The effect of differentiated instruction on academic achievement of grade eleven students in the field of derivative in Bhutan

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ABSTRACT
Given the increasing diversity of students academically and culturally, educators are being called upon to accommodate students’ diverse learning requirements through differentiated instruction strategies. In Bhutan, the Ministry of Education recently mandated the implementation of a differentiated instruction strategy in the K-12 curriculum. From this perspective, this study attempted to ascertain the effect of differentiated strategies on grade eleven mathematics students within the framework of the pre_test and post_test quasi-experimental research method. 64 grade eleven students participated in this study. The concept of derivative was taught using a differentiated instruction strategy for the experimental group (N=32) while a conventional one-size fits-all strategy was used for teaching the control group (N=32). A Conceptual Understanding Test on the Derivative (CUTD) was administered as pretest and posttest groups to examine the differences in their learning achievements. A t-test analysis of the pretests indicated no significant differences, indicating that the experimental and control groups’ learning abilities on the concept of the derivative were roughly comparable. However, a statistically significant difference in favour of the experimental group over the control group was discovered in the post test analysis. It was recommended that Mathematics teachers and educators should embrace the use of differentiated instruction while teaching and learning derivative. The researchers also recommended that differentiated education be used over a prolonged period of time and with a larger sample size.

KEYWORDS
Differentiated instructions, derivative, diversity of Learners, learning profiles, needs, interest.

Introduction
Bhutan’s Ministry of Education places a premium on education quality. In accordance with the aforementioned vision, the Ministry of Education has developed a number of education-related documents, including Educating for Gross National Happiness (GNH), Bhutan Education Blueprint 2014-2024, Draft National Education Policy 2019, and Bhutan Professional Standards for Teachers (BPST). The educating for GNH program focuses on incorporating GNH principles into teaching and learning to ensure that learners have access to equal, fair, and high-quality educational opportunities (Dukpa et al., 2020).

The Bhutan Education Blueprint 2014-2024, Draft National Education Policy 2019 and BPST firmly suggest offering various potential paths for learners. The BPST has seven standards. The first standard is the diversity of learners, anticipating that teachers implement instructional strategies responsive to diverse learners in the classroom. Subsequently, upon the recommendations of all the education-related documents and the National School Curriculum Conference Report 2016, the Royal Education Council (REC) conducted a need assessment for a differentiated curriculum in science and mathematics to address the declining quality of science and mathematics, and to address the varied performers (Dukpa et al., 2020).

Mathematics and science are the integral components of STEM (Science, Technology, Engineering, and Mathematics). For a developing country like Bhutan, STEM is an essential tool for our growth and development (Dema, 2018). The concept of the derivative is paramount in the field of STEM, due to its widespread application in the fields of physical science, biological science, engineering, economics, and technology (Kado & Dem, 2020). Despite its importance, most of the students fail to understand the concept of derivative relationally; for instance, even if the
students correctly find the slope of the curve at the particular instant on the graph, they fail to interpret the meaning of the slope (Kado & Dukpa, 2020). Moreover, students face difficulty in relating the concept of limit, the instantaneous rate of change and average rate of change. As a result, the concepts of the derivative is epistemologically difficult for the students.

Academic achievement disparities between Bhutanese students have long been a source of concern for His Majesty the fifth King of Bhutan, as well as other stakeholders and educators (Dukpa et al., 2020). Numerous reports such as Education in Bhutan: Findings from Bhutan’s experience in PISA for Development (Bhutan Council of School Examination and Assessment (BCSEA, 2013)), National Education Assessment (BCSEA, 2013), Quality of School Education in Bhutan: Reality and Opportunities (Royal Education Council (REC), 2008), have shown that the majority of Bhutanese students fall short of the minimum educational standards in all subjects, with the greatest disparity in mathematics and science.

Today's classrooms in Bhutan are growing culturally and academically diverse. A teacher stands in front of 35 students, each having varied interests, learning profiles, learning styles, and needs, but against that, teachers teach them the same way and expect them to do so in the same way. Despite the significant disparities amongst students in the mathematics classroom, most Bhutanese mathematics educators base their lessons on direct instruction, believing that direct instruction is the efficient strategy for imparting facts and figures to students ((Dukpa et al., 2020). When a teacher presents his or her instruction in a classroom without taking into account the students' individual differences, their mathematical learning may degrade (Ari, 2017). The learning activities specifically designed for some students may not work for others (Dixon et al., 2014). As a teacher, it is morally and professionally unethical to consider that all students learn in the same way. The same content should be tailored to students in multiple ways (Dukpa et al., 2020). Previous research has also shown a mismatch between the students' readiness level and the mathematics content, where students were exposed to the same mathematics content that they had already learned (Engel et al., 2013). The one-size-fits-all approach is most prominent, with no consideration of the diversity of learners in Jordan (Magableh & Abdullah, 2020; Siam & Al-Natour, 2016). As a result of the previous research, it is completely obvious that educators rarely consider the presence of diverse students in the classroom (Dijkstra et al., 2016).

