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Research Article

Integrating differentiated instruction to improve STEM students' mathematical engagement and academic performance

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STEM students lose engagement and show poor academic performance if student diversity is not appropriately addressed in curriculum delivery. So, differentiation must be included in lesson planning. This study integrated differentiated instruction in STEM classes to improve student mathematical engagement and academic performance in Grade 11 Statistics and Probability. The study utilized practical action research inspired by the Plan-Do-Study-Act model with 100 participants with diverse learning preferences and interests. Differentiated instruction strategies in mathematics education, such as technological tool integration, previous knowledge assessment, parallel tasks, and open questions, were implemented in two STEM sections. Before implementing differentiated instruction, there was student profiling, a pre-test, and a pre-survey. After ten weeks of consistent DI integration, post-tests, post-surveys, and interviews were conducted to elicit data. The results showed that differentiated instruction improved the student mathematical engagement behaviorally, cognitively, emotionally, and socially. Hence, they performed better academically since the pre-test and post-test scores established the statistical difference. Differentiated instruction strategies successfully improved the student's academic performance on the examination. Also, students gained confidence in dealing with mathematical problems integrated into real-life situations.

Keywords: Academic performance, Differentiated instruction, STEM education, Student engagement

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1. Introduction

Student diversity leads to teaching issues in Science, Technology, Engineering, and Mathematics [STEM] education, prompting teachers to differentiate instruction based on students' learning styles, interests, and abilities (Lavrijsen et al., 2021). In support, the National Council of Teachers of Mathematics [NCTM] promotes the use of differentiated instruction [DI] in classroom teaching to accommodate individual student differences (Smith et al., 2018). DI assumes that each student is unique and learns differently (Fogarty & Pete, 2017). So, the teacher must diversify learning based on the student's interest, readiness, and learning profile (Sayi & Emir, 2017) to create distinct learning materials, processes, products, and environments (Tomlinson, 2017).

DI is a philosophy that acknowledges student diversity while distinguishing the learning material, process, product, and learning environment (Kohnke, 2023). According to Özer and Yilmaz (2018) and Sayi and Emir (2017), the distinguishing feature of DI is the development of lessons based on the student's interest, learning profile, and readiness to meet the student's learning requirements. DI allows students to learn content, undertake procedures, display results, and adjust the learning environment according to their readiness, interest, and learning profile (Tomlinson, 2017). DI boosts students academic performance (Chen

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& Chen, 2018; Özer & Yilmaz, 2018; Valiandes & Neophytou, 2018) and school performance (Sapan & Mede, 2022). DI is built on the idea that every student deserves to learn more effectively using the many learning opportunities provided by the teacher (Tomlinson, 2017). It helps struggling students excel academically by focusing on their talents and recognizing individual differences in a diversified society.

On the other hand, the Philippines still needs to catch up in the mathematics assessment in the Program for International Student Assessment [PISA] administered by the Organization for Economic Cooperation and Development (OECD, 2023). This manifests the low student mathematical performance in international scale assessments. Various factors contribute to this phenomenon, and one of them is the need to address student diversity. To address the issue, teachers in the Philippines must address student diversity by adapting classes to provide a learning experience that meets the needs of different students (Department of Education, 2016). Furthermore, teachers must tailor their lessons to students with varying levels of intelligence and learning preferences (Department of Education, 2019). As a result, the Philippine Department of Education instructs teachers to use differentiated instruction to accommodate student diversity and increase learning.

In the local context, San Pedro Relocation Center National High School-Main in San Pedro City, Laguna, Philippines, offers STEM tracks for Grades 11 and 12 for students inclined toward science and mathematics. However, the result of the general mathematics first periodical test for the school year 2022-2023 reveals that they need to perform better in mathematics, which calls the attention of the teacher and requires an intervention (Azucena et al., 2022; Pentang, 2021). Also, they need to improve their mathematical engagement despite taking STEM subjects. As per the teacher's observation, STEM learners exhibit different learning styles, preferences, and interests. To cater to their diverse needs, the teacher employs DI core strategies in math education, recommended by the Southeast Asian Minister of Education Organization [SEAMEO] Regional Centre for Quality Improvement of Teachers and Education Personnel in Mathematics [SEAQiM], including evaluating prior knowledge, using open-ended questions, providing parallel tasks, and integrating technology.

By integrating DI, STEM students increase their mathematical engagement, which leads to better academic performance. This study supports the positive outcomes of incorporating DI into mathematics lessons to boost students' mathematical engagement and academic performance on examinations. It broadens STEM teachers' perspectives by allowing them to differentiate instruction aligned with the students' learning styles, interests, and preferences, making learning more meaningful and relevant to their daily lives. It also sheds new light on how student profiling and past knowledge may be used to improve lesson planning with DI integration.

2. Literature Review

2.1. Student Mathematical Engagement

Applying DI improves students' performance on examinations (Geel et al., 2022; Morallos, 2018). However, student mathematical engagement influences students' academic achievement because it makes learning meaningful (Maamin et al., 2022). So, mathematical engagement must be established first to make the students perform well in academic examinations. In addition, DI helps students become more engaged, expand on past information, increase student involvement, better grasp the subject, and transfer knowledge (Tomlinson, 2017). On the other side, Wang and Degol (2014) described student engagement as a multidimensional concept made up of three interwoven components: cognitive, behavioral, and emotional. However, Wang et al. (2016) consider the social component of student participation.

