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DIFFERENTIATION IN SAUDI PRE-SERVICE SCIENCE TEACHER PROGRAM

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Abstract. *Saudi students' science academic performance has declined as evidenced by (TIMSS). Saudi science teachers are characterized as using the lecture format without considering individual student differences and failing to provide differentiated Method (DM). This paper reports on an effort to help female Saudi pre-service science teachers (PSST) develop DI knowledge and skills, striving to discern how they understood and practiced differentiation during their field experience after completing a specially-designed DM-focused university course. A mixed method research design followed a sequential, connected approach wherein quantitative data were collected through classroom observations (N=47) using a Likert scale observation instrument followed by qualitative interviews (n=11). The pre and post averages of differentiated teaching skills in the DM planning stage were statistically significant (p=.0001). The PSSTs moved from very small to moderate mastery on virtually all 10 planning items, from 1.75 to 2.99 on a five-point Likert scale. The DM implementation stage (20 items) also reflected a statistically significant difference with scores moving from 1.68 to 3.01 (moderate mastery). Interview qualitative data confirmed and elucidated the quantitative results. The course was deemed effective in developing PSSTs' differentiated teaching skills (statistically significant, p=.01). Teaching PSSTs about DM should improve Saudi students' science academic achievement.*

Keywords: *differentiation, pre-service science teachers, teacher education, Saudi Arabia, TIMSS.*

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Introduction

Every four years, the International Association for the Evaluation of Educational Achievement (IEA) administers the Trends in International Mathematics and the Science Study (TIMSS) to evaluate students' performance in mathematics and science, so that to rank the effectiveness of education in schools in 50 participating countries. Saudi Arabia participated in 2007, 2011, and 2015. The total score gained was 329 for eighth grade Saudi students in 2007 and 394 in 2011. In 2011, fourth grade Saudi students scored 410. These achievement scores were significantly lower than the average score of other participating countries, ranking amongst the lowest. In addition, the majority of Saudi fourth (93%) and eighth (80%) grade students were not able to solve problems compared to nearly three-quarters (72%) of the fourth grade and half of eighth grade students internationally (National Center for Education Statistics, ca. 2016). The 2011 TIMSS science and mathematics results showed that Saudi Arabian fourth graders ranked 42nd out of 50 participating countries. The 2015 Saudi TIMSS results showed that only 42% of third graders met the minimum standard of knowledge and skills required, and 41% of sixth graders' achievements were below the minimum standard level of performance (IEA, 2015). These trends show that students' achievement levels in science and mathematics have declined recently in Saudi Arabia. Any critique of these results must consider, among other factors, the effectiveness of teaching methods and instructions used in science and mathematics.

Several studies have demonstrated that Saudi students' low science achievement levels are due largely to the science teachers' use of invariant methods. They tend to be limited to one way of teaching, namely the lecture format. They fail to take into consideration students' diverse learning needs, and do not use differentiated teaching strategies (Al-Eisa, 2010; AlJamaan, Omar, & Fodah, 2015; Alghamdi Hamdan & Alsalouli, 2013; Alghamdi Hamdan & Deraney, 2013; Ramzi, Dicky, Abdelfattah, & Al-Salouli, 2015).

This educational approach is unfortunate because students learn best when they are involved, challenged and supported. Teachers should make every effort to create such a learning environment, which is challenging with the lecture format. Improvement in student learning is possible by using teaching methods that motivate students and better address their needs (Hardré & Sullivan, 2008; Ruys, Defruyt, Rots, & Aelterman, 2013; Stavrou &

Koutselini, 2015). As determined a decade ago, and still applicable now, successful teaching is based ideally on the teacher's (a) ability to understand and correctly assess both individual and collective student needs, (b) deep knowledge of the subject, and (c) creativity in adapting the curriculum, teaching strategies, resources, learning activities, and assessment and learning environment to ensure relevancy to students' needs, interests and learning profiles (Munro, 2012; Santangelo & Tomlinson, 2008; Tobin & McInnes, 2008). However, in Saudi Arabia, like many other countries and contexts, teachers lack sufficient knowledge and skills to teach science effectively.

The inadequate education of science teachers may hence be reasonably identified as a principal cause of students' low science achievement (Gerde, Pierce, Lee, & Van Egeren 2017; Iheonumekwu, 2006; Oriaifo, 2002). The present research views improvement in science teaching and learning as beginning with teacher education programs. Pre-service science teacher (PSST) education programs in Saudi Arabia, which are still teacher-centered and exam-oriented (Alghamdi Hamdan, 2015), include very few, if any, efforts to train teachers to employ differentiation of teaching content, tasks, activities in the science classroom. In particular, PSSTs often do not receive field experience learning opportunities (i.e., practicum), which could be a supplementary setting where they could learn ways of exploring and practicing differentiation.

Research Problem

Given this situation, it is necessary that PSSTs be provided professional learning opportunities to learn how to address science students' differentiated and specific needs (Tobin & McInnes, 2008; Tomlinson, 2003). The PSSTs also need to understand differentiated strategies and techniques in planning and teaching, thereby helping improve learners' academic achievement (Cataldo, 2008; Maeng & Bell, 2015; Marvin, 2001), especially on TIMSS. This paper reports the results of an effort to provide learning opportunities to PSSTs in a Saudi Arabia teacher education program, and was guided by the following research question:

- How did pre-service science teachers' conceptions and perceptions regarding DM change upon completion of a DM-focused course during their teacher education program and the implementation of this learning in their science teaching practicum?

Literature Review

Differentiated Method (DM) is an effective teaching method aimed at responding to learners' preparedness, learning preferences, interests and learning styles (Stradling & Saunders, 1993; Tomlinson et al., 2003). DM assumes both that students learn differently and there are many ways to learn a science topic. Respecting this reality, science teachers should make every effort to provide multiple and diverse opportunities for students to learn and select learning strategies that work best for them. This teaching approach can be informed by DM. Tomlinson (1999, p.14) notes that DM is "an organized, yet flexible way of proactively adjusting teaching and learning to meet kids where they are and help them to achieve maximum growth as learners."

By using a variety of teaching methods, teachers using DM hope to ensure the growth of all students of different educational abilities, backgrounds, skills and capabilities. Teaching methods should suit students' needs and situations (Tomlinson, 2005). Differentiation of teaching and learning in mixed-ability classes involves noting and recording the difficulties encountered and actions taken to overcome them; in short, to address the learning challenges presented from multiple intelligences. Teachers desirous of implementing DM need to both restructure and adapt curricula in response to students' degrees of readiness, learning profiles, interests, and motivations (Stavrou & Koutselini, 2015).

The most important aims of DM are to increase the challenges and excitement in the educational process (Piggott, 2002) and raise learners' academic achievement, both achieved by considering students' prior knowledge. Cash (2011) believes that "if the teacher became aware of the needs of the academic, social and emotional aspects for his/her students, it would help in the face of the gaps in learning" (p. 17). In the Saudi context, addressing gaps in students' learning implies first addressing gaps in teachers' understanding of effective pedagogy, an issue explored in this research. The extensive DM literature is now reviewed along six dimensions pertaining to DM strategies ranging from student diversity, and approaches to, plus benefits and challenges of, DM to DM and pre-service teacher education, and science learning. These dimensions or topics were used to prepare a rationale for the proposed research question and provide anchors for discussion points.

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Student Diversity

All teachers face the challenge of great diversity among students who can "vary according to race, ethnicity, gender, age and ability. They can also differ according to culture, ancestry, language, religious beliefs, sexual orientation and socio-economic background" (Loreman, Lupart, & Andrews, 2015, p. 13). These differences find expression in the classroom in terms of students' responsiveness to what is taught. Hence, it is crucial for all teachers to address student diversity and learning differences, no matter their nature.

In predominantly monocultural societies like Saudi Arabia, the *nature* of student differences in the country's gender-distinct classrooms is learning preferences, levels of knowledge, abilities, motivation, and willingness to learn (Alghamdi Hamdan, 2014). As Felder and Brent (2005) observe, "students have different levels of motivation, different attitudes about teaching and learning, and different responses to specific classroom environments and instructional practices" (p. 57). Addressing these differences is fundamental to effective teaching, and "ignoring these differences may result in failure for the students" (Loreman et al., 2015, p. 13).

