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# Improving Problem-Solving Skills through Logo Programming Language

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**Abstract**

The effect of Logo programming language on problem solving skills was investigated in this study. Eighty-five fifth-grade students were assigned to either an experimental or control Logo group. They were pre-tested to assess baseline receptiveness to figural and logical word problem-solving skills. After eight weeks of learning, the Logo experimental group had significantly higher scores than the control group on the problem-solving skills tests (assessing both figural and logical word problem-solving skills). The result revealed significant differences in the figural problem-solving skill between the Logo experimental and control groups. An implication was that Logo programming exercised skills are more critical and relevant to the figural problem-solving skill. Possible alternative explanations and suggestions are provided for future research endeavors.

**Keywords:** *Logo, programming language, logical word, figural, problem solving*

## Introduction

The development of problem-solving abilities is one of the overall goals in the Indonesian National Curriculum. Governments and experts believe that developing problem-solving skills in regular classrooms is one solution to improve the education sector in Indonesia. They also believe that the use of information and computer technology (ICT) in the learning and teaching environment can support this developmental effort. The 2004 Curriculum stated that ICT should be used to exercise creativity and problem-solving based on learning models, especially in facilitating the comprehension of other subjects (Pusat Kurikulum, 2003). Logo programming language can be used to develop problem-solving skills through learning.

One popular argument is that learning Logo will enhance children's ability to solve problems. Papert (1980) has argued that the most beneficial learning is the "Piagetian learning" method, i.e., "learning without being taught." He has proposed that computers can make the abstract into concrete, tangible, and even personal concepts there by improving the learning process for children, converting thought processes into conscious ones. By having children programming the computer to do what they want it to do, children must reflect on how they might do the task themselves, and therefore, on how they themselves think on a conscious level. This claim is based on the hypothesis that children can create their own problem solutions and then "stand back" and watch themselves, as embodied in the computer program during the problem-solving process.

Many researchers have been investigating the changes in children's mathematical problem-solving skills resulting from learning Logo. Using Logo leads to geometric learning (Kappa,1999; Kull & Carter, 1990; Battista and Clements, 1990). For instance, students practise and simulate spatial relations, learning to repeat and rotate geometric figures on the screen. They conclude that understanding of geometric shapes is enhanced, leading to more sophisticated mathematical problem-solving abilities.

Logo has been implemented in teaching in the United States, the United Kingdom, Russia, Japan, and Australia for various purposes, resulting in research on Logo programming being quite established in these regions. However, in Indonesia, the implementation of Logo in teaching Indonesian students has not been much studied. This study examined whether Logo can affect the development of problem-solving skills of students in Indonesia.

## Logo Programming

Logo is a computer programming language designed for learning, including children. It is easy for the novice programmer to get started with Logo writing programs and feeling rewarded during the process. However, Logo is also powerful and can be used effectively as a mathematical problem-solving tool without limits. Logo Programming was originally developed at the Massachusetts Institute of Technology in 1967 by Seymour Papert et al., with the intention to allow people, even young children, to use computers as a learning tool (Papert, 1980). Papert combined his scientific skills with Piaget's theories on how children think and learn to create a software program that enables children to use programming language (Torgerson, 1984).

Maddux and Rhoda (1988) indicated that Logo is different from other programming languages because it can be used even with little prior knowledge on computer languages. Geometric components of Logo are recognized as turtle geometry, whereas the user points with a cursor and moves within Logo. Teachers only need a five- or ten-minute presentation to introduce the four basic commands for turtle movement to children. The triangular cursor, called the turtle, carries out the commands to create and manipulate graphics, geometrical shapes, and designs. The turtle's distance and angle are determined by the numerical inputs placed after the direction commands. In the immediate mode, children learn to create designs, drawings, and geometrics figures instantly.

Children type a command and press the ENTER key to move the turtle. Once students have mastered the immediate mode, they can advance to the next level, the program mode. In the program mode, the commands are no longer carried out individually. A series of commands are written, then the ENTER key is pressed and the command program is executed on the monitor. Therefore, Logo provides immediate feedback, allowing students to learn from their errors and reach the correct commands for a specific task, leading to exercising problem-solving skills through self-correction.

