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Walking the Equity, Diversity, and Inclusion Talk: Promoting STEM Teacher Candidates' Views, Understandings, and Implementation of Differentiated Instruction

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Abstract

Differentiated instruction (DI) is a teaching philosophy that addresses learning for students of diverse backgrounds, abilities, and interests. This study explores teacher candidates’ (TCs’) preparation to implement DI in a STEM curriculum and pedagogy course in a teacher education program at a Canadian university. The course is enriched with DI resources and training focused on equity, diversity, and inclusion (EDI). The course’s efficacy in enhancing TCs’ professional knowledge of DI is explored through the following research questions: 1) What are intermediate-secondary STEM TCs’ views and understandings of DI? 2a) How do TCs develop the curriculum to be inclusive of DI strategies? 2b) What successes and challenges do TCs encounter when developing DI-focused curricula? 2c) What models of technology-enhanced DI do TCs incorporate in their lessons? 3) How do TCs implement DI in their practicum? and 4) What are TCs’ intentions to integrate DI in their future careers? The study adopts a mixed-method approach, in which data sources include pre-post questionnaires, semi-structured interviews, and TCs’ course work. Findings suggest that the course resulted in a notable improvement in TCs’ DI views; a deeper understanding of DI principles and strategies in relation to EDI principles; and TCs’ improved ability to integrate DI practices in their assignments. TCs also implemented those practices in their practicum after the course ended, indicating potential retention of the acquired knowledge and skills. Additionally, the study shows the potential of technology facilitating DI in secondary science classrooms.

This research highlights the importance of explicit, reflective, and contextualized training experiences aimed at enhancing TCs’ preparation to integrate DI in their practices. The study equips STEM teachers and TCs with practical tools to differentiate their instruction by showcasing exemplary resources and strategies. Moreover, this research informs teacher educators, heads of departments, and curriculum designers about practical measures to include DI practices in their trainings, as they may perceive the findings relevant to their professional development plans. Furthermore, the study shows that EDI practices such as DI can and must be woven into all courses and requirements of teacher education programs, rather than restricting those principles to inclusive education courses only.

Keywords

STEM Education; Differentiated Instruction (DI); Equity, Diversity, and Inclusion (EDI); Teacher Education; Self Efficacy; Understanding and Implementation of Differentiated Instruction; Curriculum Design; Technology-Enhanced Differentiated Instruction

Summary for Lay Audience

Canadian classrooms are highly heterogenous and known for student diversity. Thus, many policies are in place heralding equitable and inclusive teaching practices. Yet, research exploring the enactment of these policies and teacher preparation to implement them is scarce. This research focuses on differentiated instruction (DI), which is an inclusive teaching approach aimed at addressing the diverse needs, interests, academic achievement levels, and backgrounds of various students in a classroom. The study explores teacher candidates' (TCs') preparation to implement DI in a science, technology, engineering and mathematics (STEM) curriculum and pedagogy course in a teacher education program at a Canadian university. The course is enriched with DI resources and training focused on equity, diversity, and inclusion. The course's efficacy in enhancing TCs' professional knowledge of DI is explored through the following research questions: 1) What are intermediate-secondary STEM TCs' views and understandings of DI? 2a) How do TCs develop the curriculum to be inclusive of DI strategies? 2b) What successes and challenges do TCs encounter when developing DI-focused curricula? 2c) What models of technology-enhanced DI do TCs incorporate in their lessons? 3) How do TCs implement DI in their practicum? and 4) What are TCs' intentions to integrate DI in their future careers?

To answer these questions, the study adopts a mixed-method approach, in which data sources include pre-post questionnaires, semi-structured interviews, and TCs' course work. Findings show that the course resulted in a notable improvement in TCs' DI views and a deeper understanding of DI principles and strategies. TCs also implemented those practices in their practicum after the course ended, indicating potential retention of the acquired knowledge and skills. The study highlights the importance of opportunities and experiences aimed at enhancing TCs' preparation to integrate DI in their practices. As such, findings are relevant to teacher educators in Canadian universities, in-service and pre-service teachers, curriculum designers, school administrators, and policy makers.

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Table of Contents

List of Tables

List of Figures

List of Appendices

List of Abbreviations

STEM: Science, technology, engineering, and mathematics

DI: Differentiated instruction

TC: Teacher candidate

EDI: Equity, diversity, and inclusion

RQ: Research question

DVG: Digital video game

ELL: English language learner

SES: Socioeconomic status

SSI: Socio-scientific issues

CPP-RIP: Content, process, product- readiness, interests, profiles

TPACK: Technological, pedagogical, and content knowledge

PCK: Pedagogical and content knowledge

ECM: Educational curriculum material

ICT: Information and communications technology

PD: Professional development

UDL: Universal Design for Learning

Chapter 1

1 Introduction

Schools in the 21st century around the globe and in North America specifically (Canada & USA) are hubs for diverse cultural backgrounds, socioeconomic status (SES), and race. Correspondingly, the classroom complexity is further exacerbated given the variation in students' levels of academic achievement, interests, attitudes, and learning profiles (Tomlinson et al., 2003). This complexity requires classrooms to welcome, celebrate, and nurture students' diversity in order to provide effective learning opportunities for all students. The focus on meeting all students' needs gained initial attention with the "No Child Left Behind Act" in the USA in 2010 (U.S. Department of Education, n.d.). The act emphasizes the right of every child to attain high quality of education regardless of their SES, academic achievement, and/or exceptionalities, among many other factors.

Additionally, academic institutions and other organizations are increasingly prioritizing matters related to equity, diversity, inclusion (EDI), with more attention to implementing inclusive and equitable policies and practices. These practices stem from theories that include culturally relevant pedagogy (Ladson-Billings, 1995, 2014), culturally responsive teaching (Gay, 2018), multicultural education (Banks, 2015; McCarthy et al., 2020), Indigenous ways of knowing (Aikenhead & Michell, 2011; Ormiston, 2010), and First Nations cross-cultural curricula (Aikenhead, 1997).

In the school context, teachers and administrators strive to implement practices aimed at considering various students' backgrounds, interests, and academic achievement levels. This research attempts to walk the EDI talk in school settings by promoting teacher candidates' (TCs') views, understandings, and implementation of differentiated instruction (DI) as an equitable and inclusive teaching philosophy.

1.1 Diversity in Canadian Classrooms

Schools in North America are well known for students from diverse backgrounds. This diversity is mainly due to the increase in the number of immigrants. According to Statista

Research Department (2021), Canada is characterized by one of the highest rates of new immigrants per population compared to other countries in the world. For instance, the number of new immigrants who landed in Canada between 2011 and 2016 was 1,212,075, with more than 250 ethnic origins existing in 2016 (Statistics Canada, 2017). According to Statistics Canada (2017), two in five Canadian children had an immigrant background in 2016, meaning they are foreign-born or had at least one foreign-born parent. By 2031, nearly half (46%) of Canadians aged 15 and older could have an immigrant background. These demographic factors are diverse in SES, cultural differences, and linguistic abilities. Statistics Canada (2017) confirms the claim that the percentage of immigrants with English or French as a mother tongue decreased from 71.2% in 1921 to 27.5% in 2016 and that 19.4% of Canadians reported speaking more than one language at home in 2016. All these societal changes directly affect the student composition of classrooms, rendering them very heterogenous spaces, especially when considering additional differences among students in their interests, individual needs, unique learning profiles, and academic achievement levels (Campbell, 2021; Tomlinson et al., 2003).

The 2015 Programme for International Student Assessment (PISA) results by the Organisation for Economic Co-operation and Development (OECD) indicate that Canada is characterized by both high performance and high equity education compared to other PISA countries. This quality is demonstrated by the small gap in scores between highest and lowest performance in mathematics, reading, and science among immigrant and non-immigrant students (Council of Ministers of Education – Canada, 2018). These positive results are foundational to maintain thus enhancing policies and actions related to EDI in Canadian classes is crucial.

1.2 Policies for Inclusion and Ties to Curriculum and Pedagogy

Canadian provinces and territories honor societal diversity through legislation and policies. The legislation of the Government of Canada includes the Canadian Human Rights Act, Canadian Charter of Rights and Freedoms, Citizenship Act, and Canadian Multiculturalism Act. These establish students' rights of equal access to quality education and go beyond anti-discrimination to reach truly inclusive education (Council of

Ministers of Education-Canada, 2018). Correspondingly, Canada's schools need to be reflective of the values of its society (Gérin-Lajoie, 2008; Porter, 2004). Accordingly, curricula in Canadian classrooms are moving toward inclusive design, an approach that considers the diversity with respect to students' ability, language, culture, race, sexual orientation, creed, gender, and lived experiences (Malloy, 2019).

Novel plans have been established across provinces to incorporate inclusive practices such as the "BC Education Plan" in British Columbia and personalizing education initiatives in Alberta (Sokal & Katz, 2015). In Ontario, the Ministry of Education (2017) has developed Ontario's Education Equity Action Plan that supports all 72 school boards to develop equity and inclusive education policies and effectively implement those strategies. The general goal of this plan is for students to feel included and accepted, irrespective of gender, race, or creed. Moreover, classes must reflect diversity in terms of race, ethnicity, culture, religion, SES, immigration status, sexual orientation, gender identity, parent engagement, language first spoken, Indigenous communities, Indigenous histories and ways of knowing, and accessibility for students with exceptionalities. This plan calls for "every student to have the opportunity to succeed in school regardless of their background or circumstances" (p. 3), and for "Ontario schools to be places where students not only learn about diversity but also experience it" (p. 4). Concerning classroom practices, the plan prioritizes the "implementation of teaching practices and curriculum that reflect the needs and diverse realities of all students" (p. 16). The plan hints at incorporating culturally relevant pedagogy (Ladson-Billings, 1995, 2014) and culturally responsive teaching (Gay, 2010). Moreover, the plan aims at strengthening inclusive and culturally responsive teaching, assessment, and resources, and providing professional development (PD) and support focused on equity and inclusion for teachers.

Despite these plans and policies in effect, there remains much work to be done in this area. Rezai-Rashti et al. (2015, 2017) highlight the invisibility of race and antiracism in Ontario's policies and call for addressing the underlying structural and systemic imbalances. This outcome can be achieved through mechanisms that hold educational institutions accountable and provide the required resources to ensure the implementation of said policies. In harmony, the Ontario Ministry of Education reports that the recommended improvements did not fully provide equitable outcomes for all students, and further actions are required to overcome persistent systematic barriers, biases, and inequalities (Campbell, 2021). To create a truly equitable system, all education partners must prioritize students' educational experience (Ontario Ministry of Education, 2009). At the classroom level, these organizational plans must identify the role of teachers and their responsibility in attending to the needs of their students. The current literature recommends that teachers be more involved in the processes of improving inclusive curricula, materials, and their support for students (Tomlinson et al., 2003). Thus, it is fundamental to target the knowledge base of pre-service teachers as they embark on teaching careers in classrooms that reflect heterogeneous student populations. This measure will enable them to utilize transformative inclusive teaching strategies, such as DI (Egbo, 2012).

1.3 DI as an Equitable and Inclusive Pedagogical Approach

At the classroom level and from a pedagogical stance, DI can address student differences (George, 2005; Specht & Metsala, 2018; Tomlinson, 2001). DI is an inclusive pedagogical approach that allows teachers to meet the needs of diverse learners (Tomlinson et al., 2003). It is an adaptive method of instruction by which teachers provide multiple possibilities for learning based on students' backgrounds, readiness, interests, and profiles (De Jesus, 2012; Tomlinson, 2001; Valiandes & Tarman, 2011). This individualized attention to each student leads to increased learning, confidence, motivation, and comfort among students (Patterson et al., 2009).

Teachers can practically implement DI by modifying the content students learn, the process (teaching strategies), and the product of student learning (assessment tools). Consequently, different groups of students can work on the same concept with varying degrees of complexity, different pacing, and various activities, and assessed through tiered assignments (Tomlinson, 1999; Willis & Mann, 2000). Research studies have demonstrated positive impacts of DI on students' achievement, attitudes, higher-order thinking levels, and social skills (Tobin & Tippett, 2014; Tomlinson et al., 2003; Watts-Taffe et al., 2012). According to Tomlinson et al. (2003), the role of educators needs to focus on *how to differentiate* rather than *if they should differentiate*. Yet, the literature on teachers' implementation of DI shows that many teachers do not regularly implement it in their classrooms (DiPirro, 2017; Robinson, 2017; Tomlinson & Imbeau, 2010), thus providing additional rationale for the need to enhance teacher preparation in this regard.

In the context of Ontario, the Education Equity Action Plan (2017) does not explicitly mention DI as a recommended pedagogical strategy. Meanwhile, the publication "Student Success: Differentiated Instruction Educator's Package" (EduGains, 2010), issued for Ontario teachers includes supplemental online teaching resources highlighting the importance of DI as an instructional approach, in response to various student interests, preferences, and readiness levels. Furthermore, research on DI implementation and teacher preparation in Canadian classrooms is scarce despite the aforementioned context and policies. Thus, this research addresses TCs' preparation in Ontario – *how to differentiate* – by specifically engaging them in developing DI-focused science, technology, engineering, and mathematics (STEM) curricula.

1.4 Curriculum Development

Tyler (2013) organizes curriculum development around four questions: 1) What educational purposes should the school seek to attain? 2) How to select the learning experiences to attain these objectives? 3) How to organize the learning experiences to ensure effective instruction? and 4) How to evaluate the effectiveness of these learning experiences? Similarly, Fink (2007) adopts an integrated course design model to develop learning experiences. This model includes three components: 1) learning goals, that is, what the students need to learn, 2) teaching and learning activities or how the students will learn, and 3) feedback and assessment, that is, how educators know if students achieve the learning goals. Fink (2007) highlights that these three components can be affected by several factors such as course context, professional expectations, and the nature of the subject, the students, and the teacher. Furthermore, a commonly-used framework for curriculum development is the "Understanding by Design" (Wiggins & McTighe, 2005), which adopts a backward design as it starts with the end first. Educators start with the desired objectives, then work backward to a curriculum based on acceptable evidence of learning by planning the instructional and learning experiences accordingly. Overall, at an operational level, these models of curriculum development are synchronous with Tomlinson's (1999) model of DI, in which teachers differentiate the content, process, and product of learning.

At a more conceptual and fundamental level, EDI principles and DI practices are in harmony with post-modern perspectives in curriculum theories that move beyond Tyler's ideals. Schwab (1973) maintains that scholars must coordinate four commonplaces upon translating scholarly material into curriculum. These commonplaces are the learners, teachers, subject matters, and milieus in which the learning takes place. Schwab emphasizes a practice in which scholars and curriculum developers deal with *specific* curriculum content, *specific* students, and *specific* instructional context rather than generalized theoretical concepts that fit everyone at all times (Deng, 2013). Moreover, the post-modern perspectives by Doll Jr (1993, 2008), Pinar et al. (2008), and Pinar (2012) are in greater synchrony with the principles of EDI in educational curricula. The integration of EDI principles in curricula necessitates a shift in the mindsets of teachers and curriculum designers. The implementation of DI practices in a classroom requires greater flexibility in curriculum, pedagogy, and assessment strategies by educators. Such innovation and reconceptualization in teaching and learning extend beyond the ideals of a rigid and prescribed curriculum. Therefore, in this study, the TCs will be focused on integrating EDI principles and DI practices while developing STEM curriculum. This curriculum development is accompanied by efforts to promote their self-efficacy and advance their mindset toward these principles to ensure effective and long-term implementation.

1.5 Teacher Education and STEM Education in Ontario

To be a certified teacher in Ontario, a TC must have completed a minimum three-year degree from a post-secondary institution and must then successfully complete a four-semester teacher education program (Ontario College of Teachers, 2021). Generally, teacher education programs span two academic years and consist of:

1) Courses focused on education foundations and teaching methods suitable for two teaching qualifications in Ontario.

2) A minimum of 80 days of practice teaching supervised by the program provider.

3) Additional components such as research and other-than-school educational experiences.

On the other hand, the intermediate and secondary curriculum in Ontario include science subjects (e.g., general science, biology, chemistry, physics, earth and space science, and environmental science), mathematics, computer studies, and technological education as stand-alone subjects (Ontario Ministry of Education, 2008). Yet, the Ministry encourages cross-curricular and integrated learning in the form of STEM education (Ontario Ministry of Education, 2020). In this study, participating TCs are in their second year of the teacher education program in Ontario. TCs are specifically enrolled in the intermediate-senior STEM Specialty Focus that emphasizes and prepares them to teach STEM subjects in an integrative approach.

1.6 Research Rationale

DI is extensively researched and theorized (e.g., George, 2005; Roy et al., 2013; Tobin & Tippett, 2014; Tomlinson et al., 2003). Yet, the literature documents several gaps:

1) There is a scarcity of DI applications in STEM education at the secondary school level. Most of the research have been conducted on DI in languages and mathematics for primary and middle school; hence there is a dire need to explore the applicability of DI in STEM at the secondary school level (Kamarulzaman et al., 2018; Maeng, 2017).

2) The available research on DI in secondary level STEM classrooms mostly addresses its impact on student outcomes, hence the need to explore in-service teachers' perceptions, understandings, and implementation of DI, as well as TCs' preparation and readiness to utilize DI in their future teaching.

3) One of the significant gaps is research on DI in a Canadian context.

After analyzing the course offerings of all teacher education programs in Canada, D'Intino and Wang (2021) concluded that "entry-level teachers may not be fully prepared to meet the demands of provincial policies regarding inclusion across Canada" (p.10).

D’Intino and Wang maintain that teachers need more support to be able to differentiate their instruction in mixed-ability classrooms. In Ontario specifically, minimal research is dedicated to teachers’ understanding and implementation of DI, as well as their preparation to implement it. Accordingly, we lack understanding in terms of whether the aforementioned policies, for example, Education Equity Action Plan (2017) are being implemented in classrooms. Hence, there is a need to explore the application and effectiveness of the policies in place in Ontario. Finally, there is a lack of PD initiatives aimed at enhancing EDI pedagogical practices in Ontario classrooms and enhancing teachers’ readiness in this aspect (Massouti, 2019; Rezai-Rashti & Solomon, 2008). Specht et al. (2016) indicate the specific need for secondary school level TCs’ training on inclusive teaching strategies, since they show lower-self efficacy in relation to inclusive teaching compared to their elementary school counterparts. My research is thus warranted as it addresses the gaps related to teacher preparation focusing on DI, including TCs’ understanding of DI, DI-focused curriculum development, and implementation in practice.

1.7 Research Objectives and Questions

This research focuses on intermediate-senior STEM TCs’ teacher preparation emphasizing their views, understandings, and implementation of DI. The study highlights the impact of integrating DI-focused strategies in a STEM curriculum and pedagogy course in teacher education at a Canadian university by 1) exploring how DI is understood and implemented by STEM TCs in Ontario; and 2) studying the impact of the course on STEM TCs' views, understandings, and implementation of DI.

The research focuses on the following questions:

1) What are intermediate-senior STEM TCs’ views and understandings of DI?

2) a) How do TCs develop curricula to be inclusive of DI strategies?

b) What successes and challenges do TCs encounter when developing DI-focused curricula?

c) What models of technology-enhanced DI do TCs incorporate in their lessons?

3) How do TCs implement DI in their practicum?

4) What are TCs' intentions to integrate DI in their future careers?

To address these questions, the study adopted a mixed-method approach (Creswell & Creswell, 2018), specifically a case study (Yin, 2014). The study involved 19 intermediate/senior TCs in a curriculum and pedagogy course in STEM education in a teacher education program at a university in Ontario, Canada. Data sources include: 1) pre- and post-course questionnaires exploring TCs' views, understandings, and implementation of DI; 2) semi-structured interviews and post-practicum open-ended survey detailing TCs' implementation of DI in the course and in their practicum; and 3) TCs' course work.

1.8 Research Significance

This research advances knowledge about DI as an inclusive pedagogical practice. The adopted TC training will significantly benefit STEM/science teacher education programs as it addresses a gap in the literature related to preparing STEM TCs at the secondary level on how to address student diversity in their future classrooms. This training model is also transferable to non-STEM disciplines and would enhance future teachers' preparation to practice EDI principles as they embark on their teaching careers.

1.9 Chapter Summary and Organization of the Thesis

This chapter introduces the thesis by presenting the research problem, background, and rationale. The chapter situates DI as a pedagogical approach within the bigger picture of EDI. It also explains the relationship between relevant educational policies, curriculum development theories, and teacher education programs. The end of the chapter introduces the research objectives and questions, along with the significance of the study. To the thesis organization following this chapter, Chapter 2 presents a comprehensive literature review of DI, while Chapter 3 explains the adopted methodology in this study. Chapters 4, 5, and 6 present the research findings in relation to the research questions (RQs). Each chapter embeds the discussion of the results. Chapters 5 and 6 also include background sections that entail a brief literature review pertaining to the concepts discussed in those chapters specifically. Finally, Chapter 7 presents the study's conclusions, limitations, and implications. The following paragraph provides more detail on the organization of the thesis by highlighting how I address each of the RQs in the findings' chapters.

RQ1 is addressed in Chapter 4 by explaining TCs' initial and final views and understandings of DI, and thereby highlighting TCs' readiness and knowledge about DI prior to the course and the impact of the course on their DI views, understandings, and implementation in the course assignments.

As an extension to TCs' DI views, understandings, and implementation in the course, RQ3 and RQ4 are also be addressed in Chapter 4 by highlighting the long-term impact of the course. This impact is highlighted through exploring TCs' implementation of DI in the practicum after the course ended, and their intentions for integrating DI in their future careers.

RQ2 is addressed in Chapter 5 by explaining how TCs developed DI-focused case studies on socio-scientific issues (SSI), and in Chapter 6 by explaining how TCs created digital educative curriculum materials (ECMs) that incorporate DI principles and strategies. Chapters 5 and 6 also include the successes and challenges encountered by TCs as they engaged in curriculum development.

Chapter 2

2 Literature Review

This chapter presents various topics related to DI including definitions, theoretical foundations, outcomes, and implementation methods. Additionally, it offers the literature on teachers' understandings, views, and implementation of DI, challenges hindering implementation, and training programs that address these challenges. As part of the rationale for this research, this chapter highlights gaps in the literature. It also discusses the theoretical framework that frames this study.

2.1 DI Definitions

Several definitions of DI exist. Shulman (1986) refers to the process of fitting the instructional material to the characteristics of the students as adaptation or laying the foundation for DI. Tomlinson (1999) defines DI as a teaching approach in which teachers proactively adjust curricula, teaching methods, resources, learning activities, and student products to address the diverse needs of individual students and maximize learning opportunities for each student. Valiandes and Tarman (2011) define DI as a constructivist-based teaching approach that aims to achieve learning for all students by meeting their personal learning needs. In more developed definitions, DI is considered a philosophy of teaching and a proactive way of thinking about teaching and learning rather than a collection of teaching strategies (Coubergs et al., 2017; Tomlinson et al., 2003; Wan, 2017). As such, Deunk et al. (2015) explain differentiation as a combination of teachers' attitudes, knowledge, practices, and professional skills needed to provide adaptive instruction to address student differences. Thus, DI requires consistent, reflective, and coherent efforts to address the full range of student differences such as their readiness to learn, interest in the subject, and learning profiles (Tomlinson et al., 2003).

2.2 Rationale for DI

2.2.1 Theoretical Foundations of DI

Many theories lay the foundations for DI such as child-centered teaching (Dewey, 1902), constructivism (Piaget & Inhelder, 1972), and socio-cultural theory (Vygotsky, 1978). Dewey was a major historical proponent of child-centered schooling. Dewey (1902) addressed the emotional and rational lives of the child (whole-child), described learning as a process, and emphasized problem-based and child-centered curriculum where the teacher creates the conditions of learning for the children instead of considering them passive receptacles of knowledge. This approach necessitates knowing the students well and personalizing the teaching to match their interests, capacities, attitudes, and experiences. Dewey (1902) considered the child as "the starting-point, the center, and the end" (p. 9), and referred to the child and the curriculum as "two limits that define a single process" (p. 16).

In harmony, constructivist learning is a process whereby learners construct their own knowledge based on their understanding (Jonassen, 1991 as cited in Inserra & Short, 2012), and by linking current experiences to prior learnings. In this model, teachers are viewed as facilitators (Alesandrini & Larson, 2002); and developers and implementers of curriculum (Brooks, 1987). Additionally, Vygotsky's (1978) sociocultural theory of human learning describes learning as a social process, in which social interactions affect cognitive development. Vygotsky (1978) stated that "every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level" (p. 57). Hence, the social constructivist approach highlights the active role of the student and the environment. Smith and Semin (2007) extend this construct to situated social cognition, whereby the learner's context, goals, and bodily states also affect their perception. Thus, the complexity surrounding how learning takes place necessitates prioritizing factors related to the student, their environment, and context in curriculum planning and implementation.

The aforementioned complexities can be addressed in a classroom through several teaching philosophies and approaches. One example that is compatible with DI is the

Universal Design for Learning (UDL). UDL is a framework that guides designing learning environments in an accessible and challenging manner for all students. The ultimate goal of UDL is to support learners to become “expert learners” in their own way. UDL intentionally designs the instructional goals, methods, materials, and assessments to reduce barriers and meet the individual needs of students (Center for Applied Special Technology (CAST), 2022).

Overall, these profound connections with child-centered teaching, constructivism, socio-cultural theory, situated social cognition, and UDL emphasize the relevance of DI in the classroom.

2.2.2 Positive Student Outcomes of DI

Empirical evidence provides the positive impact of DI on student outcomes, including improved academic achievement across all levels and subject areas. For instance, elementary students who were taught using this instructional strategy showed improved academic achievement (e.g., Altıntaş & Özdemir, 2015; Şentürk & Sari, 2018). Similar positive impacts on student learning outcomes were observed in middle and secondary school in mathematics and various science subjects (e.g., Mastropieri et al., 2006; Mitee & Obaitan, 2015; Richards & Omdal, 2007; Wambugu & Changeiywo, 2008). Moreover, DI enhances student attitudes and enthusiasm toward science (Tobin & Tippett, 2014; Westwood, 2018) as it engages students in relevant activities that increase their interest in the subject (Subban, 2006; Tomlinson et al., 2003). Furthermore, a growing body of literature investigated the social and emotional benefits of DI and demonstrated that the benefits overlap those of the inclusive classroom in general (Lawrence-Brown, 2004; Smale-Jacobse et al., 2019; Westwood, 2018). For instance, DI results in the development of communication and social skills, as well as higher self-esteem and self-efficacy (Patterson et al., 2009; Santangelo & Tomlinson, 2012; Watson & Knight, 2012). Those benefits extend to enhanced appreciation, recognition, acceptance, understanding, and respect for individual differences among students (Watts-Taffe et al., 2012). Additionally, research has shown that DI enhances students’ autonomy and independent learning (Goodnough, 2010; Roy et al., 2013), as well as higher order thinking levels and knowledge transfer (Renzulli, 1988; Santangelo & Tomlinson, 2012).

2.3 Methods to Differentiate Instruction

DI is not a single strategy but rather an approach that affords many strategies (Watts-Taffe et al., 2012). Although diverse modes of differentiation exist, establishing a systematic approach to differentiation is important to make it more attainable for teachers to implement (Levy, 2008). In practice, DI can happen through modifying the content (what is taught), process (how learning is structured) and product (how learning is assessed), in addition to the physical learning environment (Tomlinson, 2001). These modifications are achieved through adaptation of the existing curriculum, development of lessons and resources, and implementation of teaching and assessment strategies that are tailored to students' readiness, interests, and learning profiles (Beasley & Beck, 2017; Mitchell & Hobson, 2005; Tomlinson, 2014; Willis & Mann, 2000).

The content – knowledge, understanding and skills – is what students are expected to learn. The process describes the methods designed throughout the lesson to reinforce students' understanding of the content. The product refers to how students demonstrate their learning by means of assessment tools. It is how students show what they have come to know, understand, and are able to do after an extended period of learning (Tomlinson, 1999; Tomlinson & Imbeau, 2010). It is important to mention that these dimensions of DI are highly interconnected rather than independent (Watts-Taffe et al., 2012). Although there are core principles that guide the use of DI, its implementation depends on the individual needs of students in a particular classroom (Chamberlin & Powers, 2010). Tomlinson et al. (2003) indicate that when teachers differentiate the content, process, and product of teaching, three main factors must be considered as the basis of this differentiation: 1) students' readiness which mainly reflects academic achievement levels, 2) students' interest or choices, and 3) students' learning profiles including their cultural backgrounds, lived experiences, and learning styles. This DI implementation framework, the content, process, product – readiness, interests, profiles (CPP-RIP) will be utilized in this thesis to analyze TCs' implementation of DI. This framework will be highlighted in the data analysis, Section 3.5.2.2.

