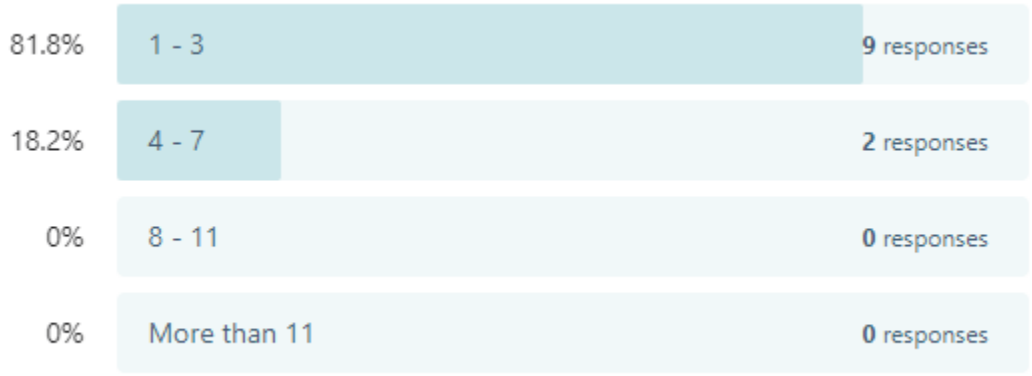


Figure 58: Post-test, task three, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Balqa University - Group B

Source: The Researcher, 2020

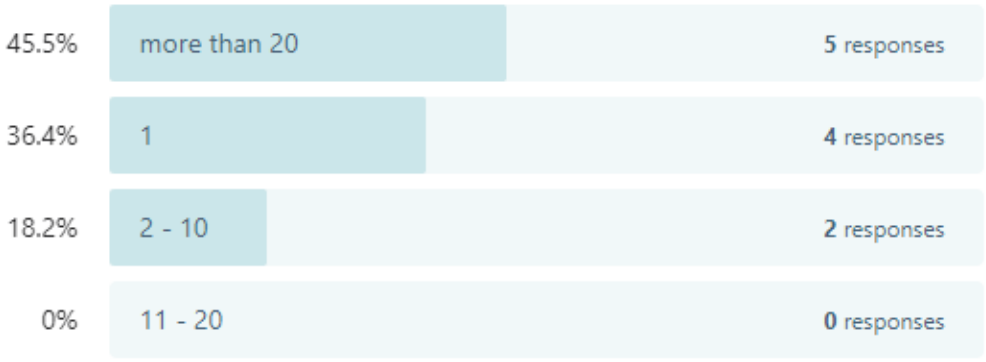


Figure 59: Post-test, task three, design iterations - possibilities on Adobe Illustrator at Al-Balqa University -Group B

Source: The Researcher, 2020

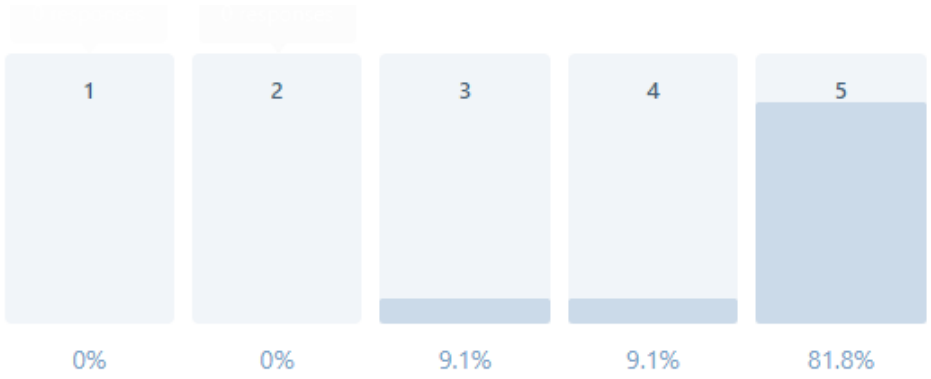


Figure 60: Post-test, task four, Participants lecture satisfaction at Al-Balqa University - Group B

Source: The Researcher, 2020

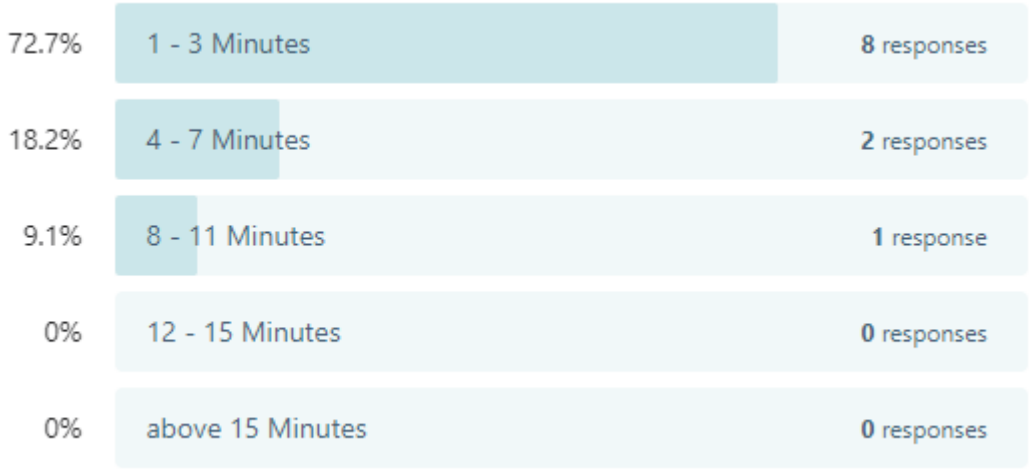


Figure 61: Post-test, task four, time consumed doing the task on Adobe Illustrator at Al-Balqa University - Group B

