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Bea Tomsic Amon




 University of Ljubljana,
Slovenia

 [bea.tomsic.amon\[at\]gmail.com](mailto:bea.tomsic.amon[at]gmail.com)

 <https://orcid.org/0000-0001-9985-8223>
(<https://orcid.org/0000-0001-9985-8223>)




Chunfang Zhou

 University of Southern Denmark, Denmark
 chzh[at]imada.sdu.dk
 <https://orcid.org/0000-0003-4994-0207>
(<https://orcid.org/0000-0003-4994-0207>)






Gabriel Julien

 University of Sheffield, UK
 abrieljulien7[at]gmail.com
 <https://orcid.org/0000-0001-5902-6617>
(<https://orcid.org/0000-0001-5902-6617>)






Intakhab Khan

 King Abdulaziz University, Saudi Arabia
 ikhan1[at]kau.edu.sa
 <https://orcid.org/0000-0001-7058-2200>
(<https://orcid.org/0000-0001-7058-2200>)



Mustafa Kayihan Erbaş

 Aksaray University, Turkey
 kayihan.besyo[at]gmail.com
 <https://orcid.org/0000-0003-0515-9099>
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Panagiotis J. Stamatis

 University of the Aegean,
Greece

 [stamatis\[at\]rhodes.aegean.gr](mailto:stamatis[at]rhodes.aegean.gr)

 <https://orcid.org/0000-0002-9459-7156>
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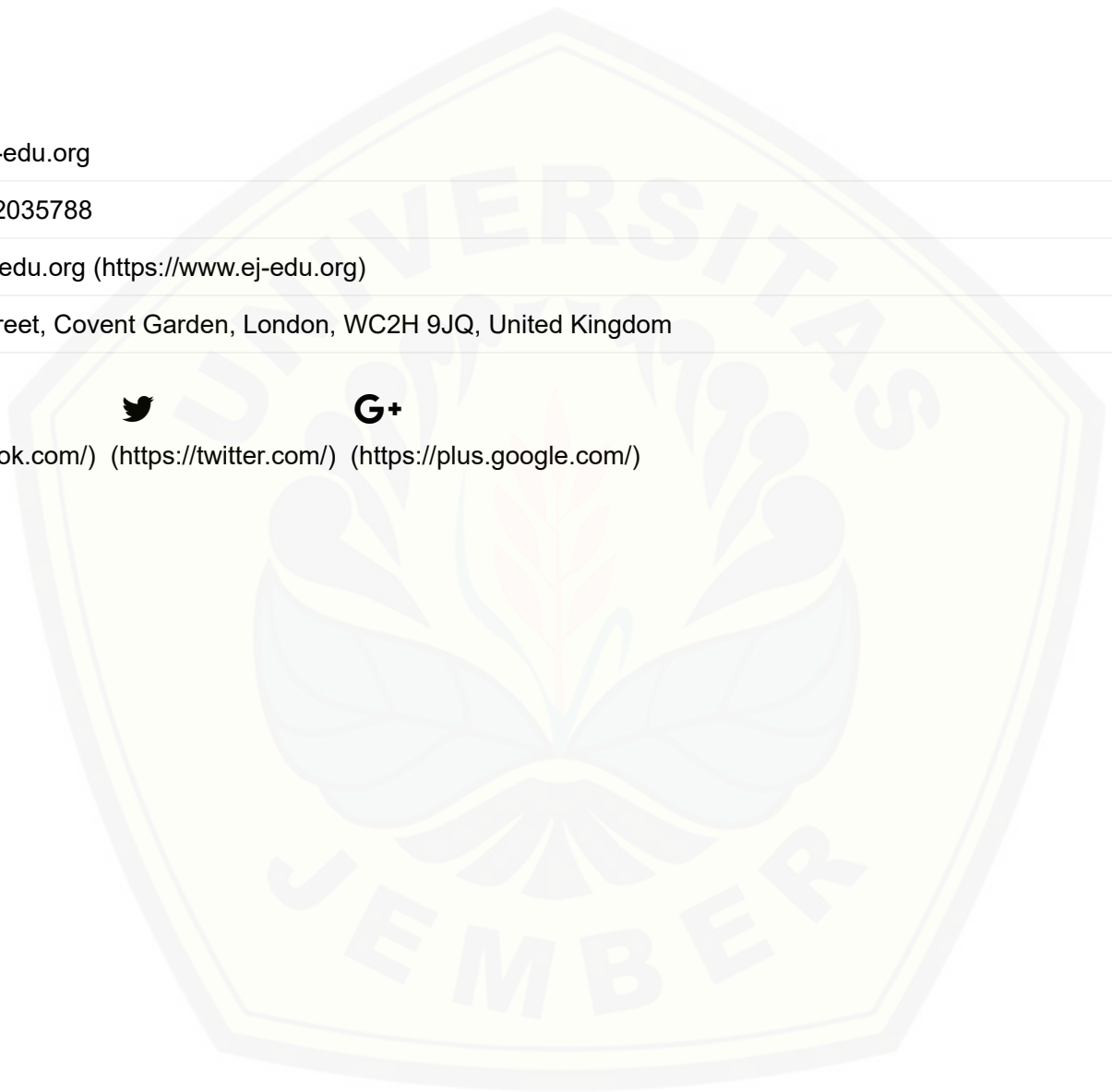
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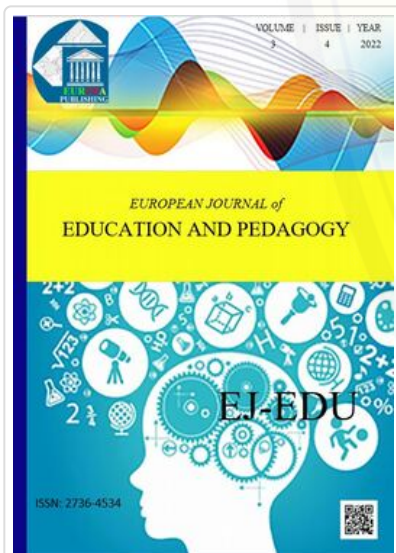