Differentiated instruction is a pedagogical theory founded on the concept of meeting the needs of academically diverse learners according to their readiness levels, interests, and learning profiles (Magableh & Abdullah, 2020). According to Tomlinson (2014); Tomlinson & Imbeau (2010), differentiated instruction is acustomized teaching and learning strategy that is geared to fit the requirements of a varied set of learners. It includes instructorn tailoring their teaching and learning responsiveness to the diverse learners in a non-differentiated classroom. Teachers can differentiate instruction based on their students' learning profiles, readiness level, and interests through content, process, product, and learning environment (Tomlinson & Moon, 2013).

The first area in which the educator will differentiate is in content. It constitutes of the knowledge, concepts, and skills that students must learn from the curriculum. According to Tomlinson & Moon (2013), diversifying the information entails employing a variety of delivery modalities such as videos, texts, lectures, audio, visual presentations, and so on. Students are given a chance to learn information based on their preferences for delivery technologies or formats. According to Sebihi (2016), teachers must adapt the same material to all students while utilizing a variety of instructional techniques to deliver the subject. The kids will study the same material in a variety of methods.

The process is the second area in which teachers can differentiate. According to Tomlinson & Moon (2013), the process is how students take in and make meaning of the material. The approach also includes developing teaching and learning activities to help students conceptualize the information. Teachers must create or use a variety of instructional techniques to suit the diverse learning requirements, learning profiles, and interests while differentiating the contents. The procedure can be differentiated by the teacher utilizing various instructional techniques such as tiered instructions, flexible grouping, and tiered assignments (Aliaabari & Haghghi, 2014).

The third area to differentiate is the product. It is how students demonstrate what they’ve learnt. A teacher can differentiate the product by giving liberty for students to show their final product of learning. Teacher can design the following assessment strategies to differentiate the product; Enabling students to decide how they want to demonstrate their learning; (b) using graded assessment scales to monitor and assess student skills; (c) allowing students to choose whether they want to work in groups or independently on their product; (b) Encouraging students to create their own original work.

The learning environment is the fourth area to differentiate. The learning environment refers to the many places, situations, and cultures that make up the actual classroom setting in which students learn (B. S. Magableh & Abdullah, 2020). To differentiate the learning environment, teachers need to consider the different learning contexts. A differentiated learning approach accounts for diverse learning environments, considering their interests, learning
profiles, and readiness (Firwana, 2017; Tomlinson & Imbeau, 2010). This is a significant approach for students to enhance their ability to learn.

In differentiated instruction, the phrase "readiness" refers to the equilibrium between the information and skills pupils need to comprehend a subject and the knowledge and skills they currently have. Tomlinson & Imbeau (2010) claimed that it is paramount to examine students’ prior knowledge and skills while differentiating according to their readiness level. After assessing their readiness level, immense assistance, more opportunities for practising, and structured activities need to be tailored to students with lower readiness levels (Tomlinson & Allan, 2000). On the contrary, students with an exceptional readiness level require less practice and easily manage abstract and complex activities (Tomlinson & Allan, 2000). Learning profiles refer to individual learning styles and preferred modes of learning that are responsive to their needs (Sebibi, 2016; Tomlinson, 2014). While differentiating the lessons, it is paramount to use a diversity of instructional strategies that address the diversity of learning profiles, which in turn will foster better learning.

The differentiated instruction caters for the needs of all learners, transcending the inequality in knowledge dispersal and promoting the quality of teaching and learning (Ariss, 2017; Valiandes, 2015). As stated by Karp et al. (2014), this technique is more consistent with mathematical reforms and also redresses the inequity in mathematics education. Further, differentiated instruction is based on the different learning theories like; Vygotsky’s social learning theory, zone of proximal development (Magableh & Abdullah, 2019); Gardner’s theory of Multiple Intelligences and brain based learning, to enhance students’ learning and maximize individual success.

Awofala & Lawani (2020) investigated the impact of varied instructional techniques on secondary students’ mathematics success in the context of mathematics teaching and learning. The quasi-experimental research used pre-tests and post-test instruments to collect data from 220 samples. The intervention lasted eight weeks, with the experimental group receiving a differentiated instructional strategy and the control group receiving traditional direct instructions. The findings revealed a statistically significant difference between the two research groups, with the experimental group outperforming the control group, indicating that differentiated teaching improved students’ math proficiency.

