Generic Green Skills for Creativity and Innovation: Tessellation of Regular Polygons

Abdullahi Musa Cledumas, Yusri Bin Kamin, Haruna Rabiu

Abstract: ***This paper proposes an improved modelling approach for tessellating regular polygons in such a way that it is environmentally sustainable. In this paper, tessellation of polygons that have been innovated through the formed motifs, is an innovation from the traditional tessellations of objects and animals. The main contribution of this work is the simplification and innovating new patterns from the existing regular polygons, in which only three polygons (triangle, square and hexagon) that can freely be tessellated are used, compared to using irregular polygons or other objects. This is achieved by reducing the size of each polygon to smallest value and tessellating each of the reduced figure to the right or to left to obtain a two different designs of one unit called motif. These motifs are then combined together to form a pattern. In this innovation it is found that the proposed model is superior than tessellating ordinary regular polygon, because more designs are obtained, more colours may be obtained or introduced to give meaningful tiles or patterns. In particular Tessellations can be found in many areas of life. Art, architecture, hobbies, clothing design, including traditional wears and many other areas hold examples of tessellations found in our everyday surroundings.***

Index Terms: Generic Green Skill, Tessellation, Creativity, Regular Polygon, Motifs

I. INTRODUCTION

A considerable amount of literature has been published on this issue. This study tessellation of polygons that have been innovated through the formed motifs, is an innovation from the traditional tessellations of objects and animals. Tessellations can be found in many areas of life. Art, architecture, hobbies, and many other areas hold examples of tessellations found in our everyday surroundings. Specific examples include oriental carpets, quilts, origami, Islamic architecture

According Jinny B. (1999) Designing Tessellations opens the door for quilters to thousands of new and exciting patterns by showing them how to create tessellations--designs made up of the repeated use of seemingly complex but deceptively simple shapes that interlock perfectly to flow across a quilt. Jinny Beyer introduces quilters to the fascinating world of symmetry and then clearly shows how to experiment with shapes and images to create sensational, tessellating designs. Quilters will not only learn how to produce interlocking geometric patterns, but also will learn how easy it is to create.

The marvels of Islamic patterns, the most recognizable visual expression of Islamic art and architecture, are not just a beautiful accident. The ancient practitioners of this craft used traditional methods of measurement to create dazzling geometric compositions, often based on the repetition of a single pattern. The results are magnificent in their beauty and awe-inspiring in their execution (Eric B.2008)

A. Generic green skills

Generic green skills are required in almost any occupation to understand and appreciate the issues and demands of green growth. According to Adzmi, Hamid, Awang, Kamin, and Atan (2018), the transition towards green economy, GGS are becoming increasingly essential due to labour demand and skills supply, Various definitions of generic green skills have been provided such as by CEDEFOP, Pavlova, Swinburne University of Technology, Mohd Zolkifli et al., UNIDO and OECD, it is defined as skills for sustainability that cover knowledge, values and attitudes that can support the green growth. Specialised green skills that relate to new green occupations are deemed to be country specific, as what is in one country may be topping up on existing skills but could be the development of new training packages for newly established occupations in other countries. In some countries occupations related to renewable energy, waste management, green business management could be new.

This study focuses on the application of generic green skills. Tessellation is a work that doesn't require much energy, therefore the surrounding environment is safe in terms of heat. Major skill needed in tessellation is attitude, enough knowledge of creativity, polygons and drawing.

II. LITERATURE REVIEW

Tessellation

What are Tessellations?

The word 'tessera' in latin means a small stone cube. They were used to make up 'tessellata' - the mosaic pictures forming floors and tiling in Roman buildings**. (David A. 2014)**

David A. further maintained that Notice, in the example at right, that the artists used many small square tiles to create one big picture of a bull. Nowadays, the term "tessellation" has expanded to have at least four meanings.

Now it has the original meaning, of big pictures made from small square tiles, but it also means tile-sized uniformly shaped pictures or big pictures made from tiles that aren't just square-shaped.

Tessellation can also mean simply filling a large surface, without gaps or overlaps, using *non*-square tiles.

Revised Manuscript Received on September 22, 2019.