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Richard K. Asomah, Douglas D. Agyei, Gabriel Assamah



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Sarit Ashkenazi, Hagar Eisner

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Işıl Aktağ, Özlem Yalçın, Ayla Esen, İlayda Duman, Ceyda Karaköse, Anıl Okçu



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Prihandini, Robiatul Adawiyah



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Edna Owusu-Bempah, Daniel Opoku, Richard Sam-Mensah



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Taufik Kurrohman, Robert Hales, Cordia Chu



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Najib Slimani, Lhoussine Qasserras

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Cristiano M. A. Gomes, Enio G. Jelihovschi, Jhonys de Araujo



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Manuel Villarruel-Fuentes, Elvira Monserrat Villarruel-López



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Ariel Epan San Jose



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Blended Learning as the New Norm: Neophyte Language Teachers' Attitude and Perceptions
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The Use of E-Training and Development as Principals Administrative Task on Secondary School Teachers' Job Performance (<https://www.ej-edu.org/index.php/ejedu/article/view/227>)

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CONTACT

-  Email: editor@ej-edu.org
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Research Based Learning and STEM Learning Activities:

The Use of R-Dynamic Coloring to Improve the Students Meta-literacy in Solving a Tessellation Decoration Problem

Arika I. Kristiana, Dafik, Zainur R. Ridlo, Rafiantika M. Prihandini, and Robiatul Adawiyah

ABSTRACT

The meta-literacy ability is very important in today's life, especially living in the disruptive technology era. Meta-literacy is an ability that goes beyond metacognition and technological literacy. However, the students' meta-literacy ability is still relatively low. One of the causes of the low ability is due to the learning model that has been applied so far has not been able to bring out this ability. Therefore, in this study, an RBL learning model that is integrated with the STEM approach will be applied in solving the r -Dynamic coloring problem. By r -dynamic coloring, we mean a proper k -coloring c of G if for every vertex $v \in V(G)$ satisfies $|c(N(v))| \geq \min\{r, d(v)\}$. The minimum k such that G has an r -dynamic coloring with k colors is called an r -dynamic chromatic number, denoted by $\chi_r(G)$. By using the r -dynamic coloring technique, we will improve students' meta-literacy in solving the tessellation decoration problem. Therefore, in this research, the syntax of learning activities of the Research-Based Learning and STEM approach will be developed including the assessment indicator of the meta-literacy ability.

Keywords: r -Dynamic Coloring, Meta-Literacy, Research Based Learning, STEM, Tessellation Decoration Problem.

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A. I. Kristiana

Department of Maths Education
Postgraduate, CEREBEL, Universitas
Jember, Indonesia.

(e-mail: arikakristiana@unej.ac.id)

Dafik*

Department of Maths Education
Postgraduate, CEREBEL Universitas
Jember, Indonesia.

(e-mail: d.dafik@unej.ac.id)

Z. R. Ridlo

Department of Sciences Education,
CEREBEL, Universitas Jember,
Indonesia.

(e-mail: zainur.fkip@unej.ac.id)

R. M. Prihandini

Department of Maths Education,
CEREBEL, Universitas Jember,
Indonesia.

(e-mail: rafiantikap.fkip@unej.ac.id)

R. Adawiyah

Department of Maths Education,
COMED, Universitas Jember, Indonesia.

(e-mail: robiatul@unej.ac.id)

*Corresponding Author

I. INTRODUCTION

Meta-literacy is a comprehensive framework of thinking which includes information literacy (Jacobson, 2015). Meta-literation is divided into four domains, namely behavioral (what students should do after successfully completing learning activities and achieving skills and competencies), cognitive (what students should know after completing learning activities and achieving understanding, organizing, implementing, and evaluating), affective (is there a change in students' emotions or attitudes through involvement with learning activities), and metacognitive (what students know about their own thinking processes, reflective understanding of how they learn and solve problems, and how they can continue to learn). Meta-literation cannot be realized with the traditional classroom system, the use of the Internet of Things

(IoT) and hypermedia in learning with a specific approach is one strategy to achieve meta-literacy. Schematically, meta-literacy indicators introduced by Jacobson and Mackey (2015) which have adopted the use of the Internet of Things can be presented in Table I. There are five main indicators of meta-literacy, namely: produce (produce), incorporate (insert), use (use), share (divide), and collaboration (collaboration). These five indicators are explained in Table I.

One specific model and approach that can endorse the arise of the students' meta-literacy is a combination of RBL and STEM. RBL stands for Research-Based Learning and STEM is Science, Technology, Engineering, and Mathematics. Furthermore, RBL requires a contextual and realistic problem and includes at least four scientific studies, namely science, technology, engineering, and mathematics.

TABLE I: THE INDICATORS AND SUB-INDICATOR OF META-LITERACY

Produce	Identify the nature/characteristic of the problem;
	Develop breakthrough problem solving
	Develop or define stages, phases, syntax, or algorithms
Incorporate	Identifying patterns of solutions
	Generalizing the solution
	Using the Internet of Things, such as software, platforms, and applications to integrate results
Use	Test/assess results
	Analyzing proven results
	Perform interpretation and prediction
	Apply results
Share	Using the Internet of Things (Social Media, OER, MOOCs, Teaching Platform)
	Distribute the results followed by reflection and evaluation
	Evaluation of feedback
	Forecasting the response trend with software
	Working together using the Internet of Things platform
Collaborate	Ask for the product taking into account some suggestions from others
	Encourage people to do more to contribute findings
	Obtaining joint works and products for publication
	Determining future work together for the wider community

Therefore, it is necessary to combine RBL with the STEM (Science, Technology, Engineering, and Mathematics) approach so that the students' meta-literacy can be developed. Some research regarding the application of RBL and STEM in the classroom, it can be found in (Baharin *et al.*, 2018; Breiner *et al.*, 2012; Leon *et al.*, 2015; Sergis *et al.*, 2017; Siregar *et al.*, 2019; Siregar *et al.* 2019; Soros *et al.*, 2019). By combining the RBL and STEM approach, in this paper we will study "The Research Based Learning - STEM Learning Activities: The Use of r-Dynamic Coloring to Improve the Students Meta-Literacy in Solving the Tessellation Decoration Problem".

