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TEACHERS' GENERAL PEDAGOGICAL KNOWLEDGE AND SELF-EFFICACY ON STEM INSTRUCTIONAL PRACTICES ON PRIMARY TEACHER

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Abstract. Not only cognitive knowledge, but also modern 21st-century instructional practices employed by primary school teachers are crucial for equipping students with a well-rounded education. But also to prepare students with the motivation, knowledge, and skills in science, technology, engineering, and mathematics (STEM) required for the digital age workforce. This study aims to determine the efficacy of STEM instructional practice training in enhancing primary school teachers' general pedagogical knowledge and self-efficacy. Forty-six primary school teachers from Sidoarjo, East Java, participated in the study. The experimental group (n=23) and the control group (n=23) comprised a total of 46 individuals. In the experimental group, participants received instruction in STEM-based mathematics learning planning. A questionnaire is used to assess teachers' general pedagogical knowledge and self-efficacy in STEM instructional practice before and after training. The study on teachers' general pedagogical knowledge revealed that, after training, the experimental group achieved better results than the control group. In the experimental group, the average score for the instructional process aspect increased to 9.5 points. The average value of the learning process aspect has increased by 15,5 points, while the average value of the assessment aspect has increased by 5,5 points. After receiving training, teachers in the experimental group demonstrated greater self-efficacy than their counterparts in the control group. The findings can be utilized by primary school teachers to enhance their STEM-related general pedagogical knowledge and self-efficacy.

Keywords**:** Teacher General Pedagogical Knowledge; Teacher self-efficacy; STEM; Primary School

I. INTRODUCTION

In contemporary 21st-century education, it is crucial to equip students not only with cognitive knowledge, but also with the science, technology, engineering, and mathematics (STEM) knowledge and skills required for the workplace in the digital era (Burton & Stehle, 2019; Rahman et al., 2022). Therefore, STEM-based instructional practice is essential for learning at all levels of education, especially at the early primary school level (Bressette et al., 2019; Yoon et al., 2014). STEM instructional practice in primary school education is the basis for controlling STEM practice itself at the next level of education (Malik, 2018).

The teacher is the maximum mediation to transfer primary school knowledge that involves STEM (Rahman et al., 2021). In this case, when implementing STEM instructional practices, primary school teachers must possess general pedagogical expertise and self-efficacy. Therefore, primary school teachers play an essential role in STEM practice because they become the foundation and strength to determine the right learning design to create a learning environment that suits student needs (Allen et al., 2016; Kelley et al., 2020). Thus, primary school teachers must use effective practices and approaches that are integrated with STEM.

Studies show primary school teachers still have problems implementing effective STEM instructional practices. For example in project-based learning (Freeman et al., 2014; Kennedy & Odell, 2014; Siew et al., 2015), inquiry-based learning (Kennedy & Odell, 2014; Mustafa et al., 2016; Siew et al., 2015), problem-based learning (Mustafa et al., 2012), and cooperative learning approach (Kennedy & Odell, 2014; Smith et al., 2015). In this case, the teacher must pay attention to several factors in determining effective learning practices to integrate STEM: good learning planning, classroom practice, teacher self-efficacy, teaching materials, and support from schools (Cheng et al., 2020; Stohlmann et al., 2012). Teachers' knowledge in managing and carrying out teaching practices so that the student class gets good results is called general pedagogical knowledge (Shulman, 1987).

General pedagogical knowledge in STEM instructional practices owned by teachers can help teachers to determine effective learning methods. So that innovative, inventive, and STEM-integrated students are formed to understand problems and solve them by applying them to real-world contexts that are useful for preparing for their future careers (Rahman et al., 2021). In addition, the ability of a teacher to manage the classroom and the quality of providing effective learning instructions are also influenced by the teacher's beliefs or self-efficacy (Holzberger et al., 2013; Klassen & Tze, 2014). In this case, Holzberger & Prestele (2021) explained that the ability of class management depends on the level of self-efficacy possessed by the teacher, the higher the self-efficacy of a teacher, and the better the ability of class management they can do.

