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Changes in Mathematics Learning Outcomes Following Active and Meaningful Learning in Grade XI

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ABSTRACT

Students often find mathematics difficult because its concepts are abstract, so instruction needs to engage students actively and connect new concepts to prior knowledge. Active and Meaningful Learning (AML) combines active physical and mental engagement with the integration of new information into existing cognitive structures. Existing studies mostly examine active learning and meaningful learning separately, and little is known about the classroom implementation of AML with explicit stages. This study examined changes in Grade XI students' mathematics learning outcomes after AML instruction on relations and functions, algebraic operations on functions, and function composition. A quantitative, pre-experimental one-group pretest–posttest design was used. The participants were 32 students from one intact class assigned by the cooperating teacher from 12 Grade XI classes at a state senior high school in Indonesia. AML was implemented in five stages (engagement, active exploration, meaning construction, reflection, and evaluation) over six 90-minute meetings. Data were collected with an essay-based achievement test and analyzed with a paired-samples t-test after the normality of the difference scores was checked. The mean score increased from to Scores; therefore, it increased significantly after AML instruction. Because there was no control group, the class was not randomly assigned, and the equivalence of the parallel pretest and posttest forms was not tested, the increase cannot be attributed to AML with certainty. The findings document a classroom implementation of AML and suggest it merits further testing with comparison groups.

Keywords: Active and Meaningful Learning: active learning; mathematics learning outcomes; meaningful learning; pretest–posttest design

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INTRODUCTION

Students often regard mathematics as difficult because its concepts are abstract. This condition calls for instruction that engages students actively while relating mathematical ideas to what they already know. ((NCTM), 2000) positions problem solving, reasoning, and conceptual understanding as central goals of school mathematics , and mathematical concepts become more accessible when students can connect them with familiar situations and prior experiences (Irwan & Murti, 2023). One learning model that integrates student activity with the organization of knowledge in cognitive structure is the Active and Meaningful Learning (AML) model.

Active learning involves students in doing things and thinking about what they are doing, rather than only listening to teacher explanations (Bonwell & Eison, 1991). Its conceptual roots lie in constructivist traditions: (John Dewey, 1938) emphasis on learning through experience, (Jean Piaget, 1952) account of assimilation and accommodation, and (Vygotsky, 1978) view that understanding develops through social interaction within the zone of proximal development. In this study, these ideas are operationalized through concrete classroom activities: students work on tasks in groups (social interaction), pose questions and explain their reasoning (verbalization), and use learning media or teaching aids (experience with concrete representations).

Studies in mathematics generally report favorable results for active learning, although they differ in educational level, topic, design, and outcome. (Evendi, 2022) used a randomized pretest–posttest control design in mathematics courses and found that active learning strategies improved students' critical thinking more than expository teaching. (Maulidiawati et al., 2022) reported that the Quiz Team active learning model influenced senior high school students' mathematical problem solving. (Shi et al., 2019) meta-analyzed the effects of technology-enabled active learning environments on college students' cognitive learning outcomes. Because these studies concern different levels, topics, designs, and outcomes (critical thinking and problem solving rather than overall achievement), they are treated here as general background on the potential of active learning, not as direct evidence for AML.

Meaningful learning is rooted in (Bryce & Blown, 2024) assimilation theory. It holds that new material is learned meaningfully when it is substantively and non-arbitrarily related to relevant concepts already present in the learner's cognitive structure, the material is potentially meaningful, and the learner is disposed to learn meaningfully. This differs from merely using everyday contexts: a real-life context may attract interest, but meaning arises only when the new concept is connected to what the learner already knows. In this study, students' prior knowledge was identified from the pretest.

In mathematics education, meaningful learning is commonly linked to contexts that carry meaning for students. (Polman et al., 2021) found that teachers' views of meaningful mathematics learning ranged from students understanding what they learn to connecting it with their daily experiences. A research synthesis by (Koskinen & Pitkaniemi, 2022) concluded that contextual, concrete, and social teaching approaches support meaningful learning in mathematics, together with an affectively favorable classroom atmosphere. (Irwan & Murti, 2023) combined Meaningful Instruction Design with Realistic Mathematics Education in a one-group pretest–posttest study and reported improved learning outcomes on fractions.

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Conceptually, AML brings together active physical and mental engagement and the integration of new information into existing cognitive structures. (Jonassen & Strobel, 2006) characterize meaningful learning as active, constructive, intentional, authentic, and cooperative. In the AML implementation reported here, five stages are used: engagement and active exploration represent the active element, meaning construction represents the meaningful element, and reflection and evaluation consolidate and measure students' understanding.