Despite the fact that there is no single formula or method to apply DI (Valiandes & Tarman, 2011), specific teaching strategies include varying the learning pace for different students, curriculum compacting and chunking, varying the difficulty levels of tasks for different students, flexible grouping and learning centers based on student interests and/or learning needs, cooperative learning strategies, tiering activities, providing various levels of support and scaffolding to different students based on their readiness, using different modalities of teaching, and utilizing formative and diagnostic assessments to keep track of students' progress (Birnie, 2017; Blackburn, 2018; Tomlinson et al., 2003). These instructional strategies allow teachers to shift their focus from completing the curriculum to catering to the needs of students. Even when teachers are focusing on key principles for all students at the same time, the pace and the channels for understanding these principles will vary. Students are able to grasp concepts at their own level and delve deeper, if necessary (Tuttle, 2000, as cited in Subban, 2006).

In conclusion, the hallmark of differentiating instruction is that it allows students to feel accepted by viewing their differences as assets that will strengthen the whole educational setting (George, 2005). Thus, it is critical for teachers to understand the importance of students' mastery of a task and ensure their growth without compromising the rigor of learning (Marshall, 2016). Students are expected to experience success and failure in order for them to assess their strengths and weaknesses as motivators to move forward, rather than as endpoints.

2.4 Teachers' Knowledge and Understanding of DI

Research on teachers' understanding of DI is inconclusive, ranging from insufficient understanding to very different understandings among teachers (DiPirro, 2017; Kendrick-Weikle, 2015; Santangelo & Tomlinson, 2012; Turner & Solis, 2017). DiPirro (2017) indicates that K-8 teachers in New Hampshire associate DI with students with special education needs only. Similarly, Whitley et al. (2019) point at a misconception among several Grades 7-12 teachers in a Canadian province who believe that DI is only necessary for students with exceptionalities or those who are struggling. Furthermore, Kendrick-Weikle (2015) reported that high school teachers in Illinois are more familiar with traditional teaching strategies compared to DI strategies, and that most of them differentiate primarily for struggling students. Teachers in this study report being most familiar with small group work as a DI strategy. Meanwhile, Turner and Solis (2017) show that practitioners understand DI differently, where most teachers understand it as differentiation of process, and the minority understand that of content and products. On the other hand, Whipple's (2012) survey revealed that K-6 teachers in Massachusetts have a general level of understanding of DI, although it varies among teachers. Yet, teachers' understanding of content differentiation is high, while those of the process, product, and student interests are least understood. Rollins (2010) on the other hand indicated that novice technology teachers in North Carolina report low levels of confidence in understanding all DI components, especially product differentiation. Adlam (2007) and Wan (2017) reported that teachers tend to be more ready to implement teacher-centered strategies rather than DI due to obstacles related to class size, greater diversity among students, and insufficient understanding of the required strategies. The latter challenges specifically, in addition to all aforementioned findings, reinforce the recommendations for teacher education and training programs to address teachers' understanding and knowledge of DI to ensure effective implementation (e.g., Nicolae, 2014; Rollins, 2010; Taylor, 2018).

2.5 Teachers' Views, Self-Efficacy, and DI

Several studies have shown that teachers' beliefs, perceptions, and self-efficacy are strong predictors of DI implementation (Dixon et al., 2014; Hall, 2018; Suprayogi et al., 2017; Taylor, 2018; Tosun, 2000; Tulbure, 2011; Wan, 2016; Whitley et al., 2019). DiPirro (2017) demonstrated that elementary teachers have stronger DI perceptions than middle school teachers, and accordingly higher implementation. Robinson (2017) maintains that elementary teachers in Tennessee find DI necessary to maximize student learning despite being time-consuming and difficult to implement. Similarly, Paone (2017) and Charles (2017) indicate that middle school teachers have positive perceptions and good knowledge about DI in general; yet they report barriers to implementing it such as lack of PD, resources, and planning time.

Correspondingly, several studies indicate that first-year teachers and TCs have less self-efficacy towards DI and thereby lower willingness to implement it when compared to experienced teachers (Garrett, 2017; Rollins, 2010; Wertheim & Leyser, 2002). Additionally, Casey and Gable (2012) conclude that beginning teachers are confident in implementing surface-level differentiation rather than a deep-structure model. On the other hand, Tomlinson et al. (2003) maintain that when teachers are not aware of how various factors related to diversity impact student learning, they will view learners' differences as problematic rather than positive capacities for the classroom. Accordingly, teachers, especially beginning teachers, who believe that they are capable of addressing varying learners' needs are better able to adopt DI in their instruction and to persist in the face of challenges (Suprayogi et al., 2017). All of the above reiterate the importance of addressing beginning teachers' perceptions and views of DI. This conclusion is in accordance with documented recommendations that call for more effective teacher education and training programs in order to enhance TCs' self-efficacy and thereby DI implementation (e.g., Griful-Freixenet et al., 2021; Paone, 2017; Wertheim & Leyser, 2002).

2.6 Teachers' Implementation of DI

2.6.1 Level of Teachers' Implementation

The literature on teachers' implementation of DI reports that most teachers are aware of the practice, but many do not regularly implement it in their classrooms (DiPirro, 2017; Tomlinson, 2001; Tomlinson & Imbeau, 2010). Niccum-Johnson (2018), for example, evaluated the consistency of 175 elementary teachers in Illinois in implementing DI. The results showed that only 60% of the teachers consistently used the elements of DI. Moreover, the study noted that teachers with a bachelor's degree implemented DI more consistently than those with a master's degree, while the years of experience had no effect. Robinson (2017) contradicted this inference and concluded that new teachers practiced the operational definition of DI more closely than veteran teachers who integrated DI into their daily activities more often. Santangelo and Tomlinson (2012) have shown that teacher educators did not implement a comprehensive model of differentiation. In line with this inference, Kendrick-Weikle (2015) stated that teachers differentiated the process component of their instruction, but they did not differentiate the contents and the products to the same extent. The study also noted that female teachers and teachers in larger schools were more familiar with DI and used accompanying strategies more often than male teachers, and teachers at smaller schools, respectively.

On the other hand, the implementation of DI in Canadian classes, especially in Ontario, is insufficiently researched. Limited studies exist. For example, research has been conducted with French language teachers in Quebec (Guay et al., 2017; Roy et al., 2013) to support inclusion practices; and in music classes (Kizas, 2016) and language arts in elementary schools in British Colombia (Tobin, 2007). Finally, a study conducted in elementary classrooms in Ontario showed that the instructional practices in public schools appeared to be cumulative rather than differentiated and that academically at-risk students received less DI than others (McGhie-Richmond et al., 2007).

de Jager (2017) observed 97% of teachers answered “never” or “seldom” when asked if they used a flexible curriculum and provided extra time for their students. The author noted the reason was in the fact that 95.6% of the teachers answered that they were “never” or “seldom” well trained in their education on how to teach learners experiencing barriers. Supporting the initial finding, Wan (2016) highlighted that differentiating instruction is more complex in reality than it appears. Teachers could not cater to learners’ diversity as seamlessly due to the lack of practice of differentiating strategies. Teachers in the study were afraid that differentiating, particularly assessment, was not fair to students in an exam-oriented environment (Wan, 2016). These findings reiterate the importance of teachers’ readiness and preparation to implement DI. Thus, it is crucial to explore how preparing TCs to implement DI would help them develop deeper understandings and practice DI more frequently and proficiently.

2.6.2 Challenges to Implementing DI

Several challenges that hinder teachers’ implementation of DI are documented, including 1) curricular requirements; 2) extensive teacher workload and lack of time; 3) limited curriculum resources; 4) lack of administrative support; 5) perceived complexity and difficulty; 6) class size and individual needs of students; and 7) insufficient number and quality of PD programs (de Jager, 2017; V. Park & Datnow, 2017; Turner & Solis, 2017; Wan, 2017). To capture the complexity of differentiating instruction, van Geel et al. (2019) use the cognitive task analysis to show what kind of knowledge and constituent skills are needed to be able to adapt instruction to the needs of the students. The results of the research identify six categories of teacher skills: 1) mastering the curriculum, 2) identifying instructional needs, 3) setting challenging goals, 4) monitoring and diagnosing student progress, 5) adapting instruction accordingly, and 6) general teaching dimension. This model serves as the basis for designing curricula and teacher PD initiatives. Moreover, research has shown the necessity and importance of PD initiatives for pre-service (Dack, 2018; Goodnough, 2010) and in-service teachers (Dixon et al., 2014; Nicolae, 2014; Pincince, 2016) to enhance their self-efficacy, understanding, and implementation of DI (e.g., Griful-Freixenet et al., 2021; J. Maeng, 2011; Nicolae, 2014; Paone, 2017; Rollins, 2010; Taylor, 2018; Wertheim & Leyser, 2002), as explained in the following section.

Correspondingly, research on exemplary differentiated STEM resources is scarce especially at the secondary school level. Thus, the aforementioned challenges of available curriculum resources, required time, and perceived difficulty are justified. This study addresses those challenges and the lack of PD related to DI. The study will engage TCs in designing and developing differentiated curriculum materials in STEM subjects. It will highlight the successes and challenges of similar teacher preparation initiatives to enhance TCs' familiarity and implementation of DI. Additionally, it will showcase specific strategies to differentiate instruction in secondary STEM classes.

2.7 Preparing Teachers for DI

Hargreaves (2005) notes how teachers respond to educational change in various ways depending on factors such as age, subject specialty, and personal orientations. A study conducted in Canada across 15 schools involving 50 elementary and secondary teachers of varying ages showed that early career teachers (five years of experience or less) were enthusiastic, optimistic, and flexible to adapt to the changes needed. On the contrary, late-career teachers (over 20 years of experience) were resistant and resilient to embracing educational change. This variation between teachers is consistent with Pfitzner-Eden's (2016) and Specht and Metsala's (2018) findings of the importance of explicitly building self-efficacy skills in preservice teachers. During this early stage, teachers and TCs are most malleable. Hence, their careers can be significantly affected during their teacher education and practicum experiences (Pfitzner-Eden, 2016). In accordance, Smit and Humpert (2012) indicate that teachers who adopt DI earlier embrace progressive instructional practices in general.

A handful of research studies highlight the importance and positive impact of teacher training on DI understanding and implementation for pre-service (Dack, 2018; Goodnough, 2010) and in-service teachers (Dixon et al., 2014; Niccum-Johnson, 2018; Pincince, 2016). Edwards et al. (2006) maintain the positive impact of teacher education on teachers' planning and practicing DI techniques. Specifically, high-intensity preparation results in more teachers' willingness to differentiate and engage in more complex differentiation (Maeng & Bell, 2015; Pettig, 2000). To attain TCs' accurate vision of DI and resourceful and robust implementation, Dack (2018) recommends crafting the learning experiences in a thoughtful and strategic approach in teacher education program courses. This approach can happen by modeling the DI framework to support TCs' appropriation of its conceptual and practical tools (Dack et al., 2019). Wan (2016) shows how a 13-session course about DI can enhance TCs' teaching beliefs and efficacy toward DI and accordingly recommends using an explicit reflective approach in training TCs on DI. In harmony, Griful-Freixenet et al. (2021) highlight the importance of training on the ongoing assessment component. It is the most important predictor for both DI and UDL. To achieve this outcome, Griful-Freixenet et al. (2021) recommend that TCs engage in systematic reflection of their practices and that they are provided with tools that enhance DI implementation. Goodnough (2010) describes how TCs' knowledge and perceptions of DI advance in a secondary science methods course after using a problem-based, collaborative learning approach focused on DI.

These positive results are not unconditional. Frankling et al. (2017) indicate that such training should accompany appropriate support and direction. Moreover, Brevik et al. (2018) recommend that teacher education programs offer practical opportunities for TCs to exercise DI to increase their confidence in its implementation. Ruys et al. (2013) highlight the importance of congruent teaching in which teacher educators implement and model DI strategies to ensure the success of TCs' training efforts. Dack (2019b) and Massouti (2019) stress the importance of coherence between all offered teacher education courses and between courses and TCs' fieldwork to attain successful teacher preparation.

While these studies show the advantages of DI-focused interventions in teacher education, more research is needed in this area, especially for STEM TCs in intermediate and secondary programs. This research study is designed based on recommendations of other studies that suggest teaching DI should be 1) deep and intensive (Dack, 2019b; Maeng & Bell, 2015; Pettig, 2000); 2) explicit (Dack, 2019b; Wan, 2016); 3) reflective (Griful-Freixenet et al., 2021); 4) integrated into coursework (Dack, 2018, 2019a); 5) designed to follow TCs into their field experiences (Goodnough, 2010); and 6) researched in a Canadian context where an insufficient preparation of TCs on DI and other inclusive pedagogies has been reported (D'Intino & Wang, 2021; Specht et al., 2016). This approach is unique as it integrates DI in the coursework of a curriculum and pedagogy course rather than a focused DI course, as in most other studies (e.g., Dack, 2018; Wan, 2016). Unlike Goodnough's (2010) study focusing on science TCs in another Canadian province, this study addresses secondary STEM teachers in an Ontarian context. The study builds on the literature above, yet it combines many features of successful interventions and provides a more comprehensive exploration of the impact on TCs' views, understandings, and implementation of DI in their practicum experience.

2.8 Theoretical Framework

Several theories inform this research. The notions of self-efficacy (Bandura, 1977, 1995) and growth mindset (Dweck, 1999) describe TCs' attitudes and views toward DI. On the other hand, socio-cultural and scaffolding theories (Vygotsky, 1978) explain how TCs learned about DI. Additionally, teachers' professional knowledge (Shulman, 1986) and knowledge retention (Semb & Ellis, 1994) explain how TCs learned and its effectiveness in promoting DI strategies.

2.8.1 Self-Efficacy and Mindset

Bandura (1977) states that people's knowledge, skills, and previous achievements are not always good predictors of their future achievements. Instead, people's beliefs, including self-efficacy, about their capabilities may be better predictors of behavior. These beliefs significantly influence how individuals set their goals, overcome challenges, choose their activities, and exert effort and persistence. Accordingly, self-efficacy is defined as "the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations" (Bandura, 1995, p. 2). It refers to a person's confidence that they can do what they have to do (Brígido et al., 2013); thus, the conception of a person's ability is an essential aspect of self-efficacy. Additionally, Bray-Clark and Bates (2003) indicate that self-efficacy is characterized by its task-specific nature, distinguishing it from more global concepts such as self-esteem or confidence. Furthermore, an important aspect of self-efficacy is personal ability as an acquirable skill and not only as an inherent capacity (Bandura, 1993).

Teachers' teaching efficacy includes the aspect mentioned earlier of confidence to teach effectively (efficacy beliefs), in addition to the belief in students' ability to effectively learn from the offered teaching (outcome expectancy) (Riggs & Enochs, 1990). Suprayogi et al. (2017) describe teachers' beliefs as a filter through which the instructional decisions are made. The literature documents the importance of teaching efficacy. Bandura (1993) states that teachers' beliefs in their instructional effectiveness constitute a significant determinant of their class atmospheres, affecting the types of learning environments teachers create. Hence, higher teaching efficacy promotes learning, motivates students, and provides a mastery experience. Teachers' self-efficacy also affects their behavior, instructional practice, and teaching effectiveness (Bray-Clark & Bates, 2003; Davis et al., 2006). Schunk (1991) maintains that teachers whose self-efficacy is low may avoid planning challenging activities, are unlikely to persist with students with difficulties, and exert little effort to enable students to understand better; unlike teachers with higher self-efficacy who tend to do the opposite, which would help students learn better (Ashton & Webb, 1986). It is worth noting that providing feedback to teachers emphasizes their self-comparison of progress rather than the competitive social comparison to others, which is an effective way to build self-efficacy (Bandura, 1993). Accordingly, in this research study feedback was provided consistently to TCs in the STEM curriculum and pedagogy course to achieve this objective.

In harmony with self-efficacy and teaching efficacy is the concept of mindsets (Dweck, 1999). Blackwell et al. (2007) define mindsets as the beliefs that people hold about their most basic qualities such as intelligence, talents, and personality. Goldstein et al. (2013)

define teachers' mindsets as "assumptions and expectations teachers have for themselves and others that guide their teaching practices and their interactions with students, parents, and colleagues" (p. 74). These definitions indicate that such beliefs are flexible rather than static, which leads to Dweck's (1999) differentiation between two types of mindsets: a growth mindset and a fixed mindset. According to Dweck (1999), the growth-mindset-oriented people see their ability as something that can be increased with time and effort and frame their experience in terms of learning goals. In the contrary, fixed-mindset-oriented people see their abilities as static and inflexible. The literature shows that mindsets play a significant role in motivation, self-regulation, achievement, and interpersonal processes (Boylan et al., 2018). Langer and Applebee (1987) indicate that teachers need positive experiences to draw upon in order to change the way they teach, and that more research is needed on how this can be attained. Coubergs et al. (2017) have specifically indicated that teachers' growth mindset is an important factor impacting their teaching philosophy and hence their willingness to engage in DI implementation. Similarly, Sharma et al. (2021) conclude that teaching efficacy is the strongest predictor of their inclusive practices' intentions. Thus, the efforts in the STEM course were directed at attaining positive experiences, with a goal of developing TCs' self-efficacy and a growth mindset when it comes to implementing DI practices.

2.8.2 Sociocultural Theory and Scaffolding

The sociocultural theory of human learning describes learning as a social process, in which social interactions affect children's cognitive development (Rogoff, 1998; Vygotsky, 1978). In science education specifically, Lemke (2001) maintains that the sociocultural perspectives include the social-interactional, the organizational, and the sociological; the social-developmental, the biographical, and the historical; the linguistic, the semiotic, and the cultural. These complexities impact how we teach and learn in a science classroom and thus need addressing. In a practical approach to sociocultural learning theory, communities of practice are groups of people who share a concern or a passion for something they do and learn how to do it better as they regularly interact (Wenger, 1998). Wenger's model consists of four interdependent components: community, practice, meaning, and identity. In a community, members engage in joint activities and discussions, help each other, and share information. They build relationships that enable them to learn from each other. In this study TCs collaborated and shared resources in a community of practice to enhance each other's understanding and level of implementation of DI.

Another component of Vygotsky's theory is the zone of proximal development (ZPD), which is "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). Accordingly, scaffolding can support students in several ways: focusing on learners' conceptions, encouraging clarification, or offering new learning possibilities (Fosnot & Perry, 1996). In this study the STEM course tasks, supported by consistent instructor feedback and learners' self-reflection, were designed to enable scaffolding and support TCs.

2.8.3 Teachers' Professional Knowledge, Learning, and Retention

While the teacher must have a depth of understanding of the subject matter, pedagogical content knowledge (PCK) is also essential (Shulman, 1986). Teachers exhibit a mastery of pedagogical approaches to teach the content. As such, teachers' professional knowledge of practice entails knowledge of the content, knowledge of teaching procedures, teacher's interpretation of situations, recognizing and attending to student learning difficulties, the materials and settings of the educational process, research related to schooling, and wisdom of practice (Berry et al., 2009; Jameau & Boilevin, 2015; Shulman, 1986). The knowledge of children's learning processes is also highlighted. It forms the basics by which the teacher can stimulate students to engage in higher-order thinking by asking them to justify, draw comparisons, and discuss (Leuchter et al., 2020). Grangeat (2015) summarizes the knowledge required for science teaching as three categories of teacher professional knowledge: 1) professional knowledge base including knowledge of curriculum, students, and content; 2) general pedagogical knowledge that entails assessment knowledge and instructional strategies; and 3) topic and content specific pedagogical knowledge including multiple representations, awareness of students' understanding (misconceptions and prior knowledge), and practices that motivate students and enhance their knowledge of the nature of science.

In terms of what affects teachers' knowledge and advances their learning, it is vital to highlight the role of PD, which can be defined as processes designed to enhance the professional knowledge, skills, and attitudes of teachers so that they might, in turn, improve student learning (Borko, 2004; Guskey, 2002). Additionally, Shulman and Shulman (2004) highlight the importance of teacher learning communities which are professional communities in which "teachers are ready, willing, and able to teach and to learn from their teaching experiences" (p. 259). These communities are a practical implementation of sociocultural learning and communities of practice. Grangeat (2015) maintains that in order to grow the professional knowledge of science teachers, instructional methods courses should be transformed to better empower pre- and in-service teachers. This empowerment can be achieved through providing teachers with tools to design their students' learning and helping them to construct their self-efficacy. This idea captures the connectedness of all the theories above. The STEM course is a form of PD designed for TCs to 1) socially-construct and advance their professional knowledge about DI, and 2) enhance their self-efficacy and mindset to implement DI effectively.

An important aspect of teacher learning is retaining the learned knowledge and skills. For instance, Semb and Ellis (1994) state that:

> The existence of schools rests on the assumption that people learn something of what is taught and later remember some part of it, which is often a prerequisite for knowing when and how to perform jobs and tasks in the real world, for making educated choices as consumers and citizens, or for taking advanced schooling. (p. 253)

The concept of knowledge retention is well documented in science education, especially in the field of nature of science (Akerson et al., 2006; Khishfe, 2015). Akerson et al. (2006) indicate that what aids the retention of the nature of science concepts is teachers' personal reflections (metacognition-learning how to learn) and contextualizing the ideas in specific courses and instructional activities. These strategies were utilized in the STEM course by integrating DI components in course assignments and consistent TCs' reflections on their coursework. Furthermore, since the implementation of DI in future practice is highly relevant for pre-service teachers, it is essential to explore the retention of DI knowledge after the course ends. This aspect will constitute one measure of the effectiveness of the STEM course enhancing TCs' DI understanding and implementation.

2.8.4 Pedagogical Content Knowledge

Content knowledge and pedagogical knowledge merge to form what is known as pedagogical content knowledge (PCK). The PCK highlights how we organize particular topics and issues to be taught, tailored to learners' interests and abilities (Shulman, 1986). Teachers have to transform content knowledge into a pedagogically powerful form for students to understand and adapt to their backgrounds and skills. Shulman indicates that such pedagogical reasoning involves a cycle of teaching processes (comprehension, transformation, instruction, evaluation and reflection). S. Park and Oliver (2008) add to this definition: PCK consists of two dimensions which are understanding and enactment. This notion highlights the role of self-efficacy (Bandura, 1995) to connect these two dimensions– as the teachers' self-efficacy increases, they are more motivated to demonstrate their understanding. Reynolds and Park (2021) caution of the dangers of separating the subject matter and pedagogy from each other in teacher education, as current programs are constructed. They suggest that teacher education design special courses that show how to link the two dimensions together through explicit teaching of the elements of PCK and not leave TCs to develop this by themselves. This reasoning is because important aspects of teaching related to context, conceptual hooks, and triggers of learning were shown to be not well understood by teachers if they do not have rich understanding of the subject content (Loughran et al., 2012). Schneider and Plasman (2011) specify components unique for science PCK including: knowledge about the orientation to teaching science, students' thinking about science, instructional strategies in science, science curriculum, and assessment of students' science learning.

2.8.5 Reflective Practice

Pollard and Tann (1997) describe reflective teaching as how teachers investigate their practice. Farrell (2015) defines reflective practice as "a cognitive process accompanied by a set of attitudes in which teachers systematically collect data about their practice, and while engaging in dialogue with others, use the data to make informed decisions about their practice" (p. 123). Hubball et al. (2005) maintain that when teachers engage in reflective practice, they question what they do, what works and what does not, and what rationales underlie their teaching and that of others. In harmony, Brantley-Dias et al. (2021) emphasize the crucial role of reflection in professional growth. By reflecting, teachers or TCs would engage in a cognitive process in which they understand an experience and make informed decisions for new actions. In this study, TCs engaged in reflective practice by reflecting on their actions consistently throughout the course. TCs reflected on various concepts throughout their learning as well as on each assignment they developed. Combined with the feedback provided by their peers and the instructor, the study will highlight how these forms of reflective practice contributed to their views, conceptions, and implementation of DI.

2.9 Chapter Summary

This chapter provided a comprehensive literature overview of DI definitions, theoretical foundations, positive student outcomes, and various methods of implementation. Concerning teachers' perspectives, the literature review highlighted the relationship between teachers' DI views, self-efficacy, understandings, and implementation in classrooms. The literature review documented how positive views and a better understanding of DI are correlated with better implementation. Yet, the literature also showed that DI implementation is usually hindered by various challenges that teachers face, thereby affecting the level of DI implementation. The literature review highlighted the literature gaps, especially those related to DI in STEM subjects at the secondary level, emphasizing on the gaps related to the Canadian context. Furthermore, the chapter presented the theories that inform this research and explain how teachers' learning takes place, including teachers' self-efficacy (Bandura, 1995) and mindset (Dweck, 1999), sociocultural theory (Vygotsky, 1978), and reflective practice (Pollard & Tann, 1997).

These theories impact teachers' PCK and professional knowledge (Shulman, 1986), and retention of acquired knowledge and skills (Semb & Ellis, 1994), which in turn impact teachers' implementation of effective pedagogical practices such as DI (Tomlinson et al., 2003).

Chapter 3

3 Methodology

3.1 Research Design

The study adopted a mixed-method approach (Creswell & Creswell, 2018), specifically a case study (Yin, 2014). The study involved 19 intermediate/senior TCs in a curriculum and pedagogy course in STEM education in a teacher education program at a university in Ontario, Canada. DI principles and strategies were integrated through seminars, assignments and resources using an explicit and reflective approach (Abd-El-Khalick & Lederman, 2000). Both quantitative and qualitative data were collected. Data sources include: 1) pre- and post-course questionnaires exploring TCs' views, understandings, and implementation of DI; 2) semi-structured interviews and post-practicum open-ended survey detailing TCs' implementation of DI in the course and in their practicum; and 3) TCs' course work analysis, including three major assignments and TCs' reflections, lesson plans, peer evaluation, projects, and presentations. Figure 1 summarizes the timeline of the course, and data sources and collection.

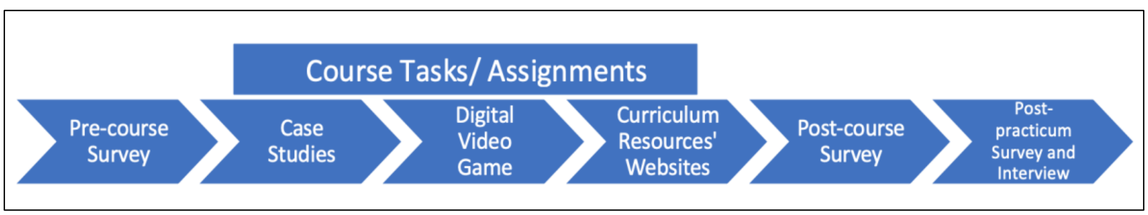


Figure 1: Course Components and Data Collection Timeline

According to Creswell and Creswell (2018), mixed methods involve collecting both quantitative and qualitative data using distinct designs. It involves the collection of closed-ended quantitative data and open-ended qualitative data. The two forms are integrated through merging the data, explaining the data, or building from one database to another. This integration minimizes the limitations of both approaches, yields additional insight beyond the information provided by either one alone, and gives a more complete understanding of research problems and questions. Moreover, it aims at explaining different perspectives from both quantitative and qualitative data, explaining quantitative results with a qualitative follow-up data collection and analysis, developing and documenting specific cases, and developing a more complete understanding. In this study, quantitative survey data provides a broad and general overview of TCs' initial and final views and understandings of DI, while the qualitative data provides in-depth and detailed insight into their views and understandings, as well as implementation in the practicum thus enabling an understanding of their experiences (Creswell & Creswell, 2018; Merriam & Tisdell, 2015). The mixed method approach followed a parallel design (Cohen et al., 2011) or also termed concurrent design (Teddlie & Tashakkori, 2006, as cited in Cohen et al., 2011). Both quantitative and qualitative data were collected simultaneously, analyzed separately, merged, and then compared to confirm or disconfirm each other.

A case study methodology was implemented, given case studies explore processes and activities by collecting detailed information and using a variety of data collection procedures over a sustained period of time (Creswell & Creswell, 2018; Yin 2014). They richly describe and deeply analyze a bounded system which is the case or the unit under investigation (Creswell & Creswell, 2018; Merriam & Tisdell, 2015). Case studies in qualitative research are based on an interpretivist epistemology (Gall et al., 2005), in which the researcher collects detailed information over a sustained period of time (Yin 2014). Yin (2009) maintains that a case study typically answers "how" and "why" questions, requires no control of behavioral events, and focuses on contemporary events. Furthermore, this case study of STEM TCs includes descriptive and exploratory components (Yin, 2009). It is used to describe an intervention and the real-life context in which it occurred, and it can also be used to generate hypotheses that are tested in larger-scale research. Overall, this study explores the multiple realities that exist among different TCs in terms of their understanding and implementation of DI as a way to observe the impact of the DI-focused STEM course components. Thus, I specifically chose the case study method to capture the complexity and the richness of the case under study, that is, how STEM TCs developed curriculum to be inclusive of DI.