Abdullahi Musa Cledumas, Universiti Teknologi, Malaysia. Johor Bahru **,** musacledumas2068@graduate.utm.my

Dr.Yusri Bin Kamin, Associate Professor: Universiti Teknologi, Malaysia. Johor Bahru

Haruna Rabiu, Student; Universiti Teknologi, Malaysia. Johor Bahru

In nature, we see this kind of tessellation in cracked mud, turtle shells, and other places. In man-made areas, we see it in architecture, for example...from brick walls and bathroom floors to decorated magnificent, beautiful buildings like the Alhambra in Spain.

In the world of three-dimensional CGI (Computer Graphic Imagery), tessellation refers to the "wire frame" shape created from small interconnected non-identical polygon shapes-- not just squares. These give us the shape-- but not the colouring-- of Jurassic Park's dinosaurs, video game monsters and heroes, and other invented animals and objects.

Tessellation now also means tile-sized pictures made from single tiles that repeat to fill a 2D or 3D space completely without gaps or overlaps. Most people call these "M. C. Escher-style tessellations". In these tessellations, the tiles aren't square. The individual tiles are the shape of animals, people, and things. Nowadays, when we say "this is an animal tessellation", we don't see lots of little tiles making a big picture of an animal. Instead, each little tile *is* a little picture of an animal. The tiles cover a surface -- usually a 2D (i.e., flat) plane -- in a symmetrical way without overlapping or leaving gaps. You can see examples in the many art galleries here at Tessellations.org.

A. Types of Tessellations

According to Karen, V. (2019) Tessellations can be divided into several categories; sample subsets include the following:

1) Regular Tessellations.

Regular tessellations form patterns consisting of a single shape. Only three types of regular tessellations exist: triangles, squares, and hexagons. These shapes by themselves can fill a surface because their interior angles are exact divisors of 360°. Of these shapes, only the squares line up with one another without requiring rotating or shifting.

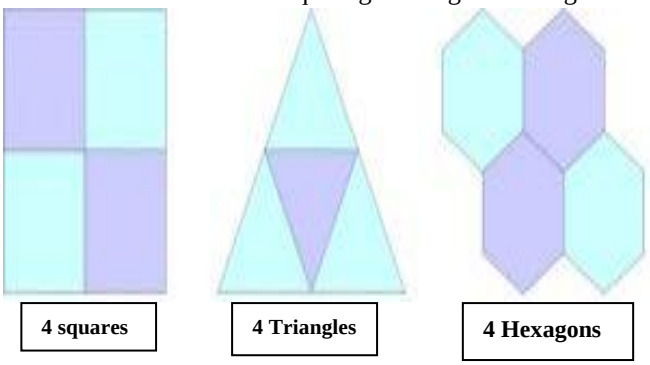


Fig 1: Tessellations using one type of polygon.

2) Semi-Regular Tessellations

Semi-regular tessellations combine two types of polygons that share a common vertex. For example, a regular hexagon with a 1″ side can line up with a 1″ square. Nine types of semi-regular tessellations exist.

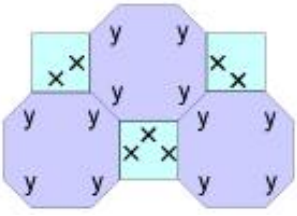


Fig 2. Tessellations using two different types of polygons.

3) Replicating Shapes (Rep-Tiles)

Rep-tiles consist of congruent shapes that are rotated to create ever-larger versions of the shaped in an infinite series. Often called polyforms, rep-tiles are implicit in such phenomena as the classic illustration of the Golden Mean and the Penrose Tile.

4) 3D Tessellations

Tessellations can take 3 dimensional forms as in truncated octahedrons and in geodesic domes. Such forms can combine combinations of shapes; only five are regular polyhedra (i.e. platonic) shapes.

5) Non-Periodic Tessellations

Non-periodic (aperiodic) tiling have no regular, repetitious patterns but rather evolve as they expand over a plane. The Dutch artist M.C. Escher produced well-known examples of such tiling, such as his graphic of birds that morph into triangles.