The main objectives of this research are as follows:

1. To describe the framework of the RBL model learning activities with the STEM approach in solving the tessellation decoration problem by using the *r*-dynamic coloring of the graph
2. To describe the framework for the development process of learning materials on the RBL model with the STEM approach in solving the tessellation decoration problem by using the *r*-dynamic coloring of the graph
3. To describe how learning materials of the RBL model with stem approach can improve the meta-literacy in solving the tessellation decoration problem by using the *r*-dynamic coloring of the graph.

II. METHOD

This type of research is a qualitative method. The research starts by collecting some pieces of literature and reviews. From the results of the literature review, we develop frameworks related to the four research objectives above. The framework for the process of developing the RBL-STEM learning activities is referred to ADDIE model of research and development, namely Analyze, Design, Development, Implementation, and Evaluation (Branch, 2009).

III. RESEARCH FINDINGS

A. The Framework of RBL-STEM Syntax

In the following, we will present a framework for integrating the RBL learning model in the STEM approach to improve the meta-literacy in solving the tessellation decoration problem by using the *r*-dynamic coloring of the graph. The framework is developed based on the syntax proposed in (Gita *et al.*, 2021). In the early stages of RBL syntax is posing problems arising from the research group's open problems. We consider the problem of tessellation decoration for block paving tessellation as follows.

In this study, we consider the uniqueness of the pattern of the decoration of block paving tessellation and the accuracy of the number of block paving required for special color and shape. Therefore the RBL-STEM model will undertake the following stages:

1. fundamental problems related to the block paving tessellation problem
2. obtaining a breakthrough by using the *r*-dynamic coloring of the graph
3. data collection related to the data type being abused
4. developing the decoration of block paving tessellation by using the *r*-dynamic coloring of the graph
5. test the resulting block paving tessellation decoration
6. reporting the research results and observations of students' meta-literacy.

The framework for this RBL-STEM integration can be seen in detail in Fig. 2.

B. Students' Learning Outcome and Objective

1) Learning outcomes

Students can develop a tessellation decoration, especially block paving decoration by using the *r*-dynamic coloring of the graph. Students can also test whether the obtained using *r*-dynamic coloring of the graph can be tested generally by using an analytic and qualitative approach and obtain the several possible decorations on block paving tessellation.

2) Learning objectives

This RBL-STEM learning will enable students to develop knowledge and skills in the following fields of Science, Technology, Engineering, and Mathematics.

Sciences - Students are expected to:

- Understand the problem of the tessellation decoration problem, especially on block paving decoration which is very useful in layouting the yard block paving process
- Determine the application of the tessellation decoration problem in other use, especially for house wallpaper decoration
- Analyze the decoration business strategy for gaining the maximum profit for the business

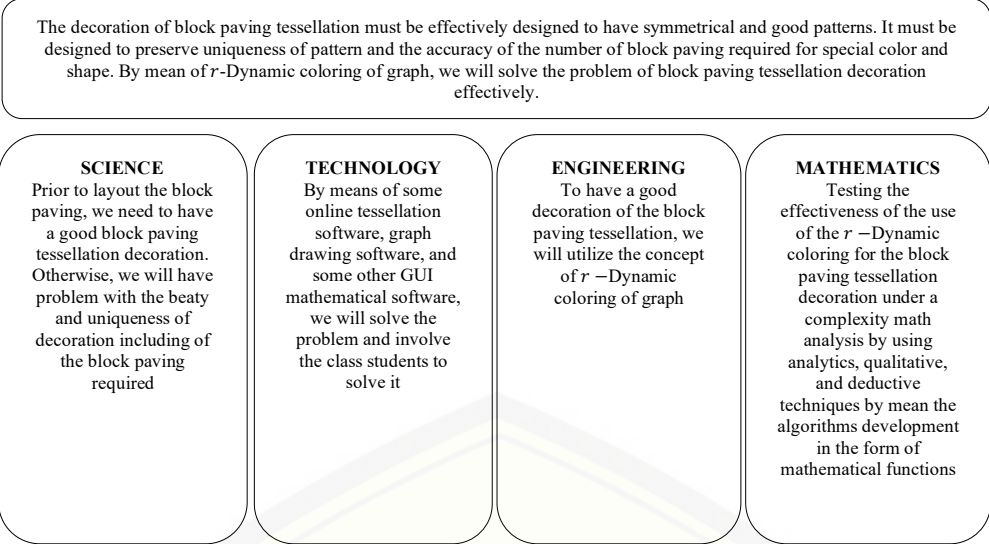


Fig. 1: The STEM problem in developing the block paving tessellation decoration.