Approaches to Differentiated Method

At the core of differentiation is the modification of four curriculum-related elements – content, process, product, and affect, which are based on three categories of student need and variance – readiness, interest, and learning profile (Tomlinson & Imbeau, 2010). They provide an extended discussion of curricular modification. According to them, *content* refers to "the knowledge, understanding and skills that we want students to learn" that need to be modified for students whose learning requirements include the use of visuals, aural comprehension, and self-study. *Process* deals with "how students understand or make sense of the content" so that they can retain, apply and transfer it beyond the classroom. *Product* deals with "how students demonstrate what they have come to know, understand and are able to do after an extended period of learning." *Affect* refers to "how students' emotions and feelings impact their learning" (pp. 15–16).

Roy, Guay, and Valois (2013) present another approach to DM. Using systematic procedures for academic progress monitoring and data-based decision making, teaching is varied and adapted to match students' abilities. To that end, DM includes two major components: (a) *instructional adaptation* wherein teachers make changes in the curriculum, diversify materials and student assignments, vary teaching strategies, and provide extra student support; and (b) *academic progress monitoring*, which involves continuous data gathering about students' performance and rates of improvement, and informed decisions about instructional adaptation based on these data. Differentiation is broadly understood to be an aspect of teachers' "professional, pedagogical competence, a shorthand for all the methods which teachers try to use within the classroom to enable each pupil to achieve the intended learning targets" (Weston as cited in Burton, 2003, p. 43).

Benefits of Differentiated Method

Researchers have identified several advantages of DM, especially gains in student achievement. Richards and Omdal (2007) report that differentiation through tiered assignments increased lower-achieving students' academic achievement. Based on a quasi-experimental study, Mastropieri et al. report gains in all students' achievement in a middle school science classroom (as cited in Maeng & Bell, 2015). Santangelo and Tomlinson (2008) found that differentiating instruction based on students' interest increased their engagement and motivation leading to renewed interest in the lesson. Student interest serves as a catalyst to evoke curiosity and motivation. DM has been shown to help students develop positive attitudes toward learning by (a) considering the diverse needs of those experiencing learning difficulties, and (b) helping them focus on what they *know* rather than what they *do not* know (Santangelo & Tomlinson, 2008). DM also assists teachers to become creative and versatile in using innovative strategies and ideas to respond to students' multiple needs (Butt & Kausar, 2010).

Challenges of Differentiation

Research has also identified two key challenges to implementing DM. Designing instruction based on diverse learning styles may be, at a practical level, difficult or even futile given that students have to achieve certain government-determined common learning objectives within a predetermined amount of time. In response to this possible challenge, Felder and Brent (2005) posit that "if it is pointless to consider tailoring instruction to each individual student, it is equally misguided to imagine that a single one-size-fits-all approach to teaching can meet the needs of every student" (p. 57). Joseph, Thomas, Simonette, and Ramsook (2013) believe that "educators no longer have the legitimate choice about whether to respond to academically diverse student populations" (p. 28).

Another challenge is the propensity for teachers to view DM as a set of methods rather than a teaching philosophy. Given this perspective, many teachers expect to receive hands-on training activities to implement DM (Tomlinson & Imbeau, 2010). In particular, pre-service teachers consider DM to be time-consuming owing to the meticulous planning and high degree of effort required during the planning process. They have also expressed doubts about the feasibility of implementing the practice in every lesson in the classroom (Goodnough, 2010). Given these reservations, DM should be incorporated into teacher-training programs so that novice trainees can appreciate the broader pedagogical philosophy that reinforces the DM methods and curricular modification parameters mentioned in the previous section (Joseph et al., 2013).

Pre-service Science Teachers and Differentiated Method

"Teacher education is blamed for not preparing student teachers adequately for differentiated instruction" (Ruys et al., 2013, p. 22). Tulbure (2011) suggests that pre-service teachers should be taught with DM in mind. As they experience the "transition from teaching-centered towards learning-centered education, [they learn that] within this paradigm, the [DM] instructional process is student-centered and aims to provide flexible learning situations to enhance the quality of instruction for all learners" (p. 448). Such a paradigm shift better ensures that pre-service teachers learn that not all students can learn unless DM is fully practiced in the planning and implementation stages of teaching.

Previous research has established that student interest toward science is directly related to student science achievement (Alliman-Brissett & Turner, 2010; Horn & Walberg, 1984; Schiefele, Krapp, & Winteler, 1992; Voss & Schauble, 1992). If insufficient efforts are made to sustain student interest in learning science, this interest declines each year a student spends in school (Hidi, 2000). This is especially pronounced for students' interest in mathematics and science (Krapp, 2002; National Research Council, 2008). These assertions reinforce the importance of using DM to nurture success and interest in mathematics and science classrooms.

The Chair of the Committee on Educational Affairs and the Saudi Council of Scientific Research states that science "teachers today suffer from poor preparation and cognitive rehabilitation and skill preparation; blurry tasks, duties and rights; low professional growth programs and supervision; weak accountability and accounting; as well as a decline in society's perception of the teacher, resulting in a low level of job satisfaction" (Al Otaif, 2012, p. 3). Implementing DM in science teacher education programs would be one way of addressing such concerns regarding the teaching and learning of science in schools. Apart from promoting relevant learning, responding to multiple intelligences, fostering success for all, and challenging students, an opportunity for pre-service science teachers to differentiate the curriculum broadens the scope of their own knowledge and understanding of the intricate relationship between DI and learning (Goodnough, 2010). DM is also valuable for teaching pre-service teachers when it is used to address a lack of knowledge in a related course of study if prior knowledge is taken into consideration (Salar & Turgut, 2015).

Science Learning and Differentiated Method

DM is of particular importance for PSSTs as it prepares them for the reality that not all students learn science at the same pace or same way (National Research Council, 2008). While implementing DM in classroom activities, it is important to assess science students' levels of interest. Curricula "based on understanding concepts, real-world problem-solving and inquiry-based learning benefited high-ability learners leading to greater interest, engagement and ultimately achievement" (Kim et al., 2012; Feng, VanTassel-Basha, Quek, Bai, & O'Neill, 2005; Robinson, Dailey, Hughes, & Cotabish, 2014, p. 194; see also; VanTassel-Baska, 1998). Further, "the development of science process skills allows students to better model and utilize authentic scientific practices. … Student understanding of concepts is substantially aided when teachers explicitly articulate overarching concepts and link content to them" (Robinson et al., 2014, p. 204; see also National Research Council, 2008).

Brousseau (1997, p. 12) observes that "one of the teacher's central responsibilities is the design of good challenging tasks to learners." To implement DM, science teachers ought to provide every student with learning

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opportunities that fit their abilities, support their science learning and motivate him or her. It is also the teacher's responsibility to help students move to the next level of conceptual ability (National Research Council, 2008). Sheffield (2009) maintains that teachers have to challenge students who are ready to move to a higher level and provide hints to students who may be frustrated. The U.S. National Science Board "recommended [that] STEM opportunities for all students begin in the elementary grades and include inquiry-based learning, peer collaboration, and open-ended, real-world problem solving" (Robinson et al., 2014, p. 190). Related studies highlight the importance of science teachers learning how to identify students' learning styles and using this information to plan lessons to raise academic achievement (Cataldo, 2008; Maeng & Bell, 2015; Marvin, 2001).

Efforts to employ differentiation in Saudi Arabian science classrooms are not fully developed as part of pre-service teacher education or in the topics covered in studies to teach science. Researchers are increasingly beginning to report on this lack of diversification in teaching methods and the unsatisfactory results that have ensued (AlJamaan et al., 2015; Mansour, EL-Deghaidy, Alshamrani, & Aldahmash, 2014). It is important for novice as well as seasoned classroom science teachers to receive professional development to increase their understanding of DM. Research has shown the wide-ranging positive impact that DM has on teaching and learning. It is therefore well worth considering the implementation of DM in science teaching in the Saudi context as a means of addressing current levels of poor student performance.

