Improving the Prospective Math Teacher's Literacy Skills by Using Digital Images in STEM-Based Instruction

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Abstract
The demands of high school education include not only increasingly complicated and challenging academic content, but also the ability to think critically and reason in the context of everyday concerns. This mathematical competence is referred to as mathematical literacy proficiency. The teacher's function as a facilitator, providing stimulus in the form of learning strategies, guidance, and aid when pupils suffer learning challenges, is a significant aspect in this. For this reason, students as prospective mathematics teachers need to have good mathematical literacy skills and knowledge and skills to guide students to achieve 21st century abilities and skills. This study's experimental design aims to provide and equip aspiring teachers with knowledge about STEM fields while enhancing their mathematical literacy skills. Participants in the research were undergraduate mathematics education students who attended the Computer Mathematics Program course. The research was carried out using problems related to the relationship between mathematics and digital images in STEM. Data is collected through tests and assessments of student activities that integrate STEM in solving problems. The research results show that digital images have the potential to help students understand mathematical concepts in various fields, especially computer graphics. Students' literacy skills showed considerable improvement at the significance level $\alpha = 0.05$. Students' mathematical literacy proficiency level increased from 90% at maximum level 1 to 90% at minimum level 5. The findings suggest that students should get more familiar with STEM applications in the classroom so they may become accustomed to studying mathematics in an applied context and understanding how it relates to other subjects. Thus, students should be conversant with STEM and able to apply it to classroom instruction when they become teachers.
Keywords: 21st-century technical skills, digital images, mathematical literacy, STEM

Introduction

According to (Saputri & Herman, 2022) 21st century learning requires thinking skills including a) critical thinking, b) problem solving, c) creativity, d) communication, e) collaboration, f) data literacy, and g) digital and scientific literacy. The application of the Science, Technology, Engineering and Mathematics (STEM) approach can be used to meet the demands of 21st century learning (Hafni et al., 2020). STEM can awaken students' potential and provide real-life problem solving skills. However, the application of STEM in learning is still not optimal. This is caused by teachers' knowledge and skills regarding STEM being very minimal. When teaching, teachers always present science-mathematics and engineering-technology concepts separately. So learning becomes less meaningful and useful. Teachers must be able to think clearly and rationally, comprehend and solve problems successfully, create concepts, apply, analyze, synthesize, and evaluate the information they produce in order to evaluate the various sources and key materials used to integrate STEM in learning. This will help them to develop students' critical thinking skills (Noor Anita et al., 2021; Nur'aini & Ruslau, 2023).

(Alifa et al., 2018) adopted the National Governor's Association Center for Best Practices explanation, the literacy skills that students need to build and possess, include: (1) Scientific Literacy: recognizing scientific facts, applying them, and finding solutions. (2) Technological Literacy: skilled at using, designing, studying technology. (3) Technical Literacy (engineering): the ability to develop creative and innovative technological designs by integrating various scientific disciplines and (4) Mathematical Literacy: the ability to study and continue formulating ideas to solve problems mathematically and their applications. In this regard, according to (Ishak et al., 221) to apply STEM it is necessary to pay attention to (1) support regarding various activities to help and make it easier for teachers to apply STEM in learning. (2) teaching involves planning and implementing learning. (3) efficacy concerns teacher optimism in implementing STEM. (4) materials regarding learning support facilities and devices.

According to the findings of the International Student Assessment Program (PISA), an international evaluation carried out by the Organization for Economic Cooperation and Development (OECD) on 15-year-old students' literacy abilities in reading, science, and mathematics, Indonesian students' mathematics proficiency is below average (OECD, 2023). The primary factor influencing learning is the teacher's capacity to facilitate it. Teachers must thus actively contribute to helping pupils' mathematical literacy skills because they are educators. Therefore, students as prospective teachers must have literacy skills, especially good mathematical literacy, in order to guide students to achieve 21st century skills, namely the ability to use literacy and other skills at any time to succeed in various areas of life (Ceylan et al., 2016; Nur'aini & Ruslau, 2020).

Image processing is one of the technical problems in everyday life that is very close to students because they are very familiar with cellphones, video games, cameras and computers (Idris et al., 2023; Mejia et al., 2011). The use of STEM in learning is provided by accompanying prospective mathematics teacher students and is expected to optimize the application of STEM in learning at school. This research was conducted through a variety of demonstrations and hands-on activities developed to help students learn about digital images and strengthen their understanding of abstract mathematical concepts such as matrices and statistics. Digital images can play a useful role to support active learning. The capacity to interest kids is the key to effectively employing digital cameras and photos with younger learners. The images present rich chances for language and literacy, which pique inquiry. Along with giving students new means to record and document learning, they also give feedback tools that let them view and report on activities as they happen. Digital image manipulation is also enjoyable, empowering, and inspiring. It is hoped that students can bridge the gap between abstract mathematics and real-world engineering.