3.2 Participants

In total, 19 TCs (9 males; 10 females) participated in the study during the 2020-2021 academic year. Participants were enrolled in a *STEM Curriculum and Pedagogy* course in the second year of the teacher education program at a university in Ontario. As shown in Table 1, all TCs in the study were eligible to teach STEM subjects in the intermediate-senior divisions (Grades 9, 10, 11, and/or 12). TCs' teachable subjects included general sciences, biology, math, physics, chemistry, health and physical education, and computer studies. TCs in Ontario teach more than one subject in their practicum and in their future careers. In terms of education, three TCs have a graduate degree (Masters) and the remaining 16 TCs have a Bachelor's degree. Furthermore, the table provides a brief snapshot of TCs' prior exposure to DI and EDI, which was obtained from the pre-survey. To provide more context about the participants, the common courses that TCs were enrolled in prior to or concurrent with the STEM curriculum and pedagogy course are highlighted.

In year one of the teacher education program, TCs enroll in 10 courses. Among these courses are those directly related to EDI pedagogies or general teaching methods: one course on special education and inclusion, one course on Aboriginal education, two teaching methods courses (each related to one of their future teachable subjects), and one course entitled Year 1- Introduction to STEM education.

In year two of the program, TCs enroll in seven courses. Among these courses are those directly related to EDI pedagogies or general teaching methods: one course on supporting English language learners, one course on multiliteracies, and one course entitled Year 2- Curriculum and pedagogy in STEM education, in which this study was conducted.

Table 1: Details of TCs' Demographics

Pseudonym	Gender	Highest Degree	Classes Taught	Subjects	Prior Exposure to DI and EDI
Angela	Female	Bachelors	9, 10	Chemistry, Science	Did not read Ontario's Equity Plan or the DI handbook
Darryl	Male	Masters	9, 11, 12	Physical Education, Biology	Did not read Ontario's Equity Action Plan or the DI handbook; Had practical experience in the practicum
David	Male	Bachelors	12	Math, Physics	Did not read Ontario's Equity Plan or the DI handbook; Attended many classes/lectures on Indigenous education, inclusive classrooms, and LGBT2Q+ education
Elizabeth	Female	Bachelors	11, 12	Biology, Science	Did not read Ontario's Equity Plan or the DI handbook
Erin	Female	Bachelors	11, 12	Biology, Science	Did not read Ontario's Equity Plan, but read the DI handbook; Volunteer experience helped her understand EDI
Gabe	Male	Bachelors	9, 10, 12	Math, Physics	Did not read Ontario's Equity Plan or the DI handbook; Learned about DI in one course on math education in his undergraduate studies
Holly	Female	Bachelors	10	Biology, Science	Did not read Ontario's Equity Plan or the DI handbook; Had practical experience in the practicum
Jan	Female	Bachelors	9, 11	Science, Math	Did not read Ontario's Equity Plan or the DI handbook; Stated that several classes in teacher education have provided EDI strategies and examples
Jim	Male	Bachelors	9, 10, 11	Chemistry, Science	Did not read Ontario's Equity Plan or the DI handbook; Had practical experience in the practicum

Karen	Female	Bachelors	9, 12	Biology, Science	Did not read Ontario’s Equity Plan or the DI handbook; Had a PD Day on EDI
Meredith	Female	Bachelors	9, 10, 11, 12	Science, Math	Did not read Ontario’s Equity Plan or the DI handbook; Had practical experience in the practicum
Michael	Male	Bachelors	11	Physics, Math	Did not read Ontario’s Equity Plan or the DI handbook
Nellie	Female	Masters	11, 12	Physics, Math	Read both Ontario’s Equity Plan and the DI handbook; Had a PD Day on EDI
Pam	Female	Bachelors	9, 10, 11, 12	Biology, Science	Did not read Ontario’s Equity Plan or the DI handbook
Pete	Male	Bachelors	11	Biology, Science	Did not read Ontario’s Equity Plan, but read the DI handbook
Phyllis	Female	Bachelors	10, 11	Science, Math	Did not read Ontario’s Equity Plan or the DI handbook; Had practical experience in the practicum
Robert	Male	Masters	11	Physics, Science	Did not read Ontario’s Equity Plan or the DI handbook
Roy	Male	Bachelors	10	Biology, Science	Did not read Ontario’s Equity Plan or the DI handbook
Toby	Male	Bachelors	9, 10, 11	Biology, Science	Did not read Ontario’s Equity Plan or the DI handbook

3.3 Overview of the Course

This course is one of two STEM courses offered to TCs enrolled in STEM Specialty Focus in the teacher education program and is strategically offered in the second year of the program. As per the syllabus description, the course "focuses on STEM education within the broader curricular spectrum, and enables TCs to develop pedagogical content knowledge, skills, technologies, instructional strategies, and assessments to support the design and development of STEM projects". Due to the COVID-19 pandemic, the 12-week course was implemented fully online, with three-hour weekly meetings. The researcher, who was also the Teaching Assistant for the course, coordinated with the course instructor in the initial planning to enrich the course content with DI-focused materials and resources.

In the first class of the course, TCs' prior understandings and views about DI were gauged through an online questionnaire and a few diagnostic activities, including prompts using interactive presentation tools. Afterwards, in the first two weeks of the course, the course instructor collaborated with the researcher to provide a seminar on DI and EDI. Throughout the course, the instructor addressed DI in an explicit and reflective approach (Abd-El-Khalick & Lederman, 2000). The instructor provided the TCs with resources to integrate DI such as course readings, which included several articles on DI definition, methods, positive outcomes, and theoretical foundations related to EDI. The 12-week course also included tailored tasks requiring the application of DI principles and strategies as one of the success criteria, without changing the nature of the tasks. TCs completed three major curriculum development projects: 1) creating case studies around socio-scientific issues (SSI), 2) developing digital video games (DVGs), and 3) creating a digital curriculum resources website. TCs were requested to explicitly address DI in their coursework. To ensure TCs' integration of DI in assignments, all progress reports, reflections, and final assignment rubrics included effective integration of DI as one of the success criteria. The instructor and teaching assistant also tracked the progress of TCs on a weekly basis. For example, in breakout rooms on Zoom, TCs were queried about their intentions, targets, and challenges integrating DI in specific assignments. Sample in-class questions included: *How are you intending/ planning to integrate DI resources in this* *assignment?* and *What challenges are you facing to integrate DI in this assignment?* The instructor and teaching assistant provided feedback on TCs' work and recommendations on how to improve or maintain certain aspects of their work. Upon the completion of one assignment, general feedback was provided to the whole class, with specific attention to gaps and exemplary methods in DI integration. TCs were constantly reflecting on their progress and hence advancing their knowledge and skills in DI implementation throughout the course. TCs were invited to share their final course work with the researcher for analysis. Moreover, TCs presented their projects to their colleagues, provided peer feedback, and reflected on their own work through written reflections. Peer evaluation rubrics as well as the reflections were also analyzed in this study.

3.3.1 Curriculum Development: Case Studies

This assignment was the first major task for TCs in the course. Over a five-week period, a team of four TCs collaborated to develop and conduct a digital case study that is interactive (including videos, images, simulations, etc.) and based on an SSI around STEM education (e.g., environmental sustainability, healthcare, social issues, etc.), for Grades 9-12 (DeCoito & Fazio, 2017). In addressing the SSI, TCs were required to complete a number of activities that comprise the research and development of the case study including lesson plans, scenario, stakeholders, graphic organizers, note-taking framework, consequence map, cost-benefit analysis, and a presentation to lay audience. The task was also accompanied with progress reports, peer feedback, and a final reflection. A sample cover page of this assignment is illustrated in Figure 2.

Figure 2: Sample Cover Page of a Case Study about Light Pollution

3.3.2 Curriculum Development: Digital Video Games (DVGs)

In this assignment, TCs worked individually or in pairs to develop a DVG to teach a concept in physics, chemistry, or biology, for Grade 11 or 12 (e.g., Figure 3). The criteria for the DVG included: STEM education content, with the integration of a minimum of three STEM disciplines, career connections, a pluriversal approach in which other knowledges are valued equally, attention to EDI (e.g., gender, DI, etc.), and DVG design requirements such as rewards, avatars, and a minimum of two difficulty levels (DeCoito & Briona, 2020). The task was accompanied by progress reports and a final reflection.

Figure 3: Sample DVG Focusing on Physics Concepts – Kinematics and Forces

3.3.3 Curriculum Development: STEM Curriculum Resources Website

In groups of four, TCs developed and produced a multimedia STEM resources website suitable for use by Grades 10, 11 or 12 STEM/science teachers. Each website addressed one unit/strand of the biology, chemistry, or physics Ontario curriculum, and included a variety of instructional and assessment exercises focused on the development of STEM curriculum-based concepts, inquiry skills (including STEM connections), and creativity. Groups established active links to specific websites, images, and multimedia learning objects on the Internet, as well as related coursework completed by their peers in different assignments. The STEM curriculum resources were required to reflect and showcase student-centered and inquiry-based pedagogical strategies. Each website included the following sections: Table of Contents, Curriculum Expectations, Misconceptions, Lesson Sequence (five lesson plans), Societal Implications, Teaching Strategies, Ideas, and Resources, Creativity, Assessment Methods, Foundations of Professional Practice, Glossary, and References (Figure 4). The task was also accompanied by progress reports, peer feedback, and a final reflection.

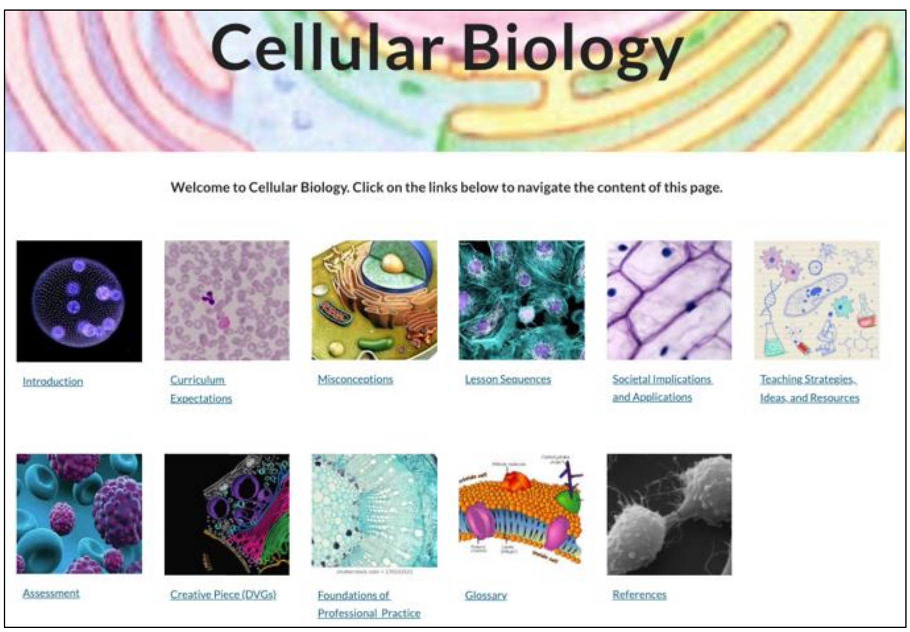


Figure 4: Sample of a STEM Curriculum Website Content Page

3.3.4 Assessing TCs' Integration of DI and EDI

To ensure that TCs integrated EDI principles and DI strategies in their assignments, the assessment criteria and the requirements of the assignments reflected this priority and were intertwined with other criteria related to each task in the course. For example, in the case studies, the peer feedback template included "*Explicit EDI"* as one of its criteria, in which the *"Distinguished Level"* stated, *"The case study addresses all EDI components".* Additionally, the written reflection included the following question: *"Did you incorporate elements of equity, diversity, and inclusion into your case study? Explain*".

In the DVGs, the progress report, final reflection, and assessment rubric probed TCs to consider how their DVG integrated the pluriversal approach, addressed EDI effectively, and varied the levels of difficulty for students.

As for the websites, one of the peer assessment items was "*Differentiated instruction, cross-disciplinary approaches, constructivism, inquiry, and principles of equity are embedded in the Curriculum Resource"*. The final reflection included the following two questions: "*Explain how you incorporated the elements of equity, diversity, and inclusion into your curriculum resources. Please refer to Ontario's Education Equity Action Plan (2017) for details*" and "*Explain how your curriculum resources are differentiated in each of content, process, and product aspects to cater for students' different academic levels/readiness, interests, and learning profiles*". Common to the assessment rubric in both case studies and websites are "*Principles of Equity, Diversity, and Inclusion (e.g., differentiating instruction, Indigenous and other ways of knowing, etc.)*" as one criterion, in which the highest level of achievement is described as "*TC demonstrates a sophisticated understanding of principles of equity, diversity and inclusion, as stated in Ontario's Education Equity Action Plan*".

It is important to note that the assessment rubric for case studies, DVGs, and websites incorporated many aspects related to the nature of each assignment, in addition to DI. In this research, only the DI component is expanded upon and analyzed.

3.3.5 Summary of Study Procedures

Table 2 summarizes the study procedures, as well as the various events that took place during the study including data collection.

Table 2: Study Procedures

Weeks	Course Events
Week 1	• Pre-Questionnaire administered at the beginning of the course • Course Introduction • Introduction to EDI in STEM Education and DI • Data collection: Pre-Questionnaire
Week 2	• DI Seminar (continued): TCs were exposed to theoretical principles and practical foundations of DI, Ontario's Equity Action Plan, DI handbook, DI definition, and practical strategies for implementing DI • TCs were provided with several readings and supporting resources to assist them with understanding DI. • Introduction to case studies on socio-scientific issues (SSI), Science, Technology, Society, and Environment (STSE)
Week 3	• Case Studies research and development: Group facilitation and discussions • The researcher entered breakout rooms to discuss TCs' ideas related to how they are implementing DI in the assignment and provide feedback
Week 4	• Continuation of Case Studies research and development • The researcher entered breakout rooms to discuss TCs' ideas related to how they are implementing DI in this assignment and provide feedback • Introduction to digital video games (DVGs)

Week 5	• DVGs research and development: TCs submitted their DVG storyboard and progress reports • The researcher and the course instructor collaborated on providing feedback on storyboards and progress reports • The researcher entered breakout rooms to discuss TCs' ideas on implementing DI in the assignment, and provided individualized feedback in terms of how they can enhance DI implementation in the assignment
Week 6	• Case study assignment: Presentations, discussions, and reflection • The researcher provided individualized feedback to each TC on the overall implementation of DI in the case studies • Data collection: Case Studies Assignment – Coursework analysis
Break	• TCs' alternative field experience (3 weeks) and Holiday Break (2 weeks)
Week 7	• No class due to the COVID-19 pandemic (break extended)
Week 8	• DVG assignment: Presentations, discussions, and reflection • The researcher provided individualized feedback to each TC on the overall implementation of DI in the DVG • Data collection: DVG Assignment – Coursework analysis
Week 9	• Seminar on curriculum development in STEM education and developing educative materials in STEM; class discussions • Curriculum resources websites: Introduction
Week 10	• Curriculum resources websites: Research and development • TCs submitted their first progress reports on websites. The researcher and the course instructor collaborated on providing feedback on progress reports. • The researcher entered breakout rooms to discuss TCs' ideas on how they are implementing DI in the assignment and provided individualized feedback in terms of how they can enhance DI implementation in this assignment

Week 11	• Curriculum resources websites: Research and development • TCs submitted their second progress reports on websites. The researcher and the course instructor collaborated on providing feedback on progress reports. • The researcher entered breakout rooms to discuss TCs' ideas on how they are implementing DI in this assignment and provided individualized feedback in terms of how they can enhance DI implementation in this assignment
Week 12	• Curriculum resources' websites: Presentations and discussions • Course wrap-up • Data collection: Post-Questionnaire and Curriculum Resources Websites Assignment – Coursework analysis
Weeks 13-18	• TCs' practicum (6 weeks) • Data collection: Post-Practicum Survey in weeks 19 and 20
Weeks 19-22	• TCs' alternative field experience (4 weeks) • Data Collection: Interviews after week 20

3.4 Data Sources

3.4.1 Surveys

Questionnaires or surveys provide quantitative description of trends, attitudes, and opinions of a population, or tests for associations among variables of a population (Creswell & Creswell, 2018). In this study, the questionnaires were administered through "Qualtrics" online survey software. In total, 19 consenting TCs completed the pre-questionnaire and 17 of them completed the post-questionnaire.

Consenting TCs were invited to complete an online pre-questionnaire that explored their initial understandings and views about DI. The pre-questionnaire (Appendix C), composed of 12 five-point Likert scale statements (1=strong disagreement to 5=strong agreement) and five open-ended questions, was administered on the first day of the course. This questionnaire explored TCs' initial views and understanding of DI, and their preparation prior to the course with respect to DI. Sample Likert scale items in the pre-questionnaire include:

- *I would describe my differentiated instruction understanding/knowledge as "Extensive".*
- *I can define and explain the term "differentiated instruction".*
- *I am familiar with at least 3 ways to differentiate the subject content for my students.*

Sample open-ended questions in the pre-questionnaire include:

- *Reflect on any professional development you've had that would assist you teach through the lens of equity, diversity, and inclusion (e.g., students of various needs, academic levels, backgrounds etc.) in your future classes. Please describe. Was your experience effective?*
- *Based on your knowledge and personal experiences (such as the practicum and other), list some challenges that you anticipate would hinder the implementation of differentiated instruction or other inclusive strategies in your classes.*
- *Based on your knowledge and personal experiences (such as the practicum and other), list the advantages and successes of the implementation of differentiated instruction or other inclusive strategies in your classes.*

Thereafter, the course instructor introduced DI through a seminar. The 12-week course included resources, tailored tasks, and assignments that required the application of DI principles and strategies as one of the success criteria. Due to the COVID-19 pandemic, the course was offered in a fully online synchronous format. On the last day of the course, TCs were invited to complete an online post-questionnaire (Appendix D). The post-questionnaire, comprised of 43 five-point Likert scale questions and four open-ended questions, explored TCs' final views and understanding of DI (same as the pre-questionnaire), their implementation of DI in the course, and their evaluation of the effectiveness of the course with respect to DI. The Likert scale questions related to the implementation of DI in the course and the evaluation of the DI component in the course were unique to the post-questionnaire. Sample Likert scale items in the post-questionnaire include:

- *I would describe my differentiated instruction implementation (in the course) as "Extensive".*
- *I differentiate the content of the lesson by using three or more of the following or other strategies: (offering choices regarding where students can begin, extending the knowledge/ skills of advanced learners, providing supplemental support to candidates with difficulty, presenting the content at varying levels of complexity, reflecting students' interests or experiences, eliminating curricular material for some students, adjusting the pacing of instruction).*
- *The course provided me with tools and resources to implement differentiated instruction in my practicum and future classes.*

Sample open-ended questions in the post-questionnaire include:

- *Explain some of the challenges you faced while trying to integrate differentiated instruction and equity, diversity, and inclusion practices in your course assignments.*

The Likert scale items were adopted from questionnaires (Roy et al., 2013; Santangelo & Tomlinson, 2012) that were tested for content validity and reliability. Santangelo and Tomlinson's (2012) questionnaire addressed teacher educators' perceptions and use of DI practices, whereas Roy et al.'s (2013) DI scale included items related to instructional adaptations and assessment strategies in DI. On the other hand, the Likert scale items related to the course effectiveness in the post-survey and the open-ended questions in both the pre- and the post-questionnaires were developed by the researcher based on the RQs, the course tasks, and the literature.

After the course, TCs completed their practicum at a school in Ontario for six weeks where they attended classes and taught lessons in the presence of an Associate Teacher. Thereafter, they participated in a four-week Alternative Field Experience which marked the end of Year 2 of the program. At the end of the program, TCs were asked to complete another online questionnaire composed of eight open-ended questions, which explored the details of DI implementation in the practicum, as well as reflections on successes and challenges encountered (Appendix E). Sample questions in the post-practicum questionnaire include:

- *Please provide examples of how you differentiated instruction in your practicum (content, process, product).*
- *Explain the witnessed advantages/ successes of implementing differentiated instruction in terms of its impact on students during your practicum.*

3.4.2 Semi-Structured Interview

Interviewing is a process in which the researcher and the participant engage in a conversation focused on questions related to the research study (Demarrais, 2004, as cited in Merriam & Tisdell, 2015). Interviews are the most common data collection methods in qualitative research. They are very effective and convenient due to their adaptability (Gall et al., 2005) and cost-effectiveness (Dexter, 1970, as cited in Merriam & Tisdell, 2015). Interviews provide an opportunity for the researcher to control the line of questioning and enable the participant to provide a historical overview about their practices which cannot be observed. In specific, semi-structured interviews are characterized by a mix of more and less structured questions (Creswell & Creswell, 2018). This approach was utilized in this study to engage in richer discussions with the TCs. Two months after the course ended, TCs were invited to participate in a 1-hour semi-structured online interview to follow-up on their responses in the pre/post-questionnaires, post-practicum questionnaire, and their course work (Appendix F). The interview explored in greater depth certain elements of the questionnaire and course work, such as details of how TCs understood and implemented DI, and/or how they would implement it in their future practices. This interview was used to clarify, detail, and increase the trustworthiness of the other data sources. It is important to note that the interviews were conducted online using Zoom software due to the COVID-19 pandemic.

With respect to the post-practicum questionnaire and interviews, emails were sent to 19 participants after their practicum ended. Four TCs participated in both, two TCs participated only in the interview, and one TC participated only in the post-practicum questionnaire. This type of sampling is based on convenience since the participants are those who indicated their availability (Merriam & Tisdell, 2015). Creswell and Creswell (2018) maintain that there is no rule that specifies the number of participants in a qualitative study, and that small numbers characterize qualitative research, with narratives including one to two participants, four to five in case studies, and one culture in ethnographies. Hence, the sample size must be based on reasonable coverage of the studied phenomenon (Patton, 2015, as cited in Merriam & Tisdell, 2015). In this study, the relatively large sample (seven out of 19) ensures variation in the responses and the required coverage.

3.4.3 Course Work

Document and artefact analysis is important in qualitative case studies as it produces rich descriptions of a single phenomenon, event, organization, or program (Stake, 1995). It mostly serves the triangulation purpose (Bowen, 2009), by complementing other research methods' evidence. The strengths of this tool are numerous. First, it is cost-effective and convenient since it saves the time of transcription and can be assessed at the researcher's convenience. Second, documents are stable and exact, and hence non-reactive. Third, they obtain the language of teachers by presenting the data they have written by themselves. On the other hand, few limitations may decrease its authenticity and accuracy. First, the chosen documents may be personal (written by the teachers themselves) and biased/self-selected; hence they may not be representative or trustworthy. Moreover, not all people are equally articulate and perceptive. Thus, the information presented by the teacher for analysis may be insufficient, incomplete, irrelevant, or un-understandable (Bowen, 2009; Creswell & Creswell, 2018; Merriam & Tisdell, 2015). TCs were invited to share their course work and 18 of the 19 consenting TCs agreed to share their course work with the researcher for analysis. TCs' course work and assignments included curriculum development projects such as STEM resource websites, DVGs, and case studies around SSI. These tasks also required writing lesson plans, peer evaluations, and reflections. Moreover, TCs were observed while they presented their lessons and projects to their colleagues and were required to reflect on their own work and provide peer feedback. To avoid any limitations related to authenticity and trustworthiness of a specific assignment, all TCs' course work were analyzed to support other collected evidence.

3.5 Data Analysis

Quantitative data from the questionnaires were analyzed using Microsoft Excel. Descriptive statistics were performed including calculating counts, averages, standard deviations, percentages, and differences between pre- and post-results. Bar graphs were plotted using Microsoft Excel to display these statistics. Additionally, inferential statistical tests were performed using SPSS. The pre- and post-test comparison was done through the Wilcoxon Test, since each of the 5-point Likert scale items represents an ordinal variable, and the pre- and post-results are the results taken at two different times for the same variable (Connolly, 2007). For example, the Wilcoxon Test was performed to compare the pre-post results related to TCs' understanding of DI such as the Likert scale item "*I can define and explain the term differentiated instruction*". Moreover, the Spearman correlation test was performed to explore the relationship between different ordinal variables i.e., different 5-point Likert items (Connolly, 2007). For example, in the post-survey, this test explored the relationship between the item "*I am familiar with at least 3 ways to differentiate the subject content for my students*" and the item "*I differentiate the content of the lesson by using three or more of the following or other strategies…*".

On the other hand, the qualitative data were analyzed differently depending on the data sources. For instance, qualitative data from open-ended survey questions and interviews were analyzed using an inductive process (Creswell & Creswell, 2018) as elaborated upon in Section 3.5.1. The coursework analysis was conducted using a deductive process (Merriam & Tisdell, 2015) according to developed frameworks suitable for each assignment, as elaborated upon in Section 3.5.2.

3.5.1 Inductive Analysis

The analysis of qualitative data from open-ended survey questions and interviews was performed as an inductive process that builds patterns, categories, and themes by organizing the data into more abstract units of information (Creswell & Creswell, 2018). Participants' responses were inputted into NVivo 12 where initial codes were developed using word clouds based on the frequency of words in TCs' responses (Figure 5). Subsequently, the codes were grouped into themes, finalized, and interpreted to draw conclusions (Gall et al., 2005). Thematic coding (Stake, 2020) was performed to provide an in-depth analysis of the responses of all participants (Figure 6), which was used later to calculate the frequency of responses in relation to each theme. Figures 5 and 6 illustrate sample analysis performed on TCs' responses to one of the pre-survey questions: *Reflect on any professional development you engaged with that would assist you to teach through the lens of equity, diversity, and inclusion.*

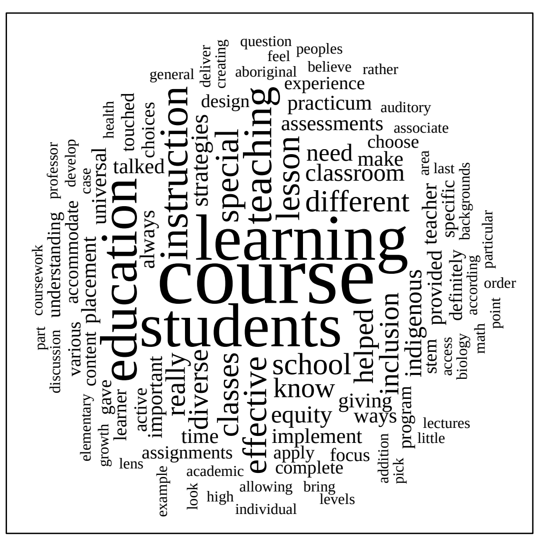


Figure 5: Sample Word Cloud Illustrating TCs' Experiences with Prior PD on EDI

					PD
					Courses
					Practicum
					Satisfied/ effective
					Superficial experience with DI-Not satisfied/ not effective
					Pre-Survey-Reflect on any professional development you've had that would assist you teach through the lens of equity, diversity, and inclusion (e.g. students of various needs, academic levels, backgrounds etc...) in your future classes. Please describe. Was your experience effective
0	1	0	0	1	I have taken a course at (University Name Redacted) on special education, focused on IEPs and accommodation within the classroom. Additionally, I have taken a course on inclusion for Aboriginal peoples at Western University. I believe the course on Aboriginal peoples was very effective, while the course on special education was not so effective. The reasons for this was the "busy work" associated with the special education course and the emphasis on elementary education (I am a high school teacher candidate).
0	0	1	1	0	Both practica that I completed were in ethnically diverse schools. I was exposed to different ways of knowing and learning. I always had to question the content I delivered and assessments in order to accommodate different ways learnings - I had experience in most high school streams (academic, applied, locally developed, workplace). This really gave me insight on how I need to adapt my lessons, approach and assessments between classes of different academic levels.
0	1	1	1	0	Working with students that have IEP's helped me get an understanding of how differentiating instruction is very important. Involving kinesthetic, visual and auditory components to a lesson help cater to different teaching styles. One important tip I received from my professor last year was that a student can be a visual learner for one lesson but the next lesson they could be an auditory learner. This really stuck with me since it emphasizes how important DI is in every single lesson. Being in the Toronto area really helped me understand how important including equity, diversity and anti-racism into lessons is. I think that it should not be restricted to areas that have a diverse population but rather everywhere in order to educate students at an early age.
1	0	0	1	0	We had a PD Day about equity, diversity and inclusion. I think it was beneficial, since it gave an opportunity for teachers to ask questions.