Research Methodology

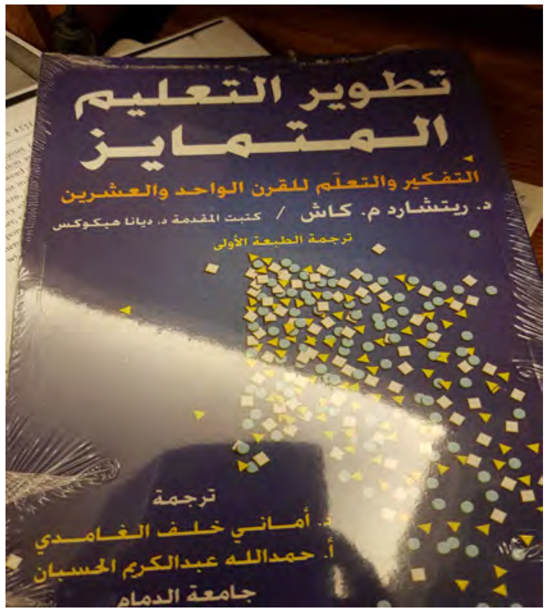
Research Design and Methods

To that end, this research employed a mixed methods research design to achieve triangulation, which is a strong way to develop understandings of a research problem. Words can add meaning to numbers and numbers can add precision to words (McGregor, 2018). To ensure data integration to answer the research question, the researchers used a sequential, connected design. Respectively, this involved collecting and analyzing quantitative data using a quasi-experimental research design followed with semi-structured interviews to generate qualitative data. It was considered a connected design because the data from the quantitative strand informed the data collection protocol during the qualitative strand (Creswell & Plano Clark, 2007). The quantitative results recounted the PSSTs planning for and implementation of differentiated instruction. The qualitative findings and analysis were used to explore the PSSTs' subjective understandings of the practice of DM. The qualitative findings (participants' words) used to help interpret PSSTs' classroom practices (quantitative results) (Creswell, 1998). This research design achieved expansion triangulation, wherein qualitative data were generated to answer questions that arose using the quantitative method, yielding further elucidation (Aarons, Fettes, Sommerfeld, & Palinkas, 2012). A mixed methods approach was considered the best way to gain understandings of the phenomenon of pre-service science teachers' understandings of the meaning of differentiation and identify potentially relevant variables that might be later tested quantitatively (see Hoepfl, 1997).

Research Context

The underlying purpose of this research was to improve Saudi PSSTs' understanding and practice of differentiation in science classrooms. To that end, the context was a female pre-service science teacher education program in a Faculty of Education at a university in the Eastern Province of Saudi Arabia. The research occurred during the 2015–2016 academic year and was conducted by two faculty members in the Faculty of Education. The research period was one, 14-week term in the pre-service education program comprising nine courses followed with a 12-week practicum (one day per week).

Pre-test data were collected during a course called *Teaching Strategies in Science*. The Principal Investigator (PI) (an author of this paper) designed and taught the course focused on teaching DM and advancing pre-service science teachers' understandings of DM. In more detail, in preparation for implementing the research design protocol, the PI obtained permission to translate into Arabic two well-known English-language textbooks on DM (Cash, 2011; Heacox, 2012), which were then published by a Saudi Arabian publisher in collaboration with the respective American publishers (see Figures 1 and 2).



Figures 1, 2: English-language textbooks on DM.

Next, the PI designed a series of four workshops/lectures about DM and presented them to the PSSTs, thereby orienting them to and educating them about DM. These workshops were also based on Tomlinson's (2003) definition of DM, best practices in science classrooms, methods for implementing DM, and specific examples of DM in science classrooms. Course topics included: (a) defining the essentials of a differentiated classroom, (b) identifying skills for the new century, (c) advancing differentiation in assessment, (d) motivating and engaging learners, (e) using assessment to engage learners, and (f) learning the characteristics of a thinking classroom, and (g) a thinking curriculum.

Participants

The research participants were 47 female pre-service science teachers enrolled in a B.Ed. teacher education program in a public university in Saudi Arabia. They were all registered and enrolled in the aforementioned course *Teaching Strategies in Science*. Participants had previously completed a Bachelor of science including physics, biology and chemistry. They had diverse educational and professional backgrounds, varied classroom teaching experience, and ranged in age from 30–45. Participation in the study was mandatory.

Data Collection Tools

To collect quantitative data about the PSSTs' understanding and practice of DM, the researchers developed an observation card comprising a checklist of observable behavior. This instrument was checked by science education experts to ensure reliability and validity. Qualitative data were collected through interviews with PSSTs using a semi-structured interview protocol. More details follow.

Observation card. Based on a review of literature on differentiated teaching skills (Cash, 2011) (as well sources cited in the literature review section), the research team developed an observation card comprising 30 items (10 items for the DM *planning* stage and 20 for the *implementation* stage) (see Tables 2 and 3 in the Results section for the 30 items). The observation card was designed using a five-point Likert scale to check the extent to which the PSSTs were able to plan and implement differentiated instruction skills, moving through the mastery of skills as very small (1), small (2), moderate (3), significant (4) and high (5).

The observation card was rigorously piloted tested and validated for reliability and content validity, with details and instrument available from the authors. In summary, a Kuder-Richardson coefficient of KR 20=0.83 was obtained,

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suggesting high internal consistency. The observation card's reliability was tested by having the PI observe five students. The Cooper equation was used to verify the stability of the observation card. The *stability coefficient = (2 x total values agreed upon by the observers)/[Total values of the first observer (a) + Total values of the second observer (b)]*. Employing this equation for the *planning* stage yieled an agreement coefficient of 0.84. The agreement coefficient for implementation stage was 0.82, while the agreement coefficient of the entire card was 0.83, indicating the stability of the card and its usability in the field. Establishing the internal consistency of the observation card was achieved by pilot testing it on 15 pre-service teachers at the Faculty of Education at a university in the Eastern Province of Saudi Arabia. Table 1 reflects the correlation coefficients between the scores of each of the 30 items and the stage to which they belong, and the total score of the observation card.

Table 1. Internal consistency of observation card.

Dimension I DM Skills in the Planning Stage			Dimension II DM Skills in the Implementation Stage					
M	The correlation coefficient with the first 10 items	The correlation coefficient with the total score of the card	M	The correlation coefficient with first 10 items	The correlation coefficient with the total score of the card	M	The correlation coefficient with second 10 items	The correlation coefficient with the total score of the card
1	0.722 **	0.542 *	11	0.954 **	0.631 *	21	0.652 *	0.582
2	0.713 **	0.528 *	12	0.563 *	0.558 *	22	0.590 *	0.588 *
3	0.850 **	0.517 *	13	0.774 **	0.730 **	23	0.849 **	0.621 *
4	0.607 *	0.519 *	14	0.636 *	0.519 *	24	0.861 **	0.641 *
5	0.775 **	0.723 **	15	0.590 *	0.582 *	25	0.864 **	0.745 **
6	0.735 **	0.713 **	16	0.736 **	0.509 *	26	0.730 **	0.622 *
7	0.909 **	0.523 *	17	0.535 *	0.571 *	27	0.731 **	0.770 **
8	0.747 **	0.532 *	18	0.515 *	0.542 *	28	0.693 *	0.678 *
9	0.759 **	0.572 *	19	0.595 *	0.584 *	29	0.628 *	0.555 *
10	0.794 **	0.577 *	20	0.707 **	0.528 *	30	0.528 *	0.588 *

** Level of significance is .05*
*** Level of significance is .01*

Interview protocol and questions. The research team developed semi-structured interview questions to obtain further insights into the PSSTs' planning and implementation of differentiated instruction strategies. These questions were validated by four referees with science education backgrounds. The five interview questions were:

- What is differentiation?
- What is your perception of differentiation?
- What differentiated teaching skills are necessary to enable science teachers to achieve differentiation in the classroom?
- How do you perceive change as a result of explicit DM in relation to the context of being a student and a teacher?
- How does your perception of DM differ pre and post classroom instruction?