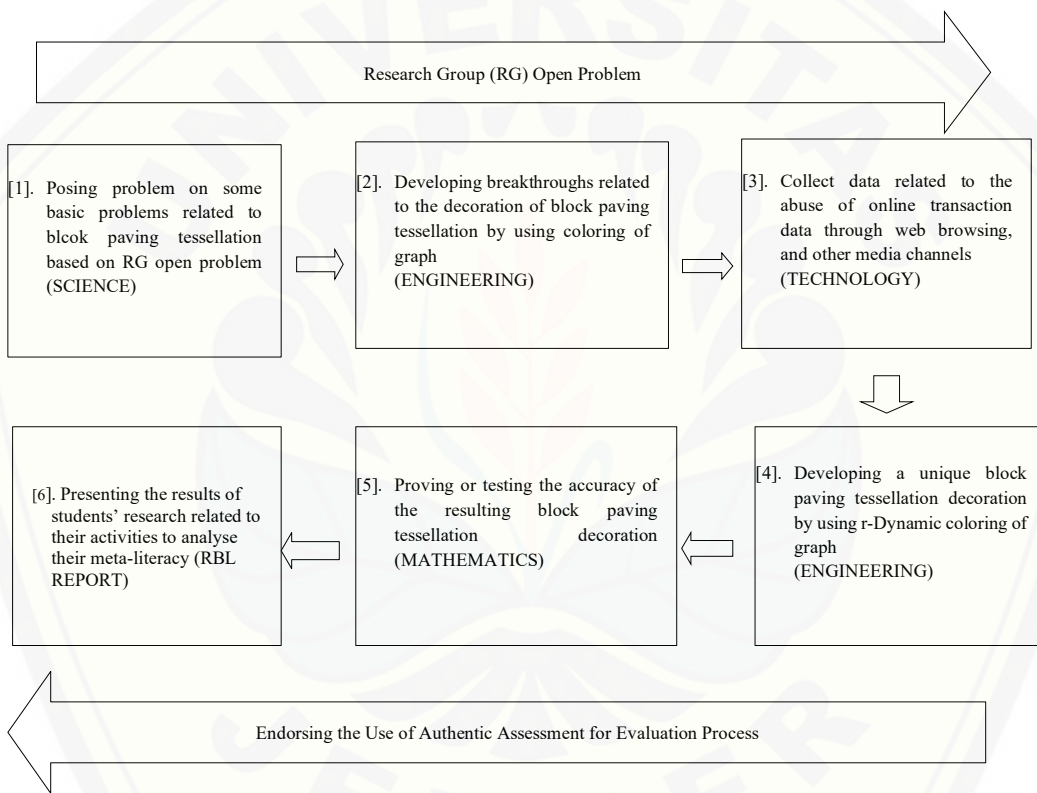


Fig. 2. The framework of RBL-STEM in developing the block paving tessellation decoration.

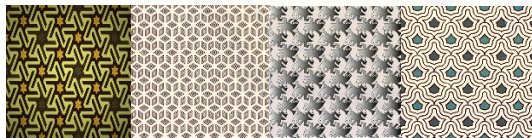


Fig. 3. The use of Tessellation for building wallpaper decoration.

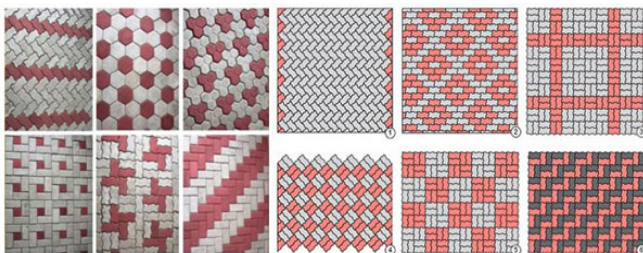


Fig. 4. The use of the tessellation technique for building block paving decoration.

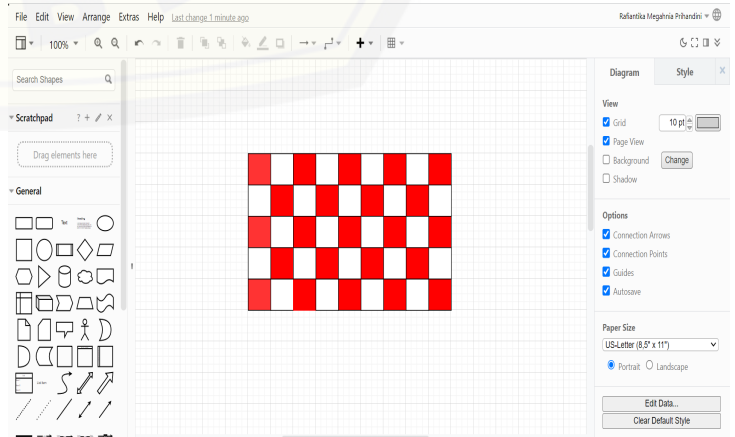


Fig. 5. The illustration of tessellation software maker by using Drawio online software.

Technology-students are expected to:

- Use a web browser to identify the concept of r-dynamic coloring and tessellation problems
- Use a researchgate site to find recent studies related to r-dynamic coloring and tessellation problems
- Use the Youtube channel to find out the tutorial for tessellation maker by using Geogebra Software
- Utilize the Geogebra Software for developing various types of tessellation shapes

Engineering - Students are expected to:

- Develop an r-dynamic coloring of the graph by using pattern recognition techniques
- Applying the r-dynamic coloring of graph algorithm in developing the tessellation decoration problem, especially on block paving decoration

Mathematics - Students are expected to:

- Develop the r-dynamic coloring function by using the piecewise function technique
- Find the r-dynamic chromatic number by using an analytic and qualitative approach
- Use Matlab or Excel software to develop programming to calculate the number of block paving for the special color required

C. On Block Paving Tessellation Decoration by Using r-Dynamic Coloring of Graph

1) The element of science problem

A tessellation or tiling of a flat surface is the covering of a plane using one or more geometric shapes, called tiles, with no overlaps and no gaps. Tessellations were used by the Sumerians (about 4000 BC) in building wall decorations formed by patterns of clay tiles. Now a day, the most popular use of tessellation is for wall building and block paving decorations (Fig. 1, Fig. 2). The decoration of block paving tessellation must be effectively designed to have symmetrical and good patterns. It must be designed to preserve the uniqueness of the pattern and the accuracy of the number of block paving required for special color and shape.

2) The use of the Internet of things

By means of some online tessellation software, Graph drawing software, and some others GUI mathematical software such as Matlab. We will solve the problem and involve the class students to solve it. In this study, we use Drawio online software (visit <https://app.diagrams.net>) to draw the tessellation of block paving decoration. For the illustration of using GeoGebra software for the tessellation maker (Fig. 3). This software can be accessed online. By choosing the GeoGebra Classic mode, arrange the workspace by right click and setting the axis and grid modes. Finally, start to draw a polygon and combine it with pressing a point menu.