Lai et al. (2020) also investigated the effect of differentiated instruction in enhancing overall mathematics achievement by employing the longitudinal approach with pre-test and post-test design of 25 students in each group. The finding reveals that differentiated instruction significantly enhances students’ overall mathematics achievement. (Fernandez et al., 2020) recommended differentiated instruction as a viable technique for enhancing academic performance. The quasi-experimental study by Valiandes (2015) has shown an improvement in the learning progress of those students who are exposed to the differentiated instructions compared to those students who did not receive the differentiated instructions. He further claimed that excellent differentiated education has a positive impact on students’ academic progress. The rapid increase in the diverse student population in western countries necessitates the adoption of differentiated teaching and learning to meet the needs of all the students in the diverse classroom. To accommodate the diversity of learners in heterogeneous classrooms, most western countries enacted a policy of inclusion, anticipating all schools and teachers would address the needs of the varied students (Westwood, 2018).

A closer examination of the literature reveals that a number of studies in global contexts have examined the impact of differentiated instruction on enhancing the performance of learning mathematics in general, and differentiation in particular in global contexts (Abbas & Abdurrahman, 2015; Awofala & Lawani, 2020; Bal, 2016; Chen & Chen, 2017; Magableh & Abdullah, 2019; Valiandes, 2015). However there are limited academic discourse in the Bhutanese contexts. Thus, this study aims to examine the efficacy of differentiated instruction on students’ achievement in differentiation at Gongzim Ugyen Dorji Central School in Haa, Bhutan.

Theoretical framework

The learning theory underpinning the differentiated instructions are; Vygotsky's social learning, the zone of proximal development (ZPD), Gardner’s theory of multiple intelligences and Brain-Based Learning theory.

The zone of proximal development (ZPD)

Vygotsky suggests that teachers should consciously tailor the instructions within learners' zone of proximal development- difference between what learners independently learn the concept and what learners can do with the help of more knowledgeable others with scaffolding (Fani & Ghaemi, 2011). (I. Magableh & Abdullah, 2019) asserted that differentiated instruction based on ZPD would help variance learners as instructions will be tailored as per the learners’ development. If the content delivered is beyond the learners’ ability to understand, it results in frustration and withdrawal of learners (Morgan, 2014) or if the content is too easy, not up to their readiness level, learners get demotivated to learn resulting in creating the chaotic learning environment.
**Gardener’s theory of multiple intelligence**

Gardner’s theory of multiples intelligence is formulated on the principle that human intelligence is not a single entity, it encompasses different modalities of intelligence. The differentiated instructions is based on the Gardener’s theory of multiple intelligence where learners learn using eight different types of intelligence (Gardner, 2011). The differentiated instruction creates a platform for learners to use their preferred intelligence while learning the assigned task (I. Magableh & Abdullah, 2019). Instructional techniques of one size fits all reliant on one type of intelligence, deprive opportunities for learners who do not have the proclivity to learn in the particular style (Gardner, 2011). Since the learners process the information using different styles, it is paramount for educators to offer the multiple potential pathway for students to acquire the contents.

**Brain-based learning theory**

The brain-based learning is about being conscious about how the brain processes, stores, and retrieves information effectively (Subban, 2006). Tomlinson & Kalbfleisch (1998) suggested three broadly related concepts that entails differentiated instruction in teaching and learning. First, the learning environment should be conducive to learning. He asserted that learners who are intimidated, unsafe, feel dejected, and pressured are improbable to learn. Second, the learners need to be appropriately challenged in order to maximize the learning (Tomlinson & Kalbfleisch, 1998). The contents delivered should be neither too easy nor too difficult but appropriate to their readiness. Third, the learners must be able to make the connection between the existing and prior knowledge (Tomlinson & Kalbfleisch, 1998). When the teachers deliver the instructions, a teacher should access the prior knowledge instead of teaching facts and figures in isolation.

**Methods**

In this study, a pretest and posttest control group quasi experimental research design was most a appropriate for comparisons, one experimental and the other control group (Abbas & Abdurrahman, 2015; Magableh & Abdullah, 2019). The depiction of the research design is shown in the figure below (Creswell, 2014).

![Experimental Process Diagram](Creswell_2014)

**Experimental process**

The experimental group was treated with flexible grouping and tiered teaching to implement differentiated instruction techniques in the areas of content, process, and product in the classroom, and the control group with a traditional method of one-size-fits-all strategy. In order to ensure credibility, two equally trained and experienced mathematics teachers taught both classes. For two weeks in the month of August 2021, the two classes were taught independently for fifty minutes daily. An identical post-test was administered to both groups at the end of the intervention in order to evaluate their academic accomplishments in the derivative and to validate the effectiveness of the intervention.