In Indonesia, STEM education has been applied in the learning process since 2014 and continues to develop yearly. The authors consider the use of STEM in the learning process at primary schools in developing competence-oriented STEM instructional practices for primary school teachers. Competency development is getting increasing attention as a means to improve the quality of teacher learning (Kim et al., 2019). In this case, schools must provide competency development facilities regarding STEM to primary school teachers because teachers play an important role in STEM implementation (Mcdonald, 2016).

Several studies have conducted teacher competency improvement training to address STEM instructional practices. These trainings are oriented towards teacher competency development, including STEM instructional processes, learning processes, and integrated STEM teaching assessments. Empirical studies have been conducted on teacher competency development or training in STEM education (Cinar et al., 2022). Within the framework of our research, training on STEM instructional practice is used to equip primary school teachers to develop general pedagogical knowledge and self-efficacy in the learning process to become professional teachers with learning methods that align with the demands of the 21st century. The urgency of this study is needed to provide positive input. for students' interest in STEM learning (Rahman et al., 2021). Moreover, continuous improvement of teacher teaching abilities is also expected to support improvements in management, academic (curriculum), and educational facilities to lead to better student learning outcomes (Şahinkayasi & Kelleci, 2013; Shahmohammadi, 2015).

Literature Review

Teachers play a crucial role in enhancing students' STEM skills (Hanushek et al., 2005; Lasley et al., 2006; Mcdonald, 2016). To effectively implement integrated STEM, teachers must have in-depth knowledge of the science, technology, engineering, and mathematics content they teach, called general pedagogical knowledge (Eckman et al., 2016). Several existing studies show that teachers can improve STEM instructional skills with sufficient general pedagogical knowledge (Nadelson et al., 2012; Shulman, 1987). Principal component of teacher knowledge is general pedagogical knowledge. General pedagogical knowledge involves broad Management and organization principles for the classroom that appear to transcend subject matter and knowledge of learners and learning, assessment, and educational goals (Shulman, 1987). Furthermore, Grossman & Richert (1988) added that General pedagogical knowledge consists of knowledge of learning theory and general teaching principles, comprehension of various general educational philosophies, knowledge of students, and knowledge of teaching methods of classroom management principles and techniques. In this case, there are three main components in general pedagogical knowledge, namely student learning (cognitive, motivational, and emotional disposition of each student, the learning process and student development, student heterogeneity, and adaptive learning strategies), and assessment (principles of diagnosis and evaluation procedures) (Sonmark et al., 2017).

If they are to become competent educators, primary school teachers must utilize this information and integrate it into a unified understanding and skill (König & Blömeke, 2012). Instructional practice refers to teachers' methods and activities in the classroom (Underwood, 2015). Through meta-analysis, it has been shown that the quality of this practice is an important prerequisite of student learning and therefore has a major influence on student learning outcomes (Hattie, 2009). There are five main principles in STEM instructional practice: Incorporate STEM content, problem-based, inquiry-based, design-based, and collaborative learning. All of these principles stem from a social constructivist perspective on learning and complementarity (Thibaut, Ceuppens, et al., 2018).

Self-efficacy is related to a teacher's instructional practice attitude. In this case, self-efficacy positively correlates with the teacher's instructional ability and class management in implementing STEM model learning (Gok, 2021; Holzberger & Prestele, 2021; Thibaut, Knipprath, et al., 2018). Teacher self-efficacy is a person's confidence in his ability to organize and carry out the desired tasks and actions to achieve maximum results (Bandura, 1986). The quality of teacher teaching instructions is also something that cannot be separated from the influence of self-efficacy (Burić & Kim, 2020). A teacher with adequate self-efficacy will be better able to manage the class well and provide quality teaching (Klassen & Tze, 2014).

Improving teacher competence in STEM is needed to develop educational opportunities that prepare students for the major challenges of various STEM career fields (Siew et al., 2015). Developing STEM skills in early education is beneficial for students to develop problem-solving skills and learn to make connections to the real world. The significance of STEM education extends far beyond the primary classroom. Providing children with a solid foundation in STEM education prepares them for future success by equipping them with the critical thinking skills required to approach any problem logically and carefully (Bressette et al., 2019; McCarthy et al., 2019). Thus, competency

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development or training, especially In the areas of lesson planning, teaching, STEM content, assessment techniques, and the development of creative thinking skills, in order to aid teachers in the formation of STEM-competent students.