Behavioral engagement refers to the student's performance on class-related duties, correct conduct, adherence to school rules, attention, focus, and homework completion (Wang & Degol, 2014). While cognitive engagement integrates self-regulated learning, deep learning, and cognitive techniques to deal with complex concepts (Wang et al., 2016). Meanwhile, emotional engagement demonstrates curiosity, delight, and value in learning. On the contrary, social engagement refers to the desire to foster positive relationships with people while learning and social contact with teachers and classmates. All aspects of student engagement are crucial because actively involved students are more likely to attend class and get higher marks (Bear et al., 2018). However, past research must pay more attention to student mathematical engagement (Maamin et al., 2022).

On the other hand, student mathematical engagement increases if the teacher uses open questions to explore ideas so that the teacher knows the student's prior knowledge, thinking process, and acquired competencies (Febrilia & Nissa, 2019). Making the lesson engaging for the student, boosting student interest, fostering teamwork, and tailoring instruction to the student's learning needs are all critical aspects of teaching (Pedler et al., 2020). However, limited studies were conducted on student mathematical engagement and mathematics achievement at the secondary level (Maamin et al., 2022). So, it is timely to investigate the mathematical engagement and academic performance of secondary students integrating DI.

2.2. Differentiated Instruction to Improve Academic Performance

DI became highly popular among secondary math learners (Marks et al., 2021). Even quickly, DI effectively improved students' math performance (Aguhayon et al., 2023; Bal, 2023). It also boosted students' confidence in answering math problems. Hence, continued varied instruction activities are recommended since they aid students who struggle with mathematics. According to Abdul Al-Bar (2018), DI helped students increase their mathematics performance and problem-solving skills. Yavuz (2020) found that students see DI as a fun, exciting, and engaging teaching technique.

Research indicates that DI improves student academic performance and academic achievement compared to conventional teaching methods (Chen & Chen, 2018; Özer & Yilmaz, 2018; Sapan & Mede, 2022; Valiandes & Neophytou, 2018). Multiple research studies on DI in math classes have generally focused on the following levels: university and graduate (Afurobi et al., 2017; Dack, 2018; De Jager, 2019), secondary school (Awofala & Lawani, 2020), and primary school (Prast et al., 2018). However, there have been limited studies in senior high schools (Pozas et al., 2020). Meanwhile, previous research has demonstrated how DI improves student achievement (Smale-Jacobse et al., 2019). For example, Magableh and Abdullah (2020) used a quasi-experimental approach. They discovered that DI considerably impacts class diversity, resulting in higher student achievement in the mixed-ability group. Similarly, Balgan et al. (2022) investigated DI for Mongolian STEM students using multiple intelligences and learning styles. Because of the intimate relationship between students' intelligence, learning style, and personality type, they discovered that when teachers correctly used DI, students learned.

Several studies claim the usefulness of DI in increasing student learning achievements (Dalila et al., 2022), whereas others produce inconsistent or even contradictory results (Peters et al., 2022). However, consistent DI implementation produces better student outcomes (Am et al., 2023). So, this study fills the gap in refining the effectiveness of DI for improving student engagement and performance, particularly in STEM. This empirical study enlightens the effectiveness of DI integration in STEM education.

3. Background

The study relied on Greg Kearsley and Ben Schneiderman's engagement theory of learning (Malik, 2021). The learner becomes fully engaged in class activities due to valued effort and contact with other learners. The teacher can produce interested students by making the material relevant, stimulating their creativity through various learning possibilities, fostering collaboration, and incorporating technology into lesson delivery. Also, DI leaned on social constructivism as a philosophy wherein the students can freely display their distinctive thinking abilities when engaging with their social environment (Afurobi et al., 2017; De Jager, 2019). However, the study relied heavily on Edward Deming and Walter Shewhart's plan-do-study-act model, widely used in classroom-based action research.

Figure 1 depicts the course of the study and the DI strategies used in the STEM Statistics and Probability class. Student mathematical engagement and academic performance were measured twice using a questionnaire and test examination before and after the DI integration in STEM sections. DI strategies such as assessing prior knowledge, open questions, parallel tasks, and technology integration were integrated during the lesson delivery. Hence, interviews were conducted twice to elicit qualitative responses supporting the quantitative findings. Comparison before and after integrating DI was done to justify the influence of DI on student mathematical engagement and academic performance.