**Participants**

The participants consist of 94 students from grade 11 mathematics students at Gongzim Uyen Dorji Central School. Cluster random sampling was adopted to select 64 out of 94 students from 3 sections. The students were the divided into two groups; one was a treatment group and the other was the control. Students in the treatment group were taught derivative using the differentiated instruction strategy, while students in the control group were taught through normal conventional learning.
Instruments

The data collection instrument was a Conceptual Understanding of Derivative Test (CUDT) consisting of twenty questions, ten for pre-test and ten for post-test, modified from BHSEC Mathematics Book-II for Bhutanese Class xii students (Malhotra et al., 2011). A respondent who gave the correct answer to an item received one point (i.e. one mark), whereas a null or incorrect response received zero points.

Validity and reliability

The CUDT were validated by the school’s two senior mathematics teachers, both of whom had more than ten years of experience teaching grade 11 mathematics. The experts’ average Item Objective Congruence (IOC) was 0.89, indicating that the study was appropriate. Following validation, the researchers tweaked a few contents based on expert advice and gave the modified CUDT to 20 students who were not part of the study. The instrument was then put through its paces to ensure its dependability. The instrument’s reliability was demonstrated to be high, with an item reliability of 0.88 validating the instrument’s suitability for the study.

Data analysis

Before the data were collected, the administrative and ethical requirements were properly met to obtain the consent of the school’s action research committee to conduct the study with the students. After receiving permission, all of the study’s participants were asked to give their informed consent. In addition, privacy and anonymity were guaranteed and protected. The quantitative data collected from both groups were entered in the SPSS for analysis. The quantitative data were evaluated using mean, standard deviation and t-test at the 5% significance. Following null hypothesis is tested at \( p \leq 0.05 \) a level of significance.

\[ H_0: \text{There is no significant difference between the performances of students taught differentiation using differentiated instructional technique against those taught with one size fits all method.} \]

Results

The normality test was performed before the inferential t-test using the Kolmogorov-Smirnov test, as shown in Table 1. For both the pre-posttest of EG and CG \((P > 0.05)\), the findings of Kolmogorov-Smirnov analysis for the degree of normality assumptions were satisfied. In addition, as shown in Table 2, Levene’s test for equality of variances of scores for two groups (EG& CG) was performed.

| Table 1. Komogorov-Smirnov normality test |
|--------------|-------------|-------------|-------------|-------------|
|              | Pretest-EG  | Posttest-EG | Pretest-CG  | Posttest-CG |
| N            | 32          | 32          | 30          | 30          |
| Kolmogorov-Smirnov Z | .978        | .944        | .986        | 1.406       |
| Sig. (2-tailed) | .294        | .335        | .285        | .038        |

Significance level: >0.05—no significant, <0.05—significant

| Table 2. Levene’s test for equality of variances |
|--------------|-------------|-------------|
|              | F           | df          | Sig.       |
| Pretest      | Equal variances assumed | 6.571 | 62 | 0.78 |
|              | Equal variance not assumed | 58.99 |       |     |
| Posttest     | Equal variance assumed | 17.714 | 62 | 0.00 |
|              | Equal variance not assumed | 42.73 |       |     |

Significance level: >0.05—no significant, <0.05—significant
Because the p value is greater than 0.05 (F,1,62.=6.571,p=0.78), the Levene's test indicated that the pre test assumption of homogeneity of variance was met. However, because the p-value was less than 0.05, the variation of post-test scores for both groups was not the same (F,1,42.73.=17.714,p=0.00). As a result, the assumption of equal variances was violated.

Comparison of pre-test and post-test scores of CUDT

Table 3 shows the results of an independent samples t-test to determine the difference in CUDT between the experimental and control groups.

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>Mean</th>
<th>Mean Difference</th>
<th>Standard Deviation</th>
<th>Sig. (2 tailed)</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>Control</td>
<td>7.58</td>
<td>0.391</td>
<td>6.10</td>
<td>0.778</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>Experimental</td>
<td>7.59</td>
<td></td>
<td>5.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-test</td>
<td>Control</td>
<td>23.83</td>
<td>33.125</td>
<td>10.52</td>
<td>0.000</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>Experimental</td>
<td>56.95</td>
<td>4.66</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significance level: >0.05—no significant, <0.05—significant

To compare the pre test scores for EG and CG, an independent samples t-test was used. There was a significant difference in pre test scores between the Experimental (M=7.59, SD=5.96) and Control groups (M=7.58, SD=6.10; t(62)=0.283, p=0.778) (two tailed). The magnitude of the differences in the means was very small (eta squared=0.006) (MD=0.391, 95 percent CI:3.147 to 2.366). This means the data were homogeneous, and treatment could be applied to these groups to see if there were any differences due to the treatment.

