Jurnal Analisa 10 (2) (2024) : 127-136
http://journal.uinsgd.ac.id/index.php/analisa/index
p-ISSN : 2549-5135 e-ISSN : 2549-5143

Diagnostic Test as Formative Test in Mathematics Learning: A Meta-Analysis Study

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Received: 21 September 2023 ; Accepted: 28 Desember 2024; Published: 31 Desember 2023

DOI :10.15575/ja.v10i2.29911

Abstrak

Peserta didik memiliki kemampuan belajar yang berbeda-beda, sehingga peran guru sebagai fasilitator sangat diperlukan. Guru harus mengetahui kemampuan awal peserta didik secara individu melalui kegiatan penilaian agar guru mengetahui kemampuan peserta didik. Artikel dibuat bertujuan untuk mengetahui pengaruh penggunaan tes diagnostik sebagai tes formatif dalam meningkatkan hasil belajar matematika. Metode yang digunakan yaitu metode meta analisis dengan cara membandingkan informasi beberapa studi literatur penelitian yang seragam. Berdasarkan analisis 4 literatur, tes diagnostik dapat meningkatkan hasil belajar peserta didik melalui pembentukan kelompok heterogen. Perbandingan peningkatan hasil belajar peserta didik dapat diamati melalui presentase hasil ketuntasan sebelum dan sesudah dilakukan tes diagnostikyang kemudian dilakukan uji statistik *paired t test*. Hasil belajar peserta didik dilihat dari presentase ketuntasan belajar sebelum dan sesudah menggunakan tes diagnostik yang kemudian diolah menggunakan uji statistik tipe *paired sample*. Uji tersebut menghasilkan rata-rata peningkatan hasil belajar dari pretest yakni sebesar 63,93 menjadi 81,68. Hal tersebut menunjukkan hasil belajar peserta didik mengalami peningkatan setelah menggunakan tes diagnostik sebagai tes formatif pada pembelajaran matematika.

Kata kunci: Matematika, Tes Diagnostik, Tes Formatif

Abstract

Students have diverse learning abilities; thus, the role of the teacher as a facilitator is profoundly needed. Teachers have to recognize the initial abilities of each student through assessment activities so that teachers can identify students' abilities. This article aims to determine the influence of using diagnostic tests as a formative test in improving mathematics outcomes. The method used is meta-analysis by comparing information from several identical literature studies. Based on the analysis of 4 literature, diagnostic tests can improve students' learning outcomes by forming a heterogeneous group. A comparison of students' learning improvement can be observed by the percentage of learning mastery results before and after the diagnostic test, which carries out a statistical test, paired t-test. Students' learning outcomes were assessed by the percentage of learning mastery before and after using diagnostic tests, which were then processed using a statistical test paired sample. The test showed that the average increase in learning outcomes from the pretest was 63.93 to 81.68. It indicates that the student's learning outcomes have improved after using a diagnostic test as a formative test in mathematics learning.

Keywords: Mathematics, Diagnostic Test, Formative Test

1. INTRODUCTION

Mathematics is a discipline that explores abstract structures and the patterns within them. According to Dienes, mathematics studies abstract structures and their inherent relationships (Sugiyamti, 2018). A teacher who will teach mathematics to students must first comprehend the object to be taught, which is mathematics. How to comprehend the concept of mathematics cannot be quickly answered. Due to the fact that until now, there is no certain definition of mathematics because every expert has different knowledge and perspectives. Some experts argue that mathematics is the science of numbers and space, mathematics is a language of symbols, mathematics is a numerical language, mathematics is an abstract and deductive science, mathematics is a method of logical thinking, mathematics is the study of pattern relationship, shapes, and structures, mathematics is the queen of sciences and also serves other sciences.

Mathematics is empirically formed from human experiences in the world. Then, the experiences were processed in the world of ratios, analytically processed with reasoning in the cognition structure, resulting in the formation of mathematical concepts. A mathematical language or mathematical notation with global (universal) value is adopted to ensure that mathematical concepts are commonly understood and can be appropriately manipulated. Mathematical concepts are obtained through the process of thinking, therefore logic is the basis for the formation of mathematics. The earliest branches of mathematics were Arithmetic or Counting, Algebra, and Geometry, after which Calculus, Statistics, Topology, Abstract Algebra, Linear Algebra, Sets, Linear Geometry, Vector Analysis, and so on were discovered. Formal logic, developed by philosophers such as Aristotle, forms the foundation of many principles in mathematics. Various branches of mathematics, including set theory, number theory, and geometry, rely on logical principles to establish consistent systems (Sadewo et al., 2022). Mathematics has not only developed as a separate discipline but has also interacted with and contributed to the advancement of other sciences, being influenced by developments in logic and philosophy.