Source: The Researcher, 2020

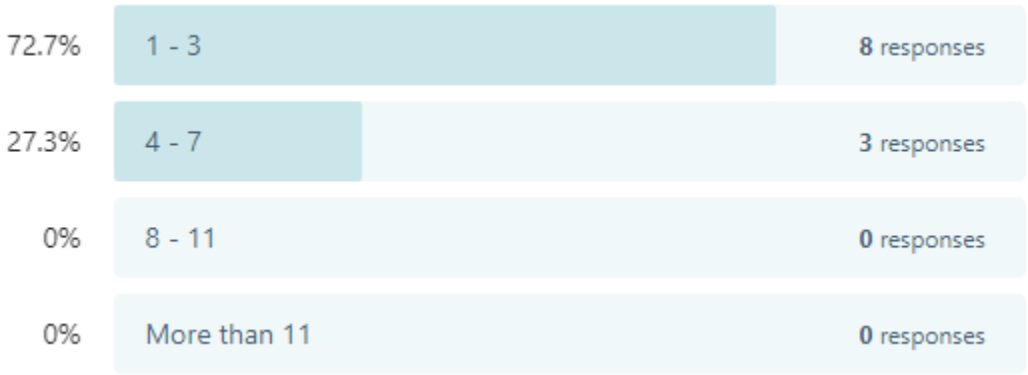


Figure 62: Post-test, task four, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Balqa University - Group B

Source: The Researcher, 2020

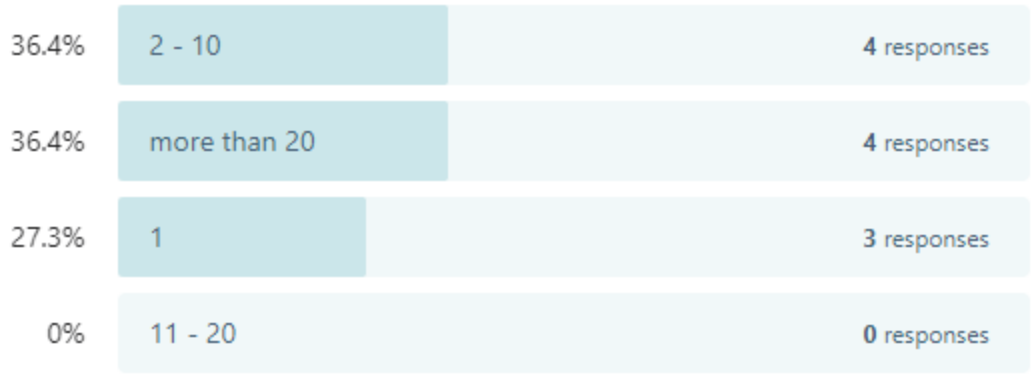


Figure 63: Post-test, task four, design iterations - possibilities on Adobe Illustrator at Al-Balqa University -Group B

Source: The Researcher, 2020

## 4.3. Group "C" Experiment Results

### 4.3.1. Introductory Questionnaire Results

The third experiments done by the researcher at Al-Balqa University based on the student's educational degree are classified as group "C." The researcher chose last year's students to control the variables of the sample and to assure the reliability of the study sample. The first experiments concluded eleven students, four females and seven males. The researcher started with introductory questions that identify general information about the candidates. One of the questions introduced age. Age gives insights into the results and assures the quality of the tool.

