THE EFFECT OF DIFFERENTIATED INSTRUCTION ON LOW-ABILITY STUDENTS: A QUASI-EXPERIMENTAL STUDY

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Abstract
Over the years, many studies have shown that teaching through differentiation has led to positive academic outcomes. In a classroom setting, instructors can differentiate according to content, process or product based on student readiness, interest or learning profile. However, in a tertiary institution where content is curriculum driven, process is chiefly a lecture style of teaching and the product is usually a final written assessment, it can be challenging to execute differentiated instruction. This article presents a non-equivalent groups quasi-experimental research design study where differentiated instruction was implemented across a pre-university mathematics course. Prior to the study, all students completed a pre-test on mathematical concepts to determine their ability level. Students’ mathematical ability in the groups ranged from highly proficient to extremely weak. The research study was then conducted over two batches: the first batch comprised of 191 students and were instructed using a differentiated approach, the second batch comprised of 228 students and acted as the control group. The differentiated approach was implemented only for a specific topic in the course, i.e. derivatives in calculus. Students in the experimental group were also given a questionnaire assessing their self-confidence and engagement level in class before and after the intervention. Academic achievement on that topic was assessed with a written examination at the end of the semester. Results indicated that there was no change in self-confidence and engagement level before and after the intervention. However, low ability students in the experimental group scored significantly higher in academic achievement for the particular topic but had a lower overall score than low ability students in the control group. There were no differences in academic achievement between the middle and high ability students. This study provides evidence that differentiated instruction has a positive effect on the academic achievement of low ability students.

Keywords: Differentiated instruction, Mathematics, Quasi-experimental research design.

1 INTRODUCTION
Increasingly, classrooms in tertiary institutions are characterised by academic diversity. It is highly likely that students who are gathered together in the same lecture theatre attending the same class could be a combination of advanced learners who have completed a similar topic, externally motivated learners, learners with prefer to learn by collaboration or learners who have an interest in the topic. On the other hand, it is also possible that there could be underachievers who find academic content challenging, have cultural or language barriers, are unable to cope with external demands, have learning problems or are simply unmotivated learners. Yet, there is little consideration in altering the teaching approach taken by teachers to guide student’s learning in tertiary education. A single mode of teaching, i.e. the traditional lecture, continues to dominate in tertiary institutes [1].

There is little impetus to change the structure of this pedagogical method as educators and students often justify the traditional approach through three arguments of individualism, victimisation and authenticity [2]. Individualism deems that success is based solely on one’s efforts and does not depend on any environmental nor contextual factors. Victimisation maintains that nothing can be done as everyone is subjected to institutional rules and expectations. All options are out of the control of lecturers and students. Authenticity refers to a failure of the student to measure up to a subjective standard imposed by peer success or pop culture [2]. All arguments point towards holding the students solely accountable for their academic success and neglects the impact of the teacher.

However, previous research has indicated that the academic achievement of students depends to a large extent on teachers and the pedagogical style they employ [3, 4]. Specifically, the traditional lecture style may not be a good teaching model to adopt as it fails to take into account the level of students’ readiness and their learning ability [5]. Students who have a low level of readiness are not given sufficient time to progress according to their needs. A possible scenario that might occur would be that of an international student who is not proficient in English constantly trying to catch up with the
lecture. Conversely, an advanced student who has either encountered the topic prior to the course or is academically inclined might end up feeling unmotivated and unchallenged. This disparity is even more keenly felt in a tertiary level mathematics course as some students come in with a high level of mathematical knowledge whilst others only have a limited understanding of the same concepts. Thus, our aim in this study is to address this variance in student readiness by differentiated instruction in the hopes of enhancing academic achievement.

1.1 Differentiated instruction

Differentiated instruction is defined as an approach to teaching in which teachers proactively modify content, process or product based on student readiness, interest or learning profile [5]. Content refers to the level of task complexity provided to students. For example, in mathematics, students may be given a straightforward question, e.g. solve $x + 1 = 3$, or a question that involves several intermediate steps. Process refers to the manner in which the content is delivered, e.g. a teacher might choose to use a visual app to demonstrate a mathematical concept or choose to introduce the same concept through an inductive approach. Product refers to the means in which students show evidence of their learning. Various ways to differentiate product could include oral presentations, drawing a cartoon or the traditional pen and paper examinations.