The study aimed to integrate differentiated instruction to improve Science, Technology, Engineering, and Mathematics (STEM) student mathematical engagement and increase academic performance in examinations. Specifically, it is intended to answer the following questions:

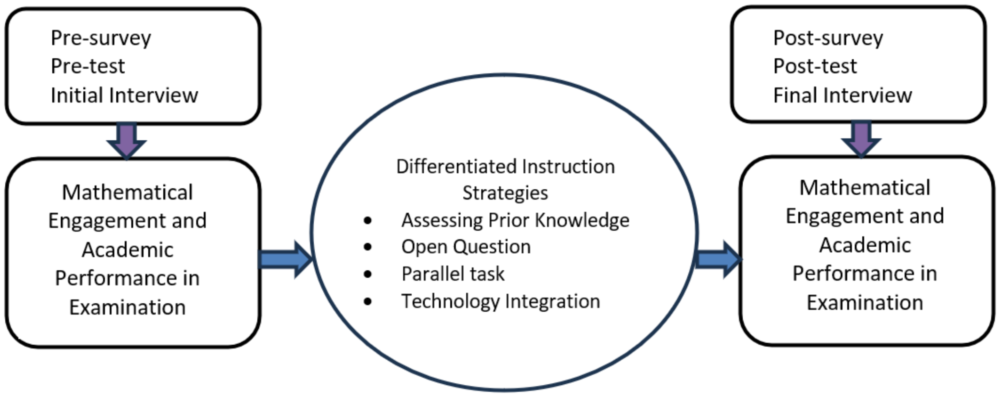
RQ 1) What are the levels of mathematical engagement before and after integrating differentiated instruction behaviorally, cognitively, emotionally, and socially?

RQ 2) What are the mean scores of the STEM students before and after the integration of differentiated instruction?

RQ 3) Are the student mathematical engagement and academic performance in examinations before and after DI integration statistically different?

RQ 4) How does differentiated instruction improve student mathematical engagement and academic performance in examinations?

Figure 1
Conceptual Paradigm



4. Method

4.1. Research Design and Participants

The study used a practical action research design following the Plan-Do-Study-Act [PDSA] model. The main objective was to improve student mathematical engagement and academic performance in examinations so practical action research was the best design. Practical action research is done by the teachers to solve local problems (Mertler, 2021). Since there were two sections of Grade 11 STEM, and most students showed low mathematical engagement, all were used as subjects so that they experienced the same treatment. One hundred Grade 11 STEM students from San Pedro Relocation Center National High School participated in the school year 2022-2023. Students nowadays are struggling in mathematics classes which calls for DI integration to promote inclusive and student-centered mathematics education (Gervasoni et al., 2021).

The student underwent profiling based on their learning interests, styles, and multiple intelligences one month before the DI integration. Then, lessons were crafted based on the students' profiles while integrating DI strategies in different parts of the lessons. For instance, in drill and review, prior knowledge assessments were conducted to see the students' readiness if the teacher had to continue the lesson or not. In the motivation part, open questions were asked to the students to ignite their thinking skills by posting questions with numerous correct answers. Eventually, parallel tasks were given during group activity to promote collaboration and engagement. Then after the group activity, open questions were given to the students to think more about the lessons.

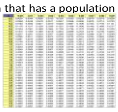
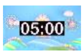
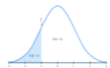
On the other hand, technology integration was always seen in the whole lesson since laptops and televisions were available in every classroom. In addition, students have options to demonstrate their acquired competencies during performance tasks like performing dance, singing songs, performing spoken poetry, artwork, construction of models, and practical application in real-life situations. Through this, students' learning preferences were considered to make the learning engaging and made a better demonstration of competencies rather than a paper-pencil test.

Figure 2 depicts the sample lesson plan with DI strategies. The lesson started with preliminary activities like greetings, prayer, dance, clap exercises, and checking of attendance. The review of the definition of a normal curve and its properties followed by finding the areas under the normal curve were used to activate the student's prior knowledge to determine their readiness. Consequently, jumbled-letter words and open questions were used as motivation to capture the student's attention and ignite their critical thinking.

Parallel tasks were given as group activity that promotes collaboration and engagement for five minutes with an analytic rubric to score the student's outputs. Also, students were given two minutes to explain briefly their output in front of the class. After the students' presentation, a discussion related to the group activity was executed with two contextualized examples with graphs. Then, open questions were used to develop student's mastery leading to formative assessment.

For application, local data were used to construct a word problem so that the students could easily grasp the context. On the other hand, in generalization, fill-in-the-blank was used to recall the mathematical concepts followed by seatwork with two items. One item for a closed question and one for an open question. However, on the performance task, students have the option to form a group and choose only one task to perform as a manifestation of their acquired competencies. The performance tasks were executed at the next meeting or other day to give the students ample time. Hence, providing student's options is one of the core principles of DI in mathematics education (Tomlinson, 2017).