Teachers must be able to manipulate and connect real-world scenarios to the context being studied during the learning process in order for students to embrace the concepts being taught and to be motivated to learn mathematics in a meaningful way. In keeping with the demands of education in the twenty-first century, this research will give students the tools they need to apply the STEM approach to learning and enhancing mathematical literacy as aspiring teachers. This will enable them to use the approach in the classroom later on to develop students who are critical thinkers (HOTS), creative thinkers, and innovative thinkers (Istiandaru et al., 2021; Noor Anita et al., 2021; Sulistiawati et al., 2021). Apart from that, students as prospective mathematics teachers must also have good mathematical literacy skills. According to (Istiandaru et al., 2021; Nur'Aini et al., 2019; Rasna et al., 2023) the teacher is the key to determining the success of a learning process by being a facilitator for students to get to know questions that require reasoning, high-level thinking skills, and questions that hone mathematical literacy skills. To be able to familiarize students with learning with PISA type questions, a teacher must have the ability to develop PISA type questions and have good mathematical literacy skills.

Research Method

The objects of research in this study were students from the Department of Mathematics Education. The data used in this research is primary data obtained from digital images of research objects that are close to students' lives, measuring the results of implementing STEM integrated learning and measuring the mathematical literacy of student.

The research procedures carried out are as follows: Design an instructional form of integrated STEM learning related to the application of mathematics in digital image processing with the following stages: Select and analyze problems related to digital images that will be used in learning; Analyze mathematical concepts that can be applied to solve specified problems; Taking images as samples according to the problem determined using a camera; Apply mathematical concepts and/or operations to images using the MATLAB program; Analyzing Results; Develop a description of each STEM component for each problem. The mathematical literacy abilities of prospective mathematics teacher students are calculated using a formula and adjusted to the level of mathematical literacy ability according to (OECD, 2017; Thomson et al., 2013).

The question instrument used was developed based on research results (M. F. V. Ruslau et al., 2020) and adopted from the Pisa problem (OECD, 2013, 2017) and literature on elementary linear algebra courses (Lay et al., 2021). Analysis of students' mathematical literacy abilities will be carried out using the t test for paired data with a significance level of $\alpha=0.05$. The hypothesis tested is that there is a significant difference between the pre-test and post-test scores for students' mathematical literacy abilities. The H0 rejection area used is for two-sided testing, as follows (M. F. V Ruslau & Suryani, 2018):

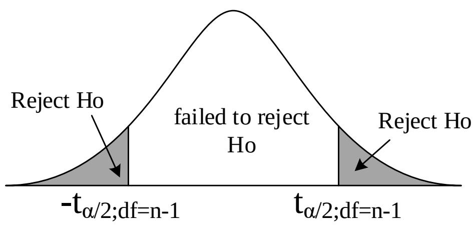


Figure 1. H_0 Rejection Area

If $t_{statistic}$ falls in the rejection area then reject H_0 and accept Ha. Conversely, if $t_{statistic}$ falls in the acceptance area then we accept the H_0 and reject Ha.

Results and Discussion

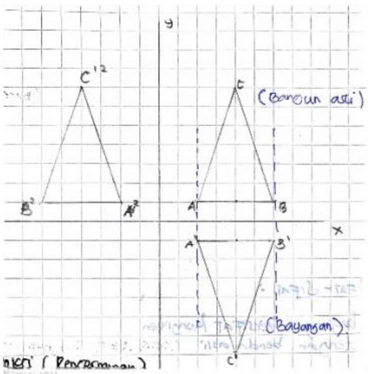
The capacity to recognize, apply, and innovate when combining concepts from science, technology, engineering, and mathematics to solve challenging challenges is known as STEM literacy. Understanding and describing STEM literacy's components and their interrelationships is the first step toward achieving it.

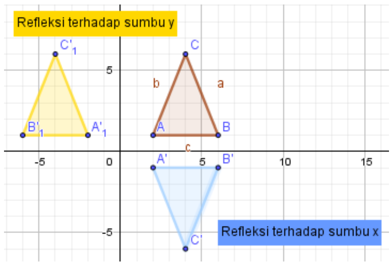
1. *Stem Integration in Student Activities*

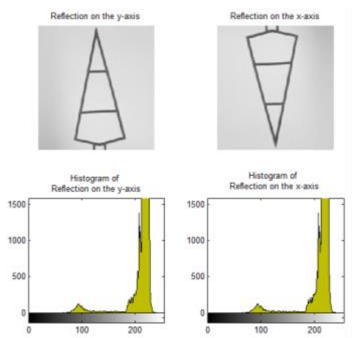
This research was designed with 3 (three) activities consisting of students integrating STEM activities using images in the form of flat shapes, images of rice plants and images of plants that were damaged/identified as sick. Before and after learning, a pre-test and post-test are carried out which are used to measure students' mathematical literacy abilities. Image processing is carried out on the image with the aim of applying mathematical concepts/operations.