Student's readiness is an indication of the extent that the students need to improve to achieve their educational goals. This is founded on the theory of Vygotsky's zone of proximal development, which is the difference between what learners can do with and without guidance [6]. These differences may have occurred due to variances in prior knowledge or learning abilities. Student's interest relates to the level of intrinsic motivation of the students. By identifying and creating classroom opportunities that tap on their interest level, teachers help students develop a sense of congruence between the activities and themselves, thereby increasing the level of intrinsic motivation [7]. Finally, students’ learning profile refers to their personal preference for learning [5]. Factors that affect this may include gender, learning styles, multiple intelligences or culture.

There is extensive empirical evidence that differentiated instruction is related to positive academic achievement in primary and secondary education [8, 9] and relatively fewer studies at the tertiary level. Possible reasons for the disparity include large class sizes, minimal number of contact hours, it is time consuming to prepare resources and there are ethical issues involved in grading [10]. Due to these constraints, studies in this area at the tertiary level have been mostly restricted to descriptive and exploratory designs [10-12]. There were only a few studies that used an experimental design. Chamberlin and Powers (2010) analysed the effects of differentiated instruction on a first year college math course using three instructors for the treatment group and four instructors for the control group. The treatment group scored higher on academic performance and had more positive perceptions of the course [13]. Dosch and Zidon (2014) researched on the differences between a differentiated classroom and a non-differentiated classroom in an educational psychology course. The students in the differentiated classroom outperformed the control group significantly in the summative assessments and perceived that they learnt better in the course [9]. Based on the comparatively few experimental research, further studies are necessary to judge the impact of differentiated instruction on academic achievement.

1.2 Mathematics instruction in tertiary education

Mathematics lecturers in tertiary institutes often face two major challenges in their daily interactions with students. The first challenge deals with the level of student readiness, which is a function of their educational and cultural background. Mathematics in secondary education is usually broken down into basic or advanced levels. For example, the Cambridge Ordinary levels have two examinable subjects, Elementary Math and Additional Math, and the International Baccalaureate offers four different courses of math to cater for differing abilities. Thus, the mathematical knowledge that students bring to the classroom can vary to a large extent and lecturers often struggle with the question: Do the students of lower ability understand the concept or are they just reproducing the procedural steps? It is a common occurrence for students who are only able to solve problems that are similar to the examples provided. They do not fully understand the key mathematical ideas and are not able to apply the same concepts to a different context.

The differing cultural aspect of student readiness is becoming increasingly common as the number of international students continue to rise. As of 2012, the number of students studying abroad reached an estimated figure of 4.5 million [14]. These international students usually face a language proficiency
issue [15] and may struggle to keep up with lectures. For example, in the institute where this research was conducted, there were students from China, Indonesia, Malaysia, Philippines, Myanmar, Vietnam, India, Ukraine and a host of other countries in which English is not their main language. A further point in teaching mathematics is that mathematical notations could also differ for the different countries, leading to more confusion. For instance, some countries write a comma instead of a dot to represent a decimal point. There is a need to implement appropriate strategies for these groups of students [16, 17].

The second challenge relates to the level of student motivation. Are the tasks set at too high a level for low ability students to manage, causing them to lose self-confidence and interest? Are the tasks set at too low a level for high ability students, causing them to be bored and uninterested? How can interest in mathematics be stimulated, e.g. by linking mathematical concepts with real life situations? Past research has shown that students who have low self-confidence tend to perform worse academically and have a lower level of persistence [18] whereas academically inclined students who are not provided with suitably challenging tasks may become bored and exhibit a decrease in positive attitude [19, 20].

The current study will thus attempt to address these two challenges using differentiated approach as an intervention. In the process, the following research questions will be investigated.