Figure 2
Sample Lesson Plan with DI Integration

DAILY LESSON LOG	School: San Pedro Relocation Center NHS-Main	Grade Level: Grade 11
	Teacher:	Learning Area: Statistics and Probability
	Teaching Date: April 22, 2023	Quarter: 4th
I. OBJECTIVES	**1st Meeting**	
A. Content Standards	The learner demonstrates understanding of key concepts of normal probability distribution.	
B. Performance Standards	The learner is able to accurately formulate and solve real-life problems in different disciplines	
C. Learning Competencies/ Objectives Write the LC code for each	At the end of the lesson, the students must be able to: 1. identify regions under the normal curve corresponding to different standard normal values.M11/12SP-IIIc-3 2. convert a normal random variable to a standard normal variable.M11/12SP-IIIc-4 3. appreciate the importance of standard score.	
II. CONTENT	Converting a Normal Random Variable to a Standard Normal Variable	
III. LEARNING RESOURCES		
A. References	Statistics and Probability pp. 147 - 155	
B. Other Learning Resources	laptop, television, calculator, cartolina, markers, chalks	
IV. PROCEDURES		
A. Reviewing previous lesson or presenting the new lesson.	Preliminary Activities (Greetings, Prayer, National Statistics Dance, Clap Exercise, and Checking of Attendance) Review. Complete the statement. The normal distribution or normal curve is a distribution of a large number of numerical data when the mean, median, and mode are ______ with skewness and kurtosis equal to _______ and symmetrical shape. The standard normal curve or normal probability distribution that has a population mean ____________and a standard deviation ___________. B. Find the areas of the following z –scores a. z = 0.58 A = 0.2190 b. z = - 2.53 A = 0.4943 c. z = 2.46 A = 0.4931 d. z = -1.56 A = 0.4406 	
B. Establishing a purpose for the lesson.	A. JUMBLED-LETTER WORD Directions: Arrange the jumbled letters to form terms related to business math. Use the hint in arranging the letters. STANDARD SCORE - It is a measure of the number of standard deviations (σ) a particular data value is away from the mean (μ). Z-SCORE - It is another term for the standard score. B. Open Questions 1. What are the possible z-scores if the areas under the normal curve is 0.4995? 2. What are the possible z-scores if the areas under the normal curve is 0.4996? 3. Construct a normal curve have the area under it of 0.4994.	
C. Presenting examples/instances of the new lesson.	Parallel Task. Answer the following problems for 5 minutes only. Task 1. Draw a normal curve. Find the area under the normal curve if z= 1.22. Shade the corresponding area. Task 2. Draw a normal curve. Find the area under the normal curve if z= - 2.16. Shade the corresponding area. Task 3. Draw a normal curve. Find the area under the normal curve if z= 2.05. Shade the corresponding area. Answer the following questions. 1. How did you find the activity? 2. What difficulties have you encountered while doing the activity? 3. How did you get the area under the normal curve?  timer (Analytic Rubric for Group Activity – see below)	
D. Discussing new concepts and practicing new skills #1	Converting the normal random variable into standard score or z-score The formula for calculating z is: $z = \frac{X-\mu}{\sigma}$ (z-score for population data) $z = \frac{X-\bar{X}}{s}$ (z-score for sample data) Where: X = given measurement μ = population mean σ = population standard deviation $\bar{X}$ = sample mean s = sample standard deviation **Find the z-score** 1. Suppose the IQ scores are normally distributed with a mean of 100 and a standard deviation of 10. If your IQ is 110, what is your z-score? (Round off your answer to the nearest hundredths). $z = \frac{X-\mu}{\sigma}$ $z = \frac{110-100}{10}$ $z = \frac{10}{10}$ $z = 1$  ∴ Area of z= 1.00 = 0.3413	
E. Discussing new concepts and practicing new skills #2	**Find the z-score** 2. The mean age of Grade 11 Aeta people is 18 with standard deviation of 2. If it is normal distributed, what is the standard score for 16 years old? What is the area below the z-score?  $z = \frac{X-\mu}{\sigma}$ $z = \frac{16-18}{2}$ $z = \frac{-2}{2}$ $z = -1$  A = 0.1587	
F. Developing mastery (Leads to Formative Assessment 3)	Open Questions 1. What are the possible scores and standard deviation of the students in National Achievement Test if the mean scores is 40 to get the z-score of 1.00? 2. In Philippine Science High School, the mean age of Grade 11 students is ______ with standard deviation of 2. The score of one of the students is ______________ to get the z-score of 1.50.	
G. Finding practical applications of concepts and skills in daily living	**Application** 1. The mean age of Grade 12 students in SPRCNHS-Main is 17 with a standard deviation of 3. If you were 21 years old, what is your standard score? (Round off your answer to the nearest hundredths). $z = \frac{X-\mu}{\sigma}$ $z = \frac{21-17}{3}$ $z = \frac{4}{3}$ $z = 1.33$  A = 0.4082	
H. Making generalizations and abstractions about the lesson	Complete the following statement. 1. A discrete random variable is a variable wherein the set of all possible outcomes is ____________ using natural numbers. 2. A continuous random variable is a variable wherein the values of possible outcomes are on a continuous scale that can be _________. These values are _______________.	
I. Evaluating learning	Seatwork: 1. The National Statistics Office (NSO) claims that the average life expectancy of a Filipino is 71 with a standard deviation of 3 years. If your grandfather's age is 75 years old, what is his standard score? 2. The average doctor's fee in the Philippines is ________with a standard deviation of ₱ 100. If your doctor charged you__________during your consultation. What is the standard score of your doctor's fee?	
J. Additional activities for application or remediation	Performance tasks. Direction: Form a group with 3 to 5 members only. Choose only one task to perform next meeting. Task 1. Construct a song, poem or spoken poetry showing the terms and concepts of standard score. Task 2. Perform a dance or skit showing the application or concepts of standard score. Task 3. Conduct a simple survey eliciting at least two quantitative varaibles of the students in school with 100 respondents. Compute the standrad scores of at least two students. Task 4. Do data mining of the results of National Achievemnet Test last school year. Graph the scores and determine your standard scores.	
V. REMARKS	11 STEM A ___ out of ___ did not reach 75% mastery level. 11 STEM B ___ out of ___ did not reach 75% mastery level.	