Logo provides students with a variety of learning strategies. Students with short attention spans can benefit from Logo because they can work at their own pace. According to research by Emihovich and Miller (1988), Logo can also facilitate the acquisition of metacognitive skills, which are rarely achieved in regular classrooms. Planning the turtle's movements provides students with the experience of simultaneous thinking and learning. This higher-level thought process applied to a concrete object teaches them content, thinking styles, and behaviors needed for academic success.

### Logo and Problem Solving

Kull and Carter (1990) observed that Logo enhances children's problem-solving skills on mathematical understanding. Students can explore numbers and number relationships by using the wrapping component of Logo. Wrapping in Logo occurs when a large number is entered into the computer, moving the turtle off the screen and back again as many times as commanded to produce a screen wrap. Young students are unable to appropriately associate numbers with their value. Students discover number relationships by finding that if a larger number is entered into the computer, the turtle wraps longer and fills up the screen more than if a smaller number is entered. Children construct these wraps and determine that numbers represent a relational amount of something. After discovering number relations, students begin to predict what will happen on the screen with numbers they choose to input.

Battista and Clements (1990) investigated the changes in children's mathematical problem solving that result from learning Logo. They concluded that the understanding of geometrical shapes was enhanced. They also concluded that children's idea about mathematical problem solving became more sophisticated. Using Logo leads to geometry. Students practise and simulate spatial relations, learning to repeat and rotate geometrical figures on the screen. Battista and Clements (1990) suggested that illustrating spatial imagery is important in geometric problem solving because it involves thinking about properties of figures. Determining how to recognize geometrical figures in their tilted form develops students' spatial imagery and visual reasoning.

Torgerson (1984) noted that Piaget's research stressed the necessity of student involvement in physical manipulation of objects to build intellectual structures. Children need to interact with their environment to understand spatial relations. The creating of geometrical shapes and designs provides practice in left, right, forward, and backward directions once they have developed the concepts of spatial relations.

## Method

This study was conducted to investigate whether or not the Logo programming language would improve Indonesian students' problem-solving skills with participants who were Grade 5 students. This study focused on Logo programming because, as previously described, it has a great potential for introducing children to many of the central concepts involved in programming and problem solving. This was quantitative research for learning computer programming in elementary school. It was conducted to determine the effect of Logo programming on students' achievements and improvements in problem-solving abilities. The degree of effect would be used to gather information about Logo programming in enhancing students' problem-solving ability. The results of this research can be used as a guide to develop problem-solving skills through the use of ICT in elementary schools.

### Study Design

This study was quasi-experimental quantitative research. Pretest was conducted prior to the start of the Logo programming course and posttest was conducted after the completion of the course; the former provided baseline problem-solving abilities measurement while the latter measured the final outcome of problem-solving skills.

Research subjects were randomly assigned to the purely experimental research groups, so that equality groups would be obtained that would fall within the limits of random fluctuations. However, in education, especially in teaching, conducting research using random selection of subjects is not always possible, because subjects naturally form intact groups (naturally formed intact group), such as groups of students included in one class (Rosenthal & Rosnow, 1991; Marhamah & Mulyadi, 2013). These groups are also often very limited in number. In these circumstances the rules in purely experimental research cannot be met in full, because the control variables which are the subject of the study cannot be done completely, so the research must be done by using the intact group. To examine the consequences (causal effect relationship) during the treatment, this study involved three groups. They were first experimental group, second experimental group, and control group.The first experimental group received the Logo