In activity 1, Students observe flat images and discuss looking for information regarding their properties or characteristics. Next, students apply mathematical operations to the image and analyze the properties/characteristics of the image and compare them with the properties/characteristics of shapes that correspond to the image. Students state the properties of the images of objects taken so that they have scientific knowledge related to the process of converting analog images to digital images. Students gain scientific knowledge about the characteristics of images taken starting from file size, image size, image type and image color type. The file format of the three sample images is in .jpg with an RGB image type consisting of 3 color components, namely Red, Green and Blue. The image sizes (pixels) are 235 x 219 x 3, 1556 x 1540 x 3 and 4080 x 3060 x 3 respectively. This image size (pixel) is mathematically a matrix size where the components express the intensity or gray value of the image.

The use of a cellphone camera to take images and identify characteristics/information related to the images taken shows that technology is used in learning. Next, students carry out mathematical operations on shapes that correspond to the selected image, namely geometric transformations: reflection, translation, rotation and dilation and state the properties of the object resulting from the transformation which will be compared with the properties of the output image resulting from the transformation of the image. Geometric transformation of the captured image is carried out by first converting the RGB image to a Grayscale image. Students sample pixels in the RGB image to convert it into a grayscale image using the formula . The expected results is the characteristics of the image from the geometric transformation are the same as the properties of the object or shape from the geometric transformation. Students will focus on the core concepts that differentiate the two contexts. The description given by students regarding the properties of the shapes resulting from the transformation is presented as follows:







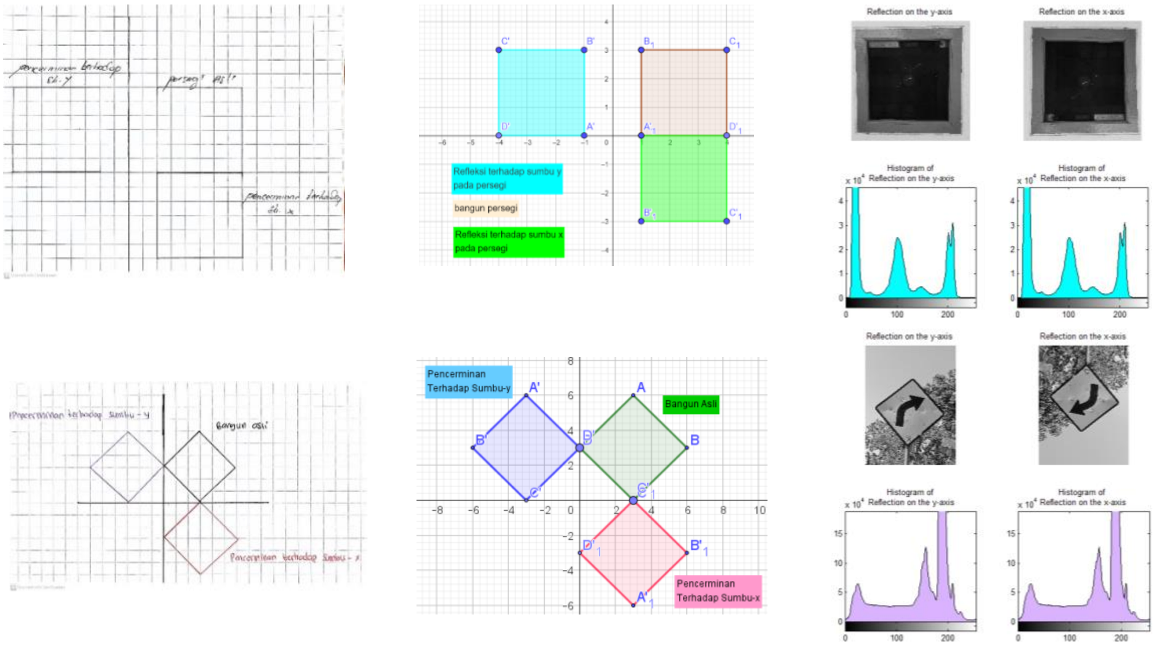


Figure 2. Image of Shapes Reflection

Based on the picture above it appears that: the reflected image has the same shape and size as the original image; The distance from the image to the mirror is the same as the distance from the original image to the mirror; The image in the mirror is opposite to the original shape