3) The element of engineering

To decorate the block paving tessellation in terms of having a unique, symmetrical, and beautiful coloring, we need a special technique. The technique that will be used in this study is an r-dynamic coloring technique. By an r-dynamic coloring of a graph G, we mean a proper k-coloring of graph G such that the neighbors of any vertex $v \in G$ receive at least $\min\{r, d(v)\}$ different colors (1).

$$|c(N(v))| \geq \min\{r, d(v)\} \tag{1}$$

$$x_r(G) \text{ is minimum as possible} \tag{2}$$

The r-dynamic chromatic number (2) is the minimum k such that graph G has an r-dynamic k-coloring. To use the r-dynamic coloring, we need to do four steps, namely:

1. Determine the block paving tessellation as a construction base
2. Draw its graph representation (a dual graph)
3. Do r-dynamics coloring as the definition
4. Consider the obtained colors to decorate the block paving tessellation
5. Use the construction base of the block paving tessellation decoration to construct a bigger tessellation complying with the area needed
6. Make sure that there do not exist two adjacent block paving sharing the same colors.

4) The element of Mathematics

Testing the effectiveness of the use of the r-Dynamic coloring for the block paving tessellation decoration under a complexity math analysis by using analytics, qualitative, and deductive techniques by meaning the algorithms developed in the form of mathematical functions and calculations. Fig. 4. tells us for the r-dynamic coloring of $r = 1$, and the r-dynamic chromatic number of this graph is 3.

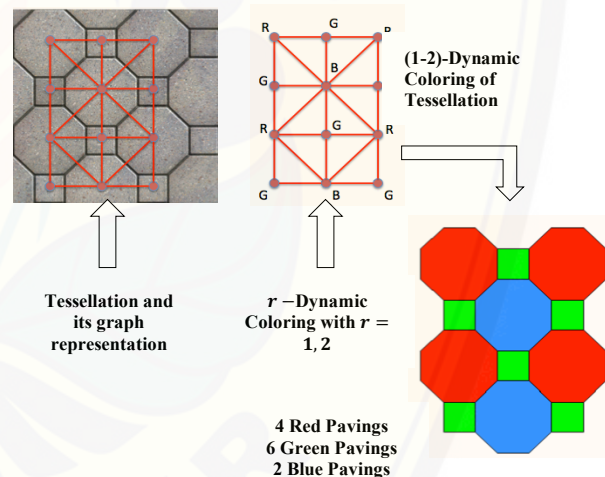


Fig. 6. The illustration of the use of r-dynamic coloring in developing a tessellation.

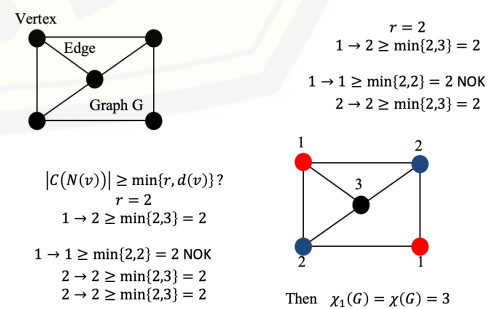


Fig. 7. The illustration of the concept of r-dynamic coloring of the graph.

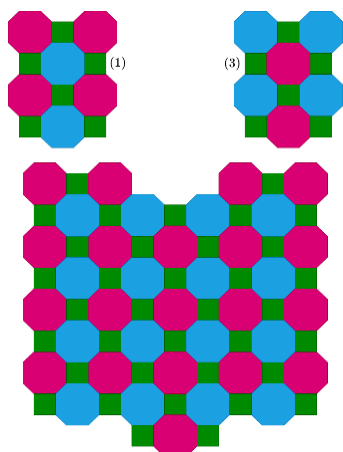


Fig. 8. The illustration of block paving tessellation decoration by using (1,2)-dynamic coloring.

When we improve the parameter $r = 2$, the number of colors does not sufficient, thus it needs to add one more color. Thus $\chi_2(G) = 4$. Furthermore, for $r = 2$, we need to find out the 3-dynamic chromatic number $\chi_3(G)$ and finally we got (2). To generalize this case, we need mathematical proof. Students are encouraged to involve in the proving process.

In terms of mathematics, we can define the simple graph representation above into the set of vertices (3).

$$V(G) = \{x_1, \dots, x_4, y_1, \dots, y_4, z_1, \dots, z_4\} \quad (3)$$

The first permutation of (1,2)-dynamic coloring can be presented in the following function: $c(x_1, \dots, x_4) = RGRG$, $c(y_1, \dots, y_4) = GBGB$, $c(z_1, \dots, z_4) = RGRG$. Furthermore, we can tabulate the following permutation tables.

With this permutation in hand, then we can have the variation of block paving tessellation decoration in many decorations.

When we choose the base construction of the two permutations of Table I, namely color permutation 1 and color permutation 3, we have the block paving tessellation decoration in Fig. 5. It tells us that by means of the r -dynamic coloring, it will be easy for the seller and paving worker to construct the variety of decoration and count the number of block paving with a special color. Consider if one base construction of 1 m^2 area. We need to decorate a yard of 200 m^2 , then we need the block paving of red color as $4 \times 100 + 2 \times 100 = 600$ pavings, green color as $4 \times 200 = 800$ pavings, blue color as $2 \times 100 + 4 \times 100 = 600$ pavings.

When we improve the value of $r = 3$, we need more colors to color all vertices. In this case, we need four colors, which implies the number of permutation also increase. Obviously, the seller can easily offer some choices to the buyer for their block paving tessellation decoration.