B. Creativity and Innovation

Companies that are doing the best for a long period of time are those that are the most creative and innovative in nature. These type of organizations normally create and innovate things rather than copying from other organizations; they may make use of some individuals in the organization to innovative from existing ideas to come up with a new and unique application, product, or service. The organization may tend to distance itself from the competition rather than compete with them. If they see another company copying what they do, they create something new and better. In other words, they are able to leverage their creativity and their innovative capabilities to attain long-term success. In fact, as well an individual can be more creative and innovative no matter what his/her expertise, product, or service. When you apply creativity and innovation to everything aspect of your business, you are able to stay ahead of a changing marketplace and the competition.

C. What is Creativity

According to Daniel B. (Oct. 2013) Creativity is seen as a function of knowledge, interest, resourcefulness, and assessment of service or product in life. The higher you grow in terms of knowledge, base and level of your interest, the more ideas, patterns, and combinations of objects you can achieve, which then correlates to creating new and innovative products and services. Daniel B. further highlighted that, however, merely knowledgeable will not guarantee someone the creation of an improved pattern, but the little steps and pieces must be shaken up and go over again in new ways. Then the developing ideas should be assessed and developed into practical ideas.In other words, there is really a process in creativity, and these process could be mastered through three important levels which includes: - discovery, invention, and creation.

Daniel B. defined these levels as:

1. Discovery is the lower level of creativity, just as the name implies, it is after you become aware of or you slip upon something, that you discover it, just like in the issue of tessellation, where you obtain different

tiles in tessellating some shapes to discover new designs.

2. Invention is a higher level of creativity, for instance, Alexander Graham Bell invented the telephone. The question is, "Would the telephone have been invented without Bell?" of course yes, because the science was there, the only thing is how long will it happen. The same thing tessellations, motifs are obtained from polygons, the idea of polygons came first before it was innovated to form what we call motifs. So invention is higher than discovery, because it is going to happen.
3. Creation is the highest level of creativity. For example, the tessellation of an object to produce tile or a design. Similarly, there are things that only you can create! The major fact is tapping into what those things are.

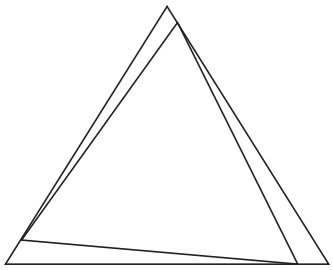
   This study is concerned with creating or innovating some designs from the tessellation of the original shapes (regular polygons) to an improved design for nowadays application.

As mentioned earlier in this study, there are only three types of regular tessellations; these include, triangles, squares or hexagons. While some Semi-regular tessellations may be obtained by combining two or more polygons sharing a common vertex; but only a very limited number of these types shapes exist. However, to create an unusual tessellation, an irregular shape can be used in tessellation, but the end product may not give smooth ending or series of shapes — using a careful but simple methodology of polygon modification. This technique was used by (Escher, M.C. 2007) to create his famous "Metamorphosis" and is common in "diaper patterns." Therefore, this study is concerned with regular polygons. These polygons include triangle, square and hexagon, where this figures reduced to smaller units and tessellated both left and right to form what is known as motifs that are created out of the regulation shapes to form a new innovation.2.1 Sub Heading (if any)

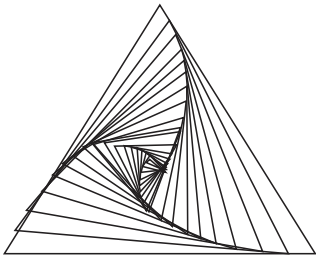
III. METHODOLOGY/MATERIALS

Regular tessellations form patterns consisting of a single shape. Only three types of regular tessellations exist: triangles, squares, and hexagons. These shapes by themselves can fill a surface because their interior angles are exact divisors of 360°. Here the innovations obtained from the side polygons are described. More designs are obtained, more colours may be obtained or introduced to give meaningful tiles or patterns

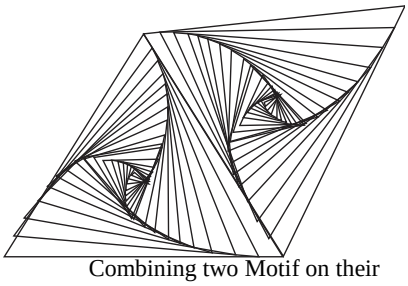
Taking from the existing polygon as can be seen, the figure (shape) is reduced to smallest visible size of the figure and tessellating each of the small figure reduced either to the right or left hand side. In doing so a figure known as a **motif** is obtained and this is the innovation in this work, then one unit of the motif is doubled and combined together to start forming a tile.