Analytic Rubric for Group Activity

Criteria	Well-mastered 4	Mastered 3	Working towards mastery 2	Needs improvement 1
Content	Complete information	With at most 2 incorrect or missing information	With at most 3 incorrect or missing information	With more than 4 incorrect or missing information
Organization of ideas/concepts	Well-organized	Properly organized	organized	Not organized
Final answer	Correct and simplified	Correct but not simplified	Incorrect answer	No final answer, but with solution
Creativity	Unique and creatively displayed	Creatively displayed	Somewhat creative	Not creative
Desired learning outcomes	Well-demonstrated	demonstrated	Somewhat demonstrated	Not demonstrated

4.2. Instruments

The research instruments, such as 50-item teacher-made test material, a 30-item adapted questionnaire from Wang et al. (2016) and Fredricks et al. (2016), and a 10-item interview guide, were validated by the education program supervisor, school head, master teacher, and head teacher in mathematics education before use. Suggestions were strictly followed in the revision, such as grammar check, simplicity of the statement, clarity of directions and questions, and appropriate format. After revision, the instruments were returned to the expert group to be examined again to ensure their appropriateness. Approval was secured before using the instruments as evidence of content validity. Hence, multiple data collection were used to address Bondie and Dahnke's (2019) assertion that previous studies on DI lack methodological rigor to prove its effectiveness,

After content validation, the questionnaire was piloted to forty non-participants for reliability testing using Cronbach's alpha of the four sub-variables. The questionnaire has .753, .725, .828, and .840 reliability indices, respectively making the questionnaire reliable. The acceptable Cronbach's alpha value ranges from .7 to .95, showing a positive item correlation (Onyefulu & Roofe, 2019). Similarly, the test material was pilot-tested to 40 non-participants before its use. It gained a .872 reliability index using Kuder-Richardson Formula 20. Meanwhile, a pilot interview was conducted with 20 non-participants to check the accuracy and appropriateness of the interview guide questions. Key learnings from the pilot testing were used to revise the said instruments like simplicity of questions, having subtitles in Filipino, and grammar check.

4.3. Data Collection

The school's principal and parents signed the permission letters in the latter week of November 2022. Then, in December 2022, student profiling was conducted for two weeks, which served as the foundation for developing math lessons using DI strategies. The tools and interventions were tested on non-participants in the second week of January 2023. The materials and plans were then revised. Pre-survey and pre-test tests were given to target students during the first week of February to assess their prior mathematical engagement and knowledge. The results were saved for future comparison.

After ten weeks of incorporating DI strategies consistently, a post-test was given, followed by a post-survey in the third week of April 2023. The qualitative responses were then elicited through an interview with thirty individuals in the fourth week of April 2023. Member checking was completed by the first week of May 2023 by returning the transcript and analysis to ensure the accuracy and completeness of qualitative data.

For positionality, the researcher had no relation to the students involved. He coached and guided the STEM teacher on incorporating DI strategies into mathematics instruction. He was responsible for write-ups, development, and validation of research tools, but he had never worked with STEM students. He has taught mathematics and research at public schools for the past sixteen years. He believed that students' varied learning preferences should be considered while organizing lessons. However, the STEM teacher administered the test materials and survey form to ensure fair data, while student teachers interviewed the participants to avoid biases.

4.4. Ethical Considerations

Ethical concerns must be addressed in any part of the research work (Astaneh & Masoumi, 2018; Stockemer, 2019). As a result, permission from the school head was sought, and consent from the parents was secured through a formal letter requesting their approval. Also, the questionnaire's author received an email from the researcher asking for permission to use it. On the other hand, participants had the option to withdraw at any time without penalty. Students received no monetary compensation for their participation. However, the participants' identities were kept secret to protect them from potential harm, and the data were treated with the utmost confidentiality. Furthermore, the data and research report were stored on the researcher’s computers for three years before being deleted. The research report was additionally presented at conferences, faculty meetings, and a journal publication.

4.5. Data Analysis

Jamovi version 2.4.14 was used for descriptive and inferential statistical analysis, while thematic analysis was used for qualitative responses, which is the most commonly used (Kiger & Varpio, 2020). Descriptive measures such as mean, median, standard deviation, and interquartile range were used. Also, the normality test using the Shapiro-Wilk test and homogeneity of variance using Levene's test were utilized as prerequisites for inferential statistics (Horváth et al., 2020).

Table 1 depicts the results of Levene's test and Shapiro-Wilk test. It can be gleaned from the table that the responses from the survey were not normally distributed ($p <.05$). However, the variances were homogenous ($p >.05$). So, the Wilcoxon Signed-Rank test was used for questionnaire responses for a significant difference before and after. Meanwhile, the test scores have homogenous variances ($p >.05$) and normally distributed data ($p >.05$). So, a paired sample *t*-test was used for a significant difference and Cohen’s d for practical significance (Grech & Calleja, 2018).

5. Results

Table 2 shows that STEM students' behavioral engagement was low; they had less attention in math class, quickly gave up on learning math, and exerted less effort. However, they gained better behavioral engagement after the DI implementation. They strived hard to deal with math and even discuss lessons outside the classroom. Also, they exerted much effort and paid attention in math class. Through the DI strategies, students increased their behavioral engagement since the lessons became more exciting and aligned with their learning preferences. Consequently, behavioral engagement predicts the students' academic performance (Maamin et al., 2022).