Research Objectives

In order to improve the pedagogic competence of primary school teachers in the framework of learning based on STEM instructional practices and teacher self-efficacy, the research objectives are divided into two.

1. Identify the effectiveness of STEM instructional practice training to improve teacher general pedagogical knowledge for primary school teachers.
2. Identify the effectiveness of STEM instructional practice training to increase the self-efficacy of primary school mathematics teachers.

II. Methodology

This investigation employs a pre-post test control group experimental design. There are three phases to the research.

1) Preparation stage: conducting an initial analysis related to teachers' understanding of STEM instructional practices in learning by giving questionnaires to teachers.
2) Implementation phase: providing teachers with an understanding of how to implement STEM instructional practice by using a module that contains an explanation of the STEM education program. This course is designed to help future educators find ways to make STEM education a path to school life that students find enjoyable. During the training, teachers will be able to apply innovative technology and scientific methods in the classroom in order to help them understand the significance of STEM education as a fun way for students to learn in school. After that, the administration was given a questionnaire about the teachers' general pedagogical knowledge about STEM instructional practices.
3) Final stage: interpreting of statistical indicators, determination of valid research samples, and processing of received data.

The Teacher Knowledge Survey Instrument (ITEL) is used to determine the level of teachers' general pedagogical knowledge in STEM education (Sonmark et al., 2017). The test consists of multiple questions divided into three categories: 1) Instructional process, which includes teaching methods, planning, and classroom management; 2) Learning process, which includes learning and development, as well as affective-motivational disposition; and 3) Assessment, which includes evaluation and diagnosis procedures, as well as data literacy and research.

To measure teachers' self-efficacy using the self-efficacy sub-scale of attitudes regarding integrated STEM education (Thibaut, Ceuppens, et al., 2018). In this case, the indicators used are 1) Integration of STEM content (INT) in terms of material content from diverse disciplines; 2) Problem-centered learning (PCL), in which students solve authentic problems; 3) Inquiry-based learning (IBL) regarding the activeness of students in asking questions, planning and designing experiments; 4) Design-based learning (DBL) regarding the activeness of students involved in the activities of making products or designs (robots, computer programs, etc.); 5) Cooperative learning (COL) regarding student involvement in group work. Questions about self-efficacy such as "How sure are you if you do the following in teaching STEM-integrated learning…". This scale uses a 5-point Likert scale with the following values: 1: strongly disagree, 2: disagree, 3: neutral, 4: agree, and 5: strongly agree. Cronbach's alpha values ranging from 0.74 to 0.94 indicate that the internal consistency of each subscale is reliable (Thibaut, Ceuppens, et al., 2018).

This research included primary school teachers from Sidoarjo, East Java. The composition of research participants remained constant throughout the duration of the study. The distribution of participants according to their demographic characteristics is shown in Table 1. Considering the number of participants specified, an experimental group and a control group were formed. Both the experimental and control groups consisted of 23 teachers. The experimental group consisted of teachers who were provided with an understanding of STEM instructional practice. The control group, in contrast to the experimental group, consisted of teachers who had already implemented STEM instructional practices.

The researcher chose the comparative and descriptive statistical analysis methods to analyze the research results. Statistical data processing is done with JASP 0.16.2.0. The standard deviation was the subject of a study. At $p<0.05$, the difference significance was determined. The differences in survey results were analyzed using the Paired t-test (Table 2).

TABLE 1.
DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

Demographic characteristics	Group	Total
Age	23-35	17
	36-48	15
	49-57	14
Gender	Woman	24
	Man	22

TABLE 2.
GUIDELINES FOR THE INFLUENCE OF T-TEST

Test Type	Categories			
	Very small	Small	Medium	Large
Cohens'd test	<0.2	0.2	0.5	0.8
Hedge's g test	<0.2	0.2	0.5	0.8
Non Parametrics (Rank-biserial)	<0.1	0.1	0.3	0.5

III. Results and Discussion

Table 3 displays the overall results of the ITEL pre-test for the control and experimental groups. Indicators of the two groups' teachers' general pedagogical knowledge

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corresponded to the average level and did not statistically differ during the initial test. The difference in average total score value was 0.913% (p=0.249).