Data Collection

Using the especially-developed observation card, two science education faculty members (one of whom is the PI) observed the 47 PSSTs in their pre-treatment microteaching sessions for three weeks at the university and then in their practicum classrooms (post treatment). The science lessons taught in the microteaching session were selected prior to class. As noted, the quantitative data were collected via a quasi-experimental research design involving pre and post observation card treatment (Shadish, Cook, & Campbell, 2002). The PSSTs were observed both before (during microteaching) and after (during their practicum) completing the specially-designed university DM course.

These quantitative data were analyzed early in the research cycle (Wellington (2000). As anticipated, quantitative data collected from the observations required further investigation to deepen insights into PSSTs' understanding and practice of DM. To that end, the study participants were approached via email to agree to take part in semi-structured, follow-up interviews, with 11 agreeing to take part (with informed consent). The PI conducted the interviews in Arabic using the aforementioned research protocol, via phone or Skype. The 40-minute, audio-taped interviews were transcribed and translated to English, checked by an expert translator.

In effect, all 47 participants were observed, before and after the university course, with 11 participants interviewed. It is common for the qualitative strand in a mixed methods research design to involve fewer participants than the quantitative strand, and 11 participants is sufficient to stave off validity concerns because these same PSSTs were also involved in the observation strand (Creswell & Plano Clark, 2007). As noted, this strategy serves as a form of expansion triangulation (elucidation), strengthening the research design (Aarons et al., 2012). The two members who observed the participants, compared their results after the observations and were satisfied they had obtained valid results since they had virtually the same comments (affirming inter-reliability).

Data Analysis

Quantitative observation data were analyzed using descriptive and inferential statistics (t-test). Qualitative interview data were analyzed and summarized by research question. When appropriate, direct quotations were used to present findings (pseudonyms were assigned for each one of the participants, so their identity is not revealed).

Results of Research

Quantitative Findings

The quantitative results address the research question. Tables 2 and 3 portray the PSSTs' ability to master DM teaching skills when planning and implementing DM strategies, captured via classroom observations. Scores were ranked on a five-point Likert scale from 1 (very small mastery) to 5 (high mastery). Results indicate that, in the DM *planning* stage, the PSSTs reported very small to small levels of mastery when it comes to differentiated teaching skills. Their overall score was 1.75. If they scored high for any item, it was related to identifying students' previous knowledge. Their average score for *implementing* differentiated teaching strategies was lower at 1.68, characterized as very small mastery.

Table 2. Differentiated teaching skills in the DM planning stage (N=47).

	DM Skills in the Planning Stage **(Items 1-10)**	Standard deviation	Distribution of participants according to their **evaluation on 1–5 point scale**					Overall average	Category Medium
			Very high	**Significant**	Moderate	Small	Very small		
1	Set differentiated learning objectives according to the abilities and skills of diverse students.	.66	0	0	12	60	28	1.82	Small
2	Prepare tools to identify differentiated skills of students.	.77	2	0	10	54	34	1.82	Small
3	Prepare tools to recognize differentiation of students in the mastery of prior knowledge pertaining to the content of the new learning.	.82	2	2	6	52	38	1.78	Very small
4	Determine the classification criteria of working groups according to their distinctiveness.	.63	0	0	12	58	30	1.82	Small
5	Determine the standards of achievement expected of students according to their distinctiveness.	.66	0	0	12	52	36	1.76	Very small

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	DM Skills in the Planning Stage **(Items 1-10)**	Standard deviation	Distribution of participants according to their **evaluation on 1–5 point scale**					Overall average	Category Medium
			Very high	**Significant**	Moderate	Small	Very small		
6	Select appropriate teaching strategies according to the differentiated educational goals of teachers.	.75	0	2	14	48	36	1.82	Small
7	Prepare appropriate activities in accordance with the differentiated educational goals of teachers.	.81	0	4	12	44	40	1.8	Very small
8	Prepare appropriate instructional material in accordance with the differentiated educational goals of teachers.	.69	0	2	10	56	32	1.82	Small
9	Prepare assessment tools that assess the differentiated educational goals of teachers.	.64	0	0	8	42	50	1.58	Very small
10	Prepare outdoor activities for students according to the extent of their distinctiveness.	.54	0	0	2	40	58	1.44	Very small
	Overall average of the axis of differentiated teaching skills in the planning stage							1.75	Very small

Table 3. Differentiated teaching skills in the DM implementation stage (N=47).

	DM Skills in the Implementation **Stage (Items 11-30)**	Standard deviation	Distribution of participants according to their **evaluation on 1–5 point scale**					Overall average	Category Medium
			Very high	**Significant**	Moderate	Small	Very small		
11	Divide students into homogeneous groups according to their distinctiveness.	.49	0	0	2	70	28	1.74	Very small
12	Give appropriate tasks to working groups according to the differentiation of students.	.60	0	0	10	62	28	1.82	Small
13	Distribute roles to students in working groups according to their differentiation.	.57	0	0	6	60	34	1.72	Very small
14	Display knowledge and skills that correspond to the intelligence of differentiated students.	.50	0	0	0	52	48	1.52	Very small
15	Balance the provision of knowledge and skills according to the intelligence of differentiated students.	.50	0	0	0	48	52	1.48	Very small
16	Encourage student to use more than one pattern of multiple intelligences.	.53	0	0	2	36	62	1:40	Very small
17	Display knowledge and skills in accordance with students with compatible auditory differentiation.	.59	0	0	6	54	40	1.66	Very small

DM Skills in the Implementation **Stage (Items 11-30)**		Standard deviation	Distribution of participants according to their **evaluation on 1–5 point scale**					Overall average	Category Medium
			Very high	**Significant**	Moderate	Small	Very small		
18	Display knowledge and skills in accordance with students with compatible visual differentiation.	.74	0	2	20	52	26	1.98	Small
19	Display knowledge and skills in accordance with students with compatible sensory differentiation.	.69	0	2	10	56	32	1.82	Small
20	Implement competitive activities among learners according to their distinctiveness.	.72	0	0	14	48	38	1.74	Very small
21	Implement appropriate activities for working groups according to the differentiation of students.	.78	0	4	16	52	28	1.96	Small
22	Provide instructional enrichment activities for gifted differentiated students.	.61	0	0	6	40	54	1.52	Very small
23	Provide remedial activities for students with differentiated learning difficulties.	.93	0	0	6	30	64	1.10	Very small
24	Use appropriate reinforcement to enhance the learning experience of working groups according to the differentiation of students.	.67	0	0	22	56	22	2:00	Small
25	Use appropriate reinforcement to enhance students individually according to their distinctiveness.	.91	0	8	22	42	28	2.10	Small
26	Encourage students to exchange experiences according to their educational distinctiveness.	.63	0	0	10	54	36	1.74	Very small
27	Implement a variety of assessments according to the differentiation of students in working groups.	.72	0	2	8	44	46	1.66	Very small
28	Provide appropriate feedback for each working group according to the differentiation of students.	.77	0	2	16	44	38	1.82	Small
29	Direct students to a range of outdoor activities in accordance with their educational distinctiveness.	.71	0	0	12	28	60	1.52	Very small
30	Prepare learners for subsequent learning subjects that correspond to their educational distinctiveness.	.63	0	0	6	24	70	1.34	Very small
Overall average of the axis of differentiated teaching skills in the implementation stage								1.68	Very small

Course Effectiveness for Developing Differentiated Teaching Skills

Before and after taking the course, the PSSTs were observed using the DM Observation Card. Table 4 compares the PSSTs' pre and post averages of differentiated teaching skills in the *planning* stage, showing a statistically significant difference (p=.0001) with t= (12.107).

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Table 4. Comparison between the pre and post averages on differentiated teaching skills in the planning stage.