Figure 6: Sample Thematic Coding of TCs' Experiences with Prior PD on EDI

3.5.2 Deductive Analysis

Data analysis related to TCs' post-practicum open-ended survey responses and coursework (case studies, DVGs, and STEM resource websites) adopted a deductive approach (Merriam & Tisdell, 2015). The deductive analysis looks back at the data from pre-determined themes (Creswell & Creswell, 2018). In specific, the case studies assignment was analyzed using the DIIM-M2 matrix (Appendix G). The post-practicum survey responses and the other two course assignments (DVGs and STEM curriculum resources websites) were analyzed according to the CPP-RIP matrix explained earlier in Section 2.3. Both matrices were utilized to form initial broad categories according to which coursework was analyzed.

3.5.2.1 DI Matrix

To analyze how TCs integrated DI in their case studies, the Differentiated Instruction Implementation Matrix-Modified (DIIM-M) (Maeng, 2011) was adopted after obtaining the permission from the author. The DIIM-M is a validated instrument that evaluates teachers' proficiency and their performance levels in DI (Downes, 2006, as cited in Maeng, 2011). This matrix is a comprehensive tool used to analyze the implementation of DI (Maeng, 2011). Since the instrument is initially designed to assess the practices in one lesson and for in-class observations, several modifications have been made to address the uniqueness of the planned case studies, and hence named DIIM-M2 (see Table 3 and detailed in Appendix G).

The initial instrument is composed of seven domains and 25 sub-criteria. Following the modifications, the DIIM-M2 reflected six domains and 20 sub-criteria. For example, some of the criteria that are unique to in-class observations were removed such as giving clear directions for multiple tasks and teacher's classroom leadership and management. This omission is due to the fact that the analysis is restricted to what the TCs planned but did not implement in the classroom. Second, certain criteria were combined such as teaching modalities and teaching strategies; intellectual abilities and high order thinking skills; and teacher role and student choice in the classroom. Third, due to the COVID-19 pandemic, this research was implemented in an online environment. TCs were also expected to conduct their practicum in an online environment, as they may be teaching online in the future. To highlight the importance of this aspect, a specific criterion was added regarding integrating technology and the ability to implement the case study in an online environment.

Additionally, one of the major amendments to the matrix was the explicit incorporation of EDI principles within the framework. This amendment was done by adding a criterion entitled "Principles of Equity, Diversity, and Inclusion (EDI) as stated in Ontario's Education Equity Action Plan (2017)" within Domain 5: Positive, Supportive, and Inclusive Learning Environment, which entails implementing inclusive and culturally responsive and relevant teaching, curriculum, assessment, and resources. This action was to ensure that students consider Ontario's Education Equity Action Plan (2017) which promotes classes that are inclusive and reflect diversity in terms of race, ethnicity, culture, religion, SES, immigration status, sexual orientation, gender identity, parent engagement, language first spoken, Indigenous communities, and Indigenous histories and ways of knowing, and are accessible for students with exceptionalities. This change takes into consideration the recommendation by Valiandes et al. (2018) calling for the blending of intercultural education and differentiated instruction in practice by deploying the strategy of interculturally differentiated teaching. This call is due to the assumption that despite both intercultural education and differentiated instruction being based on EDI principles, most research studies focus on one in isolation of the other in a way that intercultural education celebrates students' cultural backgrounds while DI focuses on academic aptitude; hence the need for a comprehensive framework that combines both aspects together in theory and instructional practice (Valiandes et al., 2018). Moreover, since the STEM TCs are most likely going to teach in Ontario schools, the Education Equity Action Plan (2017) was the most relevant framework to integrate for the aforementioned purpose.

Correspondingly, Lee (2016) presents the SSI-PCK framework that combines SSI and PCK. This framework includes an orientation for teaching SSI which shapes teachers' 1) knowledge of instructional strategies for teaching SSI, 2) knowledge of curriculum, 3) knowledge of students' SSI learning, 4) knowledge of assessment of SSI learning, and 5) knowledge of learning contexts. These aspects were considered in this STEM course and included in the DIIM-M2 matrix to analyze TCs' level of understanding and implementation of DI in the case studies assignment. Therefore, the DIIM-M22 matrix is composite model adopted and amended by the researcher to analyze the case studies specifically with an attention to Ontario's equity policies. This matrix will be referred to as the DI matrix for simplicity.

Table 3: Short Version of the DI Matrix (DIIM-M2)

Domains	Criteria
Domain 1: Quality Curriculum and Lesson Design	1. Quality and clarity of the lesson objectives: What students should know, understand, and be able to do 2. Alignment of lesson objectives and lesson activities throughout the case study
Domain 2: Response to Learner Needs	1. Preassessment and Proactive Preparation 2. Scaffolding for Struggling Learners; Special Ed., ELL, etc. 3. Challenging Advanced Students
Domain 3: Planned Instructional Practices	1. Lesson Organization 2. Modes and Strategies of Instruction 3. Engagement Capacity of Activities 4. Intellectual Development 5. Flexible Grouping 6. Teacher's Planned Role, Learner Independence, and Student Choice 7. Technology Integration
Domain 4: Student Assessment	1. Formative Assessment 2. Existence and Quality of Rubrics and Guidelines
Domain 5: Positive, Supportive, and Inclusive Learning Environment	1. Principles of Equity, Diversity, and Inclusion (EDI) as stated in Ontario's Education Equity Action Plan (Ontario's Education Equity Action Plan, 2017) 2. Respectful Behavior Toward and Among Students 3. Sense of Community and Collaboration
Domain 6: Evidence of Differentiation	1. Content: adapting what is taught and modifying how students are given access to the information (Tomlinson, 2001) 2. Process: the sense-making… without it, students either lose the ideas or confuse them (Tomlinson, 2001) 3. Product: helps students rethink, use, and extend what they have learned… [and] represent understandings (Tomlinson, 2001)

In Chapter 5, seven case studies were analyzed according to the DI matrix and included accompanying lesson plans, presentation, supporting documents and resources. Each domain in the DI matrix is composed of several criteria. A score out of four was allocated to each case study in each of the 20 criteria in the DI matrix, where (1) indicates "Novice", (2) indicates "Apprentice", (3) indicates "Practitioner", and (4) indicates "Expert". To overcome the limitations of the document analysis tool, and to avoid any limitations related to authenticity and trustworthiness of a specific part of the assignment, the researcher analyzed all the documents related to this assignment including TCs' reflections, peer feedback, lesson plans, and supplementary worksheets. Furthermore, the qualitative analysis was quantified as a way to further explore the holistic implementation of DI across all case studies. This quantitation was done by providing scores for each case study on each of the DI Matrix criteria and domains to attain a deeper understanding of TCs' successes, and the areas of improvement with respect to their utilization of DI in their curriculum development. The five types of calculations shown in Chapter 5, are explained below:

1) The total score of each case study on the DI Matrix (score out of 80) is the sum of the scores obtained by the case study on all the 20 criteria in the matrix.

2) Average score of the case studies on each criterion (score out of four) is calculated by dividing the sum of the scores of all seven case studies on an individual criterion by seven (the total number of case studies)

3) Average score of the case studies on each domain (score out of four) is the average score of the criteria within each domain. For example, the average score of the case studies on Domain 1 is obtained by calculating the average of the scores on its two criteria (explained in step 2 above).

4) Average score of the case studies on each domain in percentage is the number obtained in step 3 converted to percentages (dividing by four and multiplying by 100).

5) The count of case studies scoring a specific level on each of the DI Matrix criteria, that is, how many of the seven case studies scored 1=Novice, 2=Apprentice, 3=Practitioner, and 4=Expert on a given criterion.

3.5.2.2 CPP-RIP Matrix

This DI implementation framework, the content, process, product – readiness, interests, profiles (CPP-RIP) (Figure 7) was explained earlier in Section 2.3. This framework is utilized in this thesis to analyze TCs' implementation of DI in the DVGs and the resource websites. These digital resources were analyzed in a descriptive manner to explain the level of integration of different DI components in them.

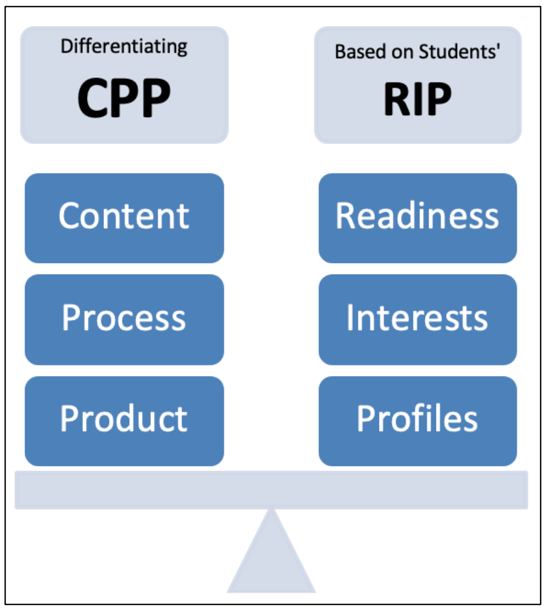


Figure 7: CPP-RIP Framework

3.6 Trustworthiness of the Data

Several measures were taken to ensure trustworthiness of the data. The next paragraphs elaborate on the steps taken to ensure the credibility, legitimacy, transferability, dependability, and confirmability of the data.

3.6.1 Credibility

Credibility is the accuracy of the data (Creswell & Creswell 2018), that is, how the findings match the reality (Merriam & Tisdell, 2015). In this study, credibility was accomplished by using 1) previously validated questions in the pre- and post-questionnaires, 2) follow-up interviews to validate the quantitative data presented by the TCs, and 3) three different methods to collect the data – questionnaires, interviews, and document analysis. The latter approach, triangulation, is the best way to validate the findings (Creswell & Creswell 2018; Merriam & Tisdell, 2015). Relying on one data source is insufficient due to the limitations of each method. Accordingly, the quantitative data in the pre- and post- questionnaires provided a general overview of TCs' views, understandings, and implementation of DI. This overview was thoroughly detailed by analyzing their coursework and reflections, as well as the interviews conducted several weeks after the course ended.

An additional strategy that was also used to enhance the credibility of the data is the prolonged engagement with data collection. Engaging with the TCs for 12 weeks throughout the course, as well as maintaining contact with them after the course to conduct the post-practicum survey and interviews, analyzing all coursework and not only one assignment, and using the semi-structured type of interviewing are all factors that ensured an in-depth understanding of the explored case (Creswell & Creswell 2018; Merriam & Tisdell, 2015). Credibility was also ensured by the participation of 19 consenting TCs, which is a relatively high number, especially given that the bulk of data is qualitative in nature. Finally, additional measures that enhanced the credibility of the data are the inclusion of thick descriptions and discrepant information (Creswell & Creswell 2018). Thick description was achieved through detailed explanations of TCs' work, with accompanying supplementary screenshots and excerpts. On the other hand, discrepant information is presented by highlighting various levels of TCs' proficiency in DI as well as reporting the challenges they encountered throughout different phases of the study.

3.6.2 Transferability

Transferability describes the extent to which the findings of the study can be applied to other situations (Merriam & Tisdell, 2015). In other terms, it is the theoretical generalization or extrapolation. With respect to the quantitative component of the study, the aim of collecting the Likert scale data included presenting a general overview of TCs' conceptions and views toward DI, and hence not assuming any generalizations. Still, 19 out of 36 TCs consented to participate in this study, which represents slightly more than 50%. This percentage is an indication of representative sampling, although it is based on convenience. On the other hand, in the qualitative section, the burden of extrapolation lies with the person seeking the application of the findings elsewhere (Lincoln & Guba, 1985, as cited in Merriam & Tisdell, 2015). With 19 TCs in the sample and the thick descriptions provided, the researcher believes that sufficient descriptive data is presented to yield a rich understanding of the case under investigation (Merriam & Tisdell, 2015).

3.6.3 Dependability

Dependability describes the consistency of the findings with the data presented (Merriam & Tisdell, 2015). This consistency is quite challenging in similar studies due to the contextual and multifaceted nature of the data (Lincoln & Guba, 1985, as cited in Merriam & Tisdell, 2015). Triangulation helps ensure dependability (Creswell & Creswell 2018; Merriam & Tisdell, 2015). In addition, avoiding the drift in defining the codes helps preserve consistency (Gibbs, 2007, as cited in Creswell & Creswell 2018), as well as documenting the steps of the implemented procedures (Yin, 2009). These measures were implemented by constant revisions of the coding process to guarantee consistency in defining the codes. Finally, the researcher's positionality (explained below) plays an important role in maintaining dependability of the findings (Merriam & Tisdell, 2015).

3.6.4 Confirmability and Researcher's Positionality

The major factor that affects the objectivity or the confirmability of the data is the researcher's position and reflexivity. This notion explains how the researcher affects and is affected by the research process (Probst & Berenson, 2014, as cited in Merriam & Tisdell, 2015). In this study, I fulfilled dual roles – that of a teaching assistant in the course and a researcher. Being the teaching assistant enabled me to engage in a prolonged and extensive manner in the data collection, and to concurrently analyze the data. Through weekly interactions and feedback with the course instructor, we were able to provide feedback to TCs on their work and facilitate class discussions and activities accordingly. This extensive level of engagement enabled me to understand the case under investigation in detail and entertain different perspectives throughout and after the course, thus providing an additional layer for the thick and rich analysis. Additionally, being able to engage in informal and formal discussions throughout the course also enlightened me to shed light on certain aspects that I had not considered important or relevant before the data collection phase. On the other hand, as a relatively newcomer to Canada with no prior relationships with the TCs nor a specific conflict of interest, helped minimize any bias.

As a former science teacher, I experienced the wide array of advantages of DI, especially in terms of its positive impact on my students' outcomes. Yet, despite my enthusiasm for equitable and inclusive classrooms, I still had the unbiased motivation to explore if this course in its form could potentially help advance these practices and result in positive outcomes. The semi-structured approach in interviewing, phrasing the interview questions in the least leading way without directing the responses, and triangulating the data sources also helped minimizing any bias. Furthermore, the aim of the research is to figure out what works in terms of TCs' preparation for DI, what does not work, and the reasons in both scenarios. Accordingly, there were not favorable findings or hypotheses. This positionality is crucial in enhancing the objectivity of the data analysis. Finally, my research paradigm accepts various interpretations and perspectives openly without favoring a certain point of view or aiming to prove a specific hypothesis. This exploratory and descriptive approach also enhances the confirmability of the data.

3.7 Ethical Considerations

The ethical considerations pertaining this study are numerous. These are presented below according to the phase of the study as per the framework provided by Creswell and Creswell (2018). I sought to address these ethical requirements to enhance the authenticity of the collected data and the trustworthiness of the findings.

Prior to data collection, I obtained ethics approval from the Western University Research Ethics Board (Appendix A). Second, one of the first day of the course, held via Zoom due the COVID-19 pandemic, the course instructor introduced me and left the meeting in order for me to introduce the study and discuss the letter of information (LOI) and obtain consent (Appendix B). The TCs and I had not met prior to this session. Participants were not pressured to participate, and as per the LOI, could withdraw their participation at any time during the study. To avoid any conflict of interest, the course instructor had no access to the consent forms nor the master list during the course. TCs were assured that their participation was voluntary and would not affect their course grade.

During data collection, the norms and rules of the university and the course were respected. The study did not require any separation of groups into experimental and control groups and hence was an undisruptive process. Second, all participants were treated equally, and without exploitation. Third, TCs were briefed without any deception by clearly communicating the purpose and the details of the study with them. Fourth, there was no harm to any participant. TCs were asked to act normally as the study was aimed at exploring what was taking place in the course. Fifth, throughout the course, I tried to build trust and rapport with the TCs through several informal discussions. Thus, my positionality as the course teaching assistant alleviated the interviewer bias. TCs were responding to questions naturally without any attempt to please me as the interviewer, especially that the interviews took place after the course ended. Sixth, during the interviews, I avoided leading questions and questions that may disclose sensitive information. I abided by the set questions with a margin for emerging themes as per the semi-structured interviewing approach. Seventh, the documents provided by the TCs were not shared with anyone. Excerpts were taken for analysis in a way that did not risk their privacy or anonymity.

Finally, regarding data storage, participants' survey responses were collected through a secure online survey platform, Qualtrics, which uses encryption technology and restricted access authorizations to protect all data collected. Additionally, Western's Qualtrics server is in Ireland, where privacy standards are maintained under the European Union safe harbour framework. The data were then exported from Qualtrics and securely stored on Western University's server. All digital data including interview recordings, documents obtained from TCs, and field notes taken by the researcher were saved and stored using Western University's Data Management System (OWL), which is also a secure and encrypted platform. All TCs' identifiable information were collected separately from study data and linked by unique ID codes that were assigned to the TCs by the researcher.

After data collection, all transcriptions and data analyses were done by me, to ensure TCs' confidentiality. Second, in the dissemination of the study findings as publications or conference presentation, only de-identified information or data with pseudonyms will be made available. Thus, the identity of research participants in this project will not be compromised. Finally, all participants will be sent a summary of the findings and the conclusions of the study after the defense of the dissertation.

3.8 Chapter Summary

This chapter presented the methodology adopted in this study. It focused on and explained the rationale for adopting a mixed method approach, in which quantitative data provided an overview of the impact of the course on TCs' views, understandings, and implementation of DI using pre- and post-questionnaires. Qualitative data collected through open-ended responses on the surveys, semi-structured interviews, and the in-depth analysis of TCs' course work provide detailed insights on the impact of the course and the level of TCs' ability to differentiate their instruction. This chapter also presented details of the various methods of analysis for each of the data sources. Finally, the chapter explains the measures taken to ensure trustworthiness of the data and compliance by ethical considerations.

Chapter 4

4 Findings: Course Impact on TCs' Views, Understandings, and Implementation of DI

This chapter presents TCs' views and understandings of DI (initial and post), and their implementation of DI in the STEM course and in their practicum. Additionally, findings related to if, and how the course impacted TCs' teaching philosophies and their intentions to implement DI in the future are highlighted. Finally, this chapter reports on TCs' evaluation of the course components and specific benefits in terms of their DI conceptions. Findings are presented and discussed with reference to the relevant literature. By doing so, this chapter answers the following RQs:

RQ1. What are intermediate-senior STEM TCs' views and understandings of DI?

RQ2b. What successes and challenges do TCs encounter when developing DI-focused curricula?

RQ3. How do TCs implement DI in their practicum?

RQ4. What are TCs' intentions to integrate DI in their future careers?

4.1 TCs' Background Knowledge

4.1.1 TCs' Prior Preparation

Participants were asked about two specific documents to understand TCs' prior exposure to important policy publications about EDI and DI issued by the Ministry of Education in Ontario. One out of 19 TCs indicated that they had read the Education Equity Plan (2017) while three out of 19 TCs indicated reading the Differentiated Instruction handbook (2010) and/or its accompanying online resources. Furthermore, to explore TCs' readiness and prior preparation, they were asked in the pre-survey to reflect on any PD they have had that would assist them to teach through EDI lens in their classes and to evaluate the effectiveness of these PD opportunities.

Out of 15 respondents to this question, eight TCs stated specific coursework that included EDI-related topics such as Indigenous education, special and inclusive education, or/and STEM methods course in year one of the program. Five TCs noted that their year one practicum experience helped them explore EDI principles and applications. On the other hand, three TCs mentioned specific PD workshops related to the topic.

Concerning the effectiveness of the above opportunities in helping them teach through an EDI lens in the future, ten TCs responded, with six of them agreeing that these opportunities were effective and four stating they were not. Out of the six TCs who indicated their experiences were effective, four mentioned the practicum. For example, they said:

> *Both practica that I completed were in ethnically diverse schools. I was exposed to different ways of knowing and learning. I always had to question the content I delivered and assessments in order to accommodate different ways learnings - I had experience in most high school streams (academic, applied, locally developed, workplace). This really gave me insight on how I need to adapt my lessons, approach and assessments between classes of different academic levels. (Phyllis, Pre-survey)*

> *Working with students that have IEP's (individualized educational plans) helped me get an understanding of how differentiating instruction is very important. Involving kinesthetic, visual and auditory components to a lesson help cater to different teaching styles. (Meredith, Pre-survey)*

> *My practicum experience in year 1 helped me learn to teach through the lens of equity diversity and inclusion. I met students of various needs and backgrounds, I viewed students as individuals with different starting points and abilities to focus and learned to make accommodations and changes to my lesson planning according to what students need to succeed, for example providing more options for assignments and giving more choices for students to choose, this way students have a higher motivation and take on more responsibility for their learning and growth. (Holly, Pre-survey)*

The above excerpts highlight the TCs’ exploration of the concepts of EDI and DI in a practical way in their practicum rather than in their courses or through additional PD. The excerpts point to the preparation courses for TCs’ translation to the practicum. TCs said that working with IEP students in previous diverse settings allowed them to translate DI to their current practicum experiences.

On the other hand, four TCs said that their experiences were not effective in helping them teach through an EDI lens and pointed out that what they learned was irrelevant to their specific classes:

> *The strategies I learned for differentiated instruction were largely inapplicable to my most recent practicum, or at least I was ill-prepared for translating them to an online environment. (Gabe, Pre-survey)*

> *It would be more effective to see them (the strategies) in action in real life. (Jan, Pre-survey)*

> *The reasons for this (ineffectiveness) were the "busy work" associated with the special education course and the emphasis on elementary education. I am a high school teacher candidate. (Roy, Pre-survey)*

Gabe points to the challenges of applying strategies he learned about DI in education courses to his most recent practicum. Gabe claims he was unable to translate what he learned to the online learning context. Jan would have liked DI strategies that apply to real life scenarios. Roy links the ineffectiveness to the "busy work" in the special education course and the emphasis on elementary education, which did not apply to him as a TC preparing to teach in high school settings.

With respect to TCs’ preparation for DI specifically, TCs’ responses on the interview at the end of the study corroborated these findings. All six interviewees stated that they had experienced a form of DI in their coursework and/or teaching prior to the STEM curriculum and pedagogy course. Five of them mentioned taking courses related to DI (two of which mentioned special education courses), while four TCs said they had experienced DI in their practicum. Yet, five of the interviewees indicated that this exposure to DI was not quite effective. For instance, they said:

> *I definitely didn't have that much knowledge about DI then I compared to how I know about it now. So, in the past, like I mostly relied on one sort of type of instruction, like standing up in the front of the class and just kind of talking, having a PowerPoint in the back of that sort of thing. But now I know that it's learning is much more than just giving direct instruction… (Erin, Interview)*

> *Before, I had the first practicum experience. And I did not add actually as much differentiated instruction. I had some that I implemented being like, just introductions of like videos for English language learner students, in addition to other course content but that was mainly guided by my associate teacher rather than it was my own. Some of the courses touched on it. We had a course on special education, touch on differentiation... We also had an Indigenous education course which touched on it briefly, although like in all of them it's not super super in depth I believe in the ways you do it, it's more just, we learned like what it is, to look at how we could apply it… (Roy, Interview)*

These findings illustrate that TCs had varying levels of exposure to DI principles in some of their courses and their practicum experiences. Yet, the effectiveness of these opportunities is debatable. As argued by some TCs, the previous courses did not provide STEM-specific and high-school specific skills. Moreover, the emphasis on DI in mostly special education courses reinforces teachers' misconception that implementing inclusive practices such as DI is only for exceptional students (DiPirro, 2017; Whitley et al., 2019). This notion defeats the goal of integrating DI under all circumstances – a point that will be addressed later in this thesis. On the other hand, practicum experiences, referred to by the majority of TCs, are related to the environment of specific schools and the efforts of specific mentoring teachers, and are hence not consistent among all TCs. Finally, most TCs have not read the Ministry published documents which is a gap and suggests that programs need to work on this aspect as the documents are designed for the context of Ontario schools. This non-reading by TCs reflects a gap between policy makers and practitioners. Overall, the preparation of TCs for DI requires improvement so that they consistently acquire specific knowledge and skills that enables them to utilize DI principles and strategies in teaching STEM subjects in Ontario classrooms.

These results also reiterate to a certain extent D'Intino and Wang's (2021) findings from the theoretical analysis of the coursework offered in Canadian universities, indicating that the current coursework is not sufficient to prepare TCs for DI. Findings also corroborate Massouti's (2019, 2021), Rezai-Rashti and Solomon's (2008), and Specht et al.'s (2006) conclusions related to the need for enhancing TCs' preparation focusing on EDI practices in teacher education programs in Canada. Results also relate to the importance of coherence between various courses within teacher education programs to ensure that all TCs attain the knowledge and skills required to differentiate instruction in their future practices (Dack, 2019b). Moreover, the fact that the majority of TCs were referring to DI based on their practicum experience highlights the importance of the practical fieldwork and calls for further coherence between coursework and the practicum (Dack, 2019b; Massouti, 2019).

4.1.2 TCs' Initial Views of DI

In the first class of the STEM course, the researcher gauged TCs' prior views about DI using a few diagnostic activities. One diagnostic activity was done through Mentimeter, which is an interactive presentation tool. The Mentimeter prompted with several questions, and a word-cloud was created reflecting TCs' responses, with more repetitive words magnified. The questions were meant to be general and open ended to foster classroom discussion. Figure 8 illustrates TCs' responses to the prompt *How are students different in a classroom*? The 43 collected responses focused mainly on students' backgrounds (e.g., culture, race, religion, SES), personalities, interests, language proficiency, level of engagement, and academic achievement. On the other hand, Figure 9 illustrates TCs' responses to the prompt *What comes to your mind when you hear about DI*? The 46 collected responses mainly focused on inclusion, equity, accommodation, adaptation, providing options, meeting individual student needs, creativity, and active learning. Few answers hinted to challenges perceived by the TCs regarding DI implementation (e.g., more work, tedious, overwhelming).

Figure 8: TCs' Responses to "*How are Students Different in a Classroom*?"

Figure 9: TCs' Responses to "*What Comes to Your Mind When You Hear about DI*?"

In the pre-survey, TCs elaborated on the advantages and successes of DI based on their previous experiences (Figure 10). TCs' responses generated four themes. Sixty-five percent TCs indicated the importance of catering to students' needs, interests, and choices. Forty-seven percent noted that DI can enhance student achievement, understanding, and creativity. Thirty-five percent stated that DI could strengthen student motivation and engagement; and 18% felt DI utilizes more creative teaching and assessment methods.

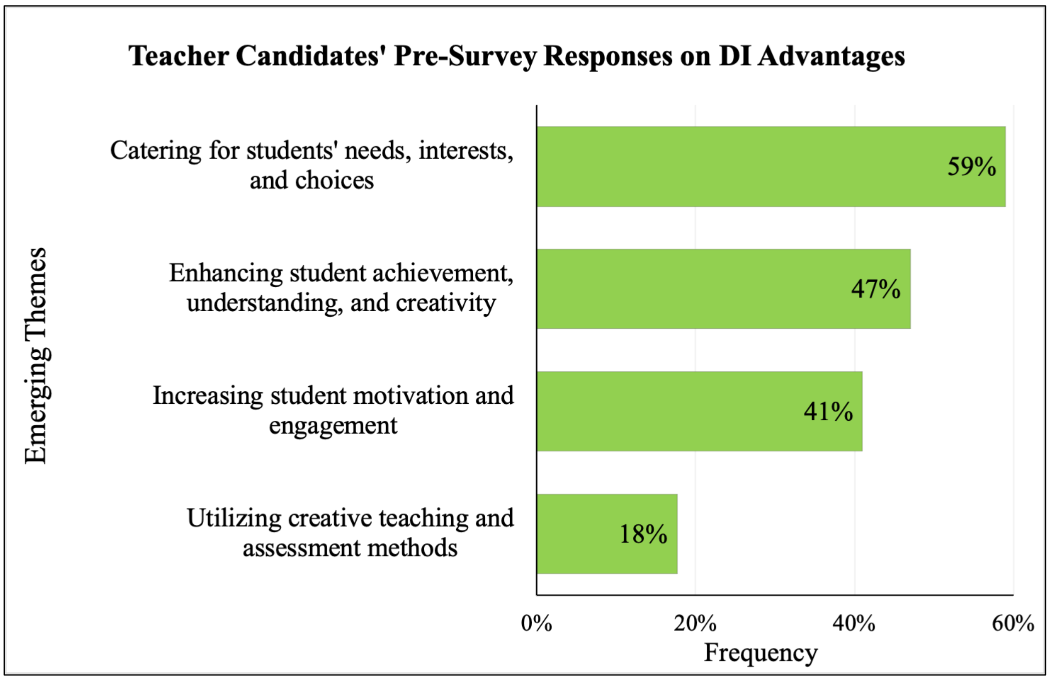


Figure 10: TCs' Initial (Pre) Views about DI (n=17)

Concerning students' needs, interests, and choices, TCs mostly focused on academic levels and their learning preferences. TCs stated:

> *Each student's individual needs are met - students feel safe, included, represented, and valued in the classroom. (Holly, Pre-survey)*

> *Students have voice and choice. Students can learn and demonstrate their learning in ways that work best for them. (Elizabeth, Pre-survey)*

Ideally each student is receiving content in a way that fully taps into their own potential. (Darryl, Pre-survey)

On achievement, TCs stated:

All students can achieve their highest potential. (Jan, Pre-survey)

Better learning for understanding, better mental well-being, less stress. Students have more confidence in their abilities. (Michael, Pre-survey)

As for student engagement and motivation, Phyllis noted:

[DI] increases student motivation across the board. I found students showed up to class more often when my associate teacher and I differentiated instruction. [DI] gives them confidence to be present in the classroom and to continue learning outside the classroom. (Pre-survey)

In general, TCs' initial views toward the importance of DI were informed and positive. TCs' responses reflected that most of them were aware of student diversity in the classroom. Furthermore, TCs demonstrated a fundamental and general knowledge about DI. This result is in accordance with the findings that teachers have positive views toward the importance of DI (Charles, 2017; Paone, 2017; Robinson, 2017), but in contradiction with Garrett (2017), Rollins (2010), and Wertheim and Leyser (2002) who noted low self-efficacy toward DI among TCs and new teachers. Yet, these positive views need to accompany deep understandings and effective implementation. Accordingly, my research aimed to ensure a more profound knowledge and deeper understanding of DI and provide TCs with STEM/science relevant teaching ideas and tools to acquire the required skills to differentiate instruction. This measure would aid in translating prior conceptualizations of DI to intentional and practical steps when integrating DI in TCs' curriculum planning and implementation.