1. Does differentiated instruction improve academic achievement for students at the tertiary level? Is it effective for all students with different levels of readiness?

2. Does differentiated instruction improve students’ attitudes towards mathematics at the tertiary level?

2 METHODOLOGY

The study was conducted over 2 cohorts of students. One cohort was the control group and comprised of 228 students (92 male, 136 female). The mean age was 19.1 years. The other cohort was the experimental group and comprised of 191 students (89 male, 102 female). The mean age was 18.9 years. The students in both cohorts were in a diploma in management studies program that leads to an undergraduate course in business or finance. Mathematics is a core module in the program but the students have very diverse mathematical backgrounds, ranging from highly proficient to extremely weak. This disparity in readiness was due to the varying high school certificates that the students achieved. For example, some students had already completed Cambridge GCE Advanced Level Mathematics whereas some other students only completed an elementary mathematics course. Classes meet once a week for a 3-hour lecture.

Prior to the intervention, all students completed a pre-test on mathematical concepts to determine their ability level. The diagnostic test consisted of 10 questions: 4 questions were on algebra manipulations and solving equations, 4 were on coordinate geometry and 2 questions were on basic calculus. The questions were straightforward and assessed basic mathematical concepts and procedures. The same lecturers taught classes in both the experimental and control group. In the experimental group, differentiated instruction was then implemented for a specific topic, namely derivatives in calculus, and lasted for three weeks. During the intervention, lecturers introduced key ideas of the learning objectives at the start of each session. Students were given an assignment that was differentiated according to ability level. Lecturers walked around the lecture theatre to gather formative feedback and to respond to students’ needs. After the intervention, lectures continued as normal for several more weeks before the end of semester written examination. In the control group, there were no interventions at all.

The short version of the Attitude towards Math Inventory [21] was used to assess students’ attitudes towards the subject at the pre and post intervention stages. The inventory had 3 subscales of self-confidence (SCO), engagement in lessons (ENJ) and perceived value of math (VAL). Each subscale had 5 items that were measured on a 7-point Likert scale with 1 corresponding to “Disagree strongly” and 7 corresponding to “Agree strongly”. The subscales demonstrated good internal consistency (Pre: $\alpha_{\text{SCO}} = .94$, $\alpha_{\text{ENJ}} = .94$, $\alpha_{\text{VAL}} = .90$, Post: $\alpha_{\text{SCO}} = .95$, $\alpha_{\text{ENJ}} = .92$, $\alpha_{\text{VAL}} = .95$). Academic achievement was measured using an end-of-semester written examination. The format of examinations in the two groups were exactly the same. To ensure content validity, the exams were vetted by an external subject expert. There was 1 question made up of 3 parts that assessed students on concepts and applications of derivatives that constituted 20% of the total marks. The corrected item-total correlations were calculated for the same question to show reliability. The correlations for
both the experimental group ($r = .82, p < .001$) and the control group ($r = .75, p < .001$) were both high and significant, indicating that the question was consistent between the two examinations.

3 RESULTS

3.1 Pre-intervention diagnostic test

The pre-test indicated students’ readiness by assessing their prior knowledge on algebra, coordinate geometry and basic calculus. In questions 1 and 2, students had to solve a simple linear equation and quadratic equation respectively, e.g. $5x - 3 = 9x + 5$. In questions 3 and 4, students were tested on algebraic manipulations of rational expressions. In questions 5 to 8, students were given a graph and tasked to read values of the graph, e.g. they had to find the values of $x$ for which $f(x) = -1$. In questions 9 and 10, students had to find the first derivatives of functions, e.g. $3x^2 + 5$. Questions 1, 2, 5 and 6 were classified as “easy” as the tasks merely involved simple calculations. Questions 3, 4, 7 and 8 were classified as “average” as the tasks either involved more difficult expressions or tested a higher level of conceptual understanding. Questions 9 and 10 were used to identify students with an advanced background of mathematics. Students were awarded 1 mark for a correct answer, $\frac{1}{2}$ mark for a partially correct answer and 0 for a wrong answer. Based on the difficulty level of the questions, students who scored a total of less than 4 marks were classified as “Low ability”, between 4 to 7 marks inclusive were classified as “Average ability” and more than 7 marks were classified as “High ability”. The number of students in each category is shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Experimental</th>
<th>Control</th>
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<tbody>
<tr>
<td></td>
<td>Score</td>
<td>Frequency</td>
</tr>
<tr>
<td>“Low ability”</td>
<td>0 - 3.5</td>
<td>45</td>
</tr>
<tr>
<td>“Average ability”</td>
<td>4 - 7</td>
<td>106</td>
</tr>
<tr>
<td>“High ability”</td>
<td>7.5 - 10</td>
<td>40</td>
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</table>