(Nurahmah et al., 2024) developed the AML model and reported it as valid, practical, and effective, including pretest–posttest evidence from a senior high school class. However, that report is brief and gives little detail on the instructional stages, topics, or classroom processes. The five stages used in this study were formulated by the researcher (see Method). To the authors' knowledge, based on a literature search in Google Scholar using the keywords "Active and Meaningful Learning", "Active and Meaningful Learning in Mathematics", "*hasil belajar matematika*", and "*pembelajaran aktif dan bermakna*", few studies describe the classroom implementation of AML with explicit stages and report its learning outcomes in senior high school mathematics. This study addresses one question: Do Grade XI students' mathematics learning outcomes differ before and after instruction with the AML model? Because the design has no control group, the study examines observed change rather than a causal effect.

METHOD

Research Design and Setting

This study used a quantitative approach with a pre-experimental one-group pretest–posttest design. The same group took a pretest, received AML instruction, and then took a posttest. This design can document change in learning outcomes but cannot isolate the contribution of AML from other influences such as testing, maturation, history, regression to the mean, or changes in the instrument (Campbell & Stanley, 1963; Shaadish et al., 2002). The study was conducted at a state senior high school Indonesia, in six meetings on 22–23 July, 29–30 July, and 5–6 August 2026.

Participants, Instruments, and Procedures

Participants. The population comprised all Grade XI students of the school, who were distributed over 12 classes. The sampled class was assigned by the cooperating teacher according to the school's class allocation, so the sample was a convenience sample of one intact class and students were not randomly assigned. All 32 students of the class took both tests, giving 32 pairs ($df = 31$).

Ethical procedures. The study was carried out with the permission of the cooperating teacher and the consent of the students, as part of regular classroom instruction. Only aggregated and anonymized scores are reported.

Instruments. Two instruments were used. The first was an essay-based mathematics achievement test, administered as a pretest and a posttest. Both tests had 5 main items (11 sub-items in the pretest and 13 in the posttest) and covered the same indicators: relations and functions (ordered pairs, domain, codomain, range, identifying functions and their properties), algebraic operations on functions (sum, product, quotient, and their domains), function composition, and contextual composition of sequential processes. The pretest and posttest were constructed to be equivalent but not identical: they used the same indicators, item types, and comparable difficulty, with different numbers and contexts. Each item was scored with an analytic rubric that assessed the steps and the final answer (for example, 4 points for

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the sample item below), and the total was converted to a 0–100 scale (score obtained divided by maximum score, multiplied by 100). A sample item of the type used in both tests is: "A coffee small enterprise produces coffee in two processing stages. In the first stage, coffee beans are processed into coffee powder with the function $f(x) = 2x$, where x is the kilograms of beans used. In the second stage, the powder is packed with the function $g(x) = \frac{x}{5} + 3$. (a) Determine the composite function that gives the number of coffee packs produced from x kg of beans. (b) If 35 kg of beans are available, determine the number of packs produced." The item assesses solving contextual problems with function composition and is scored 4 points: setting up the composition (1), substitution and result for part (a), $(g \circ f)(x) = (2/5)x + 3$ (1), substitution of x = 35 (1), and the final result of 17 packs (1).

The equivalence of the two forms was based on the test blueprint and expert review; it was not tested empirically (for example, by item difficulty analysis), so differences in difficulty cannot be excluded (see Limitations). Content validity was judged by two validators: an experienced senior high school mathematics teacher who had taught the topic and a peer colleague; no content validity index was computed. Reliability was not tested, so the results are interpreted with this limitation in mind. All scripts were scored with the rubric by the researcher, who was also the teacher; no second scorer was used.

Procedures. The pretest was given before the first meeting. Instruction on relations and functions, algebraic operations on functions, and function composition was then delivered by the researcher in six meetings of 90 minutes each (22–23 July, 29–30 July, and 5–6 August 2026), using student worksheets (LKPD) and presentation slides. The five AML stages were formulated by the researcher by integrating principles of active learning (student activity through discussion, questioning, and the use of media) and meaningful learning (linking material to prior knowledge and real-life contexts), with reference to the characteristics of meaningful learning described by (Bryce & Blown, 2024; Jonassen & Strobel, 2006) meaningful learning theory. Engagement and active exploration represent the active element, meaning construction represents the meaningful element, and reflection and evaluation consolidate and measure students' understanding. The stages and the activities in each are summarized in Table 1. In this study, the evaluation stage (stage 5) was operationalized as the posttest, which students took individually after the instructional activities and which also served as the measure of learning outcomes; no separate formative evaluation scores were collected.