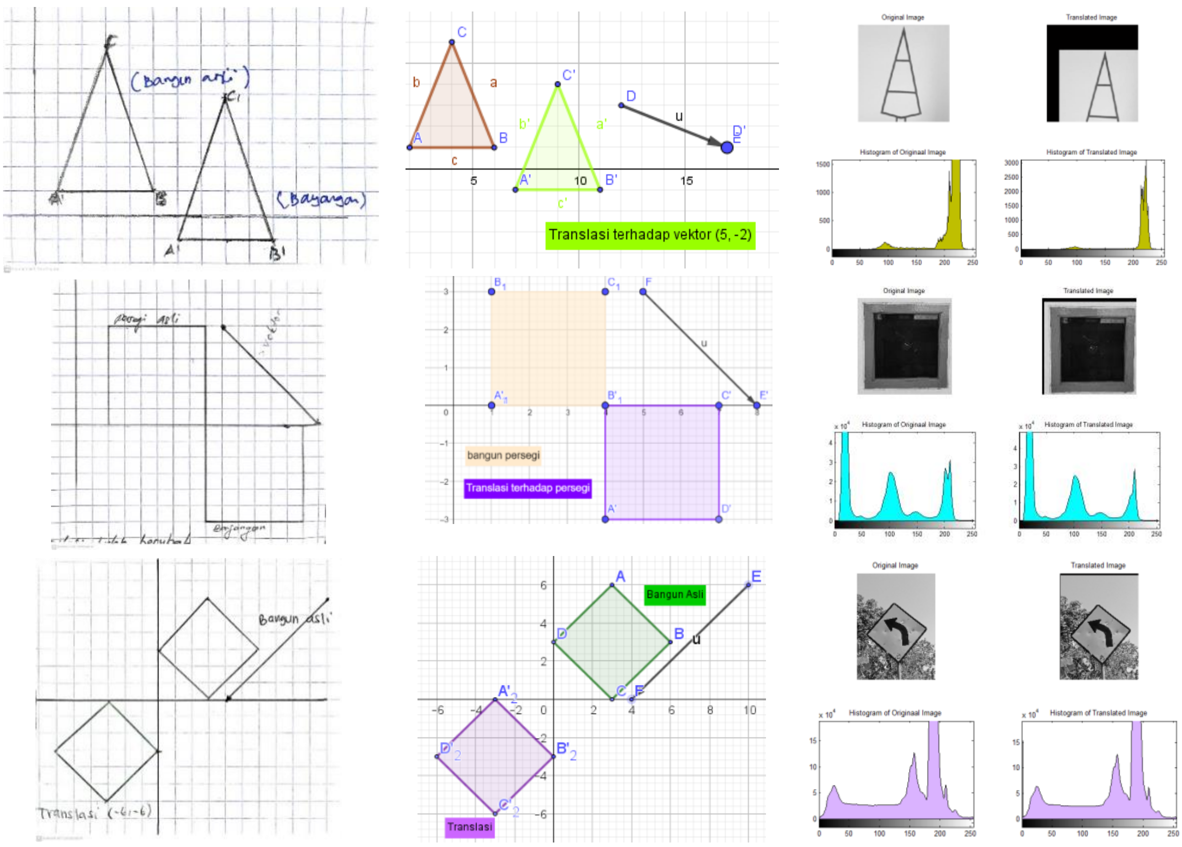


Figure 3. Image of Shapes Translation

Based on the picture above it appears that : Each shape that is translated does not change its shape and size; The image is congruent with the original shape; The image moves or shifts according to the translation component vector on the *x*-axis and *y*-axis