TABLE 3.
RESULTS OF PRE-TEST FROM TEACHER KNOWLEDGE SURVEY INSTRUMENT

Test	Control Group (n= 23)	Experimental Group (n=23)	t	p
	M (SD)	M (SD)		
Instruction process	22.739 (5.387)	20.174 (4.141)	-1.811	0.077
Learning process	16.826 (4.648)	18.174 (4.224)	1.038	0.305
Evaluation	20.043 (4.258)	22.174 (4.144)	1.720	0.092
Total	59.609 (12.423)	60.522 (12.424)	0.249	0.804

*p<0,05

In Table 4, it can be identified that after attending training on STEM instructional practices, there are differences in every aspect and total teacher general pedagogical knowledge between the experimental and control groups. Based on these data, it shows that the total score of post-test results from the two groups has a significant average difference (p<.001) with a mean difference of 31.78, and the experimental group has a higher mean (M=91.087) = 59.304), compared to the control group (M). ITEL demonstrated a significant difference between the experimental group and the control group in terms of the instructional process (p<.001); the average difference between the two groups was 7.566.7 The ITEL learning process section also reveals a mean difference of 16,870 between the experimental group and the control group (p <.001). As for assessment, it revealed a significant difference between the experimental and control groups of 7,348 individuals (p<.001). A comparison of the experimental group's results with those of the control group revealed that training on STEM instructional practices had a positive impact on teachers' pedagogical knowledge in general.

TABLE 4.
RESULTS FROM POST-TEST ITEL TEACHER KNOWLEDGE SURVEY INSTRUMENT

Tests	Control Group (n= 23)	Experimental Group (n=23)	t	p
	M (SD)	M (SD)		
Instruction process	22.130 (3.293)	29.696 (7.277)	4.542	< .001
Learning process	16.826 (4.366)	33.696 (7.298)	9.534	< .001
Evaluation	20.348 (3.833)	27.696 (7.283)	4.285	< .001
Total	59.304 (10.84)	91.087 (21.83)	6.253	< .001

*p<0,05

After conducting experiments by providing training on STEM instructional practice, every aspect of teachers' general pedagogical knowledge increased. Table 5 displays the dynamics of the pre-test and post-test results in the experimental group.

TABLE 5.
DIFFERENCES OF AVERAGE PRE-TEST AND POST-TEST FROM THE EXPERIMENT GROUP

Aspects	Pre-test (n=23)	Post-test (n=23)	t	p
	M(SD)	M(SD)		
Instruction process	20.174 (4.141)	29.696 (7.277)	-9.053	< .001
Learning process	18.174 (4.224)	33.696 (7.298)	-14.75	< .001
Evaluation	22.174 (4.144)	27.696 (7.283)	-5.250	< .001
Total	60.522 (12.424)	91.087 (21.83)	-9.687	< .001

*p<0,05

Table 5 presents the outcomes of the STEM training. instructional practice that there is an increase in aspects of the instructional process with an average score of 9.5 points. The aspect of the learning process has increased the average value by 15.5 points, and the aspect of the assessment has increased significantly with an average value of 5.5 points.

TABLE 6.
RESULTS FROM PRE-TEST AND POST-TEST TEACHER SELF EFFICACY

Test	Control Group (n= 23)	Experimental Group (n=23)	p	T
	M (SD)	M(SD)		
Pre-test	88.21 (5.28)	92.13 (10.7)	0,125	1.563
Post-test	88.95 (7.66)	101.04 (16.3)	0,002	3.219

*p<0,05

TABLE 7.
DIFFERENCES IN AVERAGE OF TEACHER SELF-EFFICACY PRE-TEST AND POST-TEST FROM THE EXPERIMENT GROUP

Test	Pre-test (n= 23)	Post-test (n=23)	p	T
	M (SD)	M(SD)		
Teacher Self Efficacy	92.13 (10.78)	101.043 (16.29)	<.001	-5.783

*p<0,05

The experimental group's average total self-efficacy score was significantly higher than the control group's average total self-efficacy score, as shown by the analysis of data in Table 6, which was conducted after the experimental group

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received training on STEM instructional practice (p = 0.002 < .005) with a mean difference of 12,086. The experimental group had a higher mean (M=101,043) when compared to the control group (M=88,957). Meanwhile, Table 7, in more detail, describes Comparison of the experimental group's average pre- and post-test teacher self-efficacy showing a significant increase of 8,913 points (p<.001).