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Table 1. Stages of the AML Model as Implemented

Stage	Student and teacher activities	Example task or activity
1. Engagement	Builds curiosity and links the topic to a real context.	Illustration of the weaving process (cotton to thread to cloth) and the trigger question: How can the relationship between the amount of cotton and the amount of cloth be expressed as a function?
2. Active exploration	Groups investigate patterns through discussion, using the student worksheet (LKPD).	Groups analyze tables of production cost f(x) and distribution cost g(x) of a local snack business, add the two functions, and compare the results for several values of x.
3. Meaning construction	Students turn exploration results into mathematical conclusions and link them to symbols and context.	Formulating $(f + g)(x) = f(x) + g(x)$ and explaining its meaning as total production and distribution cost.
4. Reflection	Students become aware of their understanding, difficulties, and learning process.	Reflection sheet: What concept did I understand today? What difficulty did I experience? How does the concept of function help solve contextual problems?
5. Evaluation	Students take the posttest individually; it evaluates their understanding and also serves as the outcome measure.	Item type: if spinning is $f(x) = 2x$ and weaving is $g(x) = 3x - 1$, determine $(g \circ f)(x)$ and its value for $x = 3$.

Data Analysis

Analysis followed the steps shown in **Figure 1**. First, descriptive statistics (minimum, maximum, mean, and standard deviation) were computed for pretest and posttest scores. Second, because the paired-samples t-test assumes that the difference scores of the pairs are approximately normally distributed and that pairs are independent, normality was examined on the difference scores (posttest − pretest) with the Shapiro–Wilk test. A non-significant result is read as lack of evidence against normality, not as proof of it (Ghasemi & Zahediasl, 2012). If the assumption had been clearly violated, the Wilcoxon signed-rank test would have been used.

Third, the paired-samples t-test was run at $\alpha = .05$ (two-tailed) with $H0$: the mean difference equals zero. Differences are reported as pretest − posttest, so a negative value indicates a higher posttest mean. The mean difference is reported with its 95% confidence interval and the paired effect size d_z, the mean difference divided by the standard deviation of the differences (Cohen, 1998; Lakens, 2013). Fourth, the number of students whose scores increased, decreased, or stayed the same was tabulated. Analyses were run in IBM SPSS Statistics version 26.

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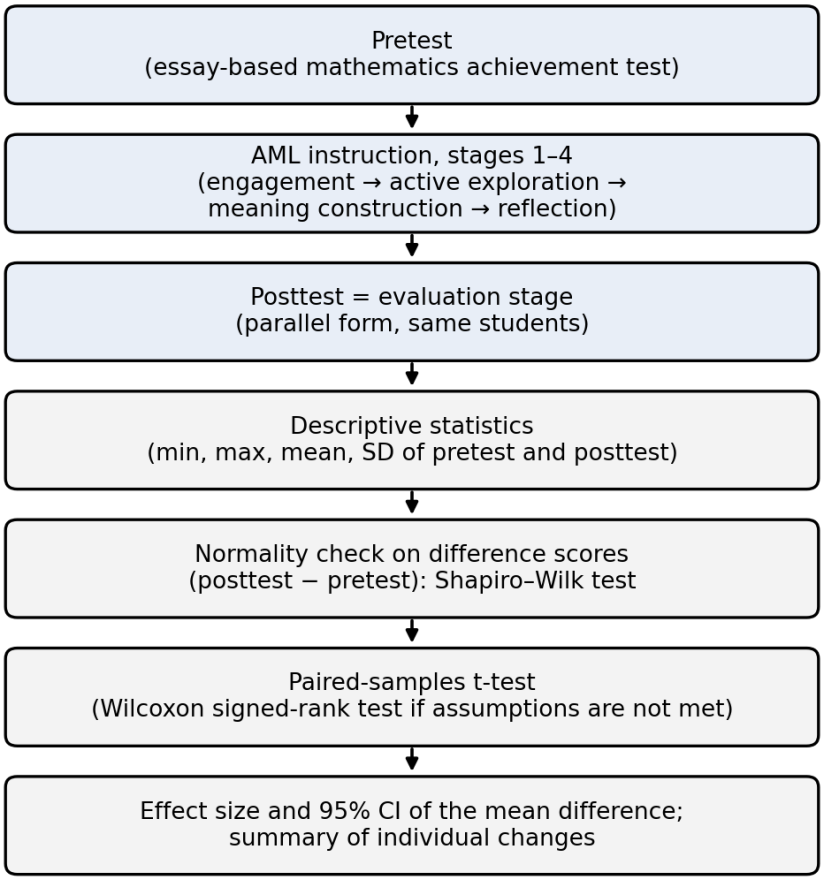