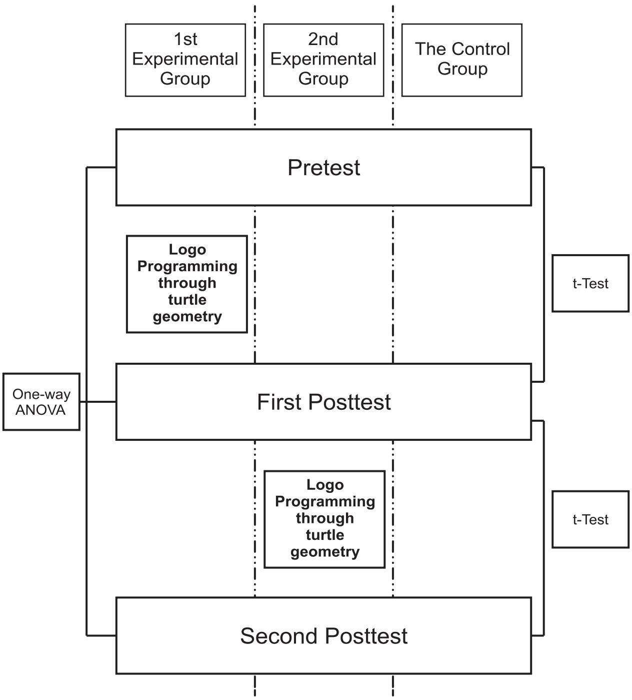


Figure 1. Study Design Diagram

programming course during the first month of the study period while the second experimental group obtained the Logo programming course during the second month of the study. All the participants studied a module of Logo programming within 16 sessions. Each session lasted 40 minutes of the school's IT course curriculum. This module ran for four weeks, four sessions every week, teaching the introduction of Logo programming through turtle geometry.Figure 1 shows the diagram of the study design.

### Data Collection Method

Problem-solving skills assessments were collected with the Figural Problem Solving Test (FPBT) and the Logical Word Test (LWT). Psychologists used both tests to measure the problem-solving abilities of the children for figural and verbal skills. Both tests applied the same scale for scoring: a score between 9 and 15 indicated an average level of problem-solving skills; a score below 9 indicated less than average abilities; a score above 15 indicated superior abilities.

The test of Logo programming was measured by using the assessment of Logo programming for Jordanian students developed by Amal Khasawneh based on a study that assessed the Logo programming ability to measure problem-solving skills (Khasawneh, 2009). This study used the Assessing Logo programming of Jordanian seventh grade students to serve as a standard of measurements. The assessment consisted of three open problems that students were supposed to answer within the construct (i.e. specific shapes) using the turtle. The Logo programming aspects assessed included: the primitive commands, the repeat commands, and the constructed procedures used to create complex commands. The geometrical aspects were assessed as well and included: rotation, angle of rotation, circle, square, and rectangle.

The modules of Logo programming were declared to be suitable for fifth-graders based on the standard curriculum as stated in *Kurikulum Tingkat Satuan-Pelajaran (KTSP)*. This module aims to provide students with the experience in using a computer program through Logo language, and to improve students' problem-solving skills and creativity. The Logo programming module included Logo language primitives and Logo procedures. The activity types practised by the students were using the turtle in order to draw paths and geometrical shapes, as well as constructing more complex shapes requiring multiple procedures.

At the end of every session, a test of Logo programming was given. The researchers and school teachers administered this test during a 40-minute session. All the participants completed the tests individually using the computer in order to construct Logo programming. All the students' test results were assessed and assigned a score within the range between 0 and 100.

### Population and Sampling Technique

The sample population of this study were fifth grade students at a private, co-education elementary school near Jakarta, Indonesia. There were 128 fifth grade students divided into three groups. They were grouped into the first Logo experimental group, the second Logo experimental group, and the overall control group. The first Logo experimental group consisted of 43 students. The second Logo experimental group consisted of 42 students. The control group consisted of 43 students. The groups were clustered based on the student's fair of intelligence score that was based on the final grade of the fourth grade, gender, and socio-economic status.

The Logo experimental groups studied a module of Logo programming within 16 forty-minute sessions during their IT classes as a part of their school curriculum. This module ran for 4 weeks with four sessions per week, including an introduction to Logo Programming through turtle geometry. The students often worked with peers to cover the turtle activities. However, they did tests and assessments individually. The students were assigned homework from every session to be collected in next session. The teacher's role was to guide the students and be a source of learning. PC LOGO for Windows version 6.5b 2002 was utilized in the school.

This study utilized convenience sampling, a non-probabilistic sampling technique. A probabilistic sample was not required for this research since all the students in the fifth grade participated in the study. Table 1 provides some relevant demographics of the participating students.