Application	Number	Medium	Standard deviation	Degrees of freedom	t Value	Significance
Pre- test	50	5.395	.763	49	12.107	.0001
Post-test		8.756	1.238			

A detailed comparison of the differences for each of the 10 *planning* items is presented in Table 5. The PSSTs moved from very small mastery to moderate mastery on virtually all 10 DM planning items, moving from an average pre-test score of 1.75 to a post-test score of 2.99. The largest shifts occurred on items 7 (appropriate activities) and 9 (assessment).

Table 5. Differentiated teaching skills in the DM planning stage for each item N=47.

	Sub skills of DM skills in the planning stage	Pre-test		Post- test	
		Mean	Average	Mean	Average
1	Set differentiated learning objectives according to the capabilities and skills of diverse students.	1.82	Small	2.88	Moderate
2	Prepare tools to identify differentiated skills of students.	1.82	Small	2.84	Moderate
3	Prepare tools to recognize differentiation of students in the mastery of prior knowledge pertaining to the content of the new learning.	1.78	Very small	2.88	Moderate
4	Determine the classification criteria of working groups according to their distinctiveness.	1.82	Small	3.06	Moderate
5	Determine the standards of achievement expected from students according to their distinctiveness.	1.76	Very small	3.04	Moderate
6	Select appropriate teaching strategies according to the differentiated educational goals of teachers.	1.82	Small	3.18	Moderate
7	Prepare appropriate activities in accordance with the differentiated educational goals of teachers.	1.8	Very small	3.26	Moderate
8	Prepare appropriate instructional material in accordance with the differentiated educational goals of teachers.	1.82	Small	3.18	Moderate
9	Prepare assessment tools that assess the differentiated educational goals of teachers.	1.58	Very small	2.98	Moderate
10	Prepare outdoor activities for students according to the extent of their distinctiveness.	1.44	Very small	2.68	Moderate
Overall average		1.75	Very small	2.99	Moderate

Regarding the effectiveness of the course in the development of differentiated teaching skills in the *implementation* stage, there was a statistically significant difference between the mean scores before and after completing the course, with a t -value of 22.883 (see Table 6).

Table 6. Differentiated teaching skills in the implementation stage (N=47).

Application	Number	Mean	Standard deviation	Degree of freedom	t Value	Significance
Pre-test	50	9.171	1.297	49	22.883	.0001
Post-test		21.999	1.838			

A detailed comparison of the differences for each of the 20 *implementation* items is presented in Table 7. The PSSTs moved from very small mastery to moderate mastery on 13 items and very small to moderate mastery on six items, moving from an average pre-test score of 1.68 to a post-test score of 3.01. The largest shifts occurred on Items 23 (remedial activities) and 27 (assessments). In effect, during both the planning and implementation stages, the PSSTs benefitted the most by learning about appropriate learning activities and assessment tools.

Table 7. Differentiated teaching skills in the implementation stage per 20 items (N=47).

Sub skills of differentiated teaching skills in the implementation stage		Pre-test		Post-test	
		Mean	Average	Mean	Average
11	Divide students into homogeneous groups according to their distinctiveness.	1.74	Very small	3	Moderate
12	Give appropriate tasks to working groups according to the differentiation of students.	1.82	Small	3.02	Moderate
13	Distribute roles to students in working groups according to their differentiation.	1.72	Very small	3.1	Moderate
14	Display knowledge and skills that correspond to the intelligence of differentiated students.	1.52	Very small	2.72	Moderate
15	Balance the provision of knowledge and skills according to the intelligence of differentiated students.	1.48	Very small	2.72	Moderate
16	Encourage learners to use more than one pattern of multiple intelligences.	1:40	Very small	2.7	Moderate
17	Display knowledge and skills in accordance with students with compatible auditory differentiation.	1.66	Very small	2.92	Moderate
18	Display knowledge and skills in accordance with students with compatible visual differentiation.	1.98	Small	3.4	Moderate
19	Display knowledge and skills in accordance with students with compatible sensory differentiation.	1.82	Small	2.94	Moderate
20	Implement competitive activities among students according to their distinctiveness.	1.74	Very small	3.18	Moderate
21	Implement appropriate activities for working groups according to the differentiation of students.	1.96	Small	3.26	Moderate
22	Provide instructional enrichment activities for gifted differentiated students.	1.52	Very small	2.62	Moderate
23	Provide remedial activities for students with differentiated learning difficulties.	1.1	Very small	3.36	Moderate
24	Use appropriate reinforcement to enhance learning experience of working groups according to the differentiation of students.	2.00	Small	3.2	Moderate
25	Use appropriate reinforcement to enhance students individually according to their distinctiveness.	2:10	Small	3.44	Significant
26	Encourage students to exchange experiences according to their educational distinctiveness.	1.74	Very small	3	Moderate
27	Implement a variety of assessments according to the differentiation of students in working groups.	1.66	Very small	3.14	Moderate
28	Provide appropriate feedback for each working group according to the differentiation of students.	1.82	Small	3.24	Moderate
29	Direct students to a range of outdoor activities in accordance with their educational distinctiveness.	1.52	Very small	2.72	Moderate
30	Prepare learners for subsequent learning subjects that correspond to their educational distinctiveness.	1.34	Very small	2.6	Moderate
	Overall average	1.68	Very small	3.01	Moderate

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On the whole, the course was effective in developing differentiated teaching skills. Results indicate a t value of 24.128, which was statistically significant (p=.0001) (see Table 8).

Table 8. Comparison of pre and post application of the differentiated teaching skills education course on the whole (N=47).

Application	Number	Mean	Standard deviation	Degree of freedom	t Value	**Significance**
Pre-test	50	15.349	2.170	49	24.128	.0001
Post-test		23.521	3.326			

Qualitative Findings

The interview protocol involved five questions related to insights into the PSSTs' planning and implementation of differentiation strategies, designed to gather more data to address the research question. The interview data were analyzed and summarized by interview question, and direct quotes were used when reporting the findings (McGregor, 2018). Responses to three of the five questions are reported in this paper: (a) skills necessary to implement DM, (b) perceptions of DM before and after taking the specially-designed course, and (b) big changes they faced as a result of learning about DM and science education.

Necessary DM Skills

For the question related to their ideas about what DM skills are necessary to enable them to achieve differentiation in the classroom, they identified differentiating (a) "*learning objectives for each group*" (Teacher A), (b) "*roles of students in a working group*" (Teacher C), (c) "*tasks for gifted students*" (Teacher D), and (d) "*time to help students with learning difficulties*" (Teacher E).

A popular strategy among the PSSTs was analyzing students' learning needs to help plan differentiated instruction. To illustrate, Teacher A said, "*I prepared tools to identify the difference in learners' prior knowledge pertaining to the content to be taught.*" Teacher D commented that "*I learned to apply [the] learning styles questionnaire to be able to help my students' learning; at least I am trying to help support my students' learning according to their levels and interests.*" And, Teacher E said, "*I use the evaluation results to diagnose students' strengths and weaknesses.*"

Perception of DM Pre and Post Course

The PSSTs were asked to compare their understanding of DM at the end of the course titled *Teaching Strategies in Science* as compared to that at the beginning. Teacher B acknowledged, "*I am flexible in dividing students [into groups] according to their preferences, but after the course, I also became aware of the [learning] needs [of individual learners] and was able to differentiate according to students' [ability] levels*." She claimed that after the course, she started implementing "*continuous assessment of the readiness of the students and their interests*" to assign appropriate tasks according to their abilities and needs. Now, she reads more about differentiation, so she can be skillful to teach diverse learners according to their distinct capabilities.

Teacher A reported now being skillful in designing and using tools to detect diverse learners' knowledge and skill levels. "*After the course, and because I understood the importance of evaluation, I was able to design a variety of evaluative methods to assess my students' knowledge levels and learning styles*." Teacher C noted her ability to "*display the knowledge and skills that correspond to the [multiple] intelligences of diverse learners.*" She noted that she is now able to "*encourage learners to use multiple intelligences*."

Teacher D expressed her progress in understanding different learning styles by showing her ability to assign students in groups according to their learning styles in each unit, which she was not able to do before this course. Teacher D also articulated her learning about realizing the importance of helping students to voice their opinion in a science classroom. She stated that she would now "*give students the opportunity to express their opinions and encourage them to participate in classroom discussion and dialogue*."