Figure 1. Analysis Flow of the Study

RESULTS

Descriptive Statistics

Table 2 shows that the mean score rose from 43.91 ($SD = 25.52$) at pretest to 62.59 ($SD = 21.29$) at posttest, an increase of 18.69 points on a 0–100 scale. The minimum score rose from 5.00 to 15.00 and the maximum from 85.00 to 100.00 (see **Figure 2**). The standard deviation was smaller at posttest, indicating a somewhat narrower spread of posttest scores. This does not by itself show that the benefit was spread evenly among students, so individual changes are examined below.

Table 2. Descriptive Statistics of Pretest and Posttest Scores

Test	N	Min	Max	Mean	SD
Pretest	32	5.00	85.00	43.91	25.52
Posttest	32	15.00	100.00	62.59	21.29

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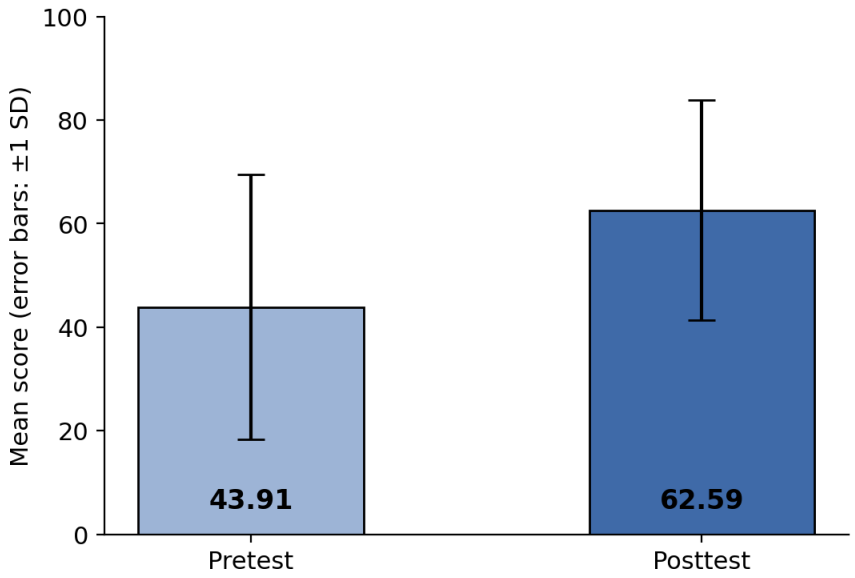

Figure 2. Mean Pretest and Posttest Scores

Assumption Check

Table 3 reports the normality tests. The Kolmogorov–Smirnov results for the pretest (Sig. = .082) and posttest ($Sig. = .170$) are given for completeness; the assumption of the paired-samples t-test concerns the difference scores. For the difference scores, the Shapiro–Wilk test gave $W = 0.987, p = .957$. Because p was larger than $.05$, there was not enough evidence that the difference scores deviate from a normal distribution, and the paired-samples t-test was considered appropriate.

Table 3. Normality Tests

Variable	N	K–S statistic	K–S Sig.	S–W statistic	S–W Sig.
Pretest	32	0.146	0.082	–	–
Posttest	32	0.132	0.170	–	–
Difference (posttest − pretest)	32	–	–	0.987	0.957

Paired-Samples t-Test

The paired-samples t-test showed a statistically significant difference between pretest and posttest scores, $t(31) = -4.904, p < .001$. The mean difference (pretest − posttest) was $-18.69, 95\%\ CI\ [-26.46, -10.92]$, and the paired effect size was $d_z = 0.87$, a large effect by (Cohen, 1998) benchmarks. $H0$ was therefore rejected. As a sensitivity check, a Wilcoxon signed-rank test also indicated a significant difference ($p < .001$). This indicates that scores were higher after AML instruction; because the study has no control group, it does not establish that AML caused the increase (see **Table 4**).

Table 4. Paired-Samples t-Test Results

Comparison	M diff.	SD diff.	95% CI	t	df	p	d_z
Pretest − posttest	−18.69	21.55	[−26.46, −10.92]	−4.904	31	< .001	0.87

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Individual Changes

Of the 32 students, 26 (81.25%) scored higher on the posttest and 6 (18.75%) scored lower; no student had an unchanged score. The median change was 16.50 points (range −29 to 70; interquartile range 3.75 to 33.50). All six students whose scores declined had pretest scores between 50 and 80, and the correlation between pretest score and gain was negative ($r = -.60$): students with low pretest scores gained the most, whereas students with high pretest scores gained little or declined.