**Table 1.** Demographics of Study Participants

| Demographics Category | 1st Experimental Group | 2nd Experimental Group | Control Group | Total |
|---|---|---|---|---|
| | N(%) | | | |
| **Gender:** | | | | |
| Male | 19 (44.2) | 20 (47.6) | 19 (44.2) | 58 (45.3) |
| Female | 24 (55.8) | 22 (52.4) | 24 (55.8) | 70 (54.7) |
| **School Fee:** | | | | |
| Below Standard | 5 (11.6) | 5 (11.9) | 15 (34.9) | 25 (19.5) |
| Standard | 38 (88.4) | 37 (88.1) | 28 (65.1) | 103 (80.5) |

### Method of Analysis

This study was conducted to determine whether Logo programming could improve students' problem-solving skills. This study compared the differences of scores in the students' problem-solving skills before and after the Logo programming course, thereby comparing the pre- and post test scores. One-way ANOVA analysis was used to compare pre- and post-test scores among the groups. Furthermore, t-test analysis was performed on matched pairs of the student's problem-solving skills pre- and post-test scores.

## Results and Discussion

Table 2 shows the means and standard deviations of the problem-solving pre-test scores for all the study participants. In the pretest, the mean score of LWT and FPST did not differ significantly by the Logo experimental 1st, 2nd, and control groups.

**Table 2.** Means (SD) of Pre-test Scores Comparison

| Measured Area | 1st Experimental Group (N $2 42) | 2nd Experimental Group (N $2 42) | Control Group (N $2 41) | *F* | *p* |
|---|---|---|---|---|---|
| LWT | 9.64 ( 3.06) | 9.86 (1.37) | 9.24 (2.93) | 0.608 | 0.546 |
| FPST | 10.33 (3.09) | 9.05 (2.67) | 10.28 (2.76) | 2.752 | 0.068 |

Table 3 presents the means and standard deviations of the problem-solving first post-test scores. In the first post-test, the mean LWT (F $2 3.507, p $2 .033) and FPST (F $2 3.440, p $2 .035) differed significantly by groups.

**Table 3.** Means (SD) of 1st Post Test Scores Comparison

| Measured Area | 1st Experimental Group (N $2 43) | 2nd Experimental Group (N $2 41) | Control Group (N $2 43) | *F* | *p* |
|---|---|---|---|---|---|
| LWT | 11.91 (3.50) | 10.71 (3.54) | 10.00 (3.08) | 3.507 | 0.033* |
| FPST | 12.22 (2.31) | 10.80 (2.92) | 11.65 (2.09) | 3.44 | 0.035* |

* *indicates p $2 0.05 for significant difference between means*

Table 4 presents the means and standard deviations of the problem-solving second post-test scores. In the second post-test, the mean LWT (F $2 5.987, p $2 .003) differed significantly. The opposite, however, is observed with FPST, whose mean (F $2 1.622, p $2 .202) did not differ significantly.

**Table 4.** Means (SD) of 2nd Post Test Scores Comparison

| Measured Area | 1st Experimental Group (N $2 43) | 2nd Experimental Group (N $2 40) | Control Group (N $2 43) | *F* | *p* |
|---|---|---|---|---|---|
| LWT | 11.91 (3.23) | 12.59 (3.36) | 10.26 (2.89) | 5.987 | 0.003* |
| FPST | 12.53 (2.35) | 12.59 (2.05) | 11.84 (1.99) | 1.622 | 0.202 |

* *indicates p $2 0.05 for significant difference between means*

Figure 2 shows the trends in the students' problem-solving pretest–posttest1–posttest 2 scores for the first group of Logo experimental participants. This figure shows that there was an increase in the students' problem-solving scores (LWT and FPST) from the pre-test to posttest 1. Table 5 shows the means of LWT (t $2 -9.261, p $2 .001) and FPST (t $2 -4.458, p $2 .001). The paired pre-test and post-test 1 scores differed significantly. This occurs because of the effect of Logo programming in the first Logo experimental group. Otherwise, Table 5 shows that the means of LWT and FPST post-test 1 and post-test 2 when paired did not differ significantly (t $2 -.064, p $2 .949) and (t $2 -.856, p $2 .397).