Nowadays, the progress of the times has led us to an industrial revolution that is closely related to mathematical reasoning skills. Mathematics is now a subject that students must learn in terms of computing. However, students have diverse characteristics in learning mathematics, particularly in learning ability. Some students quickly grasp what has been taught, and some are slow and have obstacles in learning. Thus, the role of the teachers as facilitators is profoundly needed. One form of a teacher's attempt as a facilitator is by implementing group learning to encourage students to participate in the learning process actively. The group formation may consist of heterogeneous groups based on different academic abilities, such as low, medium, and high.

According to Widdiharto, the essence of a teacher's job is the same as a doctor's job. A doctor will try to find out the cause of the disease suffered by the patient (Hikmasari et al., 2018). After the doctor knows the illness suffered by the patient, the doctor will provide medicine according to the disease suffered by the patient. The doctor's efforts by means of intensive examination are called diagnosis. With this, researchers associate learning evaluation with the use of diagnostic assessments which are expected after knowing the shortcomings of students in learning, they will get the right solution to achieve the completion value. Based on research by Duskri et al, that the product of the development of diagnostic tests for learning difficulties in mathematics is in the form of multiple-choice diagnostic test instruments (Duskri et al., 2014). Suwarto, said that diagnostic tests are useful for finding out learning difficulties faced by students, including conceptual misunderstandings, while summative tests are given at the end of a lesson to determine student learning success (Hikmasari et al., 2018).

As a facilitator, teachers do not serve as information providers that always allow students to merely obtain students the whole information but rather show the more prominent students in learning (Nurpaidah, 2016). Teachers as facilitators must understand students' abilities individually through assessment activities so that teachers can determine the student's initial abilities. Measuring students' abilities can be conducted by diagnosing students' learning difficulties individually (Anggraeni et al., 2017). A diagnostic test is an assessment that is applied to determine students' weaknesses; therefore, the results of the tests can be utilized as a basis for providing appropriate follow-up treatment that follows the weakness they have. According to Mehrens and Lehmann, an excellent diagnostic test can provide an accurate picture of students' misconceptions based on information about their errors. According to Van den Heuvel-Panhuizen and Becker (2003), assessment has the potential to be a lever to improve the quality of mathematics education and become a tool for systemic innovation (Azka Fuadia & Lya Diah Pramesti, 2023). Thus, the relationship between assessment and mathematics education is very close.

Based on this perspective, a diagnostic test can be defined as a means to discover misconceptions that students have based on information about their mistakes so that appropriate follow-up treatment can be provided according to the test results. There are various types of diagnostic test models such as multiple choice instruments, multiple choice instruments with reasons, multiple choice instruments with multiple reasons, multiple choice and description instruments and description instruments.

This diagnostic test can capture information regarding student errors in understanding the concepts (misconceptions), which is in line with one of the characteristics of a diagnostic test, that it must be able to capture information regarding students' difficulties in understanding a concept. With diagnostic evaluation, teachers are expected to find all the obstacles, how many students have problems in learning, and know how many students have the same learning problems. With diagnostic evaluation, teachers are expected to find all the obstacles, how many students have problems in learning, and know how many students have the same learning problems (Yasir, 2016).

Diagnostic test was originally a term from the health sector: diagnosis. Diagnostic activities can identify the type, character and background of a particular weakness, which then can be implied as an attempt to predict possible actions to resolve it (Putri et al., 2013). In education, weakness is often found in students learning difficulties in understanding a subject concept. One of the functions of diagnostic tests is to identify students' learning difficulties in the form of conceptual errors.

A diagnostic test is an assessment to determine the difficulties students face in a particular subject precisely. The material in this test is a material that is commonly considered to be challenging to understand by students. According to Arikunto a formative test is a test used to determine the extent to which students have been formed after following a particular program (Alzahra et al., 2024). The main purpose of the formative test itself is to provide feedback to students and teachers about the extent to which students understand the material that has been taught by the teacher so that it can be improved in the next learning process. Student performative test results can provide information about material students usually find difficult. Nitko and Brookhart divided six approaches to assess diagnostic tests related to learning problems (Saidah & Rinaningsih, 2012). They are the strength and weakness profile approach in the field, the approach to identifying prerequisite knowledge gaps, the approach to identifying learning targets that are not mastered, the approach to identifying student errors (misconceptions), the approach to identifying students' knowledge structures; also an approach to identify competencies for solving narrative questions.