DISCUSSION

Students' mean score was 18.69 points higher at posttest than at pretest, with a large paired effect size. This is an observed increase following AML implementation in one class. Without a control group, it cannot be attributed to AML alone, and the interpretations below are theoretical explanations rather than empirical findings. The direction of the result is consistent with other studies of active or meaningful learning in mathematics. (Maulidiawati et al., 2022) reported that an active learning model influenced senior high school students' mathematical problem solving, and (Irwan & Murti, 2023) reported improved fraction outcomes after Meaningful Instruction Design combined with Realistic Mathematics Education, using a one-group pretest–posttest design like the present one. (Nurahmah et al., 2024), who developed AML, likewise reported better learning outcomes after AML than before in a senior high school class. These studies differ in topic, level, and design, so they are comparable in direction only.

The five stages operate together, and this design cannot separate their individual contributions. Theoretically, each stage can be linked to the result as follows. Engagement may have raised students' involvement and motivation at the start of each lesson. Active exploration, through group discussion, questioning, and the use of media, gave students chances to verbalize and test their ideas, which is consistent with the role of social interaction in (Vygotsky, 1978) account and with the contextual, concrete, and social approaches identified by (Koskinen & Pitkaniemi, 2022). Meaning construction linked new concepts to prior knowledge and real-life contexts, which is the core of (Bryce & Blown, 2024) assimilation theory. Reflection may have helped students monitor their understanding, and the evaluation stage (the posttest) measured attainment. These links are theoretical, because implementation fidelity was not quantified. Retention and conceptual understanding were not measured separately, and motivation and attitudes were not measured, so these explanations remain tentative

Of the 32 students, 26 improved and 6 scored lower at posttest than at pretest (see Results). No supporting data (such as interviews or student records) were available to identify the reasons, so the decline is not attributed to any specific factor; it is a reminder to attend to individual learning needs. The negative correlation between pretest score and gain is consistent with regression to the mean, which the one-group design cannot separate from the effect of instruction. The smaller standard deviation at posttest should likewise not be read as evidence that the benefit was equalized, because it describes the spread of scores, not the distribution of individual changes.

This study adds a documented classroom implementation of AML with explicit stages in Grade XI mathematics, reporting observed pretest–posttest change with an effect size and confidence interval. It does not show why or for whom AML works, which would require comparison groups and process data. For practice, teachers may consider combining active participation with meaningful connections to prior knowledge as one alternative for supporting mathematics learning.

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Several limitations should be noted. First, there was no control group and the class was assigned by the cooperating teacher, not randomly, so threats such as selection, testing, maturation, history (other lessons during the intervention), regression to the mean, and instrument or scoring changes cannot be excluded. Second, the pretest and posttest were parallel forms whose equivalence was not tested empirically, so differences in difficulty may have contributed to the score change. Third, test reliability was not tested, content validity relied on two validators, and one rater, who was also the teacher, scored all scripts without a second scorer, which may introduce bias. Implementation fidelity of the AML stages was also not quantified. Fourth, only one class from one school was involved, which limits generalization, and the posttest followed instruction directly, so long-term effects are unknown.

CONCLUSION

This study found a statistically significant increase in Grade XI students' mathematics learning outcomes from pretest to posttest after the AML model was implemented in one class. Because the one-group design has no control group and the equivalence of the pretest and posttest forms was not tested, the increase should be read as an observed change, not as a causal effect of AML. Within this limitation, AML, which combines student engagement with meaningful connections to prior knowledge, can be considered a promising alternative for mathematics instruction that merits further testing. Future research should use control or comparison groups, equivalent pretest and posttest forms, larger and more diverse samples, and process data (observation or interviews) to explain individual differences, and should examine long-term effects across other mathematics topics.

DECLARATIONS

Author Contributions: All authors contributed to the conceptualization, research design, data collection, analysis, interpretation of results, and manuscript preparation. All authors reviewed and approved the final manuscript.

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Ethics Approval and Consent: This study examined Grade XI students with the school's approval. It involved collecting and analyzing students' mathematics outcomes while adhering to ethical guidelines and confidentiality requirements.

Data Availability: This study uses data on students' mathematics learning outcomes from active and meaningful learning. To ensure privacy, this data is not publicly available but can be requested from the corresponding author with appropriate permissions.

Conflict of Interest: The authors declare no conflicts of interest related to this research

Use of Generative AI: The authors declare that no generative AI tools were used in conducting the research or preparing the manuscript

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