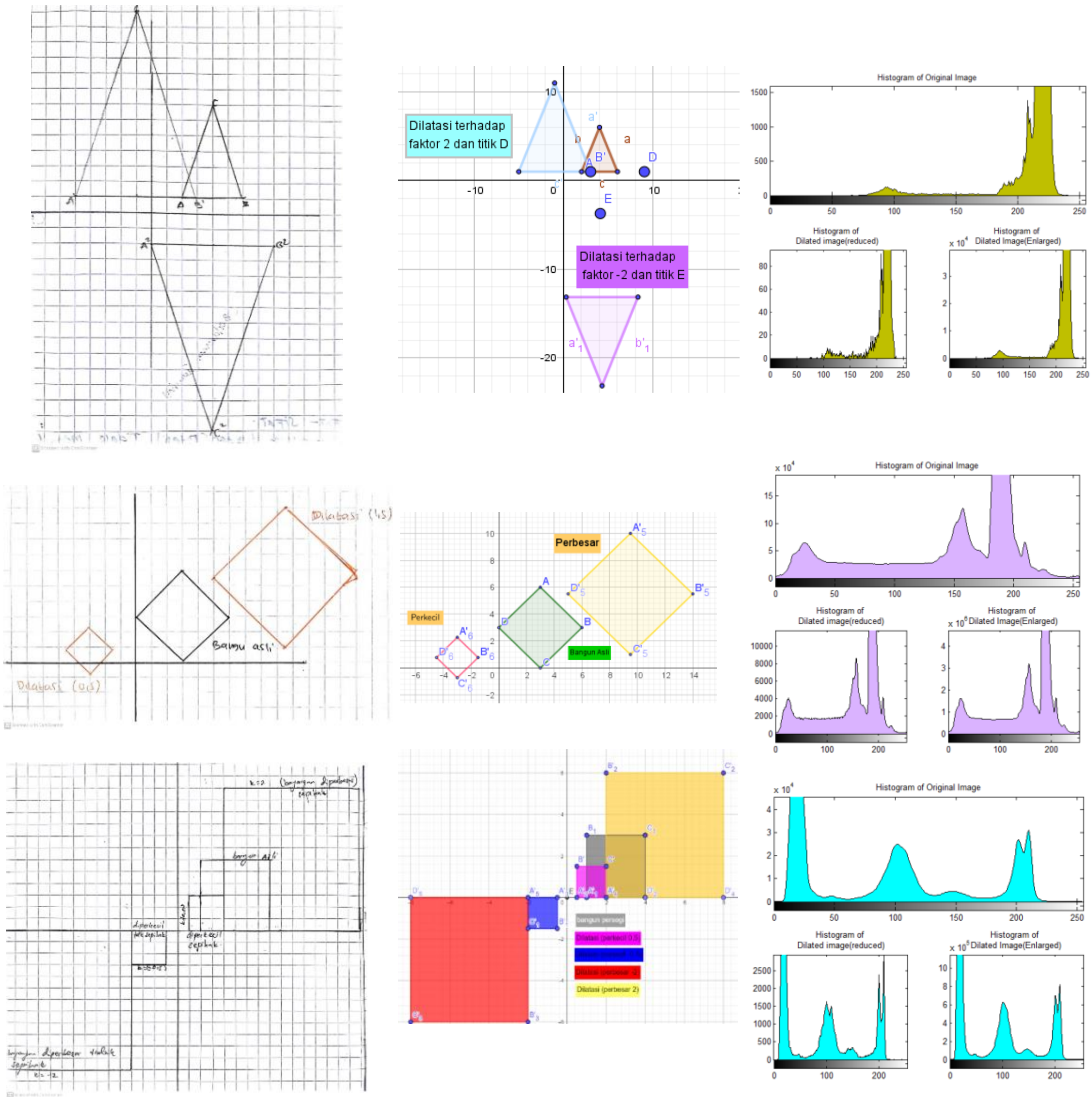


Figure 4. Image of Shapes Scalling

The picture above shows that: The dilated image changes size relative to the original shape according to the scale factor *k*, but does not change shape. If *k*>1 then the image is enlarged and located one side to the center of dilation and the original shape. If 0<*k*<1 then the image is reduced and located one-sidedly towards the center of dilation and the original shape. If -1<*k*<0 then the image is reduced and is not aligned with the center of dilation and the original shape. If *k* <-1 then the image is enlarged and located not one-sided to the center of dilation and the original shape.