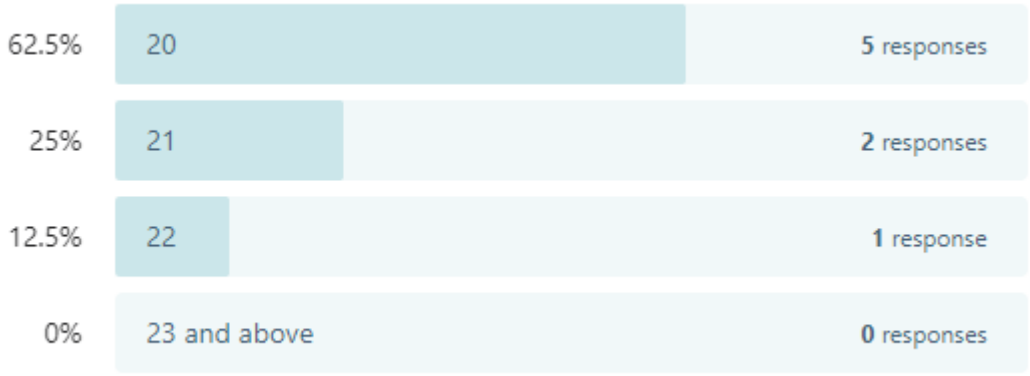


Figure 64: Age statistics at Al-Balqa University - Group C

Source: The Researcher, 2020

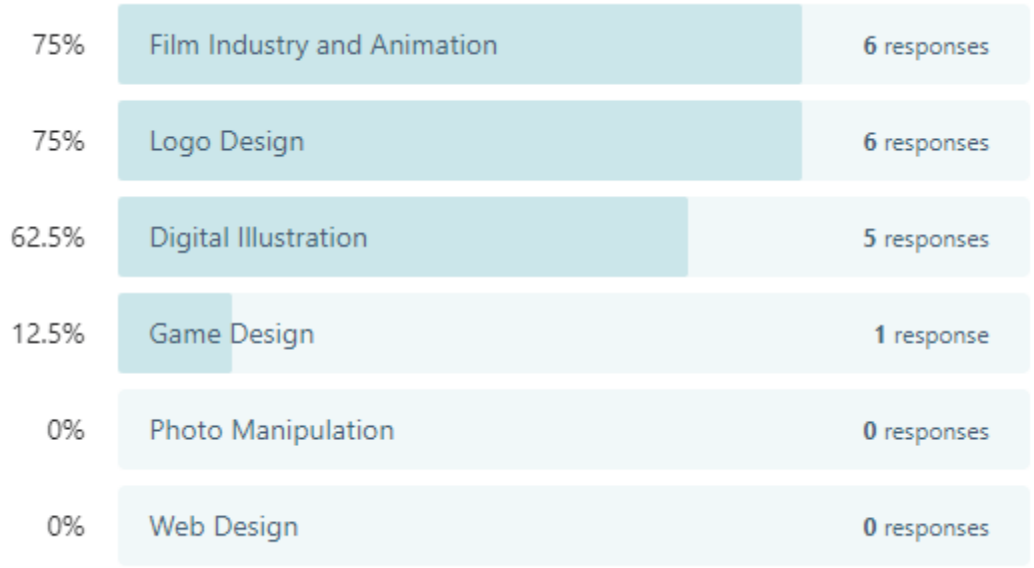


Figure 65: Design Interests at Al-Balqa University - Group C

Source: The Researcher, 2020

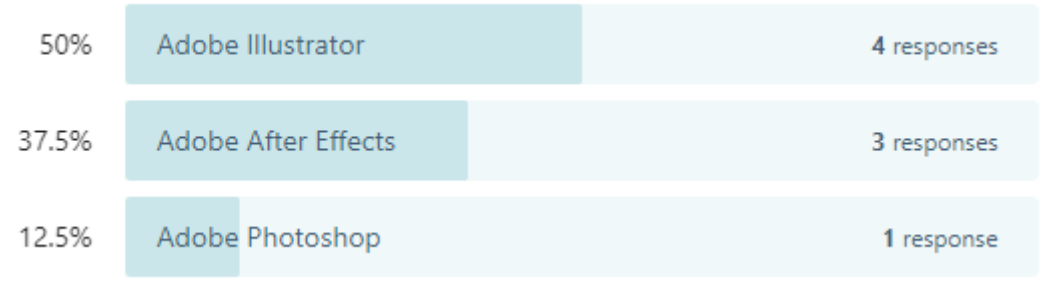


Figure 66: Most usable program at Al-Balqa University - Group C

Source: The Researcher, 2020

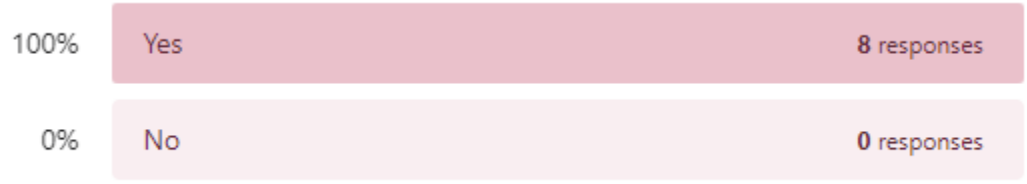


Figure 67: Candidates using Adobe Illustrator professionally at Al-Balqa University - Group C

Source: The Researcher, 2020

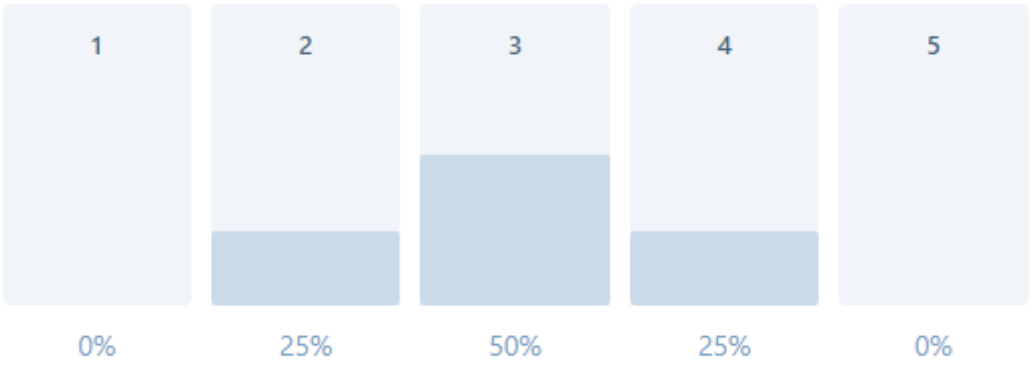


Figure 68: Experty level on Adobe Illustrator at Al-Balqa University - Group C

Source: The Researcher, 2020

### 4.3.2. Pre-Test Results

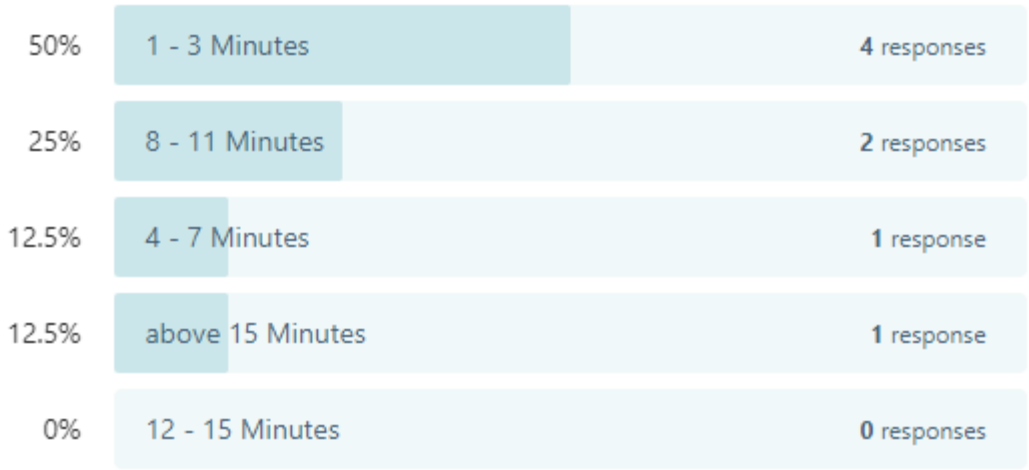


Figure 69: Pre-test, task one, time consumed doing the task on Adobe Illustrator at Al-Balqa University - Group C