Teacher E found she was now confident that she would be able to implement "*innovative teaching strategies* *based on scientific research to achieve differentiation and teach students according to their capabilities and needs*." She said that because of the course, she has become "*highly supportive of students' grouping when doing any activity to achieve differentiation*."

Perceptions of Changes Caused by DM Course

When asked how they perceived change as a result of explicit DM in relation to the context of being a student and a teacher, the PSSTs identified challenges they faced when implementing DM in classrooms. These were big changes for them. One of the major challenges was a lack of the pre-requisite "*psychological knowledge*" required to constitute mixed-ability or homogenous groups, considering the unique learning needs of diverse students and difficulty levels of the science topics (Teacher E). She admitted, "*I am not [an] expert*" in this knowledge. This comment indicates a need for courses or learning experiences to help PSSTs understand individual differences among learners.

Another challenge (i.e., big change) the PSSTs faced is similar to that reported by many teachers when implementing DM – a lack of ongoing support, which is imperative for engaging all learners in science activities. Teacher B noted: "*Students did not show interest in all activities, and that is because of their [different] levels and learning styles*," which she found impossible to handle without support. Similarly, Teacher D asserted "*classification of students in working groups according to their unique learning needs*" could be performed better with the help of an assistant. Teacher C found it difficult to *"encourage learners to use multiple intelligences"* to perform an assigned task as learners tended to fall back to their preferred or natural learning styles.

Teacher E identified the traditional textbooks used in classes as a big change she faced. She realized that their authors do not consider Saudi student diversity when designing various science activities. This leaves teachers to re-work these activities, involving extra time. This finding points toward the need for a revision of science textbooks, focusing on inclusive learning activities. Teacher D affirmed, "*adding specific criteria of student working groups according to their distinctiveness is a time-consuming task, which I cannot do for all activities*." She emphasized that such "*classification criteria of working groups do not exist as a rule in teaching science*," making it even harder to implement it for each activity in the classroom, which is "*critical to make science comprehensible*" to all learners.

Discussion and Implications

The results of this research suggest that Saudi female science students in a B.Ed. program are likely to perceive both possibilities and potential barriers afforded by implementing DM in science teaching. They expressed the sentiment that the possibilities around improving students' learning outweighed the barriers they faced as educators striving to implement DM (see Joseph et al., 2013). As with other research, our results imply that a specially-designed course about DM increased the PSSTs' motivation to learn more about ways to implement DM in science teaching (Burton, 2003; Fenner, Mansour, & Sydor, 2010).

As anticipated, the qualitative findings elucidated the quantitative results (Creswell & Plano Clark, 2007). The latter revealed a statistically significant improvement in learning about DM after taking the DM-focused course titled *Teaching Strategies in Science*. In the qualitative strand of the research, participants shared many benefits from taking the course ranging from being able to (a) differentiate learning strategies after determining students' ability levels and learning styles to (b) designing a variety of assessment methods to match students' learning styles. Many affirmed a new-found ability to design innovative instructional strategies that support students' science learning, similar to previous studies (Butt & Kausar, 2010; Joseph et al., 2013; Richards & Omdal, 2007). The PSSTs also noted a new sensitivity to student diversity as did Loreman et al. (2015).

Rusek, Starkova, Chytry, and Bilek (2017) found that pre-service science teachers wanted proof that an innovation would work in their future classroom before they use it. The PSSTs in our study obtained direct proof that DM works (i.e., a teaching innovation) because they had a chance to implement what they had planned ahead of time in their B.Ed. course in their practicum. This success means they are more likely to embrace this approach in their professional career. The PSSTs developed some confidence in implementing DM as evidenced in their belief that they successfully identified students' learning needs and planned instructions accordingly to help students understand the science content at hand (similar to Joseph et al., 2013). This result points to the success of the course, used as the context for this research, and provides evidence that participants were able to develop a modest understanding of DM and related skill sets during the course to implement during their practicum field experience.

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Joseph et al. (2013) reported that the majority of pre-service teachers in their study were satisfied with their DM-focused curriculum course. Similarly, in the interviews in our study, eight of the 11 PSSTs said they learned a great deal about DM from the course, but also said it was not enough. They felt the need to find more information on their own. Our finding (that they needed more information) suggests that one lone DM course is insufficient for pre-service science teachers, who seemed to appreciate being introduced to this teaching approach but wanted more. In our study, the *Teaching Strategies in Science* course introduced DM as a teaching strategy, but the entire B.Ed. program was not focused upon DM. To ensure a more comprehensive exposure to DM, we feel that the differentiated philosophy should be integrated into the entire B.Ed. program. Joseph et al. (2013) agreed that "teacher education institutions must put in place systems that support effective teaching and modelling of differentiated instruction" (p. 29).

Quantitative results (see Tables 5 and 6) showed that during both the planning and implementation stages for using DM instruction in their science practicum, the PSSTs reported moderate learning for most items. But results indicate that the PSSTs benefitted the most by learning about appropriate learning activities, and assessment tools. Joseph et al. (2013) also found that students appreciated learning about how to prepare appropriate activities and learner assessment. Regarding the other 28 DM skill items (see Tables 5 and 6), the PSSTs experienced moderate mastery on the remaining planning skills related to identifying how students are different, setting appropriate standards to gauge their achievement and selecting suitable teaching strategies and materials. They also achieved moderate mastery of most of the DM implementation skills, with examples being reached students experiencing visual, sensory, auditory, gifted and other learning difficulties; encouraging and respecting multiple intelligences; and, working effectively with groups (i.e., assigning students to the groups, distributing roles and tasks, and reinforcing group learning). The qualitative data corroborated these results, with students saying the most necessary DM skills pertained to group dynamics and students with learning challenges (especially gifted). Joseph et al. (2013) discussed similar learnings as a result of taking a DM course, but did not employ a pre-test and post-test protocol.

From another perspective, the PSSTs benefitted equally from taking the course with respect to DM planning and DM implementation, with virtually identical average scores, 2.99 and 3.01, respectively. These results were statistically significant meaning it was not by chance that students learned how to both plan and implement DM. What is telling is that the shifts in scores before and after the course were nominal, with students achieving moderate mastery but not significant or very high, as would be the ideal. Perhaps the short-term, limited exposure to the DM-related content played a factor in that students were taking other B.Ed. courses with no DM focus. If more instructors focused on DM in their courses, its influence would increase.

Similar to previous research, the qualitative findings suggest that the PSSTs viewed DM as a method and not an educational philosophy. They wanted more technical support when designing DM and made no mention of DM as an underlying philosophy (Goodnough, 2010; Tomlinson & Imbeau, 2010). Philosophy was not the focus of our research but this finding merited attention. Some of the PSSTs faulted existing science texts claiming that the lack of DM strategies compounded their attempts to implement DM in science classrooms. If textbook authors wove DM into their books, teachers would be more likely to assume it is a philosophy as well as a set of instructional strategies informed by that philosophy (see Cash, 2011; Gregory & Hammerman, 2008). Joseph et al. (2013) concur that all prospective teachers should be exposed to the differentiated philosophy in their teacher education program.

This research highlights the challenges that the PSSTs faced when implementing DM in science classrooms, challenges that are corroborated by previous studies where pre-service teachers considered differentiated instruction to be time-consuming, necessitating greater effort in planning (Felder & Brent, 2005; Goodnough, 2010; Joseph et al., 2013). Participants in our study also said they required ongoing support within the classroom, similar to Goodnough's (2010) results. From a unique perspective, our research affirmed that differentiated instruction alone may not be enough. Pre-service students may need to take courses in educational psychology to better understand individual differences and be skilled in assessing students' learning needs. One participant expressly said she lacked the pre-requisite "*psychological knowledge*."