TABLE II: THE PERMUTATION OF (1,2)-DYNAMIC COLORING OF GRAPH G WITH THREE COLORS

Color function of vertices	Color Permutations for (1,2)-dynamic coloring					
	(1)	(2)	(3)	(4)		
$c(x_1, \dots, x_4) =$	RGRG	GRGR	GBGB	BGBG	-	-
$c(y_1, \dots, y_4) =$	GBGB	BGBG	RGRG	GRGR	-	-
$c(z_1, \dots, z_4) =$	RGRG	GRGR	GBGB	BGBG	-	-

TABLE III: THE PERMUTATION OF THE 3-DYNAMIC COLORING OF GRAPH G WITH FOUR COLORS

Color function of vertices	Color Permutations for 3-dynamic coloring					
	(1)	(2)	(3)	(4)	(5)	(6)
$c(x_1, \dots, x_4) =$	BYBR	BYBR	YBRB	YBRB	BYBR	YBRB
$c(y_1, \dots, y_4) =$	RGR	RGR	GRGR	GRGR	YBY	BYB
$c(z_1, \dots, z_4) =$	YBY	BYB	YBYB	BYBY	RGR	RGR
	B	Y			G	G

D. RBL-STEM Learning Activities on Block Paving Tessellation Decoration

In this section, we will discuss one by one the six stages of the RBL learning model complemented by the STEM approach. These six stages will illustrate how students do in learning with the RBL-STEM approach regarding the use of r -dynamic coloring to improve the students' meta-literacy in solving the tessellation decoration problem. Based on Fig. 2, the first stage (SCIENCE) is proposing the fundamental problems related to the decoration of block paving tessellation. It must be effectively designed to have symmetrical and good patterns and the important one is the accuracy of the number of block paving required for special color and shape for yard block paving layouting. We will ask students to think about the block paving layouting in their yard. For more details, see Table IV.

The learning activities by using the RBL model with the STEM approach at the six-stage (RBL REPORT) are carried out by students to do a presentation of the research results related to the use of rainbow antimagic coloring to build CryptoKey. In this case, students will take a focus group discussion (FGD), so that the researcher can observe their combinatorial thinking skills. For more details, see Table 9.

The learning activities of the RBL model with the STEM approach at the second stage (ENGINEERING) are developing breakthroughs related to the use of r -dynamic coloring to improve the students' meta-literacy in solving the tessellation decoration problem. The Lecture asks students to identify some graph families that admit an r -dynamic coloring. For more details, see Table V.

The learning activities of the RBL-STEM approach in the third stage (TECHNOLOGY) is using online tessellation creator software, see Table VI for detail.

The learning activities by using the RBL model with the STEM approach at the fourth stage (ENGINEERING) is applying the r -dynamic coloring on block paving tessellation problems. This step begins by selecting the construction base of block paving tessellation, and draw the graph representation, and applying the obtained r -dynamic coloring. For details, see Table VII.

The learning activities by using the RBL model with the STEM approach at the fifth stage (MATHEMATICS) are proving that the r -dynamic coloring of any order and size of the graph. Since the tessellation decoration can be in the form of very large are the pattern availability can be easily determined. For more details, see Table VIII.

E. The Instruments Framework for Assessing Students' Combinatorial Thinking Skills

The following will present the instruments framework of combinatorial thinking skills assessment, see Table X.

TABLE IV: THE RBL-STEM LEARNING ACTIVITIES ON BLOCK PAVING TESSELLATION DECORATION PROBLEM

STAGE ONE	LEARNING ACTIVITIES
Posing problem on some basic problems related to block paving tessellation decoration (SCIENCE)	<p>The lecturer asks students whether they have ever seen the block paving tessellation process in their yard</p> <p>The lecturer shows to the students a specific tessellation decoration and ask them whether they can develop the block paving tessellation by them self or not.</p> <p>The students works on developing a construction base with specific block paving tessellation decoration and try to analyse the required block paving for each color</p> <p>The students start to have a group discussion</p>

TABLE V: THE RBL-STEM LEARNING ACTIVITIES OF R-DYNAMIC COLORING AS A BREAKTHROUGH

STAGE TWO	ACTIVITIES
Developing breakthrough related to solve the tessellation decoration problem by using the r-dynamic coloring of graph (ENGINEERING)	<p>The lecturer guides students to discuss breakthroughs on how to solve the tessellation decoration problem by using the r-dynamic coloring of graph.</p> <p>The lecturer explains to students how to decorate the block paving tessellation by using a simple graph representation.</p> <p>The students are asked to find the r-dynamic coloring of simple graph on simple tessellation.</p>

TABLE VI: THE RBL-STEM LEARNING ACTIVITIES ON ONLINE TESSELLATION CREATOR SOFTWARE USAGE

STAGE THREE	ACTIVITIES
Utilizing the online tessellation creator software, namely Geogebra and Tessellation Maker software (TECHNOLOGY)	<ol style="list-style-type: none"> 1. Students under the guidance of lecturers download and try to use the online tessellation creator software, namely drawio.org. 2. Data collection related to r-dynamic coloring and tessellation shape is carried out by browsing the scientific journals/articles via research gates or other online library channels. 3. Students can use an encyclopedia, research gates (orcid, mendeley), research profile sites (scopus, publons), cloud storage (slideshare, LinkedIn, MOOCs), cloud meetings (Google Meet, Zoom, Cisco Webex) to find the research results related to r-dynamic chromatic number of graph

TABLE VII: THE RBL-STEM LEARNING ACTIVITIES ON SOLVING BLOCK PAVING TESSELLATION BY USING R-DYNAMIC COLORING OF GRAPH

STAGE TWO	ACTIVITIES
Developing the block paving tessellation decoration by using the r-dynamic coloring of graph (ENGINEERING)	<p>Lecturers and students choose graphs for developing r-dynamic coloring of graph and test the r-dynamic chromatic number for obtained graph coloring.</p> <p>Lecturers and students develop the block paving tessellation decoration by using the r-dynamic coloring with smallest r-dynamic chromatic number.</p> <p>Lecturers and students select two possible base constructions with different permutation.</p> <p>Lecturers and students try to generalize for bigger order of graph and develop the r-dynamic coloring of graph and test its r-dynamic chromatic number.</p> <p>Construct the block paving tessellation decoration with obtained r-dynamic coloring.</p>

