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Effect of The Teaching and Learning Mathematics Strategy Based-on Meta-cognitive Scaffolding on Instructional Efficiency

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Abstract. Meta-cognitive scaffolding (MS) with self-questioning is helpful in promoting student's problem solving skill and independent learning. MS deals with the process of learning which helps the students to think, control, and monitor their learning. The instructional condition will be more efficient if the performance of students' achievement in problems solving needs less than mental effort invested or equivalent. Therefore, the purpose of this paper was to examine the effect of the scaffolding meta-cognitive strategy on instructional efficiency. The results of quasi-experimental indicated that the MS strategy fulfilled the direct effect to instructional efficiency. This data provided support for the claim that MS strategy is superior in comparison to the conventional teaching. Students in the experimental group showed an overall favourable view towards the implementation of MS strategy. They viewed that the MS strategy is an interesting, new, easy, and fun instructional format to use in mathematics learning.

Keywords: Meta-cognitive Scaffolding, mathematics, teaching and learning

INTRODUCTION

In teaching and learning mathematics, problem solving directs student to use higher order thinking skills that requires them to use meta-cognitive behavior. Meta-cognitive scaffolding (MS) is an effective way to guide and help students in mathematical problem solving, because it guides students to develop high-level cognitive strategies by increasingmeta-cognitive awareness during the learning process and their problem-solving [3]. Meta-cognitive scaffolding deals with the process of learning which helps the students to think, control, and monitor their learning. One of techniques of meta-cognitives scaffolding is self-questioning [2]. This technique is helpful in promoting the students' problems solving skill and independent learning.

The potential of meta-cognitive scaffolding in helping and learning is often discussed, and is mainly related to learning mathematics base-on problem-solving. In learning, student needs guidance to solved of problems or task and if the guidance is not available, the students cannotto perform the task, they will lose the interest and then they may continue to give up [8]. The guidance is part of the scaffolding mechanism. Scaffolding is a set of teacher instructions or colleagueswho is more expert to guide student in shorten the gap between the actual ability with the potential ability, identified as zone of proximal development (ZPD) [12].

In learning, student cognitive loads can be considered as an important factor in determining the strength of different learning processes. However, meaningful interpretations can only be given in contexts related to performance level and vice versa. The correlation between mental and performance is used to compare the efficiency of the teaching process. A particular teaching process is considered more efficient if it achieves higher achievement of invested lower mental effort [7] [11]. Based on the strength of the technique, it is plausibly significant to develop a research-based process of learning mathematics on the basis of meta-cognitive scaffolding as a purpose of this research.

In a broad sense, cognitive load theory (CLT) has conducted about instructional efficiency. CLT refers to the development learning processes. The teaching environment that results in higher learning outcomes with lesser mental effort is more efficient than the environment that leads to a high which less mental effort is more efficient than a lower-yielding environment with greater mental effort. Define teaching efficiency in two-dimensional variables, namely student performance and mental effort. Instructional scientists use the measure of efficiency to measure instructional efficiency index.

The conceptual framework of this study is the experimental research from the meta-cognitive scaffolding (MS) strategy. The research design aims atlooking for the efficiency of the MS strategy by comparing between the MS strategy and the conventional teaching (CT) strategy in performance, students' mental effort, and instructional efficiency (IE), as illustrated in Figure 1.

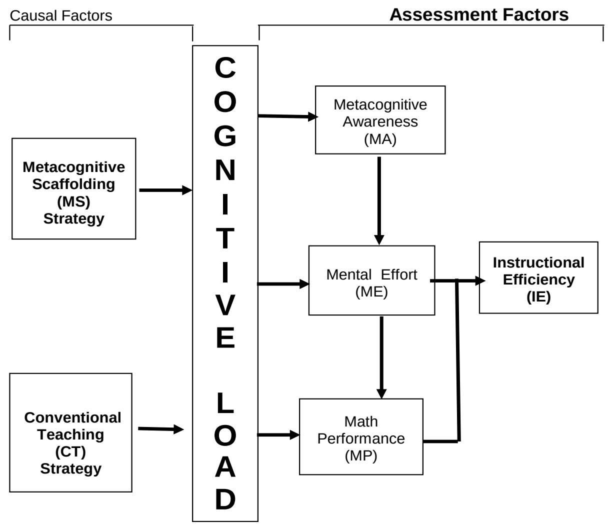

Figure 1. Path Diagram for MS, CT, and IE

METHOD

This study is conducted by using a quasi-experimental with pretest-posttest nonequivalent control group design. Two mathematics teaching and learning strategies based on meta-cognitive scaffolding (MS) and conventional teaching (CT) is compared on major dependent variables of the study (performance, mental effort, and instructional efficiency). This study measured and calculated the instructional efficiency that represented of instructional condition. This study is also identified students' responses (SR) for the implementation of MS strategy.