Qualitative findings showed that the PSSTs focused more on developing strategies to differentiate instruction, and less on students' learning as a result of those strategies. The PSSTs often referred to developing evaluation tools to diagnose students' strengths and weaknesses and student readiness so they could *plan* DM before the lesson, but seldom mentioned summative evaluation of students' learning as a result of DM. Valdmann, Holbrook, and Rannikmae (2017) also found that PSSTs taking a specially-designed course about science inquiry embraced the first two stages of the model underpinning the course in their study but struggled with the follow through, akin to the PSSTs privileging the DM planning stage over the implementation and its effectiveness stage. This finding reflects

Roy et al.'s (2013) notion that teachers can opt to focus on instructional adaptation, academic progress monitoring, or both. Future studies should focus on what is involved in moving teachers beyond the technical aspects of planning and implementing DM to a concern for whether or not DM is working in their science classrooms. This would involve a combination of attention to content, process, product, and affect (Tomlinson & Imbeau, 2010).

Limitations

This mixed methods research was focused on a small sample of female Saudi B.Ed. students completing a science education course structured around DM – at one university in one country. While insights from analyzing the quantitative data can be generalized to the wider population of female B.Ed. pre-service science educators, understandings emerging from the qualitative data are transferable (not generalizable). Users of the qualitative findings and their discussion have to determine if they apply in their context based on similar descriptors (i.e., transferable to their setting) (McGregor, 2018). This includes other Middle Eastern countries as well as B.Ed. programs in other nations that are interested in orienting pre-service science educators to DM.

Conclusions

There are very few published studies about the use of DM in science. This study adds to that knowledge base by reporting on efforts to expose Saudi female pre-service science teachers to differentiated instruction, so they can more effectively teach in their monocultural, gender-distinct classrooms where diversity manifests as female learning preferences, levels of knowledge, abilities, motivation, and willingness to learn. Furthermore, others can avail themselves of the observation card from the authors for use in other studies, contributing to cross-study validation of an already-validated instrument.

While Saudi pre-service science teachers are taught that they should be facilitators with students at the center of learning and teaching, there is little training given to support such a teaching philosophy. This study represents an inaugural attempt at one Saudi teacher education program to expose PSSTs to differentiated instruction. The course is still being taught but no longer has a DM focus; meaning PSSTs are no longer receiving DM at this university as it was presented in the course designed for this research.

Research results and findings support the recommendation that to be effective, Saudi science teacher education programs should help pre-service teachers develop (a) an appreciation for the need to differentiate, (b) a desire to learn how to acquire the skills and knowledge necessary to plan and implement differentiated lessons and (c) an inclination to consciously engage in the diversification of teaching strategies (see also Koutselini, 2008). Further research is required on how to inculcate DM as a teaching philosophy so that it becomes infused into science educators' regular teaching practice. Successful integration of DM into teacher education programs could lead to a powerful paradigm shift wherein science educators embrace the DM philosophy.

References

Aarons, G. A., Fettes, D. L., Sommerfeld, D. H., & Palinkas, L. (2012). Mixed methods for implementation research: Application to evidence-based practice implementation and staff turnover in community-based organizations providing child welfare services. *Child Maltreatment, 17* (1), 67-79.

Alghamdi Hamdan, A. (2014). The road to culturally relevant pedagogy: expatriate teachers' pedagogical practices in the cultural context of Saudi Arabian higher education. *McGill Journal of Education, 49*)1), 201-226.

Alghamdi Hamdan, A. (2015). Challenges and constraints encountered by Saudi pre-service science teachers: A critical perspective. *Learning and Teaching in Higher Education: Gulf Perspectives, 12*)1), 1-20.

Alghamdi Hamdan, A., & Alsalouli, M. (2012). Saudi elementary school science teachers' beliefs about teaching science in the new millennium. *International Journal of Science and Mathematics Education, 11*.(2). 501-525.

Alghamdi Hamdan, A., & Philline, D. (2013). Effects of teaching critical thinking to Saudi female university students using a stand-alone course. *International Education Studies, 6*, (7). 176-188.

Al-Eisa, A. (2010). *Education reform in Arabia between the lack of political vision and apprehension of religious culture and the inability of educational administration* (2nd Ed.). London, England: Saqi Books.

AlJamaan, A., Omar, S., & Fodah, O. (2015). The impact of the science writing heuristic on 10th grade chemistry students' achievement and attitude towards chemistry. *International Interdisciplinary Journal of Education*, *4* (1), 32–47.

Alliman-Brissett, A. E., & Turner, S. L. (2010). Racism, parent support and math-based career interests, efficacy and outcome expectations among African American adolescents. *Journal of Black Psychology, 36*, 197–225.

Al Otaif, M. (2012, December 20). Shoura Council: Moalemona Yoaanon men Daaf Aleadad wa Altaaheel marefia wa Mahareaa [Shura

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

member: Our teachers suffer poor preparation and cognitive rehabilitation and poor skills]. *Alwatan,* A12, p. 2.
Brousseau, G. (1997). *Theory of didactical situations in mathematics*. Dordrecht, the Netherlands: Kluwer.
Burton, D. (2003). Differentiation in schooling and pedagogy. In S. Bartlett & D. Burton (Eds.), *Educational studies: Essential issues* (pp. 42–71). Thousand Oaks, CA: Sage.
Butt, M., & Kausar, S. (2010). A comparative study of using differentiated instructions of public and private school teachers. *Malaysian Journal of Distance Education, 12* (1), 105–124.
Cash, R. M. (2011). *Advancing differentiation: Thinking and learning for the twenty-first century.* New York, NY: The Spirit.
Cataldo, A. G. (2008). *Student variances and differentiation of instruction: Teacher perception.* (Unpublished master's thesis). College of Charleston, South Carolina.
Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions.* Thousand Oaks, CA: Sage.
Creswell, J. W., & Plano Clark, V. L. (2007). Designing and conducting mixed methods research. *Education, 94* (1), 57–72.
Felder, R. M., & Brent, R. (2005). Understanding student differences. *Journal of Engineering Education, 94* (1), 57–72.
Feng, A. Z., VanTassel-Baska, J., Quek, C., Bai, W., & O'Neill, B. (2005). A longitudinal assessment of gifted students' learning using the integrated curriculum model (ICM): Impacts and perceptions of the William and Mary language arts and science curriculum. *Roeper Review, 27* (2), 78-83.
Fenner, D., Mansour, S. K., & Sydor, N. (2010). *The effects of differentiation and motivation on students' performance* (Unpublished master's project). Saint Xavier, Chicago, Illinois.
Gerde, H. K., Pierce, S. J., Lee, K., & Van Egeren, L. A. (2017). Early childhood educators' self-efficacy in science, math, and literacy instruction and science practice in the classroom. *Early Education and Development, 29* (1), 70-90.
Goodnough, K. (2010). Investigating pre-service science teachers' developing professional knowledge through the lens of differentiated instruction. *Research in Science Education*, *40* (2), 239–265.
Gregory, G. H., & Hammerman, E. (2008). *Differentiated instructional strategies for science, Grades K-8.* Thousand Oaks, CA: Corwin.
Hardré, P. L., & Sullivan, D. W. (2008). Teacher perceptions and individual differences: How they influence rural teachers' motivating strategies. *Journal of Teaching and Teacher Education, 4* (7), 1–17.
Heacox, D. (2012). *Differentiated instruction in the regular classroom* (Updated Anniversary Ed.). Minneapolis, MN: Free Spirit.
Hidi, S. (2000). An interest researcher's perspective: The effects of extrinsic and intrinsic factors on motivation. In C. Sansone & J. M. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation* (pp. 309–339). San Diego, CA: Academic Press.
Hoepfl, M.C. (1997). Choosing qualitative research: A primer for technology education researchers. *Journal of Technology Education, 9* (1), 47–63.
Horn, E. A., & Walberg, H. J. (1984). Achievement and interest as functions of quantity and level of instruction. *Journal of Educational Research, 77* (4), 227–232.
Iheonumekwu, S. (2006). Innovations and Best Practices in Education. A Paper Presented at the *4th Annual Conference of Faculty of Education*, Abia State University, Uturu.
International Association for the Evaluation of Educational Achievement. (2015). *TIMSS 2015.* Amsterdam, the Netherlands: Author. Retrieved from http://www.iea.nl/timss-2015.
Joseph, S., Thomas, M., Simonette, G., & Ramsook, L. (2013). The impact of differentiated instruction in a teacher education setting: Success and challenges. *International Journal of Higher Education, 2* (3), 28-40.
Kim, K. H, VanTassel-Baska, J., Bracken, B. A., Feng, A., Stambaugh, T., & Bland, L. (2012). Project Clarion: Three years of science instruction in Title 1 schools among K-third grade students. *Research in Science Education, 42* (5), 813–829.
Koutselini, M. (2008). Listening to students' voices for teaching in mixed ability classrooms: Presuppositions and considerations for differentiated instruction. *Learning and Teaching, 1* (1), 17–30.
Krapp, A. (2002). Structural and dynamic aspects of interest development: Theoretical considerations from an ontogenetic perspective. *Learning and Instruction, 12* (4), 383–409.
Loreman, T., Lupart, J., & Andrews, J. (2015). Introduction: A thematic preview. In J. Andrews & J. Lupart (Eds.), *Diversity education: Understanding and addressing student diversity* (pp. 1-23). Toronto, ON: Nelson Canada.
Maeng, J. L., & Bell, R.L. (2015). Differentiating science instruction: Secondary science teachers' practices. *International Journal of Science Education, 37* (13), 2065–2090.
Mansour, N., EL-Deghaidy, H., Alshamrani, S., & Aldahmash, A. (2014). Rethinking the theory and practice of continuing professional development: Science teachers' perspectives. *Research in Science Education, 44* (6), 949–973.
Marvin, D. J. (2001). *Teachers explore differentiation in mixed ability classrooms: Investigating the influence of their beliefs on responses to differentiation and subsequent changes in beliefs and practices* (Unpublished doctoral dissertation). University of Kansas, Lawrence, Kansas.
Mastropieri, M.A., Scruggs, T.E., Norland, J.J., Berkeley, S., McDuffie, K., Tornquist, E.H., & Connors, N. (2006). Differentiated curriculum enhancement in inclusive middle school science: Effects on classroom and high-stakes tests. *Journal of Special Education, 40* (3), 130–137.
McGregor, S. L. T. (2018). *Understanding and evaluating research*. Thousand Oaks, CA: Sage.
National Center for Education Statistics. [ca. 2016]. *TIMSS overview*. Retrieved from the NCES website: https://nces.ed.gov/TIMSS.
National Research Council. (2008). *Ready, set, SCIENCE!: Putting research to work in K-8 science classrooms*. Washington, DC: The National Academies Press.
Oriaifo S. O. (2000). *Factors militating against effective science, technology and mathematics education in Nigeria.* A Monograph
Piggott, A. (2002). Putting differentiation into practice in secondary science lessons. *School Science Review, 83* (305), 65–72.
Ramzi, H., Dicky, N., Abdelfattah, F., & Al-Salouli, M. (2015). Gender difference in teachers' mathematical knowledge for teaching in the context of single-sex classrooms. *International Journal of Science and Math Education, 14* (Supplement 2), 383-401.