3.2 Description of intervention

The design of the intervention was based on a constructivist approach where students are actively involved in the learning process. Students constructed their own understanding and looked for meaning in their own fashion. The motivation to learn was sustained through increasing the students’ self-efficacy, which in turn is accomplished by successful completing tasks of appropriate difficulty [22]. The lecturer’s role was transformed into someone who facilitates students’ understanding through questioning. The intervention was also grounded on previous theories and research into the characteristics of differentiated instruction. Students worked collaboratively in small groups to solve problems, tasks were differentiated according to the readiness level of students, students were given only the key concepts of each lesson and worked at their own pace through the tasks [5].

Tasks for each session were prepared based on three levels: prerequisite, essential and higher order. Prerequisite tasks required students to activate their schema on previous mathematical concepts that they should know before the current session. For example, students have to recall the notion of gradient and its computation before attempting to understand derivatives from first principles. The essential tasks covered the learning objectives for the session. Students were provided with the key ideas in each section as well as some examples in the worksheet prior to working on the task. High ability students who have completed the essential tasks moved on to the higher order questions that covered extensions of the mathematical concepts and required a higher level of problem solving skills.

The lecturer gave a brief overview of the key concepts at the beginning of each session. Students were given the option to work individually or collaboratively to complete the allocated tasks. However, most students chose to work in pairs or groups of threes. As the lecture theatre was not conducive for collaborative work, the students also had the choice to work at the study tables just outside the lecture theatre. The lecturer moved around to guide students when needed. If the lecturer encounters an issue that most students have difficulties with, he will have the option of addressing the issue as a
3.3 Post intervention measures

3.3.1 Academic achievement

The written examination was divided into two parts for the analysis – the first part analysed the marks obtained on derivatives and the second part analysed the marks obtained for the rest of the examination. An independent samples $t$-test was subsequently conducted on the two parts between the control and experimental group. Effect size was computed using Cohen’s $d$. For the entire group, results indicated that students in the experimental group performed significantly better in derivatives ($M = 14.28$, $SD = 5.20$, $n = 191$) than the control group ($M = 12.44$, $SD = 5.64$, $n = 228$), $t(417) = 3.45$, $p < .01$, $d = .34$. However, the experimental group performed significantly worse in the other parts of the examination ($M = 57.10$, $SD = 15.57$, $n = 191$) than the control group ($M = 63.18$, $SD = 13.53$, $n = 228$), $t(417) = 4.28$, $p < .001$, $d = .42$.

The results were further analysed by partitioning the two groups into ability levels. A summary of the data analysis is shown in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Experimental</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n$</td>
<td>$M$</td>
</tr>
<tr>
<td>Derivatives</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Low ability”</td>
<td>45</td>
<td>11.07</td>
</tr>
<tr>
<td>“Average ability”</td>
<td>106</td>
<td>14.40</td>
</tr>
<tr>
<td>“High ability”</td>
<td>40</td>
<td>17.58</td>
</tr>
<tr>
<td>Rest of examination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Low ability”</td>
<td>45</td>
<td>47.22</td>
</tr>
<tr>
<td>“Average ability”</td>
<td>106</td>
<td>57.38</td>
</tr>
<tr>
<td>“High ability”</td>
<td>40</td>
<td>67.46</td>
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</tbody>
</table>

The results suggested that students in the low ability experimental group performed significantly better in derivatives than the low ability control group, $t(113) = 2.74$, $p < .01$, $d = .51$. However, the low ability experimental group performed significantly worse in the other parts of the examination than the low ability control group, $t(113) = 2.42$, $p < .05$, $d = .46$. In addition, the average ability experimental group also performed significantly worse than the average ability control group, $t(221) = 5.00$, $p < .001$, $d = .67$. Overall, this indicates that the intervention was effective in increasing the academic achievement of students, and it was most effective for students with low ability.