Source: The Researcher, 2020

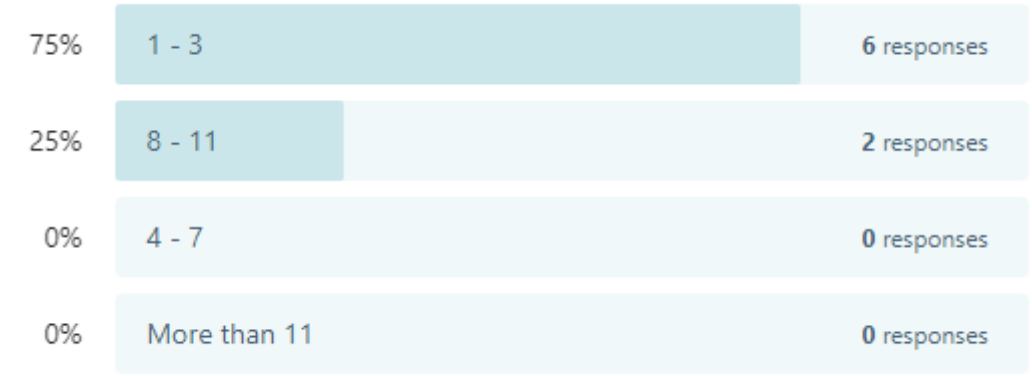


Figure 70: Pre-test, task one, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Balqa University - Group C

Source: The Researcher, 2020

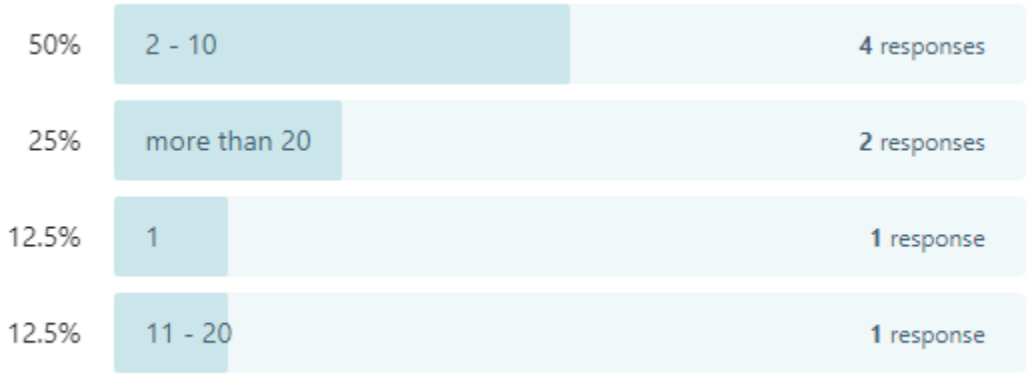


Figure 71: Pre-test, task one, design iterations - possibilities on Adobe Illustrator at Al-Balqa University - Group C

Source: The Researcher, 2020

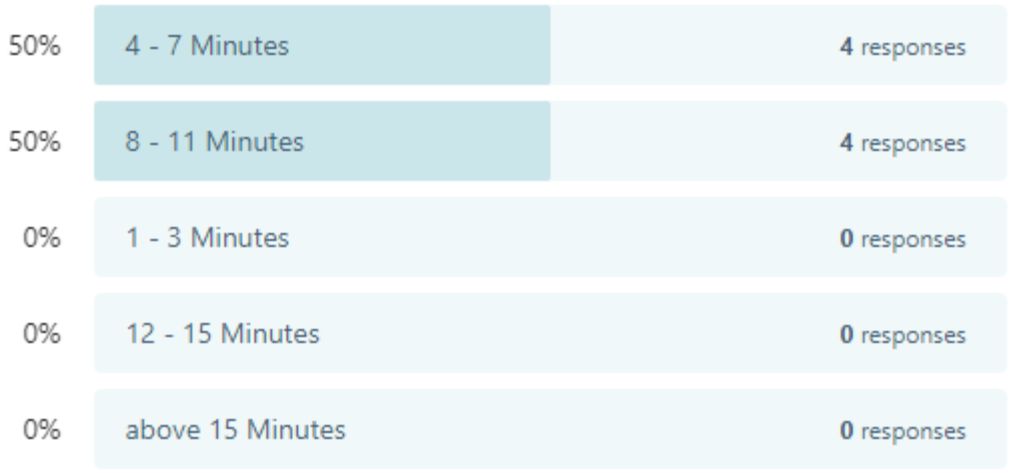


Figure 72: Pre-test, task two, time consumed doing the task on Adobe Illustrator at Al-Balqa University - Group C

Source: The Researcher, 2020

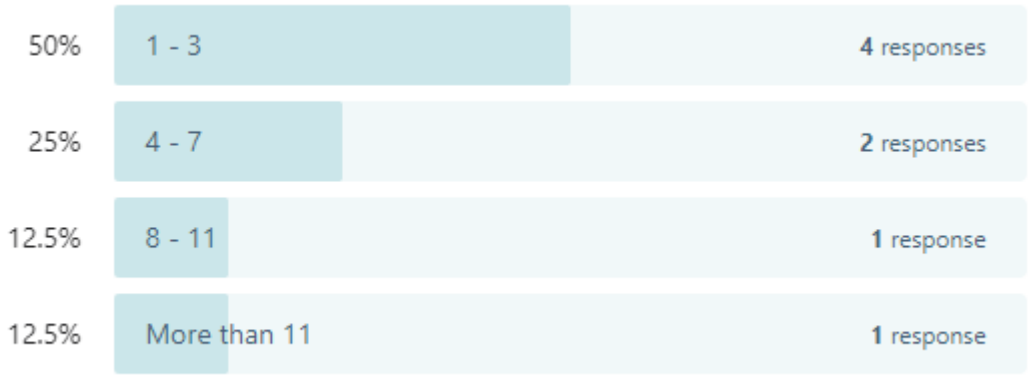


Figure 73: Pre-test, task two, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Balqa University - Group C