TABLE 8.
THE EFFECTIVENESS OF TRAINING ON STEM INSTRUCTIONAL PRACTICES IN TEACHERS GENERAL PEDAGOGICAL KNOWLEDGE

Aspects	Cohens'd Test	Effect Size
Instructional process	1.888 > 0.8	Strong
Learning process	3.077 > 0.8	Strong
Evaluation	1.095 > 0.8	Strong
Total teacher general pedagogical knowledge	2.020 > 0.8	Strong
Total Teacher Self-effcacy	1.206 > 0.8	Strong

The calculation results in Table 8 show the effectiveness of training on STEM instructional practices for developing teacher general pedagogical knowledge and teacher self-efficacy, indicating that the training provided has great effectiveness. This conclusion is based on the results of the Cohens'd test for the total score and aspects of teacher general pedagogical knowledge and teacher self-efficacy scores that were greater than 0.80. The results of the analysis of teachers' general pedagogical knowledge in the experimental group showed positive changes in all aspects.

Discussion

Competency development about STEM for primary school teachers needs to be held because teachers play an important role in STEM implementation. Competent teachers can shape students to have STEM knowledge and skills that are useful for their future careers. Literature analysis proves that teachers' STEM instructional practice training is important (Cinar et al., 2022). In developed nations such as the U.S, Turkey, Europe, and Malaysia, teacher training on STEM has been promoted. The results obtained from the effectiveness of STEM training for teachers showed positive results in teachers' knowledge of STEM instructional practices. This is in line with research by Suwarma & Kumano (2019) that STEM training for teachers improves the implementation of STEM education in schools.

The experimental training provided was effective in all teacher general pedagogical knowledge categories. In the experimental group, after being given STEM instructional practice training, it showed an increase In general pedagogical knowledge, instructional processes, learning processes, and assessment are included. During the training process, the teacher learns about the nature and integration of STEM education, determines and applies an appropriate approach, and evaluates the advantages and disadvantages of each approach that has been studied. In the training process, teachers show high initiative in participating in each stage of the training held. The use of STEM, or at least its components, arouses curiosity, promotes independent experimentation, and encourages the active exchange of experiences and ideas (Cook & Bush, 2018).

The results of this study have a significant positive impact on primary school teachers' general pedagogical knowledge. Previous studies have also argued STEM training improves teacher comprehension (Lambert et al., 2018; Siew et al., 2015). Not only increasing teacher knowledge, but training on STEM instructional practices also increase teacher self-efficacy needed by teachers when implementing it in the learning process. As the results of previous studies show that teaching internship experiences attended by teachers have a positive impact on teachers' beliefs and self-efficacy and enhance teachers' instructional abilities (Cohen et al., 2013; Michos et al., 2022; Rupp & Becker, 2021). A teacher with good self-efficacy will increase job satisfaction which will then affect the achievement of maximum performance (Caprara et al., 2013). In addition, a teacher who has adequate self-efficacy will improve their teaching skills more effectively (Klassen & Tze, 2014; Schiefele & Schaffner, 2015). Thus, it can be hypothesized that the training will equip teachers with STEM knowledge for more effective classroom application. Therefore, STEM training must be intensified to better prepare mathematics teachers (Siew et al., 2015).

IV. CONCLUSIONS

This study demonstrates the efficacy of STEM instructional practice training in enhancing the general pedagogical knowledge and self-efficacy of primary school teachers. In every category of the ITEL Teacher Knowledge Survey Instrument, experimental group mathematics teachers performed better than control group mathematics teachers (instructional process, student learning, and assessment). In the experimental group, the implementation of STEM instructional practice training resulted in a 9.5% improvement in instructional process aspects. The aspect of the learning process has significantly increased the average value by 15,5 points, while the aspect of the assessment has significantly increased the average value by 5,5 points. In addition, the self-efficacy of teachers in the experimental group averaged higher than in the control group. The experimental group increased by 8,913 points from pre-test to post-test.

Future research can concentrate on training in general pedagogical knowledge and self-efficacy for teachers at all levels of education in order for it to be effective in the development of professional STEM general pedagogical knowledge for teachers and the self-efficacy of primary school teachers in applying STEM concepts to learning on a larger scale. The results can be utilized by primary school teachers to enhance their professional development.

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