Richards, M. R. E., & Omdal, S. N. (2007). Effects of tiered instruction on academic performance in a secondary science course. *Journal of Advanced Academics*, *18* (3), 424–453.
Robinson, A., Dailey, D., Hughes, G., & Cotabish, A. (2014). The effects of a science-focused STEM intervention on gifted elementary students' science knowledge and skills. *Journal of Advanced Academics, 25* (3,) 189-213.
Roy, A., Guay, F., & Valois, P. (2013). Teaching to address diverse learning needs: Development and validation of a differentiated instruction scale. *International Journal of Inclusive Education, 17* (11), 1186–1204.
Rusek, M., Starkova, D., Chytry, V., & Bilek, M. (2017). Adoption of ICT innovations by secondary school teachers and pre-service teachers within chemistry education. *Journal of Baltic Science Education, 16*(4), 510-523.
Ruys, I., Defruyt, R., Rots, I., & Aelterman, A. (2013). Differentiated instruction in teacher education: A case study of congruent teaching. *Teachers and Teaching, 19* (1), 93–107.
Salar, R., & Turgut, Ü. (2015). Implementing differentiated instruction on pre-service physics teachers: Agendas. *Bartin Üniversitesi Eğitim Fakültesi Dergisi, 4* (2), 682–695.
Santangelo, T., & Tomlinson, C. A. (2008). The application of differentiated instruction in post-secondary environments: Benefits, challenges, and future directions. *International Journal of Teaching and Learning in Higher Education, 20* (3), 307–323.
Schiefele, U., Krapp, A., & Winteler, A. (1992). Interest as a predictor of academic achievement: A meta-analysis of research. In K.A. Renninger, S. Hidi, & A. Krapp (Eds.), *Role of interest in learning and development* (pp. 183–212). Hillsdale, NJ: Lawrence Erlbaum.
Shadish, W.R., Cook, T.D., & Campbell, D.T. (2002). *Experimental and quasi-experimental designs for generalized causal inference* (2nd ed.). New York, NY: Cengage Learning.
Sheffield, L.J. (2009). Developing mathematical creativity – Questions may be the answer. In R. Leikin, A. Berman, & B. Koichu (Eds.), *Creativity in mathematics and the education of gifted students* (pp. 87–100). Rotterdam, the Netherlands: Sense Publishers.
Stradling, B., & Saunders, L. (1993). Differentiation in practice: Responding to the needs of all pupils. Educational Research, *35*, 127-137
Stavrou, T. E, & Koutselini, M. (2015). The active involvement of teachers in action research for differentiation of the teaching-learning process: Understanding the needs of students and weaknesses of the curriculum. *Journal of Education & Social Policy, 2* (2), 97–104.
Trends in International Mathematics and Science Study. (2015). *TIMSS participating countries*. Retrieved from TIMSS website: https://nces.ed.gov/timss/countries.asp
Tobin, R., & McInnes, A. (2008). Accommodating differences: Variations in differentiated literacy instruction in Grade 2/3 classrooms. *Literacy, 42* (1), 3–9.
Tobin, R., & Tippett, C.D. (2014). Possibilities and potential barriers: Learning to plan for differentiated instruction in elementary science. *International Journal of Science and Mathematics Education, 12* (2), 423–443.
Tomlinson, C. A. (1995). *Differentiating instruction for advanced learners in the mixed-ability school classroom* (ERIC Digest #E536). Retrieved from https://www.ericdigests.org/1996-3/mixed.htm.
Tomlinson, C. A. (1999). *The differentiated classroom*. Alexandria, VA: ASCD.
Tomlinson, C. A. (2003). *Fulfilling the promise of the differentiated classroom: Strategies and tools for responsive teaching.* Alexandria, VA: ASCD.
Tomlinson, C. A. (2005). Grading and differentiation: Paradox or good practice? *Theory into Practice, 44* (3), 262–269.
Tomlinson, C.A., & Imbeau, M.B. (2010). *Leading and managing a differentiated classroom*. Alexandria, VA: ASCD.
Tulbure, C. (2011). *Differentiated instruction for pre-service teachers: An experimental investigation.* Paper presented at the 5th International Conference EDU-WORLD 2012. Arges, Romania.
Valdmann, A., Holbrook, J., Rannikmae, M. (2017). Determining the effectiveness of a design–based, continuous professional development programme for science teachers. *Journal of Baltic Science Education, 16* (4), 576-591.
VanTassel-Baska, J. (1998). *Planning science programs for high ability learners* (ERIC Digest E546). Retrieved from ERIC Clearinghouse on Disabilities and Gifted Education website: http://www.ericdigests.org/1999-3/science.htm
Voss, J. F., & Schauble, L. (1992). Is interest educationally interesting? An interest-related model of learning. In A. Renninger, S. Hidi, & A. Krapp (Eds.), *Role of interest in learning and development* (pp. 101–120). Hillsdale, NJ: Erlbaum.
Wellington, J. (2000). *Teaching and learning in secondary science.* London, England: Routledge.

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