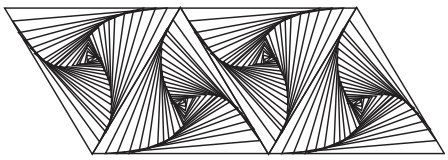
Reducing the size of the triangle continuously and tessellating it to the right will produce a Motif



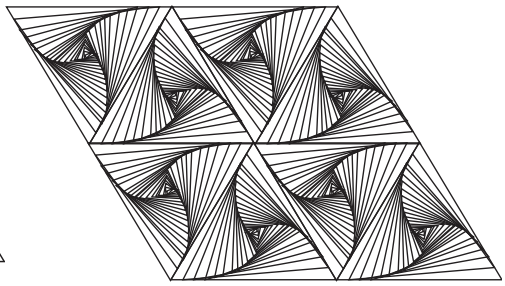
A Motif **TB** produced by tessellating the triangle to the right



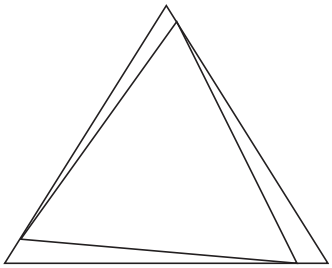
Combining two Motif on their base to obtain this figure



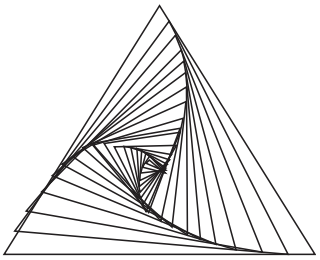
Combining four Motif on their base to obtain this figure



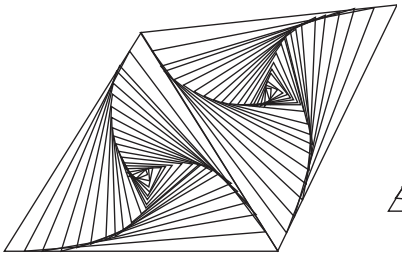
Combining eight Motif on their base to obtain this figure



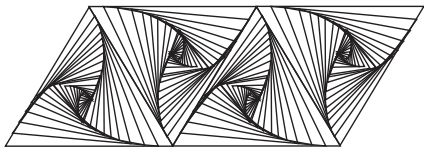
Reducing the size of the triangle continuously and tessellating it to the right will produce a Motif