4.2 Impact of the Course on TCs

4.2.1 TCs' Views

TCs' pre-survey responses elaborated on their views and understandings of DI and how these changed after the course. Figure 11 highlights average responses of TCs' initial and final views and understanding of DI. The results highlight an overall improvement in TCs' views about DI. Pre- and post-survey means (with standard deviations in parenthesis) describe these trends. For example, TCs believed that DI is beneficial for students (average agreement increased from 4.58 (0.59) to 4.71 (0.57)), that teachers should consider all student differences when planning their lessons (average increased from 4.47 (0.60) to 4.53 (0.61)), and that DI is feasible and applicable (average increased from 4.00 (0.56) to 4.24 (0.81)).

TCs' enhanced views of DI reported from survey responses are also corroborated in their interviews. When asked if DI should be incorporated in all levels of science teaching, all six TCs responded affirmatively. TCs' reasoning was acknowledging the existence of differences among students and that DI ensures equity among students. Additionally, two TCs specified better achievement and one TC pinpointed higher student engagement. TCs said:

> *The use of DI allows flexibility, choice, and equity to the learning material which is something that all grade levels and subjects should be incorporating. (Angela, Interview)*

> *Yes, for sure because, you know, every student is different and unique, and they all have their own sort of like background knowledge so it's important we are differentiating. (Erin, Interview)*

> *I think that it's important to allow learners to show their understanding on their own terms and in a way that they feel comfortable with, not one uniform way that's been dictated by the instructor. (Michael, Interview)*

Angela advanced the advantages of the use of DI, by suggesting that all grade levels and subjects incorporate flexibility, choice, and equity to access the learning resources. Erin affirmed the reasons that every learner has a unique background. Michael's response is further elaborated when he states that learners must reveal their "understanding" in their "terms" by a method comfortable to them instead of a teacher's belief and practice of "one fits all".

The course played a role in enhancing TCs' views and self-efficacy toward DI. TCs shared positive insights about the importance of DI and its benefits to students. This finding is in accordance with research highlighting the importance of DI-focused training in teacher education programs on TCs' beliefs and self-efficacy toward DI (Goodnough, 2010; Wan, 2016), and training focused on inclusive practices in general in teacher education (Specht & Metsala, 2018). Equally important, TCs indicated an improvement in their views that DI is applicable and feasible, which is an important outcome that addresses research findings reporting novice teachers' ambivalence to implement DI due to its difficulty, among other challenges (Garrett, 2017; Rollins, 2010; Wertheim & Leyser, 2002). Since teachers' beliefs in their instructional efficacy determines classroom contexts and instructional environment (Bandura, 1993), these results indicate the positive impact of the course on TCs' views and their future class environments.

4.2.2 TCs' Understandings

For DI understanding (Figure 11), pre- and post-survey means (with standard deviations in parenthesis) describe TCs' self-ratings. TCs described their DI understanding as extensive (an increase from 3.32 (0.92) to 4.12 (0.68)); define and explain DI (an increase from 4.05 (0.39) to 4.41 (0.49)); and familiarity with how to differentiate lesson content (an increase from 4.11 (0.72) to 4.41 (0.60)), process – teaching strategies (an increase from 4.00 (0.79) to 4.47 (0.61)), and product – assessment tools (an increase from 3.89 (0.91) to 4.35 (0.59)). On the other hand, TCs did not show any enhancement in their understandings on two statements: belief that DI is individualized instruction (an increase from 3.32 (1.08) to 3.35 (1.23)) and that DI is an approach for only students with special needs (an increase from 1.42 (0.94) to 1.65 (1.13)). By calculating the difference between the average on the post-survey and the pre-survey, it is evident that the most significant positive changes in DI views and understandings relate to six statements:

1) Describing own understanding of DI as extensive (difference= 0.80),

2) Familiarizing with at least three ways to differentiate the teaching strategies – process (difference= 0.47),

3) Being familiar with at least three ways to differentiate the assessment strategies – product (difference= 0.46),

4) Having ability to define DI (difference= 0.36),

5) Familiarizing with at least three ways to differentiate the subject content (difference= 0.30),

6) Believing that DI is feasible and applicable (difference= 0.24).

The six statements are directly related to TCs' understanding and pedagogical knowledge about DI, which shows the positive impact of the course in terms of enhancing TCs' understanding of DI and their familiarity implementing it in their classes. It is also noted that TCs' familiarity with differentiating the content component recorded the lowest difference between the post and pre-surveys, and that the product differentiation familiarity recorded the lowest post-test score compared to content and product differentiation (4.35). This finding warrants further exploration and analysis. On the other hand, for statements where the difference between the pre-survey and the post-survey was insignificant, TCs had already showed a high level of agreement in the pre-survey, for example, the belief that DI is beneficial (pre=4.58), understanding that students can reach different levels (pre=4.53), and considering all student differences (pre=4.47). All three numbers are close to "5" which is strong agreement, and hence the margin of improvement is limited.

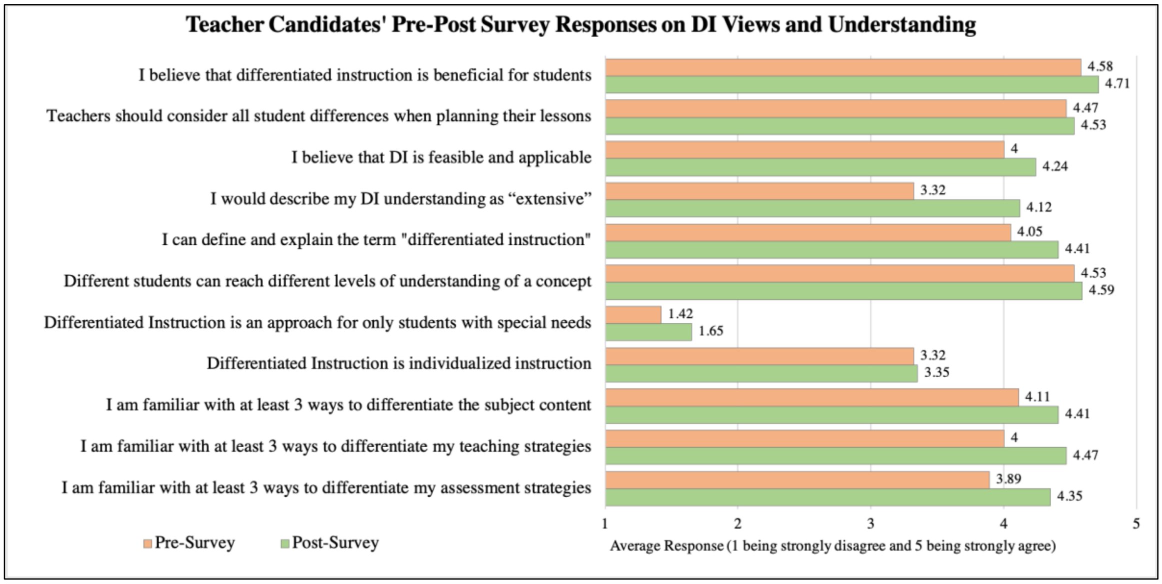


Figure 11: TCs' Initial (n=19) and Final (n=17) Views and Understandings of DI

Furthermore, results of the Wilcoxon test indicate that the pre-post change was significant on five of the Likert scale items related to DI understanding:

1) TCs indicated that they are more able to describe their DI understanding/knowledge as "Extensive" in the post-survey compared to the pre-survey (p=.016, Wilcoxon Test, Z=2.405). The change was found to be moderately significant (r=.58).

2) TCs indicated that they are more able to define and explain the term DI in the post-survey compared to the pre-survey (p=.034, Wilcoxon Test, Z=2.121). The change was found to be moderately significant (r=.51).

3) TCs indicated that they are more familiar with ways to differentiate the subject content for their students in the post-survey compared to the pre-survey (p=.13, Wilcoxon Test, Z=1.513). The change was found to be moderately significant (r=.37).

4) TCs indicated that they are more familiar with ways to differentiate their teaching strategies in the post-survey compared to the pre-survey (p=.107, Wilcoxon Test, Z=1.613). The change was found to be moderately significant (r=.39).

5) TCs indicated that they are more familiar with ways to differentiate their assessment strategies in the post-survey compared to the pre-survey ($p=.106$, Wilcoxon Test, $Z=1.615$). The change was found to be moderately significant ($r=.39$).

TCs' interview responses about their understanding of DI corroborate these findings. When describing their understanding of DI, all six interviewed TCs acknowledged student differences and the importance of accommodating those differences. For example, TCs said:

> *My understanding of differentiated instruction is that we're teaching with the goal of accommodating as many students as we can. So, it's students with different learning styles, students have different ability levels, as well as students have different backgrounds. That way they're all included in learning process and are actually able to like work to the best of their abilities, when we try to do that through a variety of different instructional strategies. (Roy, Interview)*

> *I believe differentiated instruction is when you tailor your pedagogy and your way of teaching to different students. So different students learn best are like they have different strengths and weaknesses. (Pam, Interview)*

> *Differentiated instruction is providing the ability of each learner to show understanding in a way that suited to their strengths and abilities and providing instruction and learning opportunities for each learner, based on their abilities and strengths. (Michael, Interview)*

Furthermore, five out of the six interviewed TCs reflected an adequate understanding of the content, process, and product differentiation framework when elaborating on their understanding of DI. One TC mentioned the differentiation of one component only- the process. TCs explained:

> *Differentiated content: What do you want the student to learn? Differentiated process: What activities will you use? How do these rely on different thinking processes?*

Differentiated product: How will the student show what they have learned? (Angela, Interview)

(There are) three different parts to DI: instruction, process, and products. For me the easiest is differentiating the products, because it's very easy to offer different options for the students to showcase what they have learned and like the summative assignments. So, in during my placement, I made sure that I was differentiating the products in that way. And then, the most challenging way for me to differentiate learning is through the content, because there's a lot of different like levels for the students so it's hard for me to sort of make sure I'm giving my advanced learners the opportunity to learn as well as some of my slower learners to know. (Erin, Interview)

For Angela, differentiated content means the "What" (ontology) of learning. Differentiated process means the "activities" students will engage with depending on differing abilities and thinking. Differentiated product, according to Angela, is the "How" (epistemology) of learning. Erin states that there are three components to DI: "instruction, process, and products." Erin acknowledges that differentiating the products is easier for her. In her practicum, Erin ensured differentiating the products through summative assignments. Erin admits that differentiating the content is the most challenging. Her reasoning is related to catering to the needs of varying levels of students' understanding–those that are advanced and those that struggle. Angela mislabeled instruction for content. To her, instruction and process were not the same. However, her description of instruction is more so related to content.

In conclusion, the course can positively impact TCs' views and understandings of DI. While some TCs' interview responses seem similar to their pre-survey responses, there is more emphasis on the theoretical foundation of DI as an EDI approach. This emphasis reflects a more profound understanding of the principles of DI and its applications in the classroom. This understanding and application reiterate the importance of TCs' training addressing their conceptualization of DI (Dack, 2018; Goodnough, 2010). In general, the course resulted in TCs expressing more familiarity with DI strategies for content, process, and product differentiation. This knowledge is a significant challenge among TCs that hinders their willingness and implementation of DI, as reported by Adlam (2007) and Wan (2017). Concerning the specifics of TCs' familiarity with DI strategies, the content differentiation recorded the slightest post-pre improvement among others. The product differentiation recorded the lowest post-test score compared to content and product differentiation. Erin's quote corroborates these findings by elaborating on TCs' difficulty differentiating the content component specifically. These results are per the literature indicating that content and product differentiation are the least understood by teachers, while differentiating the process is relatively better understood and implemented (Rollins, 2010; Turner & Solis, 2017).

4.3 TCs' Implementation of DI in the Course

4.3.1 TCs' Reflection on their DI Implementation

In the post-survey, TCs reflected on their implementation of DI in the course tasks. Figure 12 shows the percentages of TCs who agreed or disagreed with various statements regarding their DI implementation. Most TCs agreed that their DI implementation was extensive (76%). The vast majority of the TCs indicated that they 1) differentiated the content (88%) by offering choices, extending the knowledge of advanced learners, providing support to candidates with difficulty, presenting the content at varying levels of complexity, reflecting students' interests, eliminating curricular material for some students, and adjusting the pacing of instruction; 2) differentiated the process (88%) by offering multiple modes of learning, varying the instructional strategies, using flexible grouping, using independent study, and using interest centers; and 3) differentiated the product (94%) by varying the types of assessments, providing students with choices to express their understanding, providing tiered assignments, and utilizing rubrics that match varied ability levels.

Most TCs agreed that they allow students to play a role in designing/selecting their learning activities (82%) and assessing their own learning (76%). The majority of TCs agreed that they use diagnostic assessment (82%), formative assessment (94%), and summative assessment (94%); and that these assessments inform subsequent teaching

(100%). Eighty-eight percent of TCs stated that they evaluate the effectiveness of their teaching adjustments, while 82% stated that they evaluate students based on their improvement and growth during the semester with respect to their initial academic levels. Finally, on the use of technology, 94% of TCs stated that they use technology as a tool for DI, and 82% stated that they use technology for assessment in DI specifically. Overall, the results show high levels of TCs' implementation of DI in all aspects. This finding highlights the positive impact of the course on their pedagogical skills related to DI, and hence an adequate preparation of teachers to implement EDI principles in their future classes. These findings parallel the literature on the importance and positive impact of teacher training on DI understanding and implementation for both pre-service and in-service teachers (Dixon et al., 2014; Goodnough, 2010; Nicolae, 2014; Pincince, 2016).

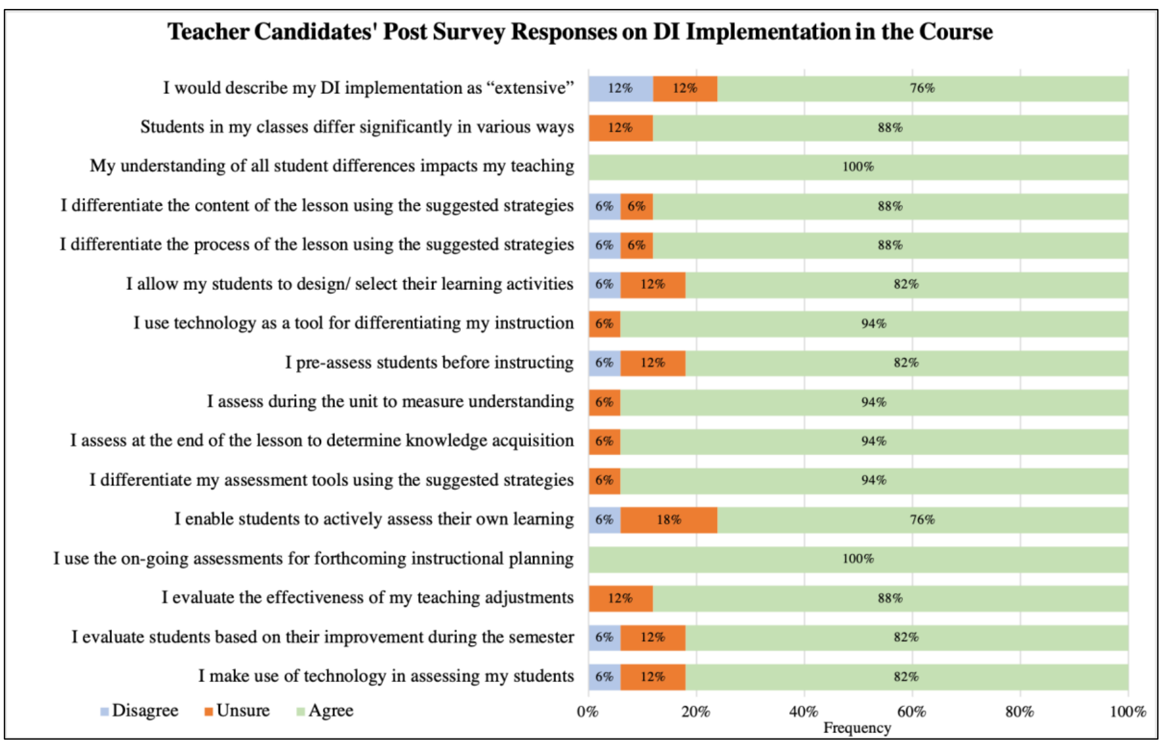


Figure 12: TCs' Post-Survey Responses on DI Implementation in the Course (n=17)

To investigate further, results of the Spearman correlation test indicate the relationship between TCs' level of DI understanding and their implementation in the course work. For example, the post-survey results indicate a significant positive correlation between TCs' familiarity with at least three methods to differentiate the content and their implementation of at least three methods of content differentiation in the course work (rs=.62, p=.009). Additionally, results of the Spearman correlation indicate a significant positive correlation between TCs' familiarity with at least three methods to differentiate the process and their implementation of at least three methods to differentiate the process in the course work (rs=.69, p=.002). Similarly, results of the Spearman correlation indicate a significant positive correlation between TCs' familiarity with at least three methods to differentiate the product and their implementation of at least three methods to differentiate the product in the course work (rs=.72, p=.001). These findings reiterate the positive correlation between TCs' understanding of DI and its implementation (DiPirro, 2017; Suprayogi et al., 2017).

Chapters 5 and 6 showcase how TCs implemented DI in their coursework. Samples from six interviewed participants are highlighted to triangulate findings originating from the post-survey and interviews.

4.3.2 TCs' Implementation of DI

TCs described in the interview how they differentiated the instruction in their course work. TCs elaborated on how they differentiated the content, the process, and the product. TCs also discussed how they attended to EDI aspects especially respecting diverse cultural backgrounds, genders, and non-Western views. Furthermore, in the post-survey TCs indicated which assignment(s) in the course was/were the most relevant for differentiating instruction – nine out of 13 TCs selected the curriculum resources websites, four TCs stated the case studies, and two specified the DVGs. One TC, Erin, said it was all three assignments:

> *Every lesson and assignment created is relevant to differentiate instruction. I achieved through offering choices, extending knowledge of advanced learners, providing supplemental support, reflecting student's interests, etc.) (Interview)*

TCs described their ability to develop resources that are inclusive of DI strategies and reflected positively on the various tasks:

4.3.2.1 Case Studies

TCs explained how they developed case studies, taking different perspectives on the socio-scientific issue into consideration, how they prepared materials with varied difficulty and readability levels, and how their lesson plans included multimodal teaching strategies. TCs said:

> *I made sure to incorporate lots of different levels of readings for my students so if I was assigning an article, I made sure that I checked out what reading level that article was and gave different levels and different options. And I also included a lot of different perspectives. And, like, we looked at issues on different scales so not just local, but also on a global scale. So, that was good! (Erin, Interview)*

> *We tried to do it (the case study) through different modes of learning and assessment. We used like a forum, kind of setting for our assessment where students would talk to each other, and they'd like exchange ideas. Specifically, always tried to use different methods of teaching, not just like direct instruction but also a collaborative group work, think pair share, stuff just different ways for students to augment their understanding. (Michael, Interview)*

On the relevance of case studies for differentiating instruction, TCs said:

> *The case study was the most relevant to me for differentiated instruction. The various ways to conduct research (KWL, Cornell framework, consequence map, etc.) are all useful tools that can benefit different learners and providing students with these resources can assist them in conducting research in ways that work for them. (Gabe, Post-survey)*

> *I believe the case study assignment was the most relevant to differentiate instruction. We did this through offering multiple ways for students to engage with the content and complete their assignments. (Roy, Post-survey)*

4.3.2.2 Digital Video Games (DVGs)

TCs explained how their DVGs were culturally relevant, and how their avatars were inclusive in nature. Moreover, they explained how the levels included in the game were suitable for addressing students' varying academic achievement levels. TCs said:

> *I had concepts outlined in different ways and had students use the visual stimulus from the pictures on the periodic table. But not just differentiated instruction, I also had diversity and equity through descriptions of elements in the periodic table. I had the related cultural backgrounds in there. (Roy, Interview)*

> *I incorporated like a more universal approach by giving students the options to like to choose their avatars, and she was like the gender of their avatar. (Erin, Interview)*

> *There are different settings for video game for different capabilities of students depending on where their levels were. (Michael, Interview)*

On the relevance of DVGs, Robert said:

> *DVG (was the most relevant to DI due to their) differing levels of difficulty. (Post-survey)*

4.3.2.3 Curriculum Resources Websites

TCs explained how they created new digital resources and amalgamated available materials, while taking DI into consideration. Their resources are multi-modal, reflect students' cultural diversity, cater for different academic and linguistic levels, and integrate technology effectively. TCs said:

> *I just included research from different countries, so we're not just focusing on North America, but we also talked about research focusing on Asia and also focusing on Europe. I also included resources where females are talking about their experiences in STEM or their experience in the field. For the lesson plans, students research about different cultures and countries in term of medicine, technology… I tried to reflect just not just the North American view. (Pam, Interview)*

For those resources, I just made sure like I had good lots of options to my students like I incorporated something called a RAFT project so students could choose the role and the audience, and the format, that kind of thing for all their assignments that they were submitting, And I also made sure that I was delivering the content in different ways. So, like I said before I was making sure I just had a PowerPoint but, in this case, I had different ways to show the learning through like live demos or incorporating technology like Ozobot. So, they had multiple ways to join the classroom learning. (Erin, Interview)

I did like a whole bunch of assessments that were differentiated, not just tests but also interesting assignments so fairly open ended that allowed students to showcase how they learned in a way that was comfortable for them, and also teaching in ways that weren't just the direct instruction with using videos and demonstrations and group activities. (Michael, Interview)

On the relevance of the STEM curriculum websites, TCs said:

The curriculum resource assignment was the most relevant. I made sure to include a variety of instructional modalities, teaching strategies, and active learning strategies in my lesson plans. I made sure to incorporate EDI into my lessons, accommodate for different learning styles, as well as providing visual support in lesson materials. (Holly, Post-survey)

For me, it is the curriculum resource website. Because it integrates all the DI through the whole package, that is, initiatives, motivations, lesson plans, activities and assessments. (Nellie, Post-survey)

Curriculum Resource Website- developing resources and lessons lends itself to differentiated instruction more easily than specific tasks. (Jim, Post-survey)

Curriculum resources website- accumulating a variety of resources that can be used to achieve different goals and support UDL/DI in the classroom. (Elizabeth, Post-survey)

Curriculum Resources Website- because we could create our own lesson plans incorporating differentiated instruction, there was more freedom than the other two projects. (Karen, Post-survey)

4.3.3 Challenges Faced by TCs: The Noted Progress

In the pre-survey, several themes emerged from TCs' responses on perceived challenges that may hinder their DI implementation. Out of 17 TCs, eight mentioned time needed for preparation; seven mentioned challenges related to resources; seven mentioned admin-related reasons such as support, funding, class size, and PD; five mentioned student factors such as engagement and interest or special needs; four TCs stated teacher knowledge or skills; three mentioned online teaching during the pandemic; and one mentioned curriculum mandates.

In the post-survey TCs reflected on the challenges they faced while trying to implement DI in their course assignments. Two main themes emerged as challenges from eight TCs' responses: 1) specific content knowledge or skills related to an assignment (mentioned by five TCs) and 2) unknown students in the case of course assignments or having too many differences to account for in one classroom (mentioned by four TCs). With respect to the specific content knowledge and specific task skills, TCs said:

Some topics lend themselves better to EDI principles whereas others are heavily rooted in science and minute processes (e.g., metabolic processes). (Meredith, Post-survey)

It was very difficult to differentiate instruction within the DVG assignment, as it required a lot of external knowledge on how to do this effectively. (Roy, Post-survey)

It was difficult in the DVG because we wanted to keep the game simple and still incorporate DI and EDI. (Karen, Post-survey)

Four TCs mentioned the challenge related to having too many differences to account for or in their case creating a course assignment for a hypothetical classroom where students are unknown. TCs said:

> *The challenge is to cater to everyone's individual needs. Yes, there are things we can do to differentiate learning that benefits all students, but there will always be some students left unaccounted for, no matter what. (Erin, Post-survey)*

> *Difficult when you are not making it for a known group of students. You are unsure what to highlight and focus on for EDI. (Angela, Post-survey)*

While the latter responses were written as a challenge, they actually represent a positive note. These statements reflect that TCs have shown appreciation and awareness of student differences, which is the core of DI principles. Finally, it is worth mentioning that in general the reported challenges are very specific in nature and are in contrast to those reported in the literature such as the lack of teachers' knowledge or skills in DI, low teacher motivation, and lack of resources. The reported challenges are not profound so as to impact TCs' implementation of DI.

Thus, when comparing TCs' pre-course survey reflections about the expected challenges to those in the post-course survey, the previously emerging themes related to resource availability and TCs' knowledge and skills implementing EDI strategies were not significant. The stated challenges at the end of the course revealed that resources and strategies provided in the course helped TCs surpass the perceived obstacle of preparing resources that reflect DI principles. This benefit is possibly due to the fact that TCs had gained practical experience creating such resources and advancing their pedagogical knowledge integrating DI strategies, which reiterates the effectiveness of the course in enhancing TCs' DI conceptions and self-efficacy toward DI.

4.4 TCs' Implementation of DI in their Practicum

To explore and assess TCs' knowledge and skill retention over time, I connected with the TCs two months after the course ended. Five TCs completed a written survey comprised of eight open-ended questions to detail if and how they implemented DI in their practicum and their reflections on the process. Additionally, interviews were conducted with six TCs, four of which had completed the survey. Their interview and post-practicum survey responses on DI implementation in the practicum were combined and analyzed according to the CPP-RIP framework.

4.4.1 How TCs Implemented DI in the Practicum

All six interviewed TCs implemented strategies related to process by using different grouping, modeling in mathematics, videos and online tools, simulations, online games, interactive tools (e.g., Gizmos, Mentimeter), labs, and hands-on activities. Three TCs mentioned strategies related to content differentiation by providing choices, assigning work at the reading levels of students, and varying the difficulty and depth of tasks. Only one TC mentioned implementing product differentiation by using different assessment options such as projects and tests.

Correspondingly, three TCs related their differentiation strategies to student learning profiles (cultural backgrounds, lived experiences, learning styles), two TCs related to student readiness (academic achievement levels), and two to student interest (respecting their choices).

Nellie's response was the most comprehensive one tackling all six aspects:

> *For the course projects of Grade 11 Math (3U) course, my associate teacher and I offered different projects based on individual interests. For instance, The Desmos project encourages students to combine algebra and function concepts with arts. The financial math project motivates students to dig deeper and think big. We also offer interdisciplinary applications like modelling the trends of COVID-19 and vaccine, so students can feel that Math is in and also comes from our daily life. Students have different learning styles. I run different groups like working individually, in pairs, small groups or relatively larger groups. There are high-ceiling students and also low-floor students. I assign different tasks and roles, so every student is engaged and able to contribute to their group work. Also, it's Math problems, but I try to get connections with Arts, music, and other subjects so students can get actively engaged. During the COVID-19, secondary schools run alternating weeks and periods, my*

associate teacher and I try to offer various options of course projects and cumulating tests. (Post-practicum survey and interview)

Nellie's response details how she differentiated the content, process, and product of her teaching in the practicum according to students' readiness levels, interests, and profiles. This proficient implementation indicates that she was able to retain the DI knowledge and skills and translate them to classroom practices.