In general, diagnosing difficulties can apply diagnostic tests and formative tests, which are conducted simultaneously or separately (in a particular way). Diagnostic and formative tests simplify for teachers, making them more efficient. Assessed by the function of a formative test, it can provide feedback and diagnostic tests, determining students' weaknesses individually and can be identified

all at once in a test. The test results obtained from students can be applied to assess students' level of learning mastery. The existence of diagnostic tests as formative tests is in forming heterogeneous groups that can break students' tension to discuss within the group.

This article aims to identify the impact of using diagnostic tests as formative tests in mathematics learning. Researchers reviewed several literature studies and concluded with a meta-analysis article comparing the diagnostic test results as a formative test in mathematics learning. The research question to be discussed in this article is "What is the impact of using diagnostic tests as formative tests on improving learning mastery?".

2. METHODS

Following the research objectives, the researchers employed a statistical test to compare the outcomes of several identical studies. The population in this research consisted of studies or research papers that addressed the same or similar topics, ensuring relevance to the meta-analysis. From this population, a sample of studies was selected based on predefined inclusion and exclusion criteria, such as publication year, research methodology, and data availability. Subsequently, a detailed data analysis was performed using the meta-analysis method, which is closely associated with literature studies. This approach involved systematically summarizing, mapping, and analyzing the primary data derived from the selected sample. The meta-analysis method allowed the researchers to synthesize findings from multiple studies, providing a comprehensive overview of the research field. By integrating statistically processed data from these studies, the researchers aimed to identify patterns, trends, and relationships that could enhance the overall understanding of the topic under investigation.

3. RESULTS AND DISCUSSION

The meta-analysis study is conducted to determine the impact of using diagnostic tests as formative tests in mathematics learning by comparing several literature studies. A diagnostic assessment or diagnostic test is a measurement that can provide opportunities in the testing process to serve an additional measure other than the objectives that have been set and integrate the learning and assessment processes (Sulastri et al., 2019).

Diagnostic assessment has five principles, which are: (1) the use of the diagnostic test as a test; (2) the instrument must be designed to be made simple, discrete, targeted, and efficient in helping teachers to diagnose; (3) in its process, the diagnostic test must include the thoughts of educators and students; (4) ideally includes diagnostic assessments, including observation, initial assessment, use of media, tests, expert assistance, and decisions; (5) there is a relationship between diagnostic test assessment and the treatment to be provided. The validation of the impact of using diagnostic tests as a formative test is tested with statistical tests before and after the use of diagnostic tests on students' learning mastery. Several relevant literature studies also reinforce the validation (Sawaluddin, 2018).

The results were analyzed by comparing three identical research articles to show the impact of the diagnostic test as a formative test in improving the student's learning outcomes. The three articles used for comparison are research conducted by George Tan Geok Shim, Abang Mohammad Hudzaifah Abang Shakawi, and Farah Liyana Azizan. (2017), Darmiyati (2017), P. Hikmasari, Kartono, S. Mariani (2017), Tiurlina (2013).

The data processing and summarization results are presented in the article with qualitative and quantitative descriptive methods. The percentage of results before and after the use of diagnostic tests as formative tests in 3 articles can be observed in Table 1.

Tabel 1. Improvement of Students' Learning Mastery

Authors	Percentage of Learning Mastery (%)		
	Before Using Diagnostic Tests	**After Using Diagnostic Tests**	**Improvement**
George Tan Geok Shim, Abang Mohammad Hudzaifah Abang Shakawi, and Farah Liyana Azizan. (2017)	78,90	79,43	0,53
Darmiyati (2017)	63,75	86,25	22,50
P. Hikmasari, Kartono, S. Mariani (2017)	70,75	78,97	8,22
Tiurlina (2013)	42,33	82,08	
Average	63,93	81,68	17,75

According to Table 1, the percentage results of students' learning mastery in three articles show that the average percentage of students' learning mastery before using the diagnostic test is % and after using the diagnostic test is %. It shows an increase in the average of students' learning mastery by %. The role of diagnostic tests as formative tests can help in improving students' learning mastery. Besides, it also helps teachers provide feedback by forming heterogeneous groups so that effective learning occurs.