A Motif **TB** produced by tessellating the triangle to the right

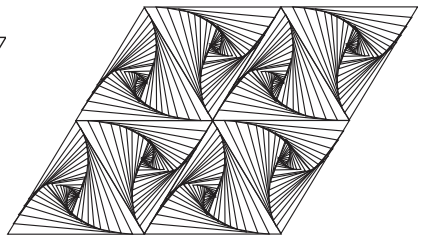


Combining two Motifs on their base to obtain this figure

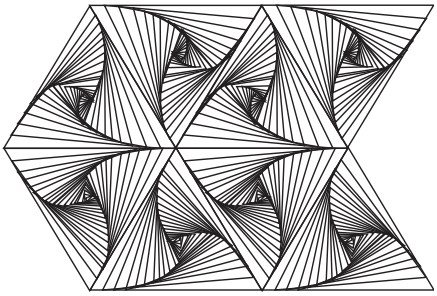


Combining four Motifs on their base to obtain this figure

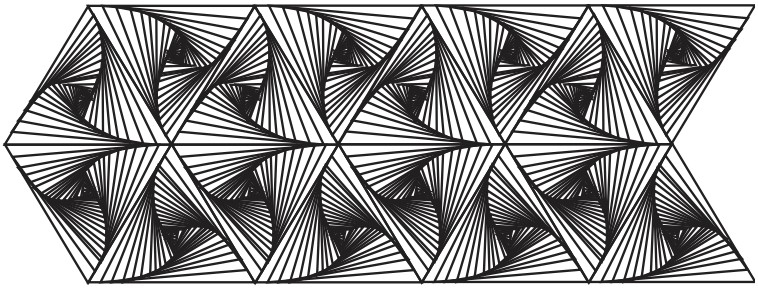
Combining multiple Motifs (both left and right tessellations) on their base to obtain this figure



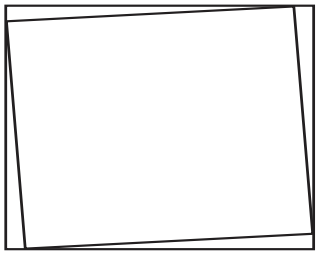
Combining eight Motifs on their base to obtain this figure



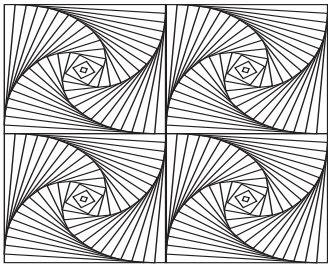
Combining 2 x 2 Motifs (both left and right tessellations) on their base to obtain this figure



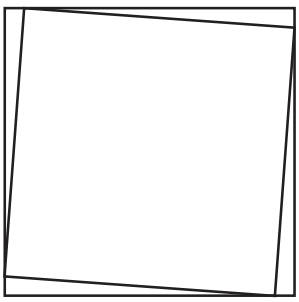
Combining multiple Motifs (both left and right tessellations) on their base to obtain this figure



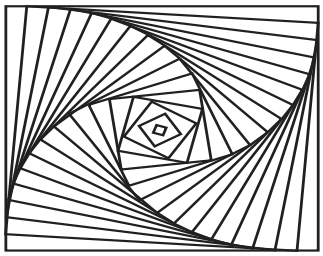
Reducing the size of the square continuously and tessellating each smaller figure to the right will produce this Motif



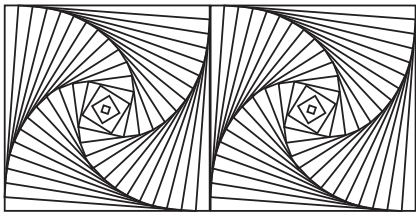
Combining 2 **SA** Motifs on their base to obtain this figure



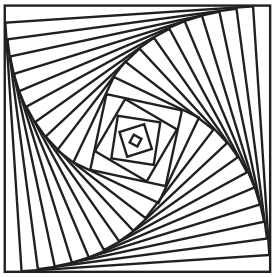
Combining multiple **SA** Motifs on their base to obtain this figure



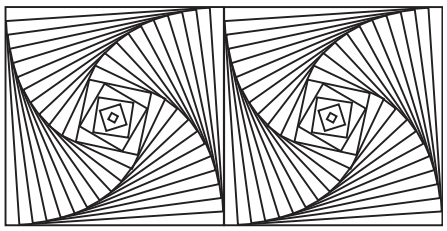
Combining 2 x 2 **SA** Motifs on their base to obtain this figure



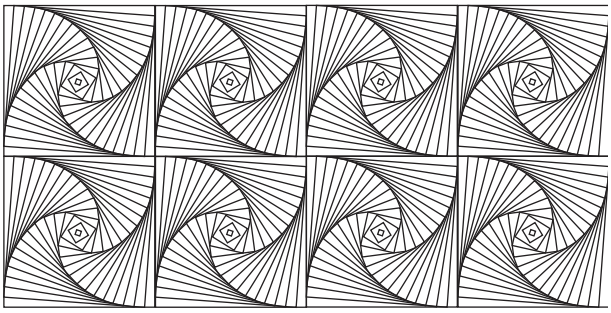
A Motif **SA** produced by tessellating the square to the right