4.4.2 Reflecting on Practicum Experiences

All six TCs reflected positively on their DI implementation successes. Four themes resulted from the analysis of these responses: enhancing student motivation and interest (four TCs), better achievement (four TCs), more collaboration due to enhanced group work (two TCs), and a welcoming and supportive environment (two TCs). In terms of motivation, TCs said it was linked to more student confidence in their ability to perform, better engagement in class activities, and willingness to learn. On achievement, TCs noted that different pacing and difficulty of tasks to different students helped them address their skills gaps. One TC stated that the process differentiation was helpful as it provided more resources to the students while another TC related it to group work. On the other hand, TCs said that product differentiation helped students understand the material better. For instance, Michael said:

Students are both more willing to learn and more successful in understanding when given the opportunity to showcase learning in various ways. Providing multiple options for students to learn (videos, notes) allowed students to learn at their own pace, which improved their understanding of the material. This also allowed the students to take notes when they saw fit, without fear that they would be unable to catch up if they missed something important. (Post-practicum survey)

On creating supportive environments, TCs said:

> *Students felt well supported, understood, and at ease. Students felt more confident, took more risks in the class, and engaged more. There was more participation, and collaboration. (Erin, Post-practicum survey)*
>
> *Students felt that teachers really care for them and hope for their success. (Nellie, Post-practicum survey)*

The above excerpts indicate that TCs witnessed in practice the documented positive student outcomes of DI. This observation confirms what they learned in the course and positively impacted their attitudes and views toward DI. The increased self-efficacy is an additional reason for TCs to implement DI in their future practices.

4.4.3 Transferring Course Assignments to the Practicum

Four out of the six TCs indicated that they used specific course assignments in their practicum, namely the curriculum resources website; two TCs used the case studies, and two TCs used the DVGs. For example, Nellie said in the post-practicum survey that she used the websites: "*I modified the lesson plans to suit my practicum in a timely manner. My associated teacher commented that I'm well prepared and think ahead*."

Pam detailed how her students created their own websites:

> *I think they really liked it so in the beginning again they complained because it was a lot of work, because idea of making website is like, why we have to make a website like that so much work like they would rather just write a test sometimes. But then as I started making it, they're like, oh yeah… My website is so cool like, yeah, like, come, come look at this channel, can you come look at this, look, this is so cool isn't it like how it looks and stuff.*
>
> *So, they were able to see they were able to make their own content and product. I think that motivated them to keep continuing and so they like that. (Post-practicum survey)*

Erin used both the case study and the DVG assignment on genetically modified organisms (GMOs), and recollected the experience below:

> *It was a GMO debate that I did with my students. I got a lot of really great feedback from my associate teacher that was a good activity, it was over the course of two days. I got to teach my students about the pros and cons or risks and benefits of GMO use and then they did independent learning. There were quite a few different activities where they were reading articles or there was a like an animation that they had to watch and it was interactive so that I got from the DVGs assignment, so I incorporated that, and collected feedback from students at the end who said it was a good learning experience. The Teacher and students both expressed that it was the best lesson ever. (Post-practicum survey)*

The above excerpts provide additional evidence that TCs found the course assignments to be helpful and effective resources in their teaching, in general, and DI specifically. This implementation also ensures that TCs are integrating tools that have been validated by the course instructor, which enhances the value of their teaching experiences and minimizes any anxiety that may be associated with first-time implementation of DI. Thus, TCs' ability to incorporate high-quality resources increased the chances of implementing DI in their classrooms and enriched their practicum experiences with DI.

Overall, TCs' implementation of DI in the practicum after the course ended reiterates the positive impact of the course on TCs' learning. This impact was evident through their understanding and PCK (Shulman, 1986) around DI. TCs reported being more familiar with various DI strategies and described how they used those strategies in their practicum – an indicator of potentially high levels of PCK and professional knowledge (Berry et al., 2009; Jameau & Boilevin, 2015; Shulman, 1986). Grangeat's (2015) categories of teacher professional knowledge in science education are also evident in TCs' practices especially the general pedagogical knowledge of assessment and instructional strategies; and topic and content specific pedagogical knowledge including multiple representations, awareness of students' understanding, and practices that motivate students and enhance their understanding. The course has shown the importance of PD in enhancing the professional knowledge, skills, and attitudes of teachers (Borko, 2004; Guskey, 2002). Furthermore, the retention aspect (Semb & Ellis, 1994) is also evident. TCs were not instructed to utilize any of the DI strategies they learned in the course. Yet, two months after the course ended, they reported implementing those strategies. This retention may be due to the consistent reflective practice they engaged in and the contextualization of DI principles in the course (Akerson et al., 2006).

4.4.4 Challenges Encountered in the Practicum

TCs also mentioned some challenges that hindered the implementation of DI in the practicum. A common response (five out of seven TCs) was teaching online as a result of the pandemic, which TCs found specifically challenging. TCs noted that online teaching and/or the hybrid learning model affected the duration and number of sessions to cover curriculum content, decreased students' access to the resources and devices to learn, decreased student motivation, and posed difficulty grouping students online. Three TCs mentioned student related challenges such as difficulty building positive rapport with students especially those battling anxiety or post-traumatic stress disorder, and those who have special needs; getting to know students; and increasing engagement with students who prefer to do less work rather than being involved in many class activities. Moreover, two TCs indicated that time to prepare DI lessons was somewhat challenging.

These challenges, especially time for planning and the vast diversity in the classroom are common in the literature on DI (e.g., de Jager, 2017; Kendrick-Weikle, 2015; Paone 2017; V. Park & Datnow, 2017; Robinson, 2017; Taylor, 2018; Turner & Solis 2017; Wan, 2017). On the other hand, the online teaching environment is relatively new for teachers and adds yet another layer to the challenges faced by teachers to differentiate their instruction. This finding is also reflected in a recent study of Ontario STEM teachers who expressed extreme difficulty in differentiating their instruction and accommodating various students' needs while teaching online during the COVID-19 pandemic (DeCoito & Estaiteyeh, 2022a). This challenge warrants further investigation in the future. Finally, it is important to note that none of the TCs mentioned challenges related to a lack in their personal knowledge and skills to differentiate instruction, which is in contrast to a common challenge reported in the literature that usually limits teachers' implementation of DI (e.g., Adlam, 2007; Wan, 2017). This finding that TCs felt confident and able to implement DI in their classes is significant and promising. Finally, it is worth noting that TCs do not have full autonomy in their practicum. While they are free to teach some lessons, they are still required to follow certain directions by the Associate Teachers. Hence, TCs may not have had opportunities to implement DI at its full potential.

4.5 TCs' Evaluation of the DI Focus in the Course

4.5.1 Course Effectiveness in Supporting DI Strategies

With respect to the specific course outcomes, Figure 13 highlights TCs' account of the effectiveness of the course. In the post-survey TCs indicated that they found the course helpful in terms of 1) providing them with extensive knowledge about DI (average agreement = 3.29 (SD=1.28)), 2) providing them with tools and resources to implement DI in their practicum and future classes (average agreement = 3.36 (SD=1.29)), 3) motivating them to implement DI (average agreement = 3.79 (SD=1.08)), and 4) enhancing their confidence implementing DI in the future (average agreement = 3.79 (SD=1.01)). Furthermore, the majority of TCs indicated that they made use of what they learned in the STEM course in other courses (average agreement = 3.92 (SD=0.92)) and that they will use the knowledge and skills learnt in the STEM course to implement DI in their future teaching (average agreement = 3.93 (SD=1.16)). The findings reiterate the positive correlation between teachers' perceptions, views, and understanding of DI from one perspective and its implementation from another (DiPirro, 2017; Hall, 2018; Suprayogi et al., 2017; Taylor, 2018). The literature documents that positive perceptions and clear understandings of DI are major predictors of its implementation. Additionally, the findings indicate that the STEM course offered a solution to one of the major challenges faced by teachers when it comes to implementing DI – finding adequate teaching resources (Goodnough, 2010; Tobin & Tippet, 2014). This challenge was also evident in the pre-survey, whereby 47% of TCs described the number of DI resources at their disposal as minimal and 53% as a fair amount, while none of them said they had no resources or resources in abundance.

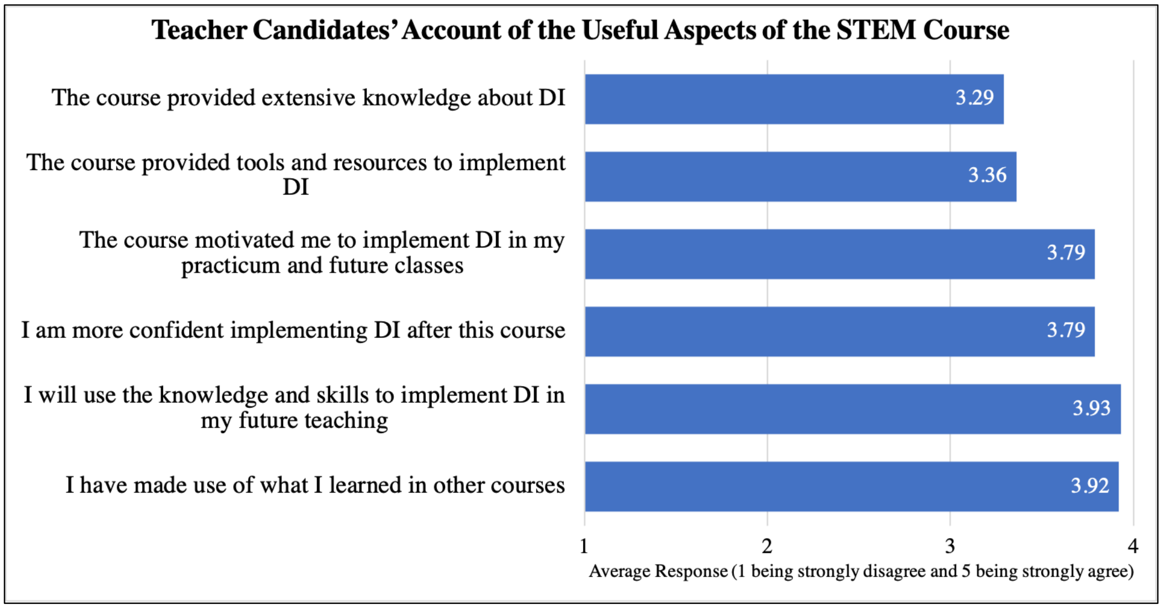


Figure 13: Post-Survey Responses on the Course Effectiveness in Supporting DI

All six interviewed TCs indicated that the course was beneficial in terms of their DI knowledge and provided detailed reasons. Four TCs said the STEM course provided beneficial materials and resources. They said:

> *I'd say terminology, resources, the presentation that (Name) gave definitely helped with starting on the differentiation of the course, as well as the material given to us, be that like readings and the actual assignments themselves, because some of them actually did again outline like things that we should do for differentiation right. So, I believe those are all very helpful and actually making sure we're able to do it successfully. (Roy, Interview)*

> *At the end of the day, we got a lot of resources, and I'm definitely going to use a lot of those in my teaching. (Erin, Interview)*

> *The knowledge and resources we obtained from this course are definitely beneficial. (Angela, Interview)*

Two TCs related their knowledge to being more mindful about EDI in their future careers. For example, Pam said:

Yes. I think it is valuable and I think it is important because knowing about EDI, it just makes you more aware of how to incorporate EDI into your teaching, and in your assessments and minor things that you can change, and just how you how you can just change little parts of something to make it more inclusive, or how. (Interview)

On a different note, Nellie described how her extensive knowledge about DI helped her stand out and impress the school principal in her job interview.

Correspondingly, all interviewed TCs maintained that the course was beneficial in terms of motivating them and increasing their confidence to implement DI. Two TCs said that the feedback provided to them was the most helpful in this aspect. They said:

So, my motivation and confidence I think that's where the feedback again came in a lot, because a lot of us going into the course together we didn't really get feedback on how good our differentiation was or where we could improve it, and knowing that we were either doing it right, or there are things we could do to do it better helped us, be confident that we're actually doing the work properly. And it helps us be confidently going forward in the future. I know if I implement it this way or two ways we talked about, I know I'm doing it correctly and I know like it's going to be successful. (Roy, Interview)

I definitely think this course and assignments have helped just because we've received feedback. So, because of the ongoing feedback, it does help with the motivation in terms of, am I doing it right? (Pam, Interview)

Two TCs said that the nature of the tasks enhanced their motivation and confidence. For example, Michael said:

> *In terms of the website, the things that I came up with… I hope to use some of it as a framework, and even the case study there's some interesting items that I think of. So, the work was useful and I'm glad I did it. (Interview)*

The results show that the course had a positive impact on TCs' knowledge and understanding of DI as well as their confidence and motivation to implement it. This finding reiterates that high intensity preparation results in more accurate visions of DI, willingness to differentiate, and resourceful implementation (Maeng & Bell, 2015; Pettig, 2000). The course addressed major challenges faced by pre-service and in-service teachers that hinder DI implementation such as knowledge of DI strategies (Adlam, 2007; Wan, 2017) and availability of resources (Goodnough, 2010; Tobin & Tippet, 2014). This approach resulted in high self-efficacy and a growth mindset toward DI as reflected in TCs' confidence, motivation, and willingness to differentiate in their other courses and future careers.

TCs reflected on the value and the benefit of each course component in preparing them to use DI (Figure 14). Specific course components recorded high ratings, including: learning community with peers (57% of TCs rated it as excellent and 43% as adequate), quality of resources provided (43% as excellent and 50% as adequate), the holistic teaching approach of the course (42% as excellent and 29% as adequate), case studies task (43% as excellent and 50% as adequate), digital game task (36% as excellent and 50% as adequate), and curriculum resources website creation task (43% as excellent and 43% as adequate). On the other hand, the specific presentation on DI was moderately rated (22% as excellent and 64% as adequate). This result shows that TCs appreciated the practical components more so in the course and reiterates the importance of establishing communities of practice with their colleagues (Wenger, 1998) in enhancing their DI understanding and implementation.

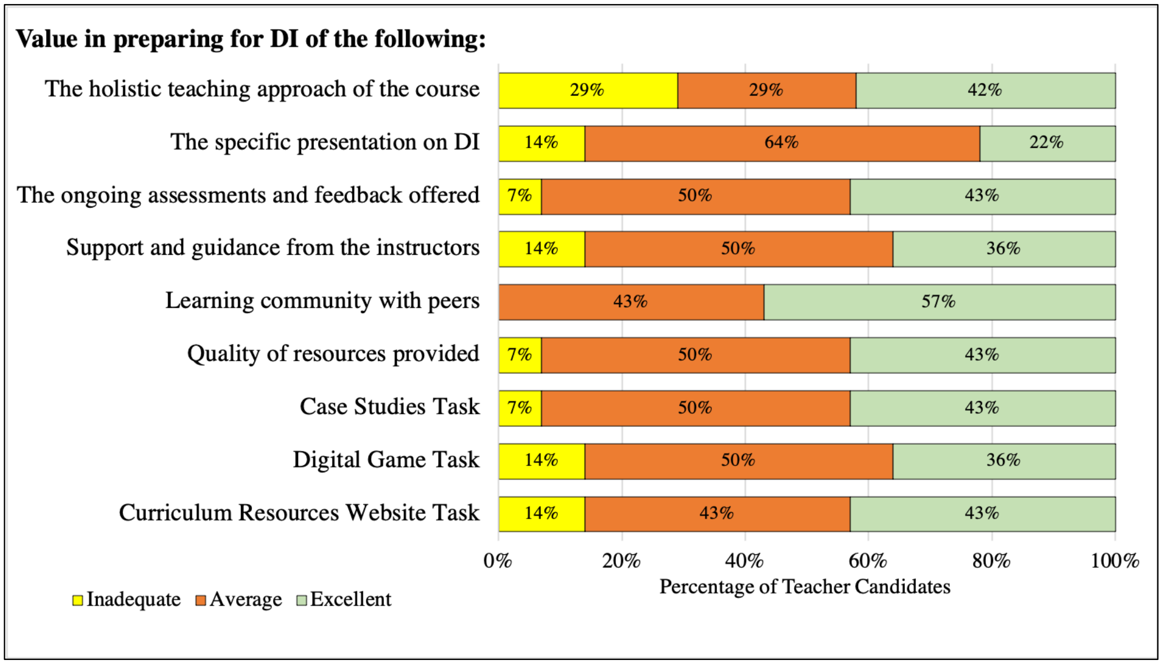


Figure 14: TCs' Post-Survey Responses on Effective Strategies in the Course (n=17)

4.5.2 Effective Strategies for Tackling DI

Based on TCs' post-survey and interview responses on the effectiveness of the course in enhancing their knowledge and implementation of DI, four themes emerged: 1) specificity and relevance; 2) course design; 3) feedback; and 4) collaboration between peers.

Four out of the six interviewed TCs said the course was more specific with its techniques, strategies, and resources than other opportunities. The tasks were specific to high school classes and STEM subjects. This contextualization made the course content and resources more relevant to their practice. TCs said:

> *This course is first of all, more specific. We were also digging deeper. So first, we have research papers, is going to talk about why DI and how it can really benefit. And how DI can boost student learning in STEM education in particular at school level. (Nellie, Interview)*

I would say the biggest difference was in the assignments you actually did it instead of just saying include EDI or include differentiated instruction of is like more specific on the criteria… The course was really good. It was actually one of the best courses to learn from… (Roy, Interview)

This course offered many great ideas and techniques of DI, that I have since then implemented in my classes. (Angela, Interview)

Three TCs said the course was well designed in a way that course tasks were application-based and that the consistent and constant inclusion of the criteria in the assessments kept TCs aware and mindful of including DI practices in their assignments. This finding relates to the importance of the adopted explicit and reflective approach in training TCs about DI. For example, Pam said:

I feel for this course, it was a lot of doing things. So, a lot of making things. So, we had to make a website we had to make a video game, etc. so it's not like we ourselves are learning about active learning strategies or pedagogic on how to teach students, but I feel like we're learning how to use resources, and that sense we can implement it in our own teaching... So, I actually implemented that in my practicum... One of the requirements for our assessments was explaining how we included equity, diversity and inclusion, because we kept focusing on that. It was just something that was more ingrained in my head, and then I thought about more. (Interview)

One TC (Roy) stated that the feedback provided in this course was crucial to their success exploring DI proficiently as it helped him improve his practice with time. He noted:

When (Name) came and looked at our stuff, like actually conversations about where we could improve it where we can implement it. That wasn't really given in the other courses nor was there too much feedback… I think that was really good this course… The feedback. (Interview)

Finally, one TC (Michael) emphasized the importance of collaboration among peers in forming a community of practice that helped them learn better. He said:

> *I think in this course, something I valued the most was the collaboration aspect because we got to work with our peers, a lot. All of the projects that we worked on and assignments. We got to learn from each other so that was most helpful. (Interview)*

As a follow-up question in the interview, TCs were asked if they would have approached DI in the same manner if the course had not included DI as a topic and as a requirement in the assessment criteria of the assignments. Four out of five TCs said that the course actually encouraged them to integrate DI to a greater extent, compared to what they would have done if it were not a requirement. Only one TC said that their work would not have changed. TCs said:

> *I would not say that I wouldn't include it, but it would not have been as extensive… The case study in particular, I know we only added the section on different approaches to the debate so like the videos or the written component after getting feedback from (Name), otherwise we would have probably just stuck with the verbal one and not had that differentiation in there. (Roy, Interview)*

> *I don't think I would have done the same just because it's something that was so ingrained in our heads in this course. That's why I was mindful and aware of it, but I feel like if it was not part of the rubric, and it was not mentioned in the course is not something that would just come to my mind on my own. And so, I think it's good that it was implemented to be mandatory in the course because now that we've kept doing it for like three assessments already. Now it's something that I that I'm more familiar with. (Pam, Interview)*

> *I think having those mandates made me like produce better work so if those weren't there like maybe I would not have paid as close attention to DI and equity and inclusion and all that, so I think having those there was a good motivating factor. (Erin, Interview)*

Therefore, the adopted explicit reflective approach, the consistent rounds of discussion and feedback about TCs' understandings and implementation of DI in their tasks, and the course tasks requiring that DI be included in the assignments all influenced TCs' choices. This finding calls for adopting a similar approach in other courses in the teacher education program and for in-service teachers' training to ensure that DI principles and strategies are deeply rooted in teachers' practices. The adopted approach reiterates the importance of scaffolding DI principles and practices until TCs reach an adequate level of mastery of those skills (Vygotsky, 1978). Furthermore, the strategies based on communities of practice (Wenger, 1998) as well as professional learning communities (Shulman & Shulman, 2004) have proven to be of great benefit to TCs. TCs were engaging in discussions and peer feedback for extended periods of time. They also shared their course work and other resources with their peers. In these discussions, TCs were able to explore exemplary work created by their colleagues, ask them questions, and get innovative ideas to enrich their own work in areas that need improvement. These interactions empowered TCs and helped enhance their self-efficacy and understanding of DI, which is aligned with findings on the importance of collaborative strategies in growing teachers' professional knowledge (Goodnough, 2010; Grangeat, 2015; Puvirajah et al., 2012).

All of the above are practices reflect socio-cultural approaches to learning in which social interactions play the most important role (Rogoff, 1998; Vygotsky, 1978). The positive impact of the adopted approach in this course is aligned with the findings that high intensity preparation results in encouraging teachers to willingly differentiate instruction (Maeng & Bell, 2015; Pettig, 2000). It also provides further evidence to Dack's (2018) recommendation related to designing the learning experiences strategically in teacher education courses to attain robust implementation and deep understanding of DI principles. This finding aligns with Massouti's (2019) recommendation calling for coherence among teacher education programs' curriculum, key assignments, course contents, and organizational structure in order to ensure effective implementation of EDI practices in schools.

4.6 Long-Term Goals for DI

4.6.1 TCs' Teaching Philosophies

TCs reflected in the post-survey on the impact of the course on their teaching philosophy in terms of EDI principles as foundations of DI. TCs' responses reiterated the positive impacts of the course whereby seven out of 11 TCs said that the course positively impacted their teaching philosophy, and four TCs said they already had EDI in their teaching philosophy and kept it. TCs said:

> *It has impacted my teaching both explicitly and implicitly for every teaching aspect, for instance, planning, designing, teaching and assessing. (Nellie, Post-survey)*

> *My teaching philosophy is that all children can learn, I should have high expectations of my students, and if I show students that I believe in them, they will start to believe in themselves. This course taught me the importance of differentiating instructions and incorporating EDI into my practices, which help me to create a more inclusive, supportive, and safe environment where all children are ready to learn and have equitable resources and supports for them to achieve success and become their best selves. (Holly, Post-survey)*

> *This course increased my thought process of equity and diversity though the inclusion of EDI in our course assignments. (Roy, Post-survey)*

Coubergs et al. (2017) have specifically linked teachers' growth mindset and teaching philosophy with more effective DI implementation. TCs' inclusion of DI principles in their teaching philosophies is highly related to their high self-efficacy (Bandura, 1995) as well as their growth mindset (Dweck, 1999) toward DI. Combined with TCs' positive views toward DI and deeper understanding of DI in relation to EDI principles, findings related to TCs' teaching philosophies suggest the occurrence of conceptual change (Fulmer, 2013). These observations confirm the positive impact of the course on TCs' perception of DI as an inclusive teaching philosophy, rather than an array of teaching strategies.

4.6.2 TCs' Future Career Intentions

Future career intentions are also an indicator to explore TCs' views about DI, and to ensure that they would implement it in the future. TCs were asked how they plan to differentiate their instruction in their future practices. Four TCs gave examples of how they would differentiate the process, and two TCs gave examples of how they would differentiate the product. When asked if they would utilize any of the course assignments in their future practice, all interviewed teachers said yes. Three TCs said they would adopt and adapt what they have done in the course. For example, they said:

> *I think it's (DI is) going to be a main part of my planning. From now, in my lesson plans I'm going to include a section of DI and inclusion and make sure I address that for every lesson. (Erin, Interview)*

> *I can't really say exactly what it is I'm going to make sure it has to be specific to the student, so I have to have conversation with the students themselves, see what it is that they need to succeed… just making sure it's personal. (Roy, Interview)*

These responses are promising as they indicate TCs' willingness to implement DI in their future classes. TCs' responses also reflect their deep understanding of DI as a practice that is based on students' needs and characteristics. As such, aligning pedagogies and assessments to match students' needs require a good knowledge of the students in the first place. These intentions are of particular importance as Sharma et al. (2021) indicate that teaching efficacy is the strongest predictor of teachers' intentions to embrace inclusive practices. Thus, TCs' intentions to utilize DI strategies in their future practice add to the evidence of their heightened self-efficacy (Bandura, 1995) and growth mindset (Dweck, 1999), and the effectiveness of the course.

4.6.3 Prospective Future Challenges

In relation to the future career implementation of DI, six interviewed TCs anticipated a few challenges. The challenges included time needed for preparation (three TCs); student factors such as engagement (three TCs); availability of resources (two TCs); support by the administration (one TC); and curriculum mandates and the fact that teaching utilizing DI would be very different from what students will encounter in the university (one TC). For instance, Michael said:

> *I have no problem creating things from scratch, but obviously it's a lot easier. And like, that's how I've taught… I've lots of things that I can use but it's just a matter of if you have the support of the school, and it makes a lot easier to do that work. But, I mean, I'm not worried about it I have a fairly strong idea of what I want to do. (Interview)*

Michael's words and the focus on administrative-related challenges implementing DI reiterates the aforementioned importance of administrative support and institutional accountability to ensure effective implementation of EDI practices in schools (Rezai-Rashti et al., 2017). Pedagogical practices by teachers in a classroom will not be as effective if there is a disconnect with school culture and if the administrative supports are not in place.

4.7 Chapter Summary

This chapter explored the efficacy of the STEM course, supplemented with DI-focused strategies and resources, in enhancing TCs' views, understandings, and implementation of DI. Findings suggest that the course resulted in a notable improvement in TCs' DI views and a deeper understanding of EDI principles and strategies. TCs also implemented those practices in their practicum after the course ended, indicating retention of the acquired knowledge and skills. The chapter also presented elements of the course that TCs considered most valuable in terms of their preparation, such as participating in communities of practice, feedback they received, and contextualized practical application of EDI-related principles learnt. Findings reiterate the importance of opportunities aimed at enhancing teachers' preparation to integrate DI in their practices.

Chapter 5

5 Findings: Curriculum Development, DI, and Case Studies

TCs' were tasked with curriculum development in the form of case studies on socio-scientific issues (SSI). In groups of four, TCs designed a case study, assuming dual roles of teachers and students. A total of seven case studies were created by consenting TCs and comprised the data set analyzed. The data set included 18 lesson plans, 18 written reflections, and supplementary teaching and assessment resources (described earlier in Section 3.3.1). This chapter presents the analysis of these curricula and artefacts. By doing so, this chapter answers the following RQs:

RQ2a. How do TCs develop curricula to be inclusive of DI strategies?

RQ2b. What successes and challenges do TCs encounter when developing DI-focused curricula?

5.1 Background

5.1.1 Socio-Scientific Issues

Socio-scientific issues (SSI) are science issues that have a significant effect on society (e.g., nuclear energy, biotechnology, human genetics, global warming) (Sibiç & Topçu, 2020). SSI involve societal dilemmas with conceptual, procedural, or technological links to science (Sadler & Zeidler, 2004). SSI acknowledge the contextual setting in which science is embedded, hence, they can provide a rich medium for argumentation due to their societal, political, and ethical implications (Hancock et al., 2019; Nielsen, 2012). Since these topics are debatable, Ekborg et al. (2009) maintain that students can take multiple positions since there are no right answers. In harmony, Levinson (2006) argues that teaching SSI requires a strong theoretical and conceptual basis and presents a model for teaching these topics. Levison's model includes three categories: 1) reasonable disagreement which includes evidence-based discussions and high level of critical thinking; 2) communicative virtues that include tolerance, respecting differences, thoughtful listening, equality, and freedom of expression among many other elements;

and 3) modes of thought that include narrative modes and logico-scientific modes based on scientific evidence. These assertions provide a strong rationale for using SSI as vehicles to capitalize on class diversity and differentiate instruction.

Sibic and Topcu (2020) propose that the integration of SSI requires advanced classroom management skills that teachers lack, as well as a lot of planning and preparation to educate themselves about these topics. In their study of preservice science teachers views of SSI, findings indicated that although teachers understood the role of SSI-based instruction in motivating students and demonstrating application in real life, preservice teachers generally did not have enough self-efficacy beliefs to integrate SSI into their curriculum. Thus, including these topics in teacher education programs is crucial in preparing STEM/science teachers to incorporate them in their future practices. Hancock et al. (2019) maintain that several factors affect teachers' choice of SSI such as their passion and existing resources. To the latter point, Hughes (2000) indicates that SSI material is marginalized through the structures and language of syllabus texts and through classroom practices in the UK, and that teachers fear extensive coverage of SSI. Hughes (2000) recommends the integration of science–technology–society (STS) topics in science curricula and teaching practices, as they promote students' socioscientific awareness of the social, political, and economic dimensions to science and render science more accessible to females and disadvantaged ethnic and class groups.