Source: The Researcher, 2020

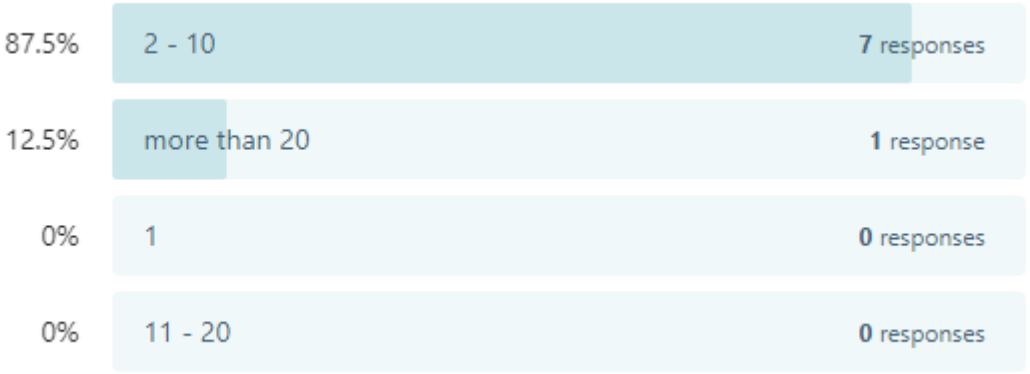


Figure 74: Pre-test, task two, design iterations - possibilities on Adobe Illustrator at Al-Balqa University - Group C

Source: The Researcher, 2020

### 4.3.3. Post-Test Results

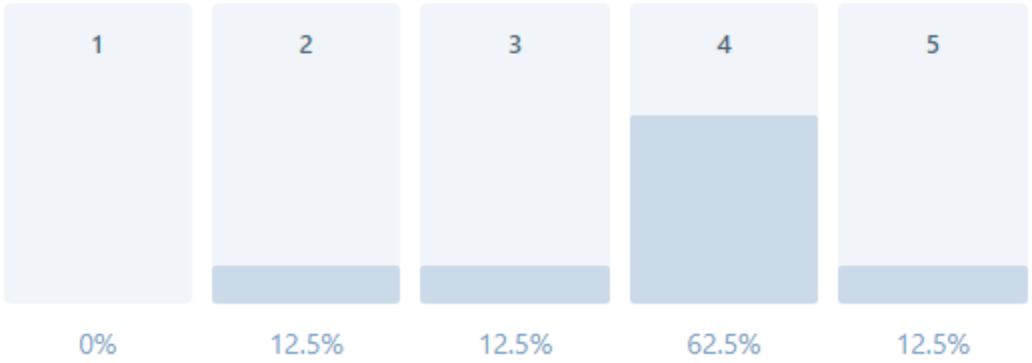


Figure 75: Post-test, task three, Participants lecture satisfaction at Al-Balqa University - Group C

Source: The Researcher, 2020

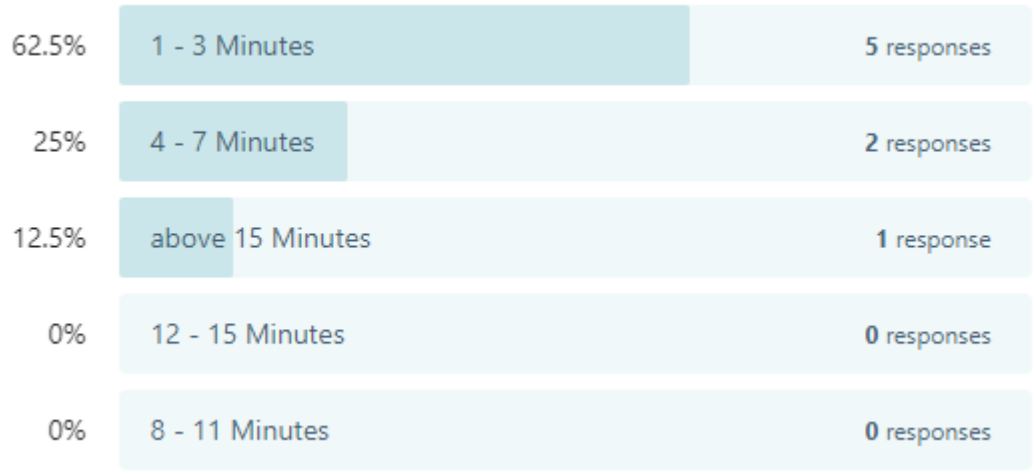


Figure 76: Post-test, task three, time consumed doing the task on Adobe Illustrator at Al-Balqa University - Group C

Source: The Researcher, 2020

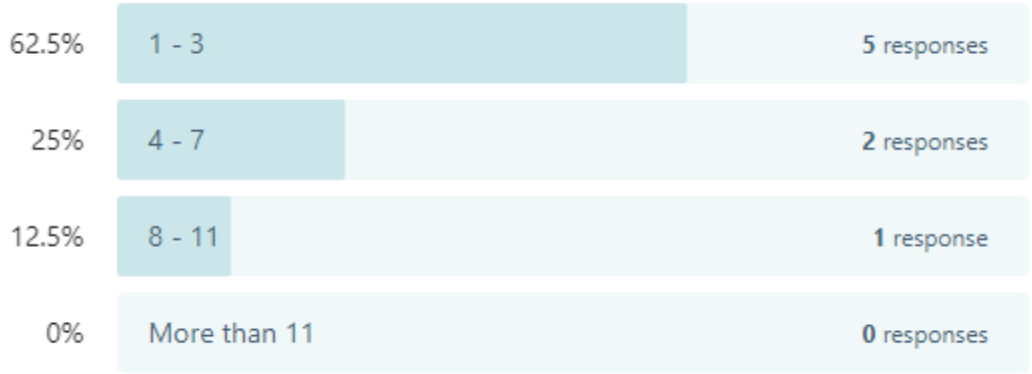


Figure 77: Post-test, task three, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Balqa University - Group C