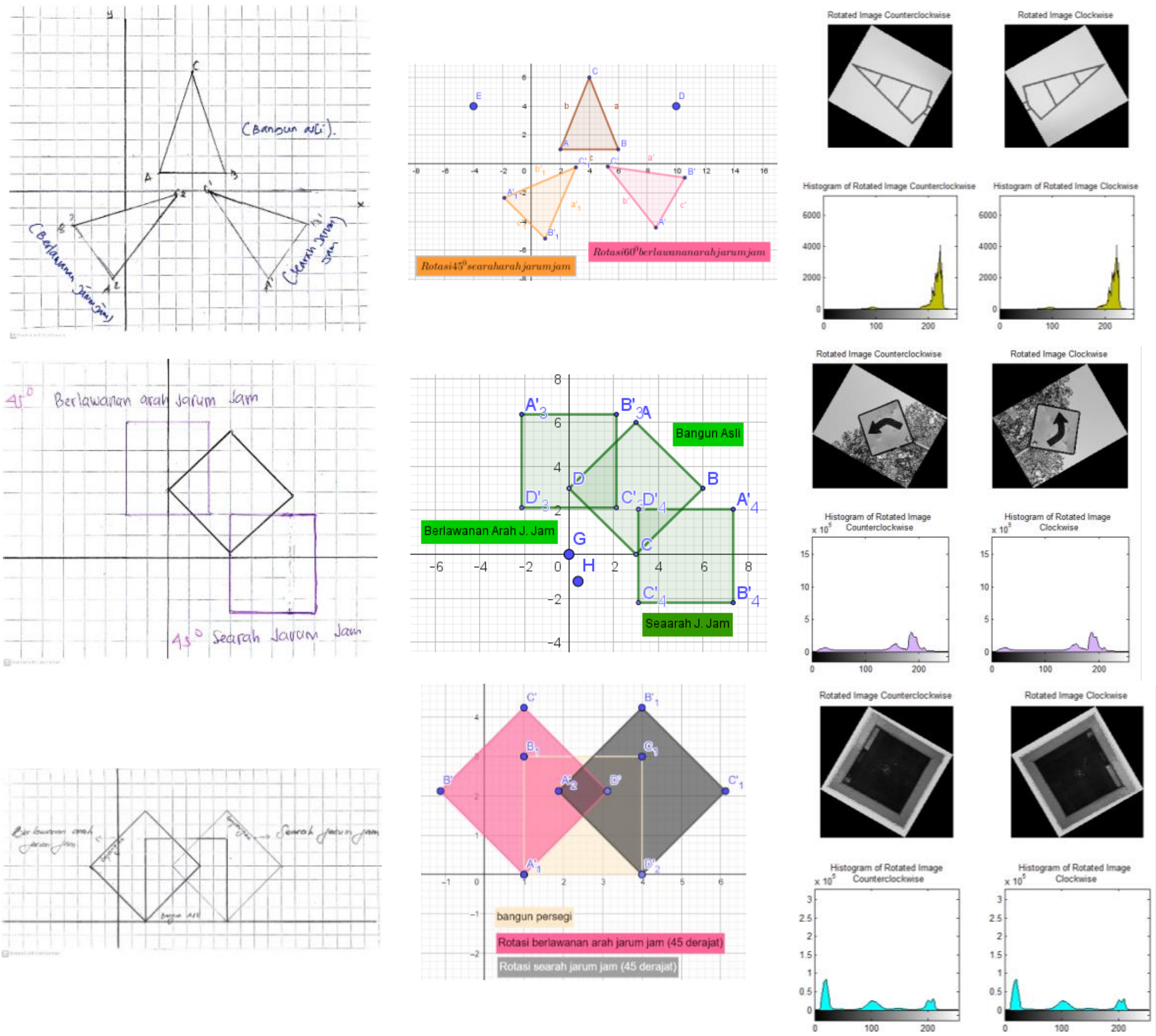


Figure 5. Image of Shapes Rotation

Based on the picture above : The image resulting from rotation does not change shape and size; The image resulting from rotation changes its position according to the direction of rotation clockwise or counterclockwise.

The results of students' interpretation of images resulting from geometric operations are still limited to their understanding visually and based on their knowledge regarding the image of objects resulting from geometric transformations in mathematics in the Cartesian plane. The results of digital image geometric operations can be interpreted not only from the shape, size and position or location, but also based on the image histogram which shows the distribution of intensity values for each pixel, the size in question is the pixel size which in mathematics is the size of the matrix where each element of the matrix is the intensity (color) value of the image and the position in question is the position of each pixel. If in the Cartesian plane the position or location of the origin (0,0) starts at the midpoint of the intersection of the x-axis and y-axis, in the image the point (0,0) starts at the top right corner of the image.

In activity 2, the science topic is related to detecting the color level of rice leaf. Students go out into the field and take random rice leaf and then match them using a Leaf Color Chart (LCC) to determine the color level of the rice leaf. Students use their visual abilities to determine the color level of rice leaf. Of course, activities are carried out with attention to lighting because it will greatly influence the results. The color levels obtained are only from level 2 to level 5. Variations in color values from level 2 to level 5 were observed. It is clear that the L value shows a decrease in brightness, similar to human visual perception: from level 2 to level 5, the color becomes darker. The following image shows the results obtained for each level of rice leaf color. Students take image samples of rice leaf to then predict the color level of rice leaf using MATLAB. Calculate the mean value of each cluster and the distance of each cluster corresponding to the mean. And finally assign points to the closest cluster. In this activity, students gain mathematical knowledge, namely those related to statistics

Level 2 Level 3 Level 4

Picture 6. Detection of Leaf Color Levels in Rice Plants

L2.jpg
68 x 66
(a)

L3.jpg
46 x 46
(b)

L4.jpg
83 x 91
(c)