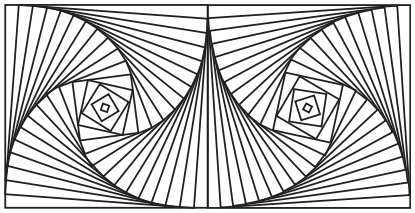
A Motif **SB** produced by tessellating the square to the left



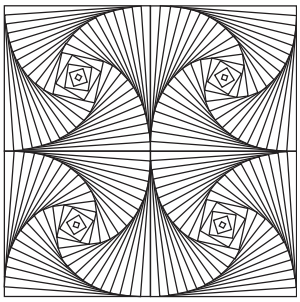
Combining 2 **SB** Motifs on their base to obtain this figure



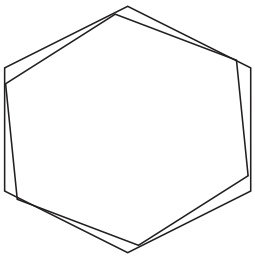
Reducing the size of the square continuously and tessellating each smaller figure to the left will produce this Motif



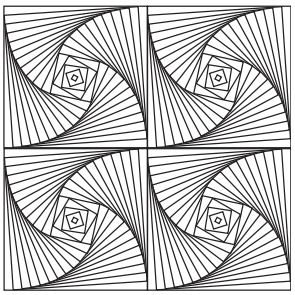
Combining **SA** x SB Motifs on their base to obtain this figure



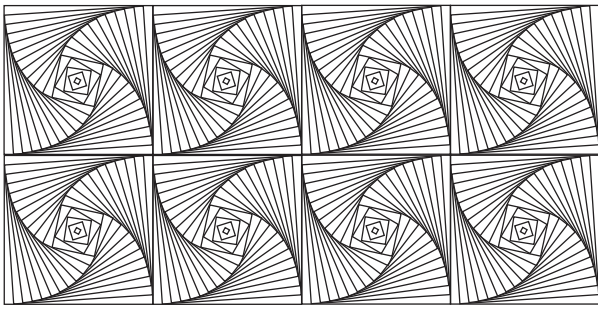
Combining 2 x 2 **SA** & SB Motifs on their base in opposite direction to obtain this figure



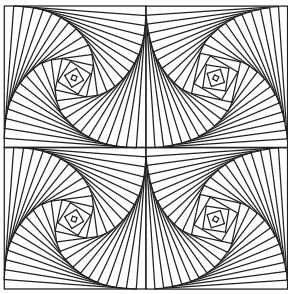
Reducing the size of the hexagon continuously and tessellating each smaller figure to the left will produce this Motif



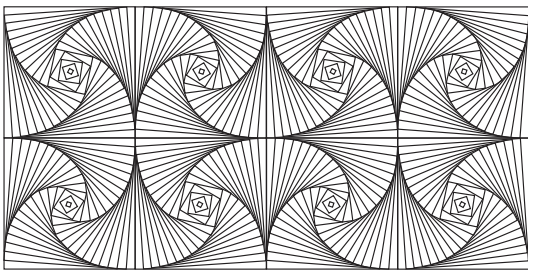
Combining 2 x 2 **SB** Motifs on their base to obtain this figure



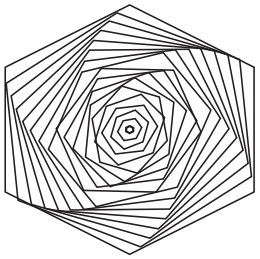
Combining multiple **SB** Motifs on their base to obtain this figure



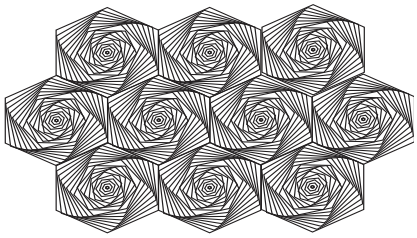
Combining 2 x 2 **SA** & SB Motifs on their base to obtain this figure