**Table 5.** Paired Score Differences for the 1st Experimental Group

| Pairs | Paired Differences | | *t* | *p* |
|---|---|---|---|---|
| | Mean | SD | | |
| LWT Pretest – Posttest 1 | –2.40 | 1.68 | –9.261 | 0.001* |
| FPST Pretest – Posttest 1 | –2.05 | 2.91 | –4.458 | 0.001* |
| LWT Posttest 1 – Posttest 2 | –0.02 | 2.38 | –0.064 | 0.949 |
| FPST Posttest 1 – Posttest 2 | –0.32 | 2.37 | –0.856 | 0.397 |

* *indicates p $2 0.05 for significant difference between means*

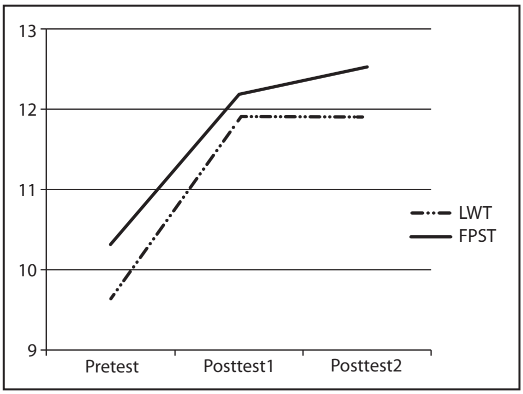


Figure 2. Pretest, 1stPostTest, and 2ndPostTest Scores for the 1st Experimental Group

Table 6 shows an increase in the students' scores between problem-solving posttest 1 and posttest 2 score for the second Logo experimental group. Similar to the first Logo experimental group, this occurred because of the cognitive improvement effect among the students. Figure 3 presents the trend of the students' problem-solving pretest–posttest1–posttest2 scores for the second Logo experimental group of participants. This figure shows that there was an increase in the students' problem-solving scores from pre-test to posttest1, and from posttest 1 to posttest 2. The increase was more obvious between posttest1 and posttest 2.

**Table 6.** Paired Score Differences for the 2nd Experimental Group

| Pairs | Paired Differences | | $t$ | $p$ |
|---|---|---|---|---|
| | Mean | SD | | |
| LWT Pretest – Posttest 1 | –0.80 | 3.50 | –1.472 | 0.149 |
| FPST Pretest – Posttest 1 | –1.66 | 2.63 | –4.034 | 0.001* |
| LWT Posttest 1 – Posttest 2 | –1.87 | 2.21 | –5.217 | 0.001* |
| FPST Posttest 1 – Posttest 2 | –1.63 | 1.53 | –6.565 | 0.001* |

* *indicates p $2 0.05 for significant difference between means*

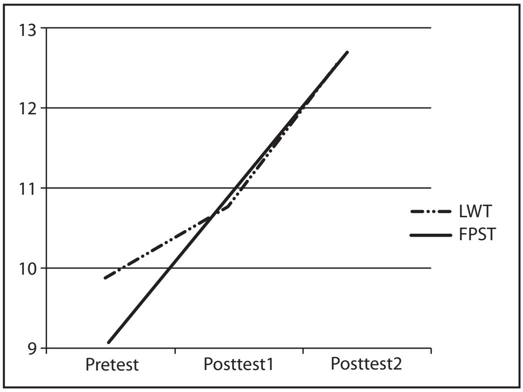


Figure 3. Pretest, 1st PostTest, and 2nd PostTest Scores for the 2nd Experimental Group

Table 7 shows a score increase between problem-solving posttest 1 and posttest 2 for the control group. Figure 4 displays the trend of the students' problem solving pretest–posttest1–posttest 2 scores for the control group. This figure shows that there was an increasing score in the students' problem solving score from pre-test to post test1, and from posttest 1 to post test 2. However, these increases were not statistically significant.