Instructional efficiency (IE) variable emerged that from the Cognitive Load Theory (CLT). With CLT, allows calculating the IE [4]. IE combines performance and mental effort invested in problem solving represented by the instructional efficiency index(E) .

The strategy can be compared not only in terms of effectiveness, but also in their IE. The difference in effectiveness is not always synonymous with different efficiencies [11].

Sample are randomly selected and involved 60 students among Form Eight students of SMPN 5 Malang City Indonesia which consisted of the experimental group (n=30) underwent learning using MS strategies and control group (n=30) underwent learning using CT strategies. A cluster-randomized sampling technique was used as the population in this study. The technique is appropriate in order to obtain selected sample from all classes as accessed population. The validity of cluster sampling also provided an accurate sample because the permission for use must be studied students in a group of students in existing classrooms.

There are four main instruments used in this study namely the Mathematics Achievement Test (MAT), Meta-cognitive Awareness Inventory (MAI), Paas Mental Effort Rating Scale (PMR), and Students' Respons Survey (SRS). Instructional efficiency index is calculated using 2-D instructional efficiency formula [12] & [9]:

$$E = \frac{Z_{performace} - Z_{mental\ effort}}{\sqrt{2}}$$

with Z is standardized performance and mental effort score.

For the purpose of this study, we focussed on MAT's instrument on 10 questions basic problem in mathematical subject of linear equation system of two variables and MAI's instrument focussed on 20 items were adopted as the measurement built byO'Neil and Jamal Abedi (1996). Each statement in MAI instrument describes their meta-cognitive awareness while solving mathematics problems. It is divided into four subscales of meta-cognitive awareness vis-a-vis the awareness subscale, cognitive subscale strategy, planning subscale and subscale self-check. MAI instrument was validated by a team of mathematics education experts resulting in a high alpha-Cronbach reliability index of 0.98. MAI and SRS to each statement on the Likert scale (1-5).The MRP instrument refers to a device built [11] and, used to measure perceived mental effort students in problems-solving, consists of 9 points symmetric Likert scale (1-9).

The results of data measurement were analyzed using three models of statistical analysis models, descriptive analysis, *t*-test independent sample, 2-way Analysis of Variance (ANOVA). Purpose *t*-test analysis to compare of mean of three major variables, performance, mental effort, and instructional efficiency index between MS and CT strategy of learning and teaching mathematics. In order to identify the main effect of teaching and learning mathematics strategy (MS and CT) and all major independent variables (performance, mental effort, and instructional efficiency) through 2-way ANOVA. Meanwhile, to describe students' view on the implementation of teaching and learning mathematics strategy base-on meta-cognitive scaffolding it is used descriptive analysis by calculate the mean of data of student response assessment for all major dependent variables.

Significant effects were found in that meta-cognitive scaffolding could be expressed as a causal factor in learning mathematics for the effects of learning strategy upon instructional efficiency. In terms of assessment factors, the instructional efficiency is represented by performance and mental effort. The significant effect is shown in Table 1. It can be noted how the total effect in the model represented by effect size (η^2), and stands as the effect of two sources: direct and indirect effects for instructional efficiency.

Table 1. *t*-test: Comparison Mean Performance of MS and CT Strategy

Measure	*d*	*t*	η^2	*p*
Performance	7.67	2.24	.08	.03 < .05
Mental effort	- .07	- 2.14	.07	.04 < .05
Instructional efficiency	.78	2.46	.09	.02 < .05

Analysis using *t*-test for comparison mean of all major variables of MS and CT Strategy showed significant difference ($p < .05$) between the MS and CT strategy on all major variables Mean difference values (*d*)and effect size (η^2) for each three major enabling studies namely performance, mental effort, and instructional efficiency is $d = 7.67$ ($\eta^2 = .08$), $d = -.07$ ($\eta^2 = .07$), and $d = .78$ ($\eta^2 = .09$) respectively.The findings showed that teaching and learning using the MS strategy is superior as compared to the CT strategy where the MS group has higher performance, and less mental effort invested during problem solving as well as induced higher levels of instructional efficiency. In conclusion, the teaching and learning of mathematics based on MS strategy is more efficient as compared to the CT strategy.