Acknowledging the importance of these topics, the Ontario science curriculum places science, technology, society, and environment (STSE) objectives at the forefront of the specific expectations in all science and technology curriculum. Pedretti and Bellomo (2013) maintain that one of the effective ways to support teachers in teaching about these topics is through professional learning communities in which teachers explore and share new ideas and practices. Pedretti and Nazir (2011) propose six currents as didactic tools to inform science educators' theoretical understandings, choices, and practices in STSE education. These include: 1) application and designing new technology with an emphasis on inquiry to solve problems; 2) understanding of the historical and sociocultural embeddedness of science; 3) logical reasoning and decision making about SSI based on empirical evidence; 4) value-centered decision making through consideration of ethics and moral reasoning; 5) sociocultural understanding of science and technology; and 6) socio-ecojustice critiquing through human agency or action. These arguments provide more alignment between SSI, STSE, and the philosophy behind DI, reinforcing their compatibility in practice.

5.1.2 Case Studies

Cases are rich and contextualized narrative accounts of teaching and learning (Levin, 1995). A case study is a description of an actual situation that usually involves a decision, a challenge, an opportunity, a problem, or an issue faced by a person or an organization (Leenders et al., 2001). The practice of using cases as a pedagogical tool is widespread in several fields such as law, business, medicine, and education. Case studies are used in a flexible manner that involves learning by doing, and hence engages students more than lectures. The aim of using case studies is not only teaching science content, but also teaching how the process of science works while developing higher order thinking skills, collaborative work, communication skills, and decision making (Herreid, 1994). Furthermore, Popil (2011) maintains the importance of using case studies in promoting active learning and developing critical thinking skills. Ching (2014) adds that case studies are recommended as one way to link theory to practice by helping students apply and integrate knowledge, skills, theories, and experience in real-life scenarios. Additionally, case studies allow learners to experience first-hand how learning in classrooms is impacted by social and political currents (Herreid, 1994). For instance, case studies can be used to debate about the nature of science topics (Herreid, 1994; McComas, 2020), and to teach about the history and philosophy of science (HPS) (Höttecke & Riess, 2009; Stinner et al., 2003). Höttecke and Riess (2009) note the importance of teaching about HPS via case studies as they include student perspectives as well as creative, open-ended, and student-centered activities like experimenting, making observations, discussing, and role-playing. Thus, when linked to SSI, case studies prove to be effective in science teaching (DeCoito & Fazio, 2017).

Important considerations when using case studies as a teaching approach include: 1) contextualizing the case in real-life scenarios to make it memorable for students (Ching, 2014); 2) promoting peer interaction to internalize cognitive processes and gain new perspectives (Levin, 1995); and 3) facilitating and supporting to scaffold the process by providing feedback and guidance (DeCoito & Fazio, 2017). Sudzina (1999) summarizes the main features of case studies, including: 1) cases are based on real life scenarios; 2) they provide supporting data and documents for analysis; 3) present an open-ended question or problem for possible solution; 4) they are most commonly worked on in groups; and 5) can be presented in different forms, ranging from simple situations to complex scenarios.

The effective use of case studies in teacher education has been documented (e.g., Ching, 2014; Levin, 1995). Ching (2014) maintains that case studies are an important pedagogy in the training of preservice teachers as it promotes critical thinking, decision making, and motivation. Levin (1995) compares the utilization of case studies as a teaching approach between experienced and novel teachers and noted that that reading, writing, and discussing cases affects teachers' thinking about the case. Levin (1995) highlights the importance of discussing case studies in promoting experienced teachers' reflection and metacognition, and novel teachers' thinking about particular issues in the case. Accordingly, this study of STEM TCs highlights the particular importance of teachers' social interaction through discussions when they are involved in training related to case studies around SSI. Furthermore, DeCoito and Fazio (2017) maintain the importance of TCs designing and enacting case studies while they assume dual roles of curriculum developers and co-constructors of knowledge. DeCoito and Fazio (2017) noted the suitability of case studies as a pedagogical tool to address SSI in science education, and the fact that they can support TCs to incorporate new strategies for teaching and motivating students.

5.1.3 Using DI in Case Studies on SSI

Based on the afore-presented literature, the integration of SSI and STSE topics in science curricula is crucial for promoting students' socioscientific awareness of the social, political, and economic dimensions to science and situating science as accessible to various underprivileged groups (Hancock et al., 2019; Hughes, 2000; Pedretti & Nazir, 2011). From a pedagogical stance, case studies allow for multiple levels of analysis and interpretation (Levin, 1995). Case studies present various perspectives of different stakeholders, which is one of the main reasons they are adequate strategies to teach about SSI and STSE topics (DeCoito & Fazio, 2017). There are many benefits of DI, including enhancing students' appreciation, recognition, acceptance, understanding, and respect for individual differences among each other (Watts-Taffe et al., 2012). These benefits are relevant to the use of case studies as a teaching strategy, rendering them appropriate for differentiating instruction. In addition, these benefits provide a strong rationale for using case studies on SSI topics as vehicles to highlight diversity and differentiate instruction. The following sections present TCs' development of STEM/science curriculum using case studies on SSI topics, with a focus on DI as a teaching approach.

5.2 Groups' Performance: A General Analysis

Table 4 describes the case studies created by TCs, including a brief and general analysis listing the major positive points and missing elements, as well as the total score obtained on the DI Matrix.

Table 4: Case Studies' Details and Brief Analysis

Case Study Title	Class and Subject	Case Summary	Brief Analysis
Health and Medicine			
Case Study A: COVID-19 and the Vaccine Race	Grade 12: Science	Explore the implications of producing and distributing a COVID-19 vaccine in Canada from the perspectives of four key stakeholders: pharmaceutical companies (for), medical ethics advisory board (against), parents (against), and public health officials (for).	• The case study scored 59 out of 80 on the DI matrix. • TCs did well on integrating multimodalities in their teaching and using flexible grouping. TCs also related their topic to EDI principles by including equity issues in relation to vaccine distribution, as well as Indigenous ways of knowledge when discussing Western science. • On the other hand, the case study did not scaffold learning for struggling learners or challenge advanced students. More variety in assessment strategies and clarity about assessment criteria are also recommended. Thus, differentiating the content and the product in this case study needs improvement.
Space Science			
Case Study B: Starlink	Grade 9: Earth & Space Science	The pro-Starlink and anti-Starlink groups assemble and plan out a case for debate. The stakeholders are: SpaceX (satellite manufacturer), consumers (rural and under-serviced communities), professional astronomers, and space explorers.	• The case study scored 58 out of 80 on the DI matrix. • TCs did well on their lessons' organization and aligning objectives with instructional activities. They incorporated rubrics in their assessment. Moreover, they encouraged collaboration and respectful behavior among students. • On the other hand, the case study did not highlight topics related to EDI principles. Their differentiation strategies in content, process, and product aspects were limited.

Environment			
Case Study C: Water Crisis in Canadian Indigenous Communities	Grade 10: Science	The decision of whether or not to upgrade the existing water treatment facility in Grassy Narrows First Nation Community is decided after a debate between various stakeholders at a town hall. The stakeholders are: government, environmentalists, utility companies, and the Indigenous community.	• The case study scored 65 out of 80 on the DI matrix. • TCs did well on diagnostic assessment of their students at the beginning of the case; varying the modes and strategies of teaching; using flexible grouping; proficiently integrating technology in their teaching; and using formative assessment. Moreover, the chosen topic relates to equity practices in Indigenous communities. This content would catalyze many discussions on topics related to EDI principles. • The case study did not scaffold learning for struggling learners or challenge advanced students. Furthermore, the case study could have been more consistent in implementing the aforementioned positive strategies throughout all lessons.
Case Study D: Microplastics	Grade 11: Biology	The costs and benefits of plastic use are investigated, based on perspectives of four stakeholders: plastic manufacturer, consumers of plastics, scientific researchers, and ocean protection groups.	• The case study scored 70 out of 80 on the DI matrix. • TCs did well on diagnostic assessment of their students; varying the modes and strategies of teaching; using flexible grouping; and using formative assessment. • TCs did not scaffold learning for struggling learners or challenge advanced students. Furthermore, EDI principles were not consistently incorporated in all lessons.
Case Study E: Light Pollution – The Effects of Artificial Light Use	Grade 10: Science	The case explored the social-scientific issue relating to artificial light use and the effects of light pollution, from a variety of stakeholder perspectives, taking on a social, economic, and environmental views.	• The case study scored 74 out of 80 on the DI matrix. • TCs effectively addressed all three aspects of DI: content, process, and product. • The case study could be improved by enhancing technology integration and being more consistent in challenging advanced learners and scaffolding learning.

Case Study F: Three Gorges Dam	Grade 9: Science	Discuss the implications of the Three Gorges Dam. The stakeholders are: The Chinese government, dam builders/hydro power companies, farmers forced to relocate, and environmentalists	• The case study scored 76 out of 80 on the DI matrix. • TCs effectively differentiated all the aspects in their lessons. • TCs can better align the objectives with the instructional activities, and challenge advanced learners.
Case Study G: Societal Impacts of Nuclear Energy – Building a Nuclear Power Plant	Grade 11; Physics	Decide on whether constructing a nuclear power plant in Innergee, a little-known Ontario town, would impact on the community. The town hall involves speakers representing major stakeholders in this decision: the government, environmentalists, engineers and the general public.	• The case study scored 66 out of 80 on the DI matrix. • TCs addressed differentiating the process of the lessons by using a variety of engaging activities. • TCs neglected to clarify the objectives, differentiate the content, ensure more student agency, and provide clarity on assessment criteria and rubrics.

5.3 A Detailed Analysis of Case Studies

As noted in Chapter 3, seven case studies were analyzed according to the DI matrix and included accompanying lesson plans, presentation, supporting documents and resources. Each domain in the DI matrix is composed of several criteria. A score out of 4 was given to each case study in each of the criteria, where (1) indicates “Novice”, (2) indicates “Apprentice”, (3) indicates “Practitioner”, and (4) indicates “Expert”. This section details how TCs addressed each of the criteria in the DI matrix, with a focus on best practices. This analysis will highlight if and how TCs implemented DI components, and to what extent.

5.3.1 Domain 1 – Quality Curriculum and Lesson Design

This domain entails two criteria: 1) Quality and clarity of the lesson objectives and 2) Alignment of lesson objectives and lesson activities. The first criterion includes what students should know, understand, and be able to do. To attain the expert level, the case studies’ lesson objectives should comply with the written curriculum standards (Ontario Ministry of Education, 2008), and the important ideas, issues, or problems specific and meaningful to the content area. The objectives need to extend learning in authentic ways. TCs showed excellent implementation of this criterion with three case studies reflecting scores at an expert level and four case studies at a practitioner level. With respect to the second criterion, the activities of the lessons within the case study need to be clearly linked to the objectives. TCs also showed excellent implementation of this criterion with four case studies showing an expert level and three case studies showing a practitioner level.

In general, TCs showed a mastery of this domain. Most TCs were able to address the case study-related skills as well as the learning goals and science content objectives. For many case studies, the four required lessons provided opportunities to address many objectives, hence offering rich science content. Yet, few TCs focused more on the case study requirements such as note-taking, KWL charts, consequence maps, and cost-benefit analysis, rather than the science content. Most TCs were able to smoothly integrate the case study components within the lessons, and thereby use the case study as a tool to teach the science content.

5.3.2 Domain 2 – Response to Learner Needs

This domain entails three criteria: 1) preassessment and proactive preparation, 2) scaffolding for struggling learners, and 3) challenging advanced students.

First, to attain the expert level on the preassessment criterion, the case study should reflect multiple sources of preassessment data and student learning profiles in advance of the lesson to address and plan for student needs. In general, TCs showed a good level of implementation of this criterion with three case studies scoring at an expert level, three case studies at a practitioner level, and one case study at an apprenticeship level. For example, TCs frequently used pre-assessment and proactive assessment within formative assessment. They included brainstorming activities and referred to students' prior knowledge in their lesson plans, which demonstrates awareness of the importance of tackling students' prior knowledge and misconceptions through diagnostic assessments before introducing new concepts. On the other hand, some groups relied on graphic organizers (e.g., KWL charts) to explore students' prior knowledge. One group did not include a diagnostic assessment. Several groups did not show consistency in tackling students' prior knowledge throughout the whole case study and included this aspect in only one or two lessons. Samples of diagnostic assessment include the following statements:

> *Find out what students know about clean drinking water in First Nations communities. Find out why a boil water advisory would be in effect. (Group C)*

> *Introduce topic of researching online, guiding discussion by asking students via discussion or via poll-everywhere: (1) their level of experience with online research, (2) how they feel about online research, (3) how can they tell if something they are reading/looking at is from a good source? (Group C)*

To recap information from the preceding day's class, a "mind-on" activity must ensure the students understand earlier concepts before moving on to the next topic. (Group D)

Reflect on the previous lesson as a class. Given events like Chernobyl, is nuclear still an appropriate energy source? Why/ why not? [Get students thinking about the case study] (Group G)

The second criterion is scaffolding, specifically for struggling learners. To attain the expert level on this criterion, the case study must be inclusive, for example for special education students, English language learners (ELLs), and students with low reading abilities. Struggling learners need to engage with high-quality tasks, with appropriate scaffolding to attain the same learning goals as other students. In certain cases, individual educational plans (IEPs) need to be provided to certain students. Multiple indicators are used when grouping students so that struggling learners experience a variety of grouping strategies. Four case studies scored at an apprenticeship level, two at a practitioner level, and one at an expert level. The majority of case studies did not indicate any special arrangements in this regard. This criterion was superficially addressed through flexible grouping and the use of multimodalities. For example, one group included:

Students are given the opportunity to read the case study on their own or have a PDF read out loud with their Chromebooks. This helps accommodate ELL students, who may have a difficult time with written material. The teacher can also provide students with the option to use a translator extension if they require one to read the case study. (Group F)

One group also included a voice-over option along with the provided text to students, demonstrating more inclusivity to specific groups of students with special needs. Yet, TCs demonstrated a lack of awareness and consistency in addressing various student needs. Several groups referred to ELLs in their lesson plans which reflects an accepted level of awareness. Yet, there were no practical strategies planned to cater for their needs. An example of an incomplete adaptation is:

"Ask students with IEPs and ELLs how they find the lesson if they feel they need to go to resource or would like additional materials." (Group D)

In general, this criterion requires improvement. For example, none of the groups mentioned modifying the pace of learning for different groups of students or modifying the learning objectives at certain learning stages. Moreover, the adaptations were inconsistent throughout the same case study and thereby needing much reinforcement.

Finally, the third criterion is challenging advanced students. To attain the expert level on this criterion, the case study must challenge high-achieving students at higher levels of complexity and quality, not quantity. Five case studies reflected scores at an apprenticeship level, two at a practitioner level, and none of the case studies scored at an expert level. The average score on this criterion was the lowest among all 20 criteria indicating that the majority of case studies did not include special arrangements for challenging advanced students. Furthermore, most case studies did not mention this group of students. The arrangements included flexible grouping and independent research by students to reach a more in-depth understanding, yet worksheets, rubrics, and class activities did not address this category of students explicitly. While certain tasks enable students to work independently, and others require critical thinking, high achievers in general were not provided with multiple options to expand their knowledge. Thus, this is one criterion that needs to be further developed in the future.

5.3.3 Domain 3 – Planned Instructional Practices

This domain entails seven criteria: 1) lesson organization; 2) modes and strategies of instruction; 3) engagement capacity of activities; 4) student intellectual development; 5) flexible grouping; 6) teacher's planned role, learner's independence, and student's choice; and 7) technology integration.

For the first criterion – lesson organization – in order to attain the expert level, the case study lessons and elements need to be organized in a coherent (organized, unified, and sensible) manner, producing a unified whole. TCs showed an excellent implementation of this criterion with six case studies scored at an expert level and one at a practitioner level.

In all case studies lesson plans were clear and comprehensive, well-organized and easy to follow. As well, all lessons and activities were linked and connected appropriately. Figure 15 shows how one group organized and presented their lessons.

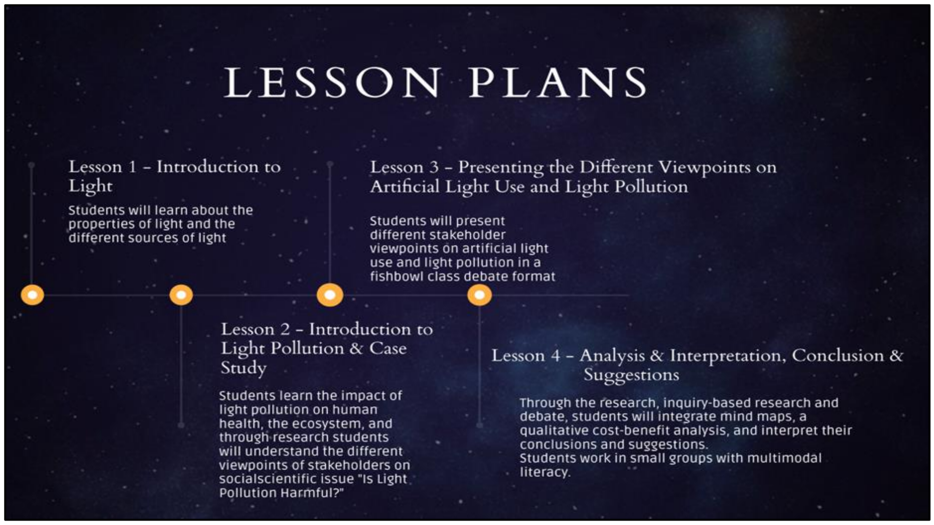


Figure 15: Lesson Organization Details of Group E – Light Pollution

For the second criterion – modes and strategies of instruction – in order to attain the expert level, the case study lessons and elements should utilize multiple modes of instruction that require active learning and exploration of student understandings. The lessons should intentionally match the learning profiles and the learning needs of students. As well, the strategies and activities should reflect best practices in that content area. TCs showed very good implementation of this criterion, with four case studies scoring an expert level and three at a practitioner level. For example, Group C used think-pair-share, map visualization and analysis activity, video and picture analysis, note-taking activities, class discussions, online game activity, independent and group research, and a debate throughout their four lessons. Activities of Group B included videos, jigsaw, hands-on activities, drawing graffiti activity, class discussions, and group activities. Group D included labs, Kahoot activities, table group discussions, infographic analysis, debates, article analysis, and hands-on activities such as extracting microbeads. Thus, there was an evident utilization of multimodalities especially digital resources, a variety of student-centered activities, and inquiry-based instruction by all groups. An excerpt from one of the case studies states:

> *Throughout the lesson, students will get opportunities to participate in technological activities. They can take notes on their Chromebook or use pen and paper. There will be a Think-Pair-Share. Dams will be explained orally, through pictures and a video (multimodal). (Group F)*

On the other hand, two main points of improvement are consistency in integrating multiple tools throughout all lessons and avoiding long phases of direct instruction. One possible reason for prolonged direct instruction is the variety of new case study elements which TCs chose to introduce through teacher explanation.

For the third criterion – engagement capacity of activities – in order to attain the expert level, the case study lessons and elements should be stimulating, motivating, and engaging to learners; link to students' prior learning or experiences; and clearly connect to their lives and/or goals. Students should be able to explicate connections between lesson content, practical applications, current events, the real world, or other aspects of the content area. TCs demonstrated very good implementation of this criterion with four case studies scoring at an expert level and three at a practitioner level. The variety of activities presented in the case studies ensured high levels of student engagement. For example, lessons included hands-on activities, roleplay, demonstrations, digital games, online simulations, videos, mind maps, note-taking activities, infographics, group work, class discussions, think-pair-share, student independent research, debates, and jigsaw activities. Furthermore, the topics tackled by the seven case studies and the questions raised are highly linked to students' daily lives and real-world implications.

For the fourth criterion – student intellectual development – in order to attain the expert level, the case studies should enable each student to work at levels of readiness, interest, and/or learning profile that are appropriately challenging. The lessons should be designed so that all students are encouraged to do their best and complete high-quality work. The strategies and activities should promote higher order thinking for all students. TCs demonstrated very good implementation of this criterion, with three case studies scoring at an expert level and four at a practitioner level. Three major factors contributed to TCs achieving this level. The first factor is the inclusion of a variety of activities and case study components requiring students to engage different levels of thinking in each activity. Some activities require advanced levels of high order thinking skills such as critical thinking and evaluation. For example, Group C planned the following activities:

> *"Break the fake activity": Students will learn about criteria to assess online resources to determine the validity and reliability of the information. They will learn about two different methods of note taking while researching to help keep the information they find organized. Then they will have time to independently research and complete notes based on the case study and their stakeholder perspective.*
>
> *"Cost-Benefit Analysis": Ensure that students are using valid reasoning to create their cost and benefit values on a scale from 1 to 5 and the probability of the result occurring. Where possible, they should include references for the sources of their information.*

The second factor contributing to implementation of this criterion is the 5E inquiry model, which requires students to explore content. Finally, the third factor is engagement in discussions and debates about a controversial topic from various opposing perspectives and viewpoints, thus requiring students to be prepared with different arguments that enhance their analytical and critical thinking skills. This argumentation also extends students' personal knowledge to a new context. For example, Group F stated:

> *The teacher should encourage students to consider opposing arguments in preparation for the debate during the research period (lesson 3). One way to do this is with a consequence map. If the claimant will open with, for example, a positive economic consequence for the Three Gorges Dam, a member of the opposition can use a negative economic consequence as part of their rebuttal.*

Furthermore, student readiness is reflected in the depth of information they research and present to their peers, with higher performing students presenting deeper understandings of the subject matter. Also, students' interests were addressed by most groups who allowed students to choose the stakeholders they want to represent, take a stand and defend it using their own arguments. This strategy ensures students relating on a more personal level and thereby contributing more so to the ongoing class discussions.

On the other hand, the major notable point of improvement in this criterion relates to certain case studies in which students' roles are restricted to the application level rather than encompassing higher order thinking. Moreover, many TCs did not explicitly indicate how they would promote higher order thinking especially for high achievers. This result was discussed earlier in Domain 1.

For the fifth criterion – flexible grouping – in order to attain the expert level, the case study lessons should include various student groupings such as individual, pairs, and small groups, whenever applicable. Students are grouped for a great variety of reasons to differentiate content, process, and/or product by readiness, interest, and/or learning profile. The lesson may combine grouping rationales (i.e., readiness and interest), and flexibility in grouping strategies is in response to a clear analysis of student needs. TCs showed excellent implementation of this criterion, with six case studies scoring at an expert level and one at a practitioner level. All case studies included a variety of independent work, think-pair-share, group work, and general class discussions across the lessons. The last lesson in all case studies also included a debate (e.g., fishbowl debate) or a townhall between students to discuss and present their viewpoints. Moreover, several groups stated that they would change the group members' composition throughout the case study to ensure more student interaction and exchange of ideas. The following excerpts are taken from two lesson plans:

> *Flexible groupings can be used to assign groups, and group members are able to take on various roles within their group to contribute in the way that is best suited to their strengths and needs. (Group C)*

> *Students will work in groups of 4 or 5 (these can be self-selected or assigned). Each group will be given a piece of chart paper and colored markers (or 1 Chromebook per group) to create their consequence map. Group members should engage in conversation and collaborate to consider a variety of implications and/or consequences regarding individual choice in receiving vaccinations (e.g.,*

personal/public health, social implications, moral/ethical implications, economic implications etc.). (Group A)

For the sixth criterion – teachers' and student roles – in order to attain the expert level, the case studies need to ensure that the teacher's overall planned role is primarily that of coach or facilitator. Both students and teacher need to have consistent input into lesson content, with a balance of student and teacher choice, with students taking on increasing responsibility for their own learning. TCs demonstrated good implementation of this criterion with two case studies scoring at an expert level and five at a practitioner level. The role of the teacher as a facilitator and the prevalence of student choice were evident in most case studies. For example:

The teacher should circulate the room and support/observe group progress. Once all groups have completed their consequence maps, the teacher can facilitate a discussion where ideas from all groups can be consolidated. (Group A)

There will be two distinct sides that students will be placed in by the teacher. Depending on your stakeholder position, you will either fight FOR the funding of a functioning drinking water treatment facility OR be advocates for the side who fight AGAINST funding this operation. Consider the scientific, health, ethical, legal and economic implications regarding this matter. The debate will be divided into three groupings, each given an equal amount of time to be discussed: 1) Scientific/health implications, 2) Ethical implications, and 3) Legal implications. (Group C)

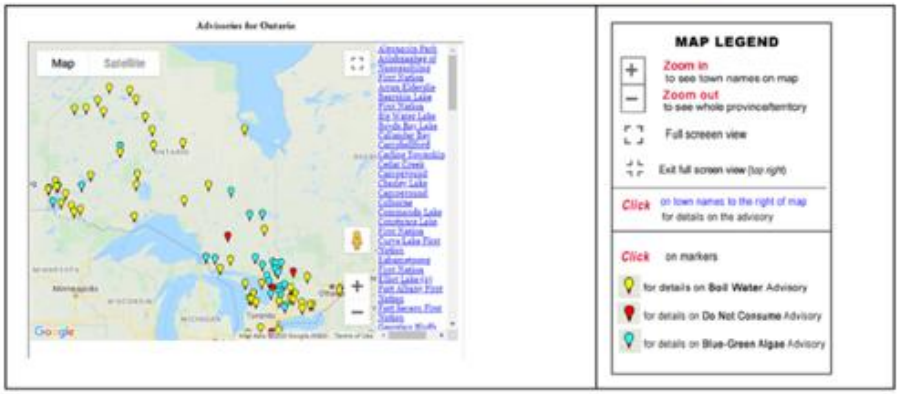
While most lessons followed a student-centered approach, some TCs chose direct instruction to introduce certain concepts or case study components such as the cost-benefit analysis and consequence maps. For example, Group C stated:

Introduce students to consequence map and option for how to organize. Provide time for independent research and note taking using three methods. Provide time for group research for 'stakeholders' to amalgamate their research and formulate a stance.

Moreover, some TCs' excessive reliance on showing videos to explain certain concepts posed a few challenges in terms of the level of inquiry and student agency in the classroom. While videos and other audio-visuals are engaging, they may situate students as passive recipients of knowledge. Accordingly, TCs were advised to substitute those with other activities that enable students to lead and understand the content on their own. Furthermore, some TCs showed hesitation when providing students will full autonomy. This hesitation is expected from novice teachers who may not have the confidence to provide this agency to their students. For example, Group G stated: "*Students will be assigned a stakeholder- they can also choose depending on class dynamics.*"

For the seventh criterion – technology integration – in order to attain the expert level, the case study should exhibit exemplary and proficient use of digital material. This action would render the lesson fully implementable in an online environment. TCs showed a good implementation of this criterion, with one case study scored at an expert level and six at a practitioner level. TCs included a vast array of digital resources (e.g., Figure 16) such as Kahoot activities, simulations, digital maps, digital games, online articles, internet research, and audio-visuals. Since the data was collected during the COVID-19 pandemic, TCs took into consideration the fact that they may use these case studies either in-person or in an online teaching environment and succeeded in this adaptation. Several groups were advised to maintain consistency in integrating digital resources throughout the case study lessons, and not only in some of them.

Use this map as a guide to display the distress many first nation communities go through to obtain clean drinking water: https://www.watertoday.ca/map-graphic.asp



Present video on boil water advisory (use first video, second video if enough time):
https://globalnews.ca/news/5887716/first-nations-boil-water-advisories/ (8 min)
https://www.aptnnews.ca/national-news/frequent-short-term-water-problems-new-norm-for-many-first-nations/ (3 min)

Show the following images on the board. Talk about how this is common in some communities. Relate it back to the map and video(s).

Figure 16: Sample Digital Activities, Group C – Water in Indigenous Communities

5.3.4 Domain 4 – Student Assessment

This domain entails two criteria: 1) formative assessment, and 2) existence and quality of rubrics and guidelines.

For the first criterion, formative assessment, to attain the expert level TCs should plan to regularly use formative assessments throughout the lessons. Information from these lessons should be utilized in modifying instruction within a lesson, gauging student understanding, and planning future instruction for individuals and groups. TCs showed a very good implementation of this criterion with four case studies scored at an expert level and three at a practitioner level. TCs integrated formative, diagnostic, and summative assessments in their case studies. Several case studies explicitly included assessment for, of, and as learning within the lesson plans. Moreover, multiple tools were included to assess students such as prior knowledge check, KWL charts, polling, lab sheets, fact sheets, worksheets, note-taking, exit tickets, student reflections, and rubrics for class discussions and debates. TCs' awareness of the importance of a variety of assessment strategies, especially formative assessments, is highlighted in the following excerpts from the lesson plans:

> *Ensure that students come prepared with research notes taken from previous classes. Please review the following teacher instructions for Day 1 and Day 2 of the activity and read the STUDENT TASK to all students at the beginning of class. (Group C)*

> *Constant check-ins with the class to see if we are moving too fast or if they understand concepts. (Group D)*

Furthermore, TCs provided students multiple ways to present their understanding, especially at the end of the case study. This strategy offers students multiple options to express and convey their understanding in ways that match their levels of readiness and interest.