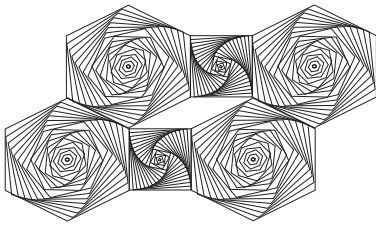
Combining multiple **SA** & SB Motifs on their base in opposite direction to obtain this figure



A Motif **HA** produced by tessellating the square to the left



Combining multiple **HA** Motifs on their base to obtain this figure



Combining multiple **HA & SA** Motifs on their base to obtain this figure. This figures do not tessellate, because gaps are left between the figures

A. Pra

B. ctical Application of Tessellation

In design and architecture, tessellation refers to the tiling of walls, floors, or other surfaces in building with a pattern of small tiles (tesserae) made of ceramics, glass, metal leaf, stone, or other materials. These tessellations normally are design into geometric shapes that combined together perfectly in either simple or complex designs in an apparently vast patterns while providing continuous and smooth surface coverage. Though there are some new innovations the ancient technique that can be seen in buildings and wall paintings in some countries like, Greece, Italy, Turkey, India, and many other countries. Tessellations are particularly more pronounced in Islamic art, but always forbids representational images of creator or His creations; therefore, designs always favour abstract forms with mathematical substructures. Tessellations can be found in many areas of life. Art, architecture, hobbies, clothing design, including traditional wears and many other areas hold examples of tessellations found in our everyday surroundings. Specific examples include oriental carpets, quilts, origami, Islamic architecture, and they are of M. C. Escher.

IV. CONCLUSION

The objective of this study was to propose an improved modelling approach for tessellating regular polygons in such a way that it is environmentally sustainable. In this innovation it can be concluded that the proposed model is superior than tessellating ordinary regular polygon. The observation from this study suggests that more designs are obtained, more colours may be obtained or introduced to give meaningful tiles or patterns. This work has open up several questions that need of further investigation. Further work needs to be done to establish whether other polygons may be made to be tessellated or combining two or more polygons to form a pattern because tessellations have many practical applications today.

REFERENCES

[1] Adzmi, N. H. M., Hamid, M. Z. A., Awang, Z., Kamin, Y., & Atan,
[2] N. A. (2018). Generic Green Skills Development: Initiatives of Green Manufacturing Industries in Johor, Malaysia. *Advanced Science Letters*, *24*(4), 2931-2935.
[3] Daniel B. (Oct. 2013) Creativity and Innovation: Your Keys to a Successful Organization
[4] retrieved from https://www.huffingtonpost.com/daniel-burrus/creativity-and-innovation_b_4149993.html
[5] David, A. (2014) Tessellations retrieved http://www.tessellations.org
[6] Karen, V. (2019) An intersection of Design information retrieved from
[7] https://karenvagts.com/2017/05/24/post-2/
[8] M.C. Escher – Image Categories – Symmetry." Official M.C. Esher
[9] website. http://www.mcescher.com/gallery/symmetry/
[10] Pavlova, M., & Huang, C. L. (2013). Advancing employability and green skills development: Values education in TVET, the case of the People's Republic of China. In *Skills Development for Inclusive and Sustainable Growth in Developing Asia-Pacific* (pp. 327-343): Springer.
[11] Weisstein, Eric W. "Tessellation." http://mathworld.wolfram.com/Tessellation.html
[12] Zolkifli, H., Kamin, Y., Latib, A. B. A., Buntat, Y., & Awang, Z. (2016). Generic Green Skills: Industry and perspectives on technical education and vocational training (TVET). *TVET@ Asia*, *6*, 1-13.

AUTHOR'S PROFILES

Abdullahi Musa Cledumas, is a PhD scholar at Universiti Teknologi, Malaysia. Johor Bahru**,** The research interest includes teaching and Learning, Renewable Energy Technologies.

Dr.Yusri Bin Kamin, is an Associate Professor at Universiti Teknologi, Malaysia. Johor Bahru. The Comparative studies in Technical and Vocational Education Training, Work-based Learning, Workplace Environment, Employability Skills.

Haruna Rabiu, Is a PhD Scholar at Universiti Teknologi, Malaysia. Johor Bahru. The research interests include; pedagogy and education and education research.