TABLE VIII: THE RBL-STEM LEARNING ACTIVITIES ON PROVING R-DYNAMIC COLORING OF GRAPH OF ANY ORDER AND SIZE

STAGE FIVE	ACTIVITIES
Proving the accuracy of the resulting r-dynamic coloring of graph (MATHEMATICS)	<p>Define the sets of graph elements to determine the cardinality of the selected graph, i.e triangular regular grid graph. Determine the number of vertices and edges to obtain the order and size</p> <p>Determine the lower bound of the r-dynamic chromatic number based on the existing lemma</p> <p>Determine the upper bound by developing the rainbow coloring function.</p> <p>Evaluate the edge weights whether all edge weights induce the existence of a rainbow path according to the properties of rainbow antimagiccoloring</p> <p>Check the cardinality of the edge weight set to consider the r-dynamicconnection number</p> <p>Compare the lower and upper bounds, if it is the same then we can set this number as the r-dynamic</p> <p>Present the table consisting of the data of rainbow antimagiccoloring path</p> <p>Take an example of a graph with a certain order and size to illustrate its r-dynamic coloring</p>

TABLE IX: THE RBL-STEM LEARNING ACTIVITIES ON SHARING THE STUDENT'S RESEARCH RESULTS

STAGE TWO	ACTIVITIES
(6) Presenting the results of on students research related to the resulting key of H-antimagic total graph on $G=Shack(Cn, v, m)$ (RBL REPORT)	Students develop a research report on the use of rainbow antimagiccoloring to develop CryptoKey Students do the presentation in front of the class to do focus group discussion. Lecturers evaluate and clarify all the results of student's research activities. Lecturers make observations on the students' combinatorial thinking skills by using observation sheets

TABLE X: THE FRAMEWORK OF STUDENTS' META-LITERACY ASSESSMENT INSTRUMENTS

INDICATOR	SUB-INDICATOR	TEST ITEMS
Identifying some cases	Identify the characteristic of the problems	Explain the types of online transaction data that can be abused.
	Find out a breakthrough	Discuss breakthroughs on how to avoid the abuse.
Recognizing the pattern for all cases	Identify patterns of the case resolution	Consider the breakthrough by using a rainbow antimagiccoloring of graph
	Extend the pattern for solving the bigger order of cases	Choose a graph to find rainbow antimagiccoloring of a graph by assigning the vertices of the graph with $\{1,2,3,\dots, n\}$, where n is the order of the graph. Test the existence of a rainbow path, If so, consider the bigger order of graph
Generalizing all cases	Apply the mathematics symbolization	Proceed whether the rainbow connection number is optimum? If so, proceed with the generalizations
	Test the accuracy and generalization Develop an algorithm	Develop encryption using this rainbow antimagiccoloring of online transaction data (plaintext) to produce a ciphertext. Develop decryption on obtained ciphertext by using this rainbow anti-magic coloring Develop a simple algorithm to handle the encryption/decryption of more complex online transaction data. Trying to test the accuracy of CryptoKey
Proving mathematically	Do a counting argument	Define the sets of graph elements to determine the cardinality of the selected graph. Determine the number of vertices and edges to obtain the order and size
	Test the validity of the algorithm Develop a bijection Apply the inductive, deductive, and analytical proof	Determine the lower bound of the r-dynamic connection number based on the existing lemma Determine the upper bound by developing the rainbow anti-magic coloring function of the antimagic labeling of vertices. Evaluate the edge weights and whether all edge weights induce the existence of a rainbow path according to the properties of rainbow anti-magic coloring Check the cardinality of the edge weight set to consider the r-dynamic connection number Compare the lower and upper bounds, if it is the same then we can set this number as the r-dynamic connection number Present the table consisting of the data of rainbow anti-magic coloring path Take an example of a graph with a certain order and size to illustrate its r-dynamic coloring
Considering the other combinatorial problems	Make an interpretation Propose an open problem Recognize a new problem Find a potential conjecture for a new problem	Review the obtained results concerning the use of r-dynamic coloring of graph for a secure CryptoKey Determine an open problem respected to the use of r-dynamic coloring of graph for a secure CryptoKey Find other studies apart of the use of r-dynamic coloring of graph for a secure CryptoKey. Propose a conjecture regarded to considering another breakthrough for developing a secure CryptoKey

F. The Framework of Learning Material Process Development

The stage for the learning materials development of this research was carried out based on the ADDIE model. The development stages consist of analysis, design, development, implementation, and evaluation.

First stage: Analysis, aims to analyze the characteristics of students, the material and learning process, and the learning media to be used. Doing a literature study to find information about developmental research, learning materials, research-based learning model, STEM approach, a Secure CryptoKey, and the r-dynamic coloring of graphs.

Second stage: Design, is carried out by designing and compiling the RBL model integrated with the STEM approach. At this stage, the learning materials, namely syllabus, semester learning plan, LKM, pre-test, post-test, and other assessment instruments, are prepared by the researcher.

Third stage: Development, is carried out by testing the learning materials and instruments to check the validity of the learning materials as well as the practicability. The results of the validation are in the form of content validity, format validity, language validity, and the level of practicability.

Fourth stage: Implementation, aims to find the effectiveness of learning materials of RB-STEM in

improving students' combinatorial thinking skills in developing the block paving tessellation decoration by using the rainbow antimagic coloring of the graph.

Fifth stage: Evaluation is a reflection activity to assess whether or not the application of RBL model learning materials with the STEM approach can improve students' combinatorial thinking skills in developing the block paving tessellation decoration by using the rainbow antimagic coloring of the graph. In this stage, the use of inferential statistics is needed.