Source: The Researcher, 2020

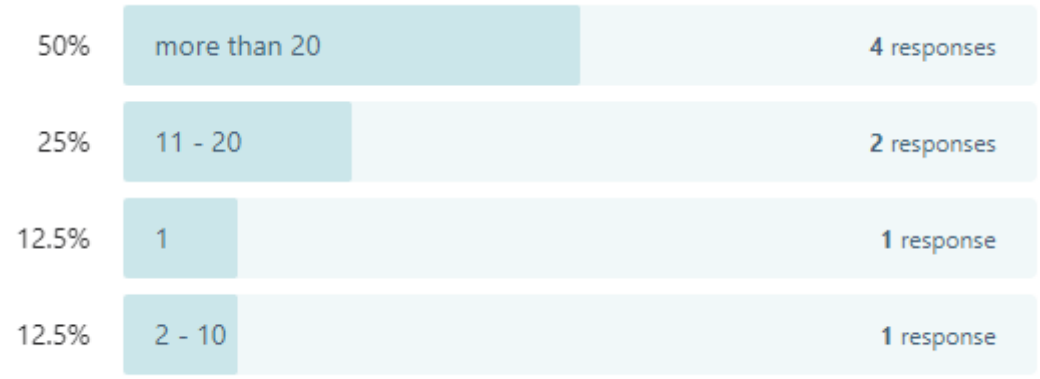


Figure 78: Post-test, task three, design iterations - possibilities on Adobe Illustrator at Al-Balqa University -Group C

Source: The Researcher, 2020

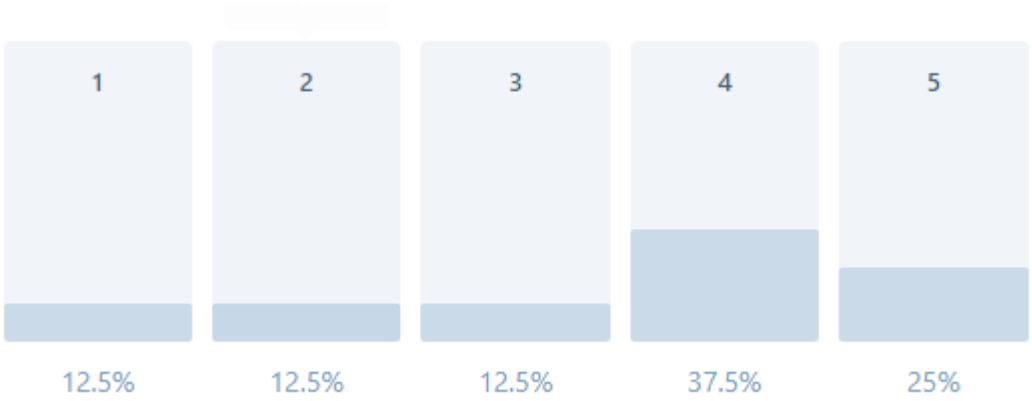


Figure 79: Post-test, task four, Participants lecture satisfaction at Al-Balqa University - Group C

Source: The Researcher, 2020

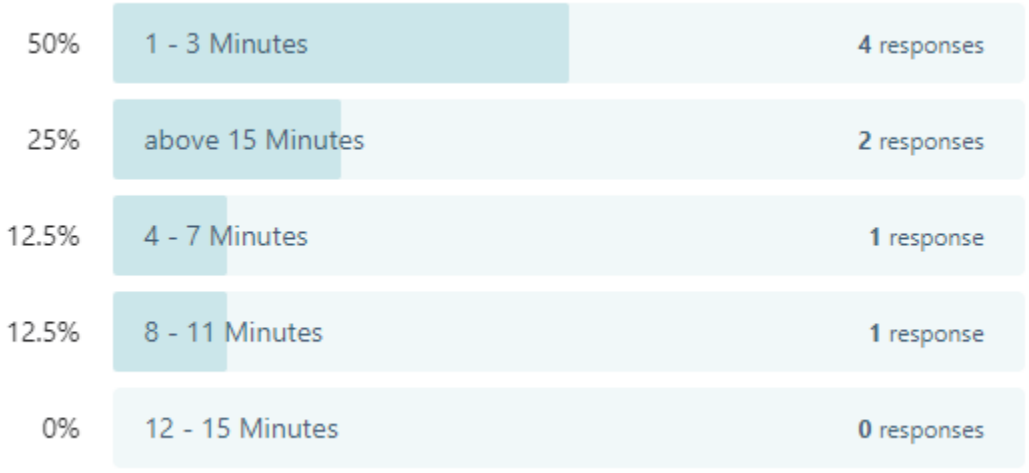


Figure 80: Post-test, task four, time consumed doing the task on Adobe Illustrator at Al-Balqa University - Group C