Using 2-way ANOVA analysis, also showed effect of teaching strategy (MS and CT) and mathematical achievement level (high and low) on three major enabling studies namely performance, mental effort, and teaching efficiency with value $F = 41.09$ ($p = .00 <.05$), $F = 10.41$ ($p = .00 <.05$), and $F = 29.1$ ($p = .00 <.05$) respectively with the size effect of the squares the lowest was .16 (high level). The findings, the 2-way ANOVA analysis showed that there were significant effects of teaching strategy (MS and CT) and mathematical achievement (high and low) on three key enabling findings: performance, mental effort, and instructional efficiency respectively.

Analysis of students' responses to the implementation of teaching and learning with MS strategies was obtained from the results of the SR questionnaire answered after teaching and learning activities with MS strategy. This indicates that the overall students' views towards the implementation of MS strategy such as the MS is interesting, new, easy, and fun to use in increasing mathematics learning understanding. The results as an assessment of the four indicators are presented in the Table 2.

Table 2. Mean Students' Response to The Implementation of MS Strategies

Aspect	***Mean***	***Criteria***
Interesting	3.72	Favourable
New	3.79	Favourable
Easy	3.57	Favourable
Fun	3.72	Favourable

The findings show that there is enhancement by the overall favourable students' views toward the implementation of MS strategy such as the MS is an interesting, new, essay, and fun to use in increasing mathematics learning understanding and problem solving.

These finding indicates that MS strategies are more efficient than CT strategies. The student in the experimental group had a high positive response to the implementation of the PM strategy with a mean overall of 3.72. They consider that the MS strategy is an interesting, new, easy and fun strategy to use in mathematics. The implication of a theoretical study is that MS strategy can be used as a basis for the improvement of teaching and learning in the context of constructivism theory. Practically, this study has an impact on teachers in using MS strategies in the classroom that support students with a math understanding and skillfully problem-solving.

RESULT

The present study was motivated by our desire to generate empirical data about the relationship between meta-cognitive scaffolding strategy (MS)and problem-solving ability in teaching and learning mathematicsto understand the students' learning strategy needs within their cognitive development process. A secondary purpose of this study was to test our hypothesis that MS strategy plays an important role in mediating the effect mental effort on problem-solving skill, associated to instructional efficiency. Literature review suggests that a core function of learning strategy for mathematics teachers is the building of their professional base which has been shown to be playing a critical role in decision making in their day-to-day work of teaching. However, the nature of this strategy base-on MS has not featured prominently in studies of teacher strategy and their development. In this present study, we have analyzed that MS strategy in terms of effecttowards the instructional efficiency and provided evidence that these three major variables strands ought to drive the teaching and learning programs for Elementary Secondary School mathematics teachers as argued [5], [2], & [6].

The results of this study confirm the previous study reviewed [5]. Jbeili's study encompasses three variables based on mathematical achievement, meta-cognitive knowledge and mathematical reasoning with the factors affecting as independent variable is the type of teaching and learning meta-cognitive scaffolding strategy and control in cooperative learning with conventional learning. The scope of Jbeili's study is on students in Elementary School (Form Five), studying only the effects associated with dependent variables, without studying how far their instructional efficiency are involving mental effort invested in problem solving. It can adversely affect the effect of MS on the three variables.

[2] finds various types of meta-cognitive scaffolding required for High School students (Nine Levels) with varying degrees of ability to solve mathematical problems. The results of their studies show that teaching and learning supported by MS have improved the mathematical performance of pupils in varying degrees of ability. Even so, their result of the study did not refer to the teaching efficiency involving the mental and mathematical performance of students in solving their problems or tasks.

In addition, [6] studied the teaching efficiencies associated with performance variables, mental effort, and meta-cognitive influences affected by teaching and learning strategies that integrate graphic calculators. The results obtained that class groups intersecting the use of graphic calculators in their teaching and learning score much better in all four variables, performance, meta-cognitive awareness, mental effort, instructional efficiency. Nor'ain's research findings for teaching for secondary school students (Form Four) have a better mean score on overall test performance.

In this study, results of t-test and 2-way ANOVA indicated that MS strategy had a direct effect on instructional efficiency, this effect was mediated via mental effort in CLT. We regard this finding as significant in extending the work of precious researcher.

The implication of the study is that the MS strategy can be used as a basis in mathematics teaching and learning within the framework of the constructivism theory continuously hence enables to be part of a routine instructional strategy practice in teaching and learning of mathematics which support students' mathematical problem solving understanding.

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