Table 1
Homogeneity of variances and normality test results

	Variable	*Levene's test* Statistic	df_1	df_2	Sig.	*Shapiro-Wilk* Statistic	df	Sig.
Pre-survey	Behavioral	.624	1	98	.600	.957	100	.000
	Cognitive	.063	1	98	.979	.967	100	.001
	Emotional	.819	1	98	.485	.962	100	.000
	Social	.295	1	98	.829	.938	100	.000
Post-survey	Behavioral	.145	1	98	.933	.975	100	.005
	Cognitive	.640	1	98	.590	.957	100	.000
	Emotional	.695	1	98	.557	.972	100	.002
	Social	.235	1	98	.872	.959	100	.000
Examination	Pre-test	.237	1	98	.871	.980	100	.131
	Post-test	1.186	1	98	.202	.967	100	.120

Table 2
Behavioral engagement of the participants before and after the differentiated ınstruction strategies ımplementation

Statement	*Before*			*After*		
	Median	*IQR*	*VI*	*Median*	*IQR*	*VI*
1. I pay attention in my math class.	1	2	very low	3	1	high
2. I work hard to learn math.	1	2	very low	3	1	high
3. I never give up learning math, even if it is hard.	1	2	very low	4	1	Very high
4. I complete my assignments and math exercises on schedule.	3	2	high	3	1	high
5. I regularly participate in math class discussions.	3	2	high	3	1	high
6. I make an effort to learn more math.	1	2	very low	3	1	high
7. I even discuss math outside of the classroom.	2	2	low	4	1	high

Note. Legend: IQR = Interquartile Range; VI = Verbal Interpretation.

Table 3 depicts the low cognitive engagement of the STEM students before DI implementation.

Table 3
Cognitive engagement of the participants before and after the differentiated instruction strategies implementation

Statement	Before			After		
	Median	IQR	VI	Median	IQR	VI
1. I review my math classwork to ensure that it is correct.	2	2	low	3	1	high
2. I consider several approaches to solving math problems.	2	2	low	3	1	high
3. I relate the current math teachings to what I have already learned.	2	2	low	3	1	high
4. When I make a mistake in mathematics, I strive to understand why.	1	2	very low	4	1	very high
5. I study all the components when a math activity is challenging.	2	2	low	3	1	high
6. When I am doing classwork, I find math lessons easy.	2	2	low	3	1	high
7. I do math exercises beyond what is required in class.	2	1	low	3	1	high

Note. Legend: IQR = Interquartile Range; VI = Verbal Interpretation.

Before, STEM students had a low cognitive engagement in math despite belonging to the academic track. They seldom explored math problems, did not care about why they got incorrect answers and did not try several problem-solving approaches. However, their cognitive engagement became high after the DI integration, similar to the findings of Dalila et al. (2022). It implies an improvement resulting in the DI integration into math lessons. Students were fearless of making mistakes, could analyze their math errors, and developed strategies for solving math problems. Moreover, they could relate prior knowledge to the lessons and became more engaged in math activities, similar to the findings of Tomlinson (2017).

The emotional engagement before was low, as seen in Table 4. They did not want to learn more math lessons and did not feel excitement. However, it increased after the DI integration in math lessons. STEM students developed positive feelings about math learning and a desire to learn more, enjoying attending math classes. They felt good and excited to learn more. The excitement and enjoyment of learning ignited the student's passion for learning math lessons. DI increased the student's emotional engagement, yielding better academic performance (Maamin et al., 2022).

Table 4

Emotional engagement of the participants before and after the differentiated instruction strategies implementation

Statement	Before			After		
	Median	IQR	VI	Median	IQR	VI
1. I appreciate learning about math.	3	2	high	3	1	high
2. I want to learn more about math lessons.	1	0	very low	3	1	high
3. I feel good in math class.	3	2	high	3	1	high
4. I enjoy my math class.	2	2	low	3	1	high
5. I want to continue taking math classes.	2	2	low	3	1	high
6. Learning new math lessons makes me feel fantastic.	1	2	very low	3	1	high
7. I am excited about math class.	2	2	low	3	1	high

Note. Legend: IQR = Interquartile Range; VI = Verbal Interpretation.

The social engagement before was low but changed after the DI integration, as seen in Table 5. Before, students needed to interact more with co-students and brainstorm ideas. Also, they preferred to do math activities individually rather than in groups. However, after the DI integration, more collaboration and interactions occurred. They exchanged ideas with others, collaborated, and did activities in a group. They shared ideas, assisted struggling classmates, and cared for others' ideas. Through DI integration, STEM students found math learning fun and engaging, similar to Yavuz's findings (2020).

Table 5

Social Engagement of the Participants Before and After the Differentiated Instruction Strategies Implementation

Statement	Before			After		
	Median	IQR	VI	Median	IQR	VI
1. I am interested in other people's thoughts about doing math activities.	1	2	very low	3	1	high
2. I strive to grasp other people's mathematical ideas.	1	2	very low	3	1	high
3. I collaborate with individuals who can assist me with math.	2	2	low	3	1	high
4. When dealing with others, I communicate my mathematical concepts.	1	2	very low	3	1	high
5. I assist my classmates who are failing with math.	1	2	very low	3	1	high
6. I prefer doing activities in groups rather than alone.	1	2	very low	3	1	high
7. I enjoy collaborating with my classmates on math assignments.	1	2	very low	3	1	high

Note. Legend: IQR = Interquartile Range; VI = Verbal Interpretation.