A diagnostic test was also applied as a formative test where teachers can provide feedback and discover the weaknesses of individual students individually in one test (Yasir, 2016). Feedback was provided by analyzing students' weaknesses in understanding several indicators that need to be emphasized or improved. A diagnostic test as a formative test was not applied to determine the grade. The better the diagnostic evaluation, the more defined the applied learning objectives. Diagnostic tests as formative tests have a particular emphasis on treating students' learning difficulties. Diagnostic tests used as a reference in assisting learning can facilitate students in understanding the material with guidance from the teacher and their own friends. Diagnostic tests also keep students focused on individual abilities (individualized learning) (Yasir, 2016).

The utilization of individualized learning can not be separated from the formation of heterogeneous groups. The formation of heterogeneous groups is done by considering students' academic ability. Learning progress from the use of diagnostic tests in learning as a consideration for the formation of heterogeneous groups can be seen from the data on the percentage of students' learning mastery results carried out paired sample type statistical test analysis, and the obtained statistical test results can be observed in Table 2, Table 3, and Table 4.

Tabel 2. *Paired Samples Statistics*

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRE	63.9325	4	15.67594	7.83797
	POST	81.6825	4	3.33924	1.66962

Tabel 3. *Paired Samples Correlations*

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	PRE & POST	4	.392	.608

Tabel 4. *Paired Samples Test*

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	PRE – POST	1.77500E1	17.26182	8.63091	45.21742	9.71742	12.057	3	.132

Based on table 2 shows that testing diagnostic tests as formative tests from several studies has an average student learning mastery before using a diagnostic test 63.93 and has increased after using a diagnostic test of 81.68. Meanwhile, Table 3 shows the correlation number of the average value before and after using the diagnostic test as a formative test reached a correlation number of 0.392. The significant value before and after using the diagnostic test in Table 3 results in (0.608) > α (0.05), which means that there is no correlation between before and after using the diagnostic test as a formative test. The calculation of the hypothesis test is as follows:

Hypothesis testing can be concluded if H0 = no significant difference in the improvement of students' learning outcomes before and after applying the diagnostic test as significant to students' learning outcomes before and after applying the diagnostic test as a formative test.

Noted :
T count = 2,057 Df = 3
Dk = n – k
Dk = 4 – 1 = 3
Assumed :
T count < T table, then H0 = rejected dan H1 = accepted
Questioned :
T table ?
Then :
T table = 1 – ½ *x* (α)
1 – ½ x (0,05)
1 – 0,025 = 0,975

Afterwards, the T table value was calculated. Given that t is 0.975 and dk is 3, the T table value is 4.303. Hence, the result of T count (12.057) < T Table (4.303) shows that H0 is rejected and H1 is

accepted. There is a significant difference in learning outcomes obtained by students before and after applying diagnostic tests as formative tests in mathematics learning. Subjectively, it is expected to make teaching better. Based on the result of statistical data processing, it can be seen that using diagnostic tests as formative tests to determine learning difficulties can assist teachers in providing feedback. The diagnostic information of students obtained by the teacher will invite students to play an active role in improving learning activities. This kind of diagnostic focuses on the learning process; thus, the application of the diagnostic test is almost the same as the formative assessment (Maharani & Rinaningsih, 2015).

Teachers use assessment to plan the learning process, but assessment should remain separate from the learning process, ensuring that students perceive diagnosis as part of the support or learning process (Zhao, 2013). The support is reflected in improving learning outcomes by providing feedback and considering diagnostic tests as formative tests in heterogeneous group formation. The continuation of using diagnostic tests as formative tests in heterogeneous group formation can provide students opportunities to teach and support each other and improve relations and interactions between race, ethnicity, and gender (Purba, 2016).

However, heterogeneous teaching in the classroom is challenging. The main challenge in heterogeneous teaching is customizing instruction to the individual needs of each student. Applying diagnostic tests as formative tests can provide information on students' current level of development. Diagnostic test contribution focuses on personalizing learning, such as teaching, to align with individual students' needs. Diagnostic tests as instruments are assumed to be more appropriate because diagnostic tests as formative tests utilize intensive observation.

Basically, assessment is a critical component in an education system and plays an essential role in the student learning process. By measuring students' learning outcomes and skill proficiency, assessment aims to support students to learn. At the same time, for teachers, assessment can improve teaching, map teaching materials, and evaluate the success of the learning program conducted by the teacher. Assessment is the process of obtaining or collecting data. When associated with learning, assessment is a strategy for teachers to discover the learning process and student learning. Also, teachers will determine whether the conducted learning process is working correctly or still needs to be revised or improved. Again, for students, it defines whether the learning provided by the teacher has been able to encourage them to study or not. The quality of education at the micro level determines the learning process in the classroom, including the evaluation system.