3.3.2 Student attitude

For the experimental group, student’s attitude was assessed during the pre and post intervention stages. The attitudinal components were self-confidence, enjoyment of lessons and perceived value of mathematics. The descriptive statistics for the entire group are shown in Table 3 and a paired sample $t$-test was conducted to determine if there was a change in attitude due to the intervention. The results indicated that there were no differences in the level of self-confidence $t(147) = .415$, $p > .05$, $M_{\text{diff}} = .04$, enjoyment of lessons $t(147) = 1.27$, $p > .05$, $M_{\text{diff}} = .11$ or perceived value of mathematics $t(147) = -.13$, $p > .05$, $M_{\text{diff}} = .01$. 


Table 3. Independent samples t-test of academic achievement by ability.

<table>
<thead>
<tr>
<th>Pre-intervention</th>
<th>Mean</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Self-confidence</td>
<td>4.47</td>
<td>1.62</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Enjoyment</td>
<td>4.48</td>
<td>1.52</td>
<td>.64**</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Value</td>
<td>5.06</td>
<td>1.23</td>
<td>.36**</td>
<td>.61**</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>4. Academic achievement</td>
<td>71.37</td>
<td>20.05</td>
<td>.48**</td>
<td>.52**</td>
<td>.31**</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Post-intervention</th>
<th>Mean</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Self-confidence</td>
<td>4.50</td>
<td>1.62</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Enjoyment</td>
<td>4.59</td>
<td>1.47</td>
<td>.65**</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Value</td>
<td>5.08</td>
<td>1.23</td>
<td>.44**</td>
<td>.63**</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>4. Academic achievement</td>
<td>71.37</td>
<td>20.05</td>
<td>.43**</td>
<td>.46**</td>
<td>.25**</td>
<td>-</td>
</tr>
</tbody>
</table>

**p < .01

In addition, the results were further analysed by partitioning the group into ability levels and conducting a paired sample t-test for each partition. The results indicated that there were no differences in the level of self-confidence for the low ability students t(32) = .978, p > .05, Mdiff = .19, enjoyment of lessons t(32) = -.27, p > .05, Mdiff = -.04 or perceived value of mathematics t(32) = -.24, p > .05, Mdiff = -.04. There were no differences in the level of self-confidence for the average ability students t(80) = - .04, p > .05, Mdiff = .00 or perceived value of mathematics t(80) = .75, p > .05, Mdiff = .08. There were no differences in the level of self-confidence for the high ability students t(33) = -.03, p > .05, Mdiff = -.01, enjoyment of lessons t(33) = -.33, p > .05, Mdiff = -.06 or perceived value of mathematics t(33) = - 1.24, p > .05, Mdiff = -.19. The only significant difference was in the level of enjoyment of lessons for average ability students, t(80) = 2.08, p < .05, Mdiff = .23, d = .23.

4 CONCLUSIONS

The aim of the current study was to examine the impact of differentiated instruction in mathematics at the tertiary level. The study was conducted over two cohorts of students with one cohort being the experimental group and the other cohort being the control group. Both cohorts were taught by the same group of lecturers. Differentiated instruction was applied in a mathematics course for students who were in a diploma program that led to an undergraduate course. The key concepts were presented to students at the beginning of the session and students were allowed to work at their own pace, either individually or in groups, to complete differentiated tasks. Students who encountered difficulties could interact with the lecturer who moved around the lecture theatre. A summary of the key learning objectives was provided at the end of the session.