An independent samples t-test of post-test scores between the experimental and control groups revealed a significant mean difference between EG (M=56.95, SD=4.66) and CG (M =23.83, SD=10.52);t,42.730.=16.276, p=0.000 (two tailed). The magnitude of the mean differences (mean difference=33.125, 95 percent CI:29.057 to 37.193) was extremely large (eta squared =0.91). This indicates that the experimental and control groups had statistically significant differences in post-test scores. The experimental group’s test scores were significantly higher than the control group's test scores.

Discussion

The purpose of this study was to see how effective differentiated instructions were at improving students’ understanding of derivatives in grade eleven. The results of the study revealed that the experimental group's mean post test score (M=56.95, SD=4.66) when the concept of the derivative was taught using differentiated instruction was significantly higher than the control group’s mean post test score (M=23.83, SD=10.52) when the concept of the derivative was taught using a traditional one-size-fits-all strategy. This difference in the mean score indicates that differentiated instruction had a significant impact on improving students’ learning achievements in the derivative concept. As a result, the statistically significant difference in pre test and post test scores was caused by the intervention rather than chance.

A differentiated teaching method that customised the instructions based on learners' learning profiles, interests, and needs, inspiring learners to study at their own pace, may be responsible for the experimental group’s higher mean score compared to the control group. This backs up what was found by Magableh & Abdullah (2020) that Differentiated instruction is an inclusive pedagogy that reduces learner diversity in classes, homogenising them and improving their overall understanding of derivatives. A one-size-fits-all approach, on the other hand, did not reduce variety in the classroom and thus did not improve students' learning achievement in the derivative.

Each student in the classroom was taught at his or her own level in this study, with lessons and tasks assigned to him or her based on their level of proficiency; differentiated teaching enhanced students’ overall achievement in the experimental group (Magableh & Abdullah, 2019). The experimental group’s teacher made the below-average topic easier to understand while challenging the above-average content, pushing them to do better. The one-size-fits-all strategy, on the other hand, had no influence on student learning since all students got the same instruction as if they were all at the same level. In addition, participants in the experimental group were asked perform their exercises based on their ZPD proficiency level. The differentiated instruction used to achieve mixed ability class learning is based on constructivism, in which students actively construct their knowledge and teachers arrange lessons based on
their readiness level, learning style, interest, socioeconomic position, and learning environment (Subban, 2006; Valiande & Tarman, 2010).

The most important finding of this study is that the mean scores of the experimental and control groups during the pre test did not differ statistically significantly. During the post-test, however, there was a statistically significant difference between the experimental and control groups. This result was in line with the findings of a study conducted by Chen & Chen (2017) who conducted research among 60 college students in Taiwan. Initially, both the experimental and control groups achieved the same results in calculus, but following the implementation of the differentiated teaching approach, the experimental group’s performance was seen to be to the advantage of the experimental group. A similar study by Bal (2016) claimed that using differentiated instruction in sixth grade algebraic lessons improves students’ achievement, demonstrating positive cognitive and affective developments.

Conclusion

Based on my findings, this novel study demonstrates that differentiated instructions customized to students’ learning profiles, needs, and preparedness improve their derivative performance. Students who received differentiated instruction strategy excelled those who received a typical one-size-fits-all approach. Since differentiated teaching has consistently improved students’ achievement in mathematics in general and in derivatives in particular, it is a promising technique for meeting the demand for a variety of learners in mixed ability classes.

Moreover, this work will unravel and shed light on the understanding of the differentiated strategy as a unique and novel educational pedagogy for teaching and learning the derivative concepts relationally rather than through rote memorization, which is a cornerstone of traditional teaching methods. Though the research evidence restricts its generalization, it is congruent with literature in demonstrating that tailored instruction has a favourable effect. Consequently, mathematics teachers might consider implementing a differentiated instructional technique that is based on multiple learning theories and learning styles in teaching and learning mathematics in general, and derivatives in particular.

Despite the positive effect of differentiated instruction on students’ derivative achievement, this study has a number of flaws, most notably a small sample size and a short implementation period for the differentiated instruction strategy. As a result, the researchers advise using the differentiated instruction strategy for longer periods of time and with larger sample sizes.

References


Tomlinson, C. A. (2014). The differentiated classroom: Responding to the needs of all learners. ASCD.