**Table 7.** The Paired Score Differences for Control Group

| Pairs | Paired Differences | | *t* | *p* |
|---|---|---|---|---|
| | Mean | SD | | |
| LWT Pretest – Posttest 1 | –.078 | 2.76 | –1.810 | 0.078 |
| FPST Pretest – Posttest 1 | –1.37 | 2.52 | –3.575 | 0.001* |
| LWT Posttest 1 – Posttest 2 | –0.26 | 2.12 | –0.792 | 0.433 |
| FPST Posttest 1 – Posttest 2 | –0.19 | 1.22 | –1.000 | 0.323 |

** indicates p $2 0.05 for significant difference between means*

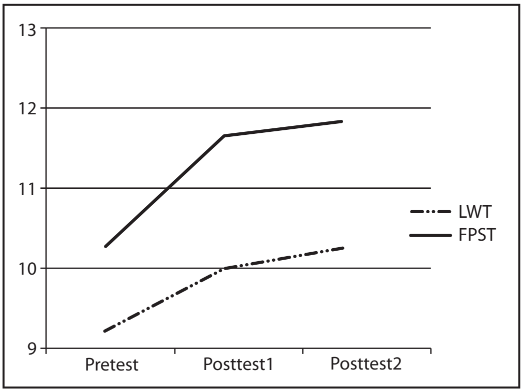


**Figure 4.** Pretest, 1stPosttest, and 2nd Posttest Scores for Control Group

Analyses of the problem-solving skills scores revealed that the Logo experimental group's scores were significantly greater than the control group's. The post-test scores of the Logo experimental group were also significantly higher than its pretest scores, as well as higher than the pre- and post-test scores of the control group. Table 8 shows that the means of LWT (F $2 .093, p $2 .015) and FPST (F $2 2.718, p $2 .039) differed significantly, indicating a differing level of problem-solving skills between the first Logo experimental group and the control group, according to post-test 1 scores. This result is in line with the results in Table 4, showing that LWT (F $2 5.987, p $2 .003) of post-test 2 score in the first Logo experimental group, the second Logo experimental group, and control group differed significantly from one another.

Interactions revealed that this effect was most pronounced in the Figural Problem Solving Test (FPST). It could mean that constructing, transforming, and manipulating shapes and lines of numerically determined length directed attention to their characteristics and, thus, increased the knowledge of the domains of geometrical figures and asymmetrical relations (Clements & Gullo, 1984). Logo

**Table 8.** Means (SD) of 1st Post Test Scores Comparison

| Measured Area | The First Experimental (N $2 43) | Control Groups (N $2 84) | *F* | *p-value* |
|---|---|---|---|---|
| **LWT** | 11.91 | 10.34 | 0.093 | 0.015* |
| | (3.50) | (3.31) | | |
| **FPST** | 12.22 | 11.24 | 2.718 | 0.039* |
| | (2.31) | (2.55) | | |

programming provided the students with better abilities to solve geometrical problems. The students practised and simulated spatial relations by learning to repeat and rotate geometrical figures on the screen. Battista and Clements (1986) suggest that illustrating spatial imagery is important in geometrical problem solving because it involves thinking about properties of figures. Determining how to recognize geometrical figures in their tilted form develops students' spatial imagery and visual reasoning. The development of problem-solving skills might also have contributed to an increase in this ability in a communicative feedback mechanism.

In line with the studies by Clements (1986) as well as Pardamean, Evelin, and Honni (2011), this study also found that the students' verbal problem-solving skills increased. Logo programming also involves the need to solve routine word problems through the experience of verbalizing visual information or representations held in language encoding. In Logo environments, students learn to use monitoring in and out of Logo. In one study (Clement & Meredith, 1992), students were given problems that misled them on purpose via extra or irrelevant information. Logo students were more likely to find and fix the error in the problem. The ability to design algorithms may have contributed to systematic problem solving in these logical word problems (LWT).

## Conclusions

This study found that Logo programming improved the students' problem-solving skills based on grade 5 students in a major city in Indonesia. The improvements can be observed quantitatively through the post-test scores. Further analyses show statistically significant differences in FPST and LWT scores. This indicates that Logo programming improved the level of the students' figural problem solving. It is suggested that the Logo programming language should be used in schools to develop problem-solving skills through the use of ICT in elementary schools. For further study, other variables such as gender, socio-economic level, parents' education, the influences of teachers and parents can be included in the analysis.

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