Table 6 displays the results of significant differences and practical significance from pre and post-survey. The p-value (p =.000) justifies the statistical difference in the responses before and after DI integration. STEM students became more engaged after the DI integration in mathematical behavior, cognition, emotion, and social aspects. Also, the rank biserial value (r=1) justifies the practical significance of DI integration in improving student mathematical engagement. Differentiated mathematics teaching activities can improve student engagement while establishing a pleasant and inclusive classroom culture (Aguhayon et al., 2023). Student engagement influences the students' mathematical performance (Maamin et al., 2022).

Table 6
Wilcoxon Signed-Rank Test for significant difference and rank biserial for practical significance before and after the implementation of differentiated instruction

Paired	*Variable*	*Computed value*	*p*	*Interpretation*	*r*	*Interpretation*
Pre-survey vs. Post-survey	Behavioral	2701	.000	Significant	1.00	Very large
	Cognitive	2145	.000	Significant	1.00	Very large
	Emotional	2346	.000	Significant	1.00	Very large
	Social	2556	.000	Significant	1.00	Very large

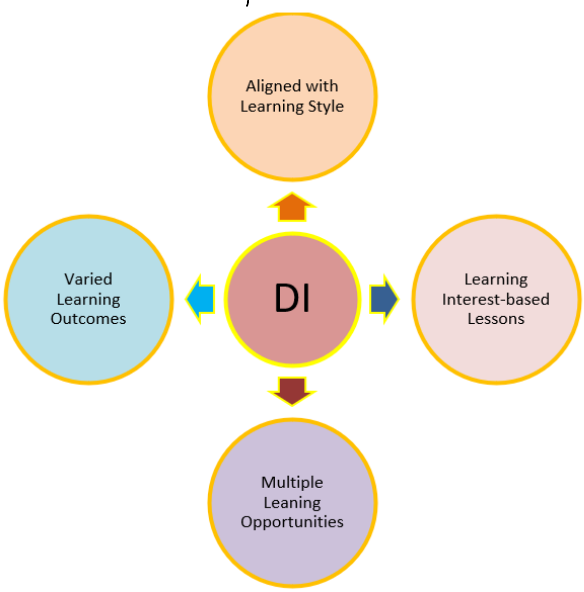
It can be gleaned from Table 7 that post-test scores(*Mean*=35.50, SD=6.99) were statistically more significant than pre-test scores (*Mean*=18.90, *SD*=4.14). The paired sample t-test result reveals a significant difference (*p*=.000) between the two mean scores. This justifies the effectiveness of the DI strategies when integrated into math lessons. Similarly, Cohen's d for practical significance (*d*=2.47) signifies a very large effect of DI strategies. Differentiated instruction was a successful intervention for helping students improve their mathematics performance, which supported the findings of Aguhayon et al. (2023) and Bal (2023). DI improves the student's academic performance, which is parallel to the findings of Awofala and Lawani (2020). The consistent DI integration into math lessons improves the STEM student's academic performance, parallel to the findings of Balgan et al. (2022).

Table 7
Descriptive and inferential statistics of the pre-test and the post-test scores

Test	*Min*	*Max*	*Mean*	*SD*	*t*	*p*	*d*
Pre-test	9	28	18.90	4.14	24.70	.000	2.47
Post-test	17	45	35.50	6.99			

Figure 3 displays the themes derived from the transcripts, showing how the DI improved the student's mathematical engagement and academic performance. Through DI, math lessons became meaningful, similar to the findings of Maamin et al. (2022), because the learning activities were aligned with the students' learning styles and based on their interests. DI made the math lessons fun and exciting, supporting the findings of Yavuz (2020) because the math lessons were based on students' interests and preferences (Özer & Yilmaz, 2018; Sayi & Emir, 2017). Moreover, the math teachers provided multiple learning opportunities, which gave the students multiple ways of learning and exploring the lessons, supporting Tomlinson's findings (2017). Also, students produced varied learning outcomes based on their preferences, resulting in passion and love for math learning.

Figure 3
Themes on How DI Improved STEM Students' Mathematical Engagement and Academic Performance



The participants' words support the findings. For instance, Participant 2 asserted that "I became more participative in my math class since I am interested in learning more because of the activities given by my teacher. She provided varied activities that caught my interest." In a similar manner, Participant 8 stated that "My math learning was improved because my teacher provided various activities that suited my interests and choices of learning outputs based on my preferences. I was able to connect math lessons to my talent and skills."

6. Discussion

The study aimed to integrate differentiated instruction to improve STEM student mathematical engagement and increase academic performance in examinations. Grade 11 STEM students from two sections were considered participants in the action research and participated utterly. Before integrating DI, STEM students had low behavioral, cognitive, emotional, and social engagement in math class. However, it increased after the DI integration. Integrating DI in math class makes the lesson interesting, fun, and engaging in the students' eyes (Yavuz, 2020). The math teacher diversified the lessons based on students' interests, readiness, and learning preferences making the lesson delivery effective and supporting the findings of Sayi and Emir (2017). DI makes the lessons meet the student's learning needs (Özer & Yilmaz, 2018; Sayi &Emir, 2017).