Figure 7. Sample of Rice Leaf : (a) Level 2 (b) Level 3 (c) Level 4

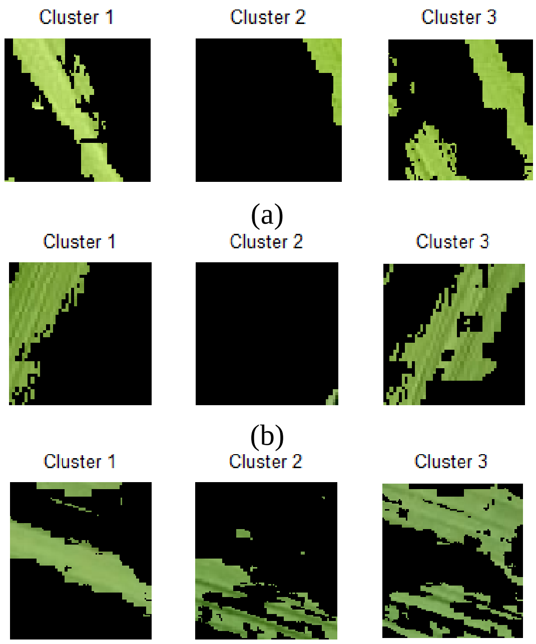


Figure 8. Segmentation Stage Using K-Mans Clustering: (a) Level 2 (b) Level 3 (c) Level 4

In activity 3, students take pictures damaged or diseased plant leaf. Next, annotate the leaf's damaged or disease-affected areas. Next, portions of the image are segmented to determine whether the plant is afflicted with a disease. By using technology and mathematical operations such as converting RGB images to Grayscale, applying thresholding and rotation with te threshold value and rotation angle adjusted to obtain good results. The results of student activity are presented in the following picture:

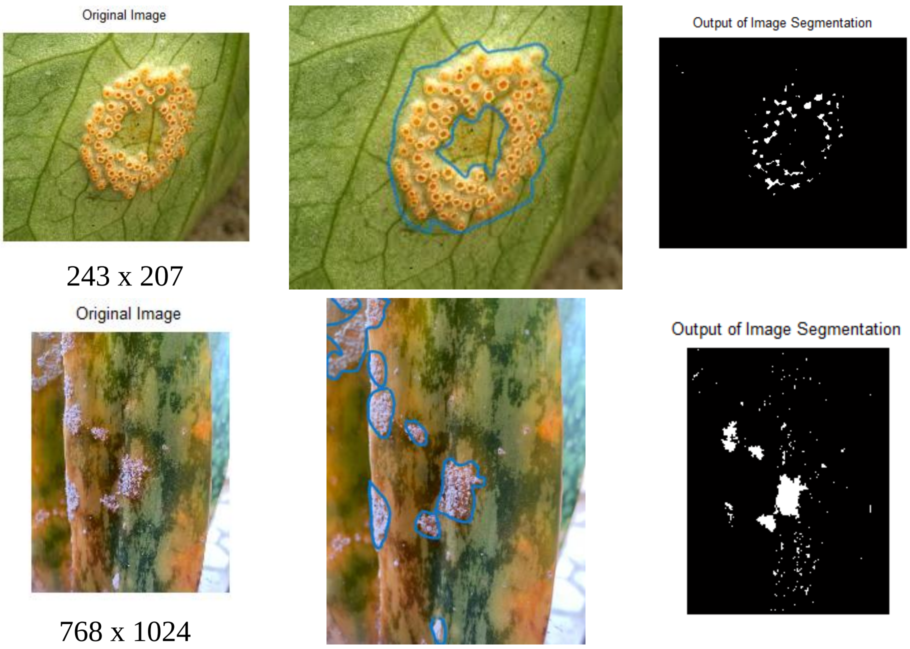


Figure 9. Detection of Plants Diseases

2. Student Literacy Skills

The importance of progressing through these three activities includes (i) demonstrating various mathematical and statistical operations and concepts, (ii) showing explicit integration of mathematics and statistics and STEM contexts in the activities, and (iii) creating interest in continuing learning and applying STEM activities especially as a candidate math teacher. Initial test results show that the majority of students' mathematical literacy skills are below or not included in the cut-scores for mathematical literacy proficiency levels. Students at this level can only answer questions involving familiar contexts where all relevant information is available and the questions are clearly defined; identifies information and performs routine procedures according to direct instructions in explicit situations; carry out clear actions and immediately follow the stimuli given. Students have the highest scores on the calculation literacy aspect (formulate), then the representation aspect (employ) and the lowest on the interpretation aspect (interpret). The average mathematics literacy ability score is 329.87 and at the 95% confidence interval the average mathematics literacy ability score is within the interval .

After following learning with a STEM approach, students' mathematical literacy abilities increased, namely at levels 4, 5 and 6. The average final student literacy ability based on the results of this research was 676.62. Based on the level of mathematical literacy proficiency, the average final literacy ability of students is at level 6. At this level, students can state mathematical concepts, generalize, and use information; have advanced mathematical thinking and reasoning abilities; master the relationship of mathematical symbols and perform operations, formulate and communicate precisely the results obtained, the results of their interpretation, and their arguments.