Source: The Researcher, 2020

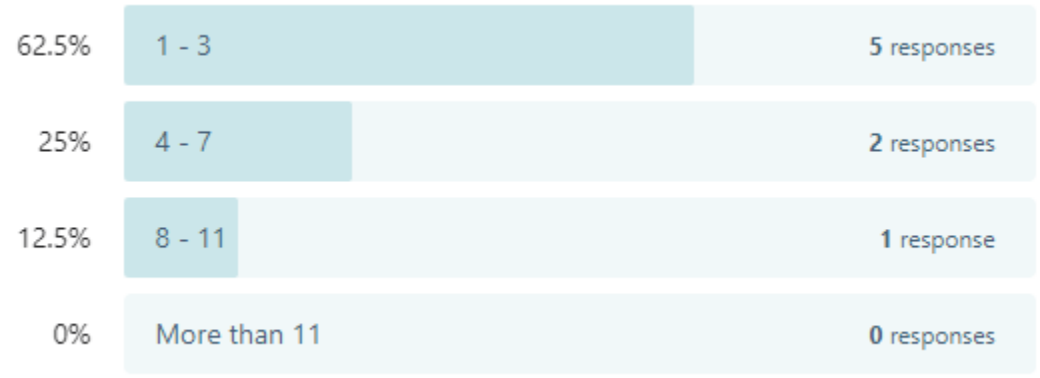


Figure 81: Post-test, task four, steps measured as effort consumed doing the task on Adobe Illustrator at Al-Balqa University - Group C

Source: The Researcher, 2020

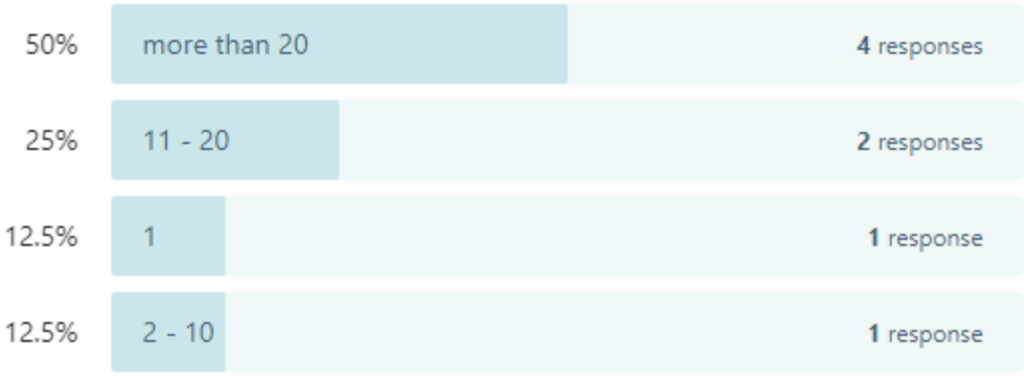


Figure 82: Post-test, task four, design iterations - possibilities on Adobe Illustrator at Al-Balqa University -Group C

Source: The Researcher, 2020

# Chapter Five:

# Conclusions and Recommendations

In this section, the researcher presents a final answer to the thesis questions and recommends methods to solve this study problem.

## Table of Contents

## 5.1. Conclusions

After the comprehensive analysis for all questionnaire results, tests, experiments, literature review, and all participant's demographics, the researcher is going to confirm all study hypotheses and answer all the previous study questions as below.

- Students from different universities preferred digital illustration over any kind of design topics, which makes it easier to identify the relation between illustration and algorithms. Group -A- chose digital illustration, Group -B- also chose digital illustration, Group -C- chose both Animation and film industries, and digital illustration.

- The importance of student demographics on age group is high, where last year students have more experience in dealing with new software due to experience level working manually and using the software.

- The mentality of participants has changed through the new school of thought, where students started thinking algorithmically, analyzing data logically through computer equations and mathematics instead of conventionally drawing sketches and developing on the requested test requirements.

- Time completing each task has been incredibly reduced using algorithm-design approaches. The analysis had resolved some attributes for the time consumed in doing the same design output. Group -A- results saved around twelve minutes of working minutes out of fifteen. Group -B- results saved ten minutes of working out of fifteen. Group -C- results saved fourteen minutes of working out of fifteen. All task times were estimated to fifteen minutes. Time efficiency increased in all groups by 172%.

- Effort completing each task has been incredibly reduced using algorithm-design approaches. The analysis had resolved some attributes for the effort consumed in doing the same design output. Group -A- results saved around five steps in the design procedure out

of eleven. Group -B- results saved around six steps in the design procedure out of eleven. Group -C- results saved around three steps in the design procedure out of eleven. All task efforts were estimated at eleven steps. Effort efficiency decreased in all groups by 82%.

- Design choices or Iterations task has been incredibly increased using algorithm-design approaches. The analysis had resolved some attributes for design iterations. Group -A- results completed seven more different design iterations Group -B- results completed fifteen more different design iterations Group -C- results completed thirteen more different design iterations. All results were estimated at the same time as completing the task, which was fifteen minutes. Choices have increased to more than 856% from the original ones.

## 5.2. Recommendations

The researcher worked on producing a guideline from this study, which could help designers choose when to use algorithm-driven design techniques with which parts of graphic design. The researcher summarizes the recommendations as follows:

- Logo Design, Product Design, Pattern, and Textile design industries always require multiple design options, relating it to generative design could help designers elaborate with various options.
- Poster Design, three-dimensional models, and textile industries elaborate the best with the parametric design algorithm approach.
- Algorithm-design techniques should be implemented within the study plan in universities for last year's undergraduate visual communication students.
- Algorithm-driven design techniques should also be implemented within design offices that has a supervisor, where the supervisor could mentor juniors to design more efficiently using algorithms
- Working with algorithmic design approaches makes the design process faster with less effort, which indicates more money paid per hour for the designer since the designer can finish duplicated tasks.

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## Appendices:

1. Introduction, Pre-test and post-test questionnaire

- Welcome to the Research Experimental Test Sample

In The First Section, you will answer General Information about yourself.

- What's your name?

- Choose your gender

1) Male
2) Female

- How old are you?

1) 20
2) 21
3) 22
4) 23 and above

In the second section, you will answer general design questions

- What is your Bachelors's degree?

1) Computer Graphics and Animation
2) Multi-Media Production and Graphic Design
3) Graphic Design
4) Architecture

- What kind of design do you use the most? (you can choose more than one option)

1) Film Industry and Animation
2) Digital Illustration
3) Photo Manipulation
4) Game Design
5) Logo Design
6) Web Design

- What kind of programs do you use the most?