Student engagement was critical to perform mathematically. As a result, the mathematics teacher attempts to maintain student engagement throughout the school year, as motivated students are more likely to attend class and receive higher grades (Bear et al., 2018). Making every learning session enjoyable, integrating various learning tasks, utilizing technology, and tailoring the lessons to the student's learning preferences are all significant approaches for the mathematics teacher to promote student engagement (Pedler et al., 2020). Similarly, DI is a successful approach for helping students develop their mathematical ability, as seen in their academic performance (Geel et al., 2022).

Through DI strategies, STEM students increase their behavioral engagement. They exerted much attention and effort in their math class making them excited since their interest are considered. On the other hand, students become brave in committing mistakes and tracing their errors in solving math problems. Their cognitive engagement increases after the teacher uses DI strategies. Similarly, their emotional and social engagement improves since math lessons are engaging and foster group work parallel to Pedler et al.'s findings (2020). The positive feelings toward math learning make the students excited to learn which ignites students' passion and eagerness.

Assessing prior knowledge provides the student's learning background and informs the teachers if the STEM students are ready or not in the next lesson. While, open question aids the teacher in exploring students' ideas and checking the student's prior knowledge and learned competencies (Febrilia & Nissa, 2019). So math teachers must constantly use this strategy to check the student's thinking process leading to a desire for learning. On the other hand, parallel task provides equal opportunities for STEM students to collaborate and engage in almost similar tasks demonstrating the same competencies. While technology integration makes lesson delivery efficient and interesting in the student's eyes. Integrating technology into the lesson is one of the features of DI (Pedler et al., 2020).

The study supported the effectiveness of DI strategies in STEM mathematics education. As a result, teachers may use various DI strategies to meet their students' unique learning demands while considering their learning styles and preferences. Mathematics teachers must foster inclusive environments for instruction that engage students in terms of behavior, cognition, emotion, and social aspects. Similarly, mathematical engagement and academic performance improve by recognizing each student's individual learning needs (Aguhayon et al., 2023; Bal, 2023). So, DI removes barriers to active and inclusive learning, making mathematics exciting, relevant, and interesting (Yavuz, 2020).

In the lens of engagement theory, students exert effort and interact more with classmates if they are fully engaged through the DI strategies of the teachers. The open questions allow them to express their ideas freely and check their prior knowledge about the lessons (Febrilia & Nissa, 2019), motivating the students to think freely. Also, making the math lesson relevant to the student's interests and styles improves student engagement, eventually leading to improved academic performance. Students engaging with their social environment through various learning activities execute better thinking abilities (Afurobi et al., 2017; De Jager, 2019).

The mathematics teachers may integrate the DI core strategies in mathematics education suggested by the Southeast Asian Minister of Education Organization Regional Centre for Quality Improvement of Teachers and Education Personnel in Mathematics. Assessing prior knowledge, using open-ended questions, providing parallel tasks, and integrating technology provide powerful strategies for improving student mathematical engagement leading to better academic performance due to meaningful learning experiences (Maamin et al., 2022). Also, mathematics teachers need to employ DI strategies consistently to master techniques of adjusting instruction based on the student's learning needs (Pedler et al., 2020). Hence, they need to consider students' interests, readiness, and learning preferences in crafting lessons suited to students' learning abilities.

For reflection, the mathematics teacher admitted that her DI practices were not perfect because flaws were discovered, such as that students preferred to form groups with other bright classmates, limited time was given to the students to produce outcomes, and due to limited time, students were always in a hurry. As a result, she wants to frequently create diverse activities for different student types, integrating the latest mobile application during the subsequent DI implementation to address various learning preferences. These allow students to engage in a variety of math-class learning activities. In addition, she intends to provide a range of stimulating exercises that allow students to rotate between groups while working on group activities and incorporate journal writing within the lesson.

7. Conclusions and Recommendations

STEM students had low engagement behaviorally, cognitively, emotionally, and socially before the DI integration in math classes. However, after the DI integration in lesson delivery, all dimensions of student engagement increased. Similarly, the mean score of the students was low and improved after the DI integration. Statistically speaking, student engagement before and after the DI integration was significantly different, which manifests the positive impact of DI. Similarly, the mean score before was statistically different from the mean score after. So, integrating DI in math classes improves STEM student mathematical engagement and academic performance. DI improved student engagement and academic performance in examinations because the math lessons were aligned with the student's learning styles and interests. Also, DI provided multiple learning opportunities for the students to excel and allowed the students to produce learning outcomes variedly.

DI integration is highly recommended for math teachers in lesson planning to improve STEM student engagement, leading to improved academic performance. However, it must be done consistently and religiously. Math teachers must provide learning opportunities, integrate DI strategies, and engage the students behaviorally, cognitively, emotionally, and socially. On the other hand, the study was limited to classroom-based data since the investigation was action research. So, future researchers may use true experimental design to rigorously verify the effectiveness of DI over student engagement and performance in mathematics learning.

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