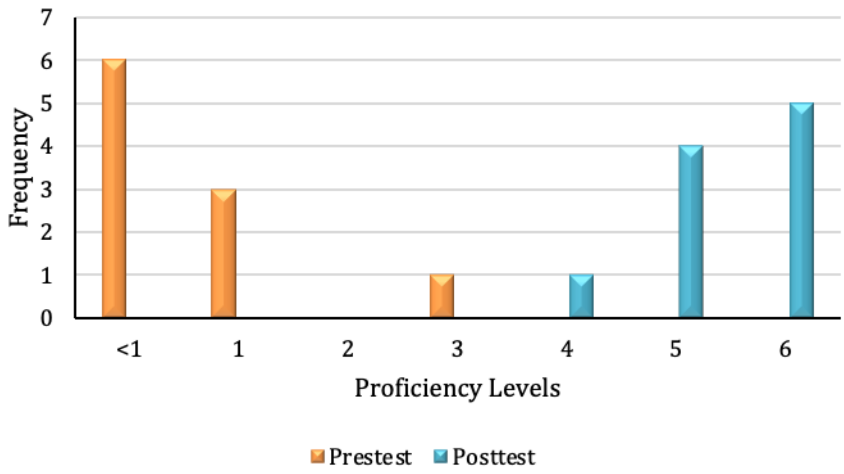


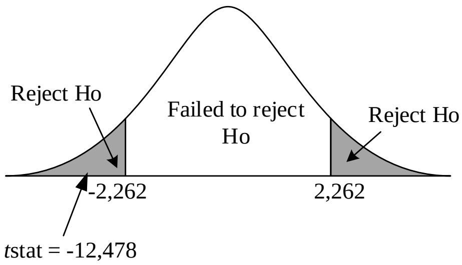
Figure 10. Distribution of Students' Mathematical Literacy Proficiency Levels

To strengthen the results obtained, a statistical test was carried out to find out whether there was a difference in the average mathematical literacy abilities of students before and after learning with a STEM approach using digital images. Test result statistics are presented in the following table:

Table 1. Descriptive Statistics

Statistics	***Pretest***	***Posttest***
Mean	329.8701	676.6234
Variance	5891.944	3240.194
Observations	10	10
Hypothesized Mean Difference	0	
Degree of freedom	9	
t Stat	-12.4776	
t Critical one-tail	1.833113	
t Critical two-tail	2.262157	

The critical value and critical region for rejecting H_0 are shown in the following figure:



Based on the picture above, it can be seen that the calculated statistical value falls in the H_0 rejection area. So the decision made is to reject H_0. And it was concluded that "There is a significant difference between the average pre-test and post-test scores for students' mathematical literacy abilities." The average mathematics literacy score is 676.62 and at the 95% confidence interval the average mathematics literacy score is within the interval.

Students have the highest score in the calculation aspect (formulate), then the representation aspect (employ) and the lowest in the interpretation aspect (interpret). A paired t test to estimate the difference mean scores before and after learning with STEM produced a statistic value of 12.48 with a table value of 2.26, indicating that there is a significant difference, suggesting that students' mathematical literacy improved.

This research was conducted on prospective future mathematics teacher to strengthen the foundation and potential of STEM integration in mathematics learning in schools in the future and is expected to be able to meet the demands of 21st century education. If mathematics teachers have good and strong mathematical literacy skills in integrating STEM, it is hoped that mathematics learning will improve, becomes more meaningful and students will be more motivated in learning and also have good 21st century skills.

Conclusion and Suggestion

Digital images have the potential to help students understand mathematical problems in other areas of life, especially in the field of computer graphics. Today, critical thinking skills and digital technology are really needed. If students understanding mathematical concepts in digital image processing and use them repeatedly in STEM projects, students will be able to think critically and creatively and by utilizing technology apply them in learning. While the effective use of STEM disciplines in education is still in its infancy, it is critical to acknowledge their potential to provide the evidence-based STEM outcomes required to address societal demands. Through technology both inside and outside the classroom, students can pick up the 21st-century technical skills required for future careers.

Students' mathematical literacy abilities have increased significantly. After learning with STEM students' mathematical literacy skills are at a minimum of level 4. Students at this level work on complex concrete problems; selecting and creating different representations of the problem; use skills to reason and create different representations of problems well, including symbolic representations; and explains the argument well. The average score for students' mathematical literacy skills is at Level 6. Students at this level can state concepts, generalize and use information; have advanced mathematical thinking and reasoning abilities; master symbolic and formal mathematical operations and relationships; formulate and explain their findings, interpretations and arguments appropriately.

Based on the results, it is recommended that the application of STEM in learning needs to be familiarized so that students can get used to studying mathematics in an applied manner and its connection with other fields. Students are not accustomed to just memorizing formulas and being able to calculate but can use mathematical concepts to solve and solve contextual problems. And when they become teachers, students will be familiar with STEM and are expected to be able to apply it in learning at school.

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