IV. DISCUSSION

The development of a framework for STEM-RBL learning activities in developing the block paving tessellation decoration by using the r-dynamic coloring of graphs to improve students' combinatorial thinking skills is very important, and it is a starting point for the R&D research format. This paper will be a guideline for researchers to do further action on the research. There are at least two more research activities that can be done further, namely: (1) developing STEM-RBL learning materials with the ADDIE development model, and (2) Studying the STEM-RBL learning materials to improve the students' combinatorial thinking skills in developing the block paving tessellation decoration by using the r-dynamic coloring of the graph. We can consider the learning activities that combine RBL-STEM to be very effective in cultivating combinatorial thinking skills in students, it is in line with the research result presented (Maylisa *et al.* 2020, Ridlo *et al.* 2020a, Septory *et al.* 2019). Thus the application in the learning process is very important. We predict that integrating RBL-STEM for other science and social science problems, will habituate students to find a good breakthrough toward a complex problem and it is the key to generating a good young generation for the future, namely a generation admitting a good 4C (creative-innovative, critical thinking, collaboration, and communication).

V. CONCLUSION

We have developed a framework of RBL-STEM learning activities in developing a secure CryptoKey by using the r-dynamic coloring of graphs to improve students' combinatorial thinking skills. We consider that it is very important to do before carrying out further research activities, namely R&D and experimental research. However, this initial research is not so easy, thus joint research for other STEM cases needs to be explored, and as well as a breakthrough for solving the STEM problems needs to be proposed.

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Arika Indah Kristiana, S.Si., M.Pd. was born in Jember, May 2, 1976. She got her bachelor's degree in mathematics from Institut Teknologi Sepuluh Nopember, Indonesia, and graduated in 2021. She got her master's degree in mathematics education from Universitas Negeri Malang, Indonesia in 2019. And she continues her study to get a doctoral degree in Mathematics and Science at Universitas Airlangga, Indonesia. She graduated in 2021. Her major field of study is graph theory.

Now, she is a lecturer in the Department of Mathematics Education, Faculty of teacher training and Education, University of Jember. Her research of interest is graph theory and mathematics education. Some titles of her publication are as follows: The 2-Distance Chromatic Number of Some Wheel Related Graphs, Local irregular vertex coloring of some families graph, On r-dynamic vertex coloring of some flower graph families.

Dr. Arika Indah Kristiana, S.Si., M.Pd is a member of InaCombS (Indonesian Combinatorics) Society. She is one of the most active researchers in University of Jember.



Prof. Drs. Dafik, M.Sc., Ph.D was born in Situbondo, August 2, 1968. He got his bachelor's degree from Universitas Jember, Indonesia, and graduated in 1992 in mathematics education. He got his master's degree in mathematics from UMIST (University of Manchester Institute of Science and Technology) Manchester, the UK in 1998. And he continues his study to get a Ph.D. degree in Mathematics at the University of Ballarat, Victoria

Australia. He graduated in 2007. His major field of study in graph theory and combinatorial education.

Now, he is a professor and lecturer in the Department of Mathematics Education, Faculty of teacher training and Education, University of Jember. His research of interest is graph theory and STEM education. Some titles of his publication are as follows: (1) The effectiveness of Research-Based Learning in improving students' achievement in solving two-dimensional arithmetic sequence problems, (2) The effect of using synectics model on creative thinking and metacognition skills of junior high school students, (2) The effectiveness of problem-based learning to improve students' conjecturing ability in solving block-paving problems.

Prof. Drs. Dafik, M.Sc., Ph.D is one of 10 top scientists in Indonesia according to SINTA. He got a SINTA Awards as the best researcher from the ministry of education, culture, research, and technology.



Zainur Rasyid Ridlo, S.Pd., M.Pd. was born in Jember, May 23, 1988. He got his bachelor's degree in physics education from Universitas Jember, Indonesia, and graduated in 2012. He got his master's degree in science education from Universitas Jember, Indonesia in 2016. His major field of study is Theoretical Physics.

Now, he is a lecturer in the Department of Science Education, Faculty of teacher training and Education, University of Jember. His research interests are theoretical Physics and STEM education. Some titles of his publication are as follows: (1) The effectiveness of research-based learning model of teaching integrated with computer simulation in astronomy course in improving student computational thinking skills, (2) The analysis of Olympiad student's metacognition skills in solving the national sciences Olympiad problem on two-variables linear equation system material, (3) Report and recommendation of implementation research-based learning in improving combinatorial thinking skills embedded in STEM parachute design activities assisted by CCR.

Zainur Rasyid Ridlo, S.Pd., M.Pd. is one of the most active researchers in the University of Jember. He is active in doing research and publishing articles related to his work.



Rafiantika Megahnia Prihandini, S.Pd., M.Si. was born in Bondowoso, 5th October 1989. She got her bachelor's degree in mathematics education from Universitas Jember, Indonesia, and graduated in 2013. She got her master's degree in mathematics from Universitas Jember, Indonesia, in 2017. Her major field of study in graph theory and mathematics education.

Now, she is a lecturer in the Department of Mathematics Education, Faculty of teacher training and Education, University of Jember. Her research of interest is graph theory and mathematics education. Some titles of her publication are as follows: Some families of a tree are elegant, Elegant labeling of some graphs, Chipertext stream construction by using super total labeling (a, d)-P2 > H -antimagic of comb product graph.

Rafiantika Megahnia Prihandini, S.Pd., M.Si is a member of InaCombS (Indonesian Combinatorics) Society. She is one of the most active researchers at the University of Jember.



Robiatul Adawiyah, S.Pd., M.Si. was born in Jember, July 31, 1992. She got the bachelor's degree in mathematics education at Universitas Jember, Indonesia and graduated in 2014. She got her master's degree in mathematics from Institut Teknologi Sepuluh November, Indonesia, Indonesia in 2016. Her major field of study is graph theory.

Now, she is a lecturer in Department of Mathematics Education, Faculty of teacher training and Education, University of Jember. Her research of interests is graph theory and mathematics education. Some titles of her publication are as follow: The Edge domination Number on Tensor Product of Cycle and Path, Related Wheel Graph and It's Locating Edge Domination Number, On The Locating Edge Domination Number of Comb Product of Graph.

Robiatul Adawiyah, S.Pd., M.Si. is a member of InaCombS (Indonesian Combinatorics) Society. She is one of the most active researchers in University of Jember.