Major points of improvement in this criterion include: 1) integrating more variety in the assessment methods throughout the case study rather than relying only on the case study note-taking sheets; and 2) making the assessment section more explicit in the lesson plan, and not only in the lesson closure section, to highlight its importance and to reinforce the importance of ongoing assessment during the lesson rather than only at the end.

In order to attain the expert level on the second criterion, assessment rubrics and guidelines, TCs should clearly articulate the rubrics and guidelines through specific assessment criteria and standards. Students should have the ability to participate in the creation of the rubric/guidelines and actively plan next steps for learning. TCs showed a good implementation of this criterion with five case studies scored at an expert level and two at an apprentice level. Most case studies included clear and comprehensive rubrics for different instructional activities, especially the consolidating debate. Rubrics entailed clear indicators and specifications that measure various components such as students' knowledge, application, thinking, and communication. Two case studies at the apprentice level included assessment criteria such as worksheets but did not include rubrics for the final class discussion/debate.

5.3.5 Domain 5 – Supportive and Inclusive Learning Environments

This domain entails three criteria: 1) integrating EDI principles as stated in Ontario's Education Equity Action Plan (2017); 2) respectful behavior toward and among students; and 3) sense of community and collaboration.

For the first criterion, EDI principles, to attain the expert level TCs must demonstrate a sophisticated understanding of EDI principles. They need to effectively implement inclusive and culturally responsive pedagogy. Planned lessons should fully reflect and attend to diversity (race, ethnicity, culture, religion, SES, immigration status, Indigenous communities, Indigenous histories and ways of knowing, sexual orientation, gender identity, etc.). TCs demonstrated good implementation of this criterion with three case studies ranked at an expert level, three at a practitioner level, and one at an apprentice level. First, the nature and choice of the case study topics around SSI made it easier for TCs to relate their cases to EDI principles. For example, Group C tackled water filtration in Indigenous reserves, which directly relates to equity practices and Indigenous communities. Similarly, Group A discussed equity in accessing COVID-19 vaccines. Second, the case study format allows for addressing various backgrounds and perspectives. Student awareness of different perspectives on scientific topics could eventually lead to a more inclusive and respectful approach when discussing those topics, as illustrated in the excerpt below and in Figure 17.

> *The Canadian Medical Ethics Advisory Board (CMEAB) is skeptical about the ethical aspects of this vaccine. They are worried about human rights and the general public's choice to receive the vaccine. The CMEAB is also concerned about how the distribution of the vaccine will occur. Will the distribution be fair and ethical? (Group C)*

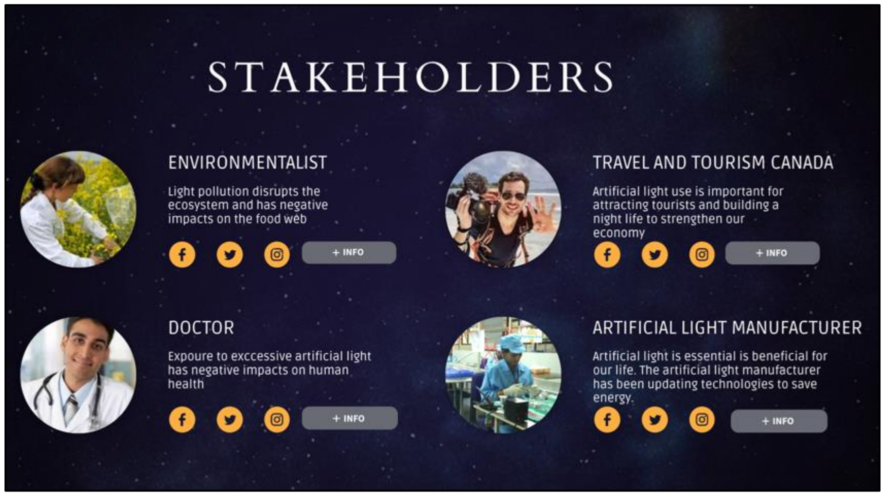


Figure 17: Different Perspectives in the Case Study of Group E – Light Pollution

Moreover, TCs were aware of non-Western centric approaches in science. Many of them integrated Indigenous ways of knowledge within their teaching, as shown in the excerpts below.

> *While vaccines are largely a product of modern and "Western" science, teachers should take care not to ignore or undermine other ways of knowing such as Indigenous ways of knowing. In the case of the prevention and treatment of communicable diseases, Indigenous science, and contributions to the development of medical treatments and remedies should be included in discussion. During the consequence map activity, students should be encouraged to consider the views of different groups regarding vaccines and the implications of choosing to be vaccinated or not (such as those of Indigenous peoples). Care and consideration should be taken as Indigenous communities have historically experienced viral epidemics (such as Smallpox) – and these epidemics took place in the context of colonialism. It is possible students in the class may have ancestors that experienced these epidemics and the subsequent introduction of vaccines into their Indigenous communities. Teachers should acknowledge the potential for students to have feelings towards vaccination that differ from their non-Indigenous peers. Below are some resources that can support both teacher's and student's understanding of Indigenous people, viral epidemics, and vaccines … (Group A)*

Students will also need to research an alternative product that does not involve plastic and is better for the environment, however, they will need to talk about the advantages and disadvantages and consider equity, diversity and Indigenous ways of knowing. (Group D)

Third, most TCs dedicated a part of their lesson plans to explicitly discuss EDI-related principles and teaching methods (Figures 18 and 19). In these samples, TCs summarize how they address different student backgrounds and how they differentiate their instruction. Figure 18 shows how Group F engaged parents as per Ontario's Equity Plan, providing accommodations and multimodal presentations, and addressing different backgrounds and perspectives. Figure 19 illustrates how Group G included multimodal presentations, addressing different backgrounds and perspectives, and integrating Indigenous ways of knowledge. This finding shows that TCs were able to link DI to EDI principles.

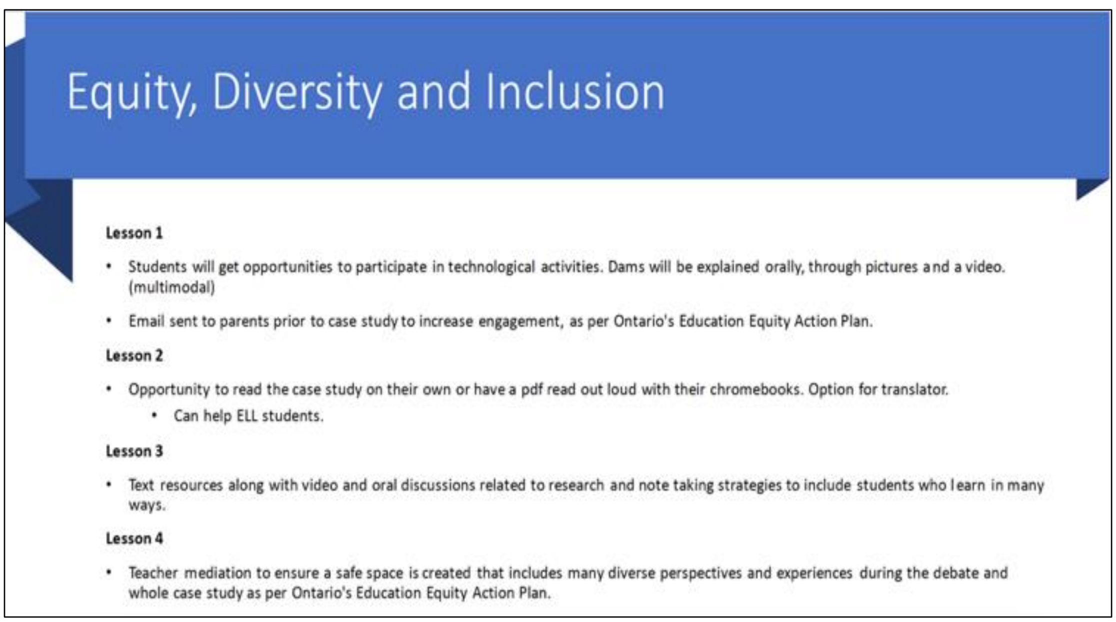


Figure 18: EDI Principles and Methods Highlighted in Group F Case Study

Specific EDI

- Students have the chance to communicate orally and in writing
- Worksheet gets students thinking from a diverse set of perspectives (disproportionate impact on low SES communities, impacts of nuclear proliferation on developing countries, future benefits of investing in renewable energies
- Students are in control of their own learning through the research and sharing experience (Jigsaw lesson style). They learn as a community while looking at physics from a holistic perspective, considering the scientific, environmental, political, social and ethical impacts of energy sources.
    - These approaches are influenced by Indigenous Ways of Knowing

Figure 19: EDI Principles and Methods Highlighted in Group G Case Study

Finally, some TCs provided accessibility accommodations for students with different needs (e.g., visually impaired, ELLs, low reading proficiency) as shown in Figure 20.

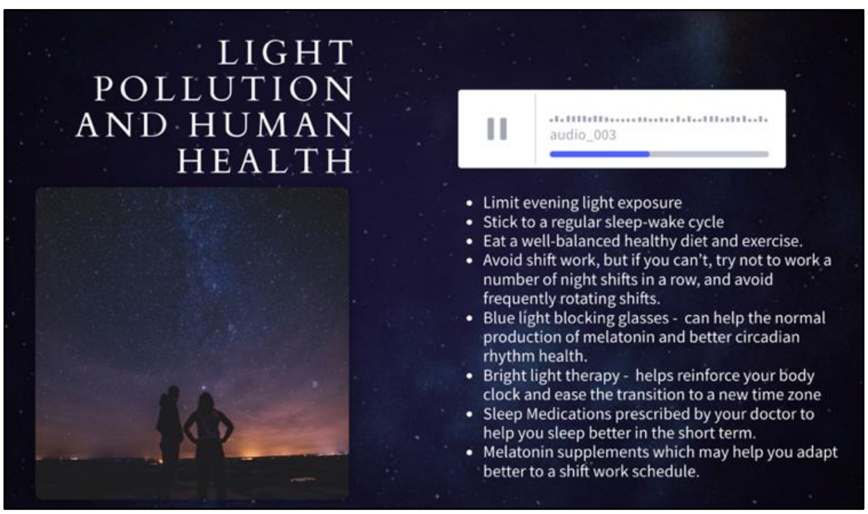


Figure 20: Group E Provided a Voice-over Option as an Accommodation Strategy

For the second criterion, respectful behavior toward and among students, to attain the expert level the case study should foster active participation and questions from all students. Awareness of students' strengths, successes, and contributions are to be cultivated and celebrated. TCs demonstrated exemplary implementation of this criterion with six case studies ranked at an expert level and one at a practitioner level. The excerpt below from Group D highlights how TCs situated their roles as facilitators in the classroom, thus respecting student choices and discussions.

Behavior Support:

• Check with class during work time to ensure they are on task

• Proximity to students to keep them on track

• During the debate it is important to keep things at a neutral level and not let emotions get out of hand

On the other hand, Figures 21 and 22 show how TCs stressed respectful behavior among students in their instructions and assessment guidelines.

Debate Expectations

- Always show respect to all team members and opponents
- Do not interrupt students during their arguments or rebuttals
- Present only appropriate and relevant information
- All students should be engaged and participate during the debate (ex. Verbally presenting arguments, recording arguments, researching, etc.)
- Written sheet of recorded arguments must be submitted to teacher by the end of the debate

Order of Debate

o Affirmative (FOR) side receives 2 minutes to present first argument
o Negative (AGAINST) side receives 2 minutes to present opposing argument of same topic
o Both teams receive 2 minutes to prepare rebuttal statements. The Negative (AGAINST) side will start with their rebuttal and the Affirmative (FOR) side will have a chance to further rebuttal.
o This order of debate will occur 3 times as there are 3 distinct subgroups for each side. The order of debate will not exceed 15 minutes for each subgroup.

Debate Agenda

1) Introduction to debate panel
2) Review Debate Expectations
3) First Topic: Scientific/Health Implications (~15 minutes)
4) Second Topic: Ethical Implications (~15 minutes)
5) Third Topic: Legal Implications (~15 minutes)
6) Closing remarks from each side of the panel (~5 minutes)

Figure 21: Group C Instructions Emphasizing Respectful Behavior Among Students

Rules:

Just like any classroom activity, debates require mutual respect and exist to facilitate healthy communication and discussion. Here are a few rules for the participants and observers to always abide by. The teacher should make sure to review these rules with the class before conducting any debates.

Participants:

-be civil! Name-calling and insults are disrespectful and distract from the topic of the debate. When making rebuttals, attack the *argument*, not the person making the argument.

-be clear! Make sure that arguments can be understood. The time limit may put pressure on students to say several points rapidly, without regard for whether anyone can understand them, be it the opponents, or audience, or teacher. But that adds little of value to the discussion. One point made well is better than five points made poorly.

-be concise! Using complicated language and run-on sentences just make your points harder to understand. They also take longer to say.

-concentrate on the topic! Going off-topic and bringing up points that are not relevant to the debate is a waste of everyone's time, including your own. At the very least, if an opponent asks why your point is relevant, you should have an answer ready.

The participant rules can conveniently be remembered by referring to them as the "four C's": clear, concise, civil, and concentrated.

Observers:

-be respectful! It is the participants' turn to debate, and no one likes being interrupted in the middle of an argument. Like with a presentation, anyone not involved in a debate should show their classmates respect by remaining quiet and paying attention.

Figure 22: Group F Instructions Emphasizing Respectful Behavior Among Students

For the third criterion, sense of community and collaboration, in order to attain the expert level, the case study should enable students and teacher to consistently focus on both individual and group excellence and growth. Students should consistently engage and support one another in learning and be supported to work with any student in the class. TCs showed very good implementation of this criterion, with five case studies at an expert level and two at a practitioner level.

5.3.6 Domain 6 – Evidence of Differentiation

This domain compiles and relates to all previous domains and their accompanying criteria. The three criteria of this domain are: 1) content differentiation, 2) process differentiation, and 3) product differentiation.

The first criterion, content differentiation, refers to adapting what is taught and modifying how students are given access to the information and understandings (Tomlinson, 2001). The planned lessons need to be highly concept-based and make use of diverse materials at various levels of readability, complexity, and/or interest. Lessons shall include, but are not limited to, one or more of the following strategies: multiple ways to access and organize information, learning contracts, curriculum compacting, flex-group mini-lessons, and varied support systems such as audio/video recorders, note-taking organizers, highlighted print materials, digests of key ideas, and peer/adult mentors. TCs showed a novice implementation of this criterion with no case studies scored at an expert level, while five were scored at a practitioner level, and two at an apprentice level. As explained previously, TCs effectively utilized the different note-taking organizers as instructed by the course instructor such as KWL charts, Cornell's note-taking sheet, and consequence map. Yet, the lesson plans of most TCs did not adeptly change the complexity levels and/or the pace of learning for various students. This shortcoming justifies the relatively lower scores on this criterion compared to others.

The second criterion, process differentiation, refers to the instructional activities that represent a diversity of approaches at varying degrees of sophistication, with several levels of scaffolding, and completed in different time spans. These sense-making activities should use essential skills and information to understand the big idea or understanding underpinning the lesson (Tomlinson, 2001). Process differentiation can happen in one or more of the following ways: readiness by matching complexity of task to student's current level of understanding; interest by giving students choices and linking to personal interests and/or goals; and learning profile by making sense of ideas reflected in the students' preferred way of learning. TCs demonstrated good implementation of this criterion, with three case studies rated at an expert level, three at a practitioner level, and one at an apprentice level. In addition to the previously included samples, the following samples reiterate the findings:

> *This lesson includes multimodal representations of information (text, videos with audio, visual diagrams/descriptions etc.). This appeals to a wide variety of preferred learning styles and can meet the needs of students who have difficulty learning from a particular modality (e.g., students with limited English language or written language skills). The consequence map activity encourages inclusion of all student voices in group work and allows students to organize and express their thinking in a way which*

is not heavily reliant on writing skills. The consequence map activity helps students describe cause and effect relationships visually and can support English Language Learners in the acquisition of new English vocabulary. (Group A)

Use of a PPT, Video and debate to accommodate for various forms of learners within the class. (Group D)

For the research and Cornell note-taking activities, both videos and text-based learning is offered, in addition to oral discussion. This allows students who learn in many different ways to all learn to the best of their abilities. Also, the arguments made during the debate do not need to strictly be verbal. Share text, images, and short videos if they can assist a student in making their point. Odds are, the sources are in a variety of media formats, and the points made to the class can be multimodal in a similar way. (Group F)

The third criterion, product differentiation, refers to providing several product options that are designed to foster deeper and richer understandings of the unit's goals. Products may differ due to curriculum requirements or student readiness, interest, or learning profile (Tomlinson, 2001). Guidelines provide the perfect balance between structure needed to focus and guide students, and freedom to support innovation and thought. Students collaborate with the teacher to design the project requirements, timeline for completion, and assessment criteria. The teacher works as a coach to facilitate, scaffold, and expand the students' thinking through flexible study groups, mini-lessons, and conferencing. TCs showed good implementation of this criterion with three case studies scoring an expert level, two at a practitioner level, and two at an apprentice level. Several groups provided a wide array of different assessment strategies for students to demonstrate their understanding. Nevertheless, additional options would provide more choice for students. TCs stated:

Several opportunities to individualize and differentiate the assessment are available:

- No more than two debates per day to give each student time to meaningfully participate. Following the debate, students will complete a cost benefit analysis of the Three Gorges Dam issue, along with the learned section of the KWL chart.

- Brainstorm, discuss, then present (mind map, infographic, skit, etc.) different ways how technologies have made a change with our energy consumption.

(Group F)

- Students have the chance to communicate orally and in writing.

- Digital, Differentiated Instruction - In lieu of writing a paper, teachers can also consider presenting students with the option of presenting their discussion and analysis in a pre-recorded video.

- Students can then use visual graphics to support their arguments. This method may also remove some essay-writing anxiety.

(Group G)

5.4 Quantifying Case Studies Analysis

A score out of four was allocated to each case study in each of the 20 criteria in the DI matrix, where (1) indicates "Novice", (2) indicates "Apprentice", (3) indicates "Practitioner", and (4) indicates "Expert". Figure 23 highlights the average scores of the seven case studies on each of the 20 criteria. In general, the average score on each criterion shows that the DI seminar and subsequent training had a positive impact on TCs' conceptions and implementation of DI. The average score of TCs' case studies between 1 and 2 was not recorded on any of the criteria, between 2 and 3 was recorded on three of the 20 criteria, and between 3 and 4 on 17 of the 20 criteria. This result shows that TCs showed practitioner to expert level on the vast majority of criteria, which reflects good understanding and implementation of DI in the case studies. The highest scores were recorded on aligning the objectives with the activities (3.57), lesson organization (3.86), modes and strategies of instruction (3.57), engagement capacity of activities (3.57), flexible grouping (3.86), formative assessment (3.57), encouraging respectful behavior (3.86), and ensuring a sense of community and collaboration (3.71). These criteria scored between 3.5 and 4 which reflects an expert level.

On the other hand, other indicators reflecting a score between 3 and 3.5 show very good performance indicative of a practitioner level. These are quality and clarity of the objectives (3.43), pre-assessment and proactive preparation (3.29), working on students' intellectual development by addressing different thinking levels as per Bloom's taxonomy (3.43), teacher's planned role, learner independence, and student choice (3.29), technology integration (3.14), using rubrics and assessment guidelines (3.43), integrating the principles of EDI (3.29), differentiating the process (3.29), and differentiating the product (3.14). The three indicators that need improvement, indicative of apprenticeship level, are scaffolding for struggling learners (2.57) with four case studies showing apprenticeship level, challenging advanced students (2.29) with five case studies showing apprenticeship level, and differentiating the content (2.71) with two case studies showing apprenticeship level, five case studies showing practitioner level, and none of the case studies showing expertise level.

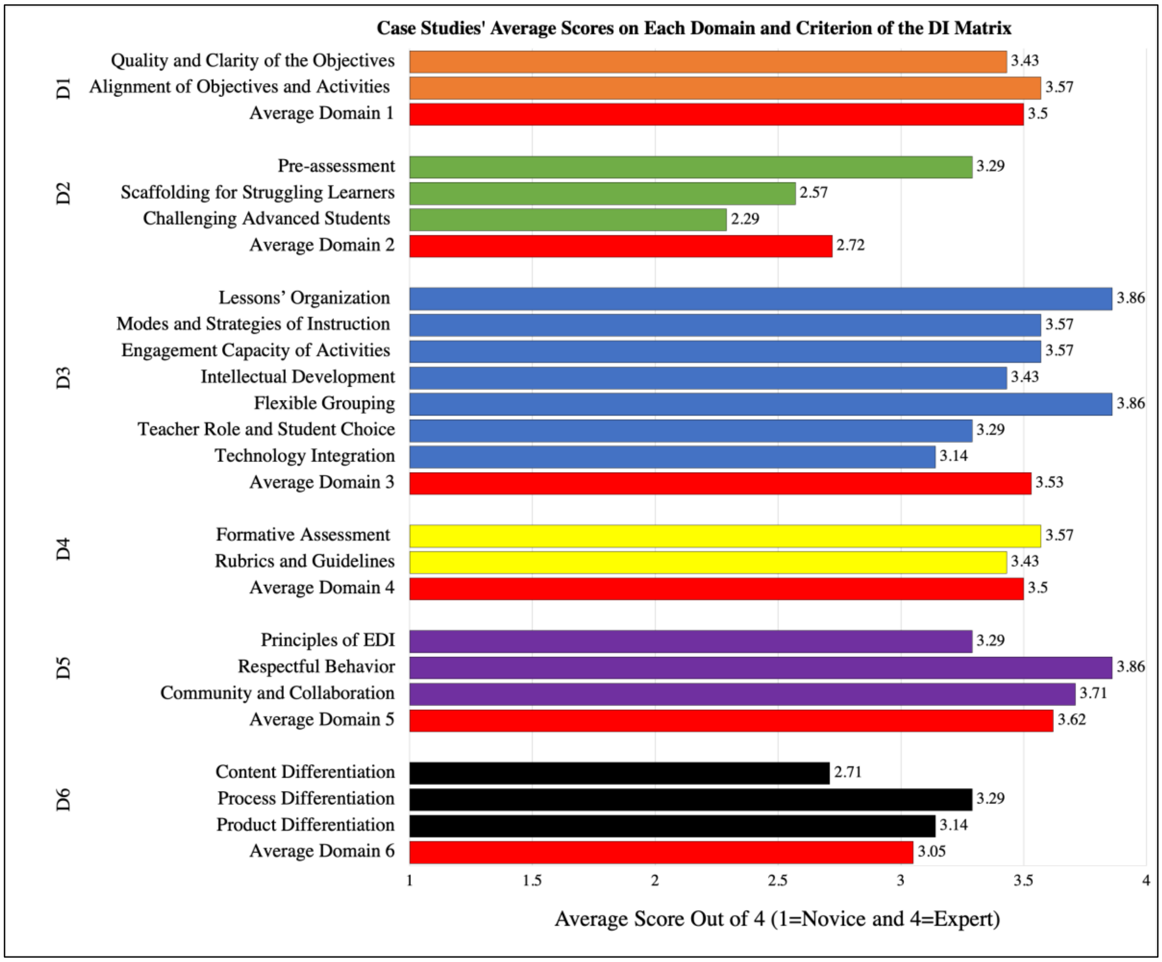


Figure 23: The Average Score (out of 4) of the Seven Case Studies per Domain (D1-D6) and Constituent Criteria

To obtain a general and holistic overview of TCs' implementation of DI in their case studies, the average score on each domain was calculated for all case studies by calculating the average score of the criteria in each domain (also shown in Figure 23). Additionally, the average scores on each domain were converted to percentages (Figure 24). TCs demonstrated exemplary performance on four of the six domains: Domain 1 – quality curriculum and lesson design (7 out of 8: 87.5%); Domain 3 – planned instructional practices (24.71 out of 28: 88.25%); Domain 4 – student assessment (7 out of 8: 87.5%); and Domain 5 – positive, supportive, and inclusive learning environment (10.86 out of 12: 90.5%). On the other hand, the averages on Domain 6 – evidence of differentiation was 9.14 out of 12 or 76.16%; Domain 2 – response to learner needs scored the lowest average of 8.14 out of 12 or 67.83%. The relatively low scores on Domain 2 are further reinforced on the content differentiation component in Domain 6. TCs showed relatively low implementation in terms of adapting the lessons to various academic achievement levels.

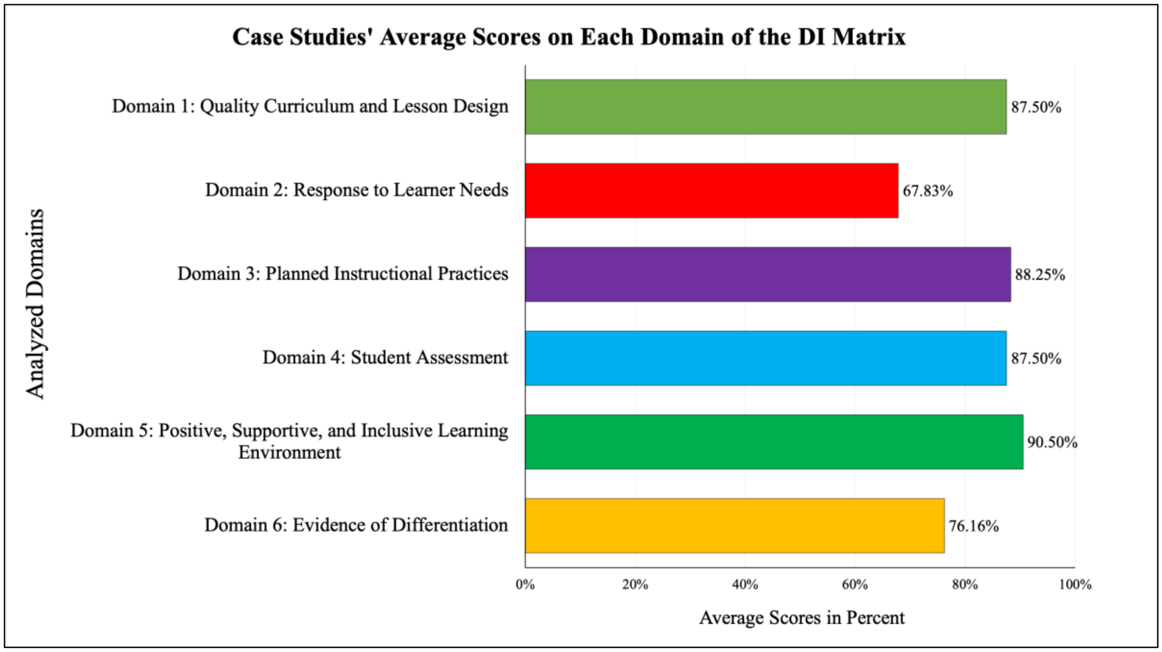


Figure 24: Average Scores (%) of the Case Studies on Each Domain of the Matrix

5.5 TCs' Reflections: Case Studies Assignment

To corroborate the case study analysis, TCs' individual reflections on the assignment were also analyzed. In specific, the researcher analyzed the responses to one question in the written reflection based on how TCs addressed EDI principles and practices in their case studies. The themes utilized in the deductive analysis are those in Domain 6 of the DI matrix – evidence of differentiation and include: content, process, and product differentiation in response to students' readiness, learning profiles, and interests. For instance, 89% of TCs explained how they addressed various learning profiles by catering for various perspectives, SES, cultures, and genders through a social justice lens, culturally responsive pedagogies, and integrating Indigenous knowledge. Moreover, 50%

of TCs explained how they addressed students' needs and interests by respecting student choices and attending to ELLs and special need students. Only 17% mentioned how they differentiated their instruction in response to students' readiness, that is, different achievement level and skill abilities.

On the other hand, the reflections of 61% of TCs included details on how they differentiated the process through cooperative learning, grouping strategies, and student-centered strategies; while 22% of TCs described their product differentiation through differentiated and multiple assessments, and assessment for/as/of learning. Figure 25 shows the frequency of the DI-related themes in TCs' written reflections. Interestingly, the same trends are observed when comparing teachers' explicit reflections on DI implementation and the researcher's analysis of their actual planning as reflected in Domain 6 in Figure 23. TCs showed the highest levels of DI planning in the process, followed by the product, and the least in the content. These results were also similar in the TCs' reflections. This finding provides an additional layer of analysis into their abilities and intentions.