Results from the study indicated that differentiated instruction has a positive impact on academic achievement, thus corroborating with previous research literature. Moreover, students in the experimental group scored significantly higher in the selected topic for differentiation but significantly lower for the rest of the examination. This indicates that the overall ability profile of the experimental group may be lower than the control group, which in turn accentuates the effectiveness of differentiated instruction.

Further analysis indicated that differentiated instruction was effective for students with low levels of readiness but had no significant impact on students with average or high levels of readiness. This is not surprising for high ability students as they are likely to perform well regardless of any intervention. Differentiated instruction was most successful for low ability students as it may have afforded them the time to work at their own pace. Moreover, they had opportunities to clarify doubts immediately with their classmates or the lecturers, a formative aspect that traditional lectures lack. Lastly, it may be that the sample group for students of average ability may not be well defined as it could have incorporated many high ability students as well. Thus, the difference in examination scores were not significant.

Results from the attitude survey showed that although students of average ability indicated a higher level of enjoyment after undergoing the differentiated instruction sessions, the effect size was small. However, there was no change in the level of self-confidence, enjoyment of lessons and perceived
value of mathematics in most students, contradicting previous studies that showed differentiated instruction has a positive impact on student attitudes. This may be due to any of the following: a) Three weeks of intervention may be insufficient to cause any changes as self-confidence, enjoyment of lessons and perceived value are relatively stable constructs, b) Differentiated instruction does not impact these constructs in the current study. For example, it may be possible that the manner in which students perceive mathematics at the tertiary level has been fostered since primary or secondary education and it is difficult to create any changes, c) Differentiated instruction has no impact on these constructs at all. Attitudinal impacts from previous research were usually reflected through end of course evaluations or observations which may be biased positively whereas the current study attempted to quantify changes through a scale or d) there were additional factors that was not considered in the study, e.g. the lecturer’s relationship with the class. Further research would need to be conducted to ascertain whether differentiated instruction has a significant impact on students’ attitude.

4.1 Reflections

Although differentiated instruction clearly has the potential to improve academic achievement, there were many obstacles in its implementation for the current study. First, the average class size was large, as each class had an average of 70 students. This made monitoring of students quite challenging as the lecturer had to move around the lecture theatre at a quick pace to ensure most students are on task. It may be more effective if additional teaching assistants were present in the class or the lecturer enlisted the help of high ability students for peer tutoring. Second, the traditional layout of the lecture theatre was not conducive for collaborative work. As spatial layouts of the environment do exert an influence on the teaching activities [23], many students found it difficult to work on the tasks in groups. As the layout of the lecture theatre is unlikely to change much, future lessons could make use of technology such as wikis or forums to enhance student collaboration.

Third, although the tasks and structure was planned with the aim of differentiating student readiness, the lessons were still unable to cater for a small group of students. This was because some assumptions of student readiness which were made in the planning stage did not hold up in practice, e.g. it was assumed that students could perform manipulations with fractions or they had basic knowledge of algebra. Some students were also amotivated [24] – they lack the motivation to do any tasks and attended sessions purely to fulfil an attendance criteria. These students would require a different form of intervention. Fourth, at the initial session, many students were not familiar with the pedagogy of differentiated instruction and requested to revert to the traditional lecture where they could adopt a passive role. This may be because students were accustomed to a single form of mathematics teaching since primary and secondary education and were unwilling to adapt. However, once the initial lesson was over, students were observed to be engaged in the subsequent sessions. This was an issue in the current study as differentiated instruction was conducted for a selected topic over three sessions only. Future interventions could last over a longer period of time to decrease the interference caused by adjustment needs.

In summary, although the differentiated instruction was used for a specific topic in mathematics and lasted a short period of time, the results clearly demonstrate a general improvement in the academic achievement of students with a low level of readiness at the tertiary level. However, this study is but a small piece in a large kaleidoscope. Future research can be conducted on different disciplines or using different instructional methods for each grouping to obtain a deeper understanding and appreciation of the impacts of differentiated instruction.

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