A set of stages in the diagnostic assessment that must be taken during the validity test to experts are: (1) identifying the basic competencies and indicators; (2) compiling the learning continuum; (3) compiling the material hierarchy; (4) compiling the attributes; and (5) question construction. First, it is known that there is a change in the position of the indicators, and it is made because of the discrepancy in the order made by the researcher during the validation process with the teacher. Changes in position occur because they adjust to the order in which students must first recognize and understand the material. Second, several indicators were eliminated. This decision was reached after researchers and teachers reviewed it together. In general, some indicators did not match the basic competencies. The reason is that the sub-material related to the indicator is too early to be taught in class. After researchers and teachers discussed, they finally agreed to complete the indicator to match the order in introducing the material to students.

The process in the second stage is the arrangement of the learning continuum. Changes occurred when the instrument entered the expert validation stage. The order of the learning continuum has been adjusted based on the order at the stage of identifying indicators. During the identification stage, researchers and teachers also adjust the order of what material must be understood first by students. The learning continuum essentially has an influential role and needs to be considered. Subali stated that "if a principle subject in the learning process does not pay attention to continuity

of material at each level, it will make the learning process ineffective. Thus, it requires a reference in drafting a lattice in the form of a functional learning continuum as a learning target.

The third stage of the process concerns the hierarchical arrangement of the material. Before arranging the hierarchy of material, it is necessary to determine the indicators that students must achieve. These indicators were chosen from the learning continuum in the previous stage. At this stage, the researcher did not change the instrument prepared when conducting validation as the only thing that needs to be changed is the sequence number adjusted to the changes in the learning continuum. In addition, only one indicator needed to be removed from the prerequisite material because it did not match the main attributes. Changes were made based on considerations and agreements between researchers and teachers. The rest are only adjustments to the changes in the second stage of the process.

The fourth stage is arranging attributes. The arrangement of attributes is obtained from the prerequisite material in the previous stage. These attributes were named and coded, which is beneficial in making the Q matrix. The arrangement also did not change, apart from eliminating one of the indicators removed in the third stage because it did not match the main attributes students had to achieve. In the Q matrix, researchers used a 3x4 Q matrix size.

The arrangement of the Q matrix has not changed, as it is already following the arrangement of the attributes. The last stage of the process is question construction. After completing the processes, the questions are designed at this stage. Diagnostic assessment questions do not have a high level of difficulty because the diagnostic test was tested to determine to what extent students understand a concept that has not been comprehended or that has been comprehended. It is not an achievement test. It is in line with Suwarto's idea that "diagnostic test contains material that students may consider to be difficult, but the difficulty level of the test tends to be low".

Therefore, at this validation stage, one question was replaced due to its high difficulty level, so it did not meet the characteristics of a diagnostic test question. In addition, there is also a justification of the language structure in the question sentence that does not follow EYD rules. Researchers considered it needs to be corrected. The rest of the questions' changes are only in the estimated working time since the researchers did not include it. This validity test is not only validated by experts but there needs to be students' involvement to see the misconceptions that exist in the minds of teachers and students, whether they have the same thoughts or not.

Hence, an empirical validation test was also conducted. The validation is similar to the non-subject field trial. At this stage, students were asked to answer questions in descriptions. Using this question, researchers quickly analyze student answers and identify the exact exemptions. This empirical validation is highly applicable if tested on students from various schools. The more diverse the students' answers, the easier for researchers to identify the exact exemptions.

4. CONCLUSION

The conclusion that can be drawn is that the existence of diagnostic tests as formative tests can improve students' learning abilities. Diagnostic tests as formative tests can be utilized in mathematics learning to form heterogeneous groups. Based on the analysis of 4 literature, diagnostic tests can improve students' learning outcomes by forming heterogeneous groups. Comparison of the improvement of students' learning outcomes can be observed through the percentage of learning mastery results before and after the diagnostic test, which is then a paired statistical t-test conducted. Students' learning outcomes are assessed from the percentage of learning mastery before and after using the diagnostic test, which is then processed using a paired sample type statistical test. The test has produced an average increase in learning outcomes from the pretest, which is 63.93 to 81.68. It

indicates that students' learning outcomes have increased after using diagnostic tests as formative tests in mathematics learning.

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