1) Adobe Photoshop
2) Adobe Illustrator
3) Adobe After Effects
4) Autodesk Maya
5) Autodesk 3ds Max
6) Other…

- in the third section, you will be asked on Adobe Illustrator software skills

- Did you take Adobe Illustrator Class before?

1) Yes
2) No

- Where did you take the class? (you can choose more than 1)

1) University
2) Institute
3) Private Class

- How many years did you work on Adobe Illustrator

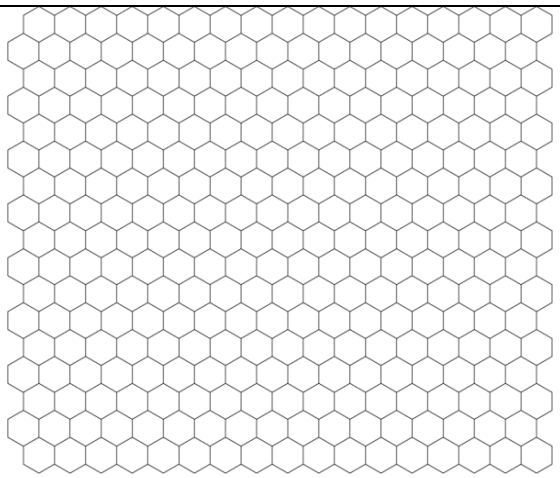
1) One year
2) Two years
3) Three years
4) more than three years

- How skilled are you on Adobe Illustrator

1-2-3-4-5

- in the fourth section, you will be running into experimental tests

- Test 1, Pre-Lecture



- How Much Time did it take you to complete the task?

1) 1 - 3 Minutes
2) 4 - 7 Minutes
3) 8 - 11 Minutes
4) 12 - 15 Minutes
5) above 15 Minutes

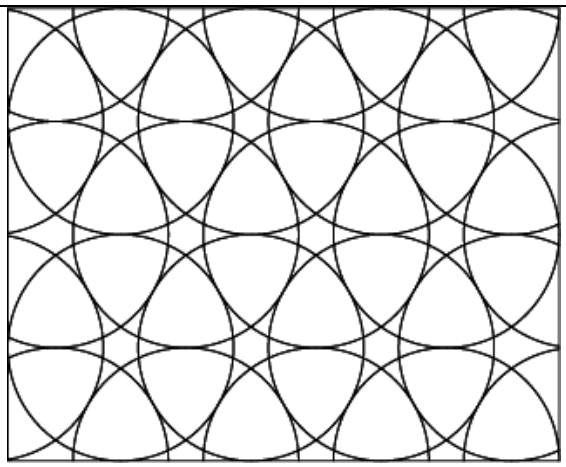
- How Many Tools did you use?

1) 1 - 3
2) 4 - 7
3) 8 - 11
4) More than 11

- How Many Design Iterations can you make?

1) 1
2) 2 - 10
3) 11 - 20
4) more than 20

- Test 2, Pre-Lecture



- How Much Time did it take you to complete the task

1) 1 - 3 Minutes
2) 4 - 7 Minutes
3) 8 - 11 Minutes
4) 12 - 15 Minutes
5) above 15 Minutes

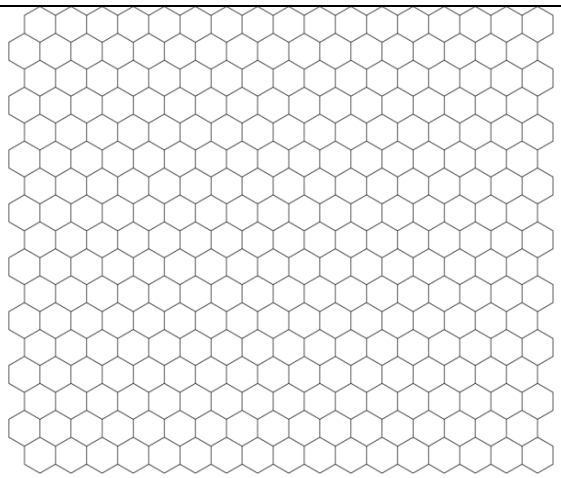
- How Many Tools did you use?

1) 1 - 3
2) 4 - 7
3) 8 - 11
4) More than 11

- How Many Design Iterations can you make?

1) 1
2) 2 - 10
3) 11 - 20
4) more than 20

- Test 3, Post Lecture



- How much did you understand from the lecture?
  1-2-3-4-5

- How Much Time did it take you to complete the task

1) 1 - 3 Minutes
2) 4 - 7 Minutes
3) 8 - 11 Minutes
4) 12 - 15 Minutes
5) above 15 Minutes

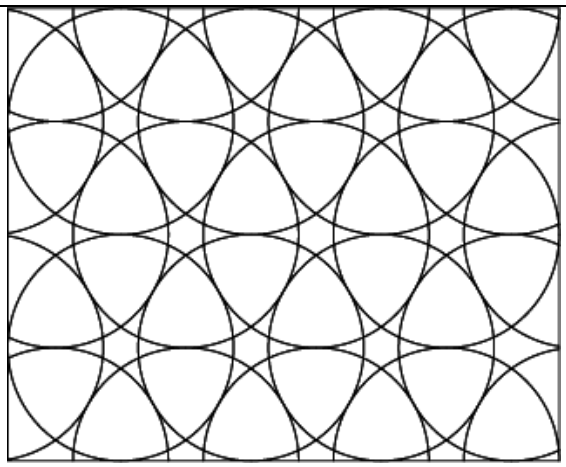
- How Many Visual Nodes did you use?

1) 1 - 3
2) 4 - 7
3) 8 - 11
4) More than 11

- How Many Design Iterations can you make?

1) 1
2) 2 - 10
3) 11 - 20
4) more than 20

- Test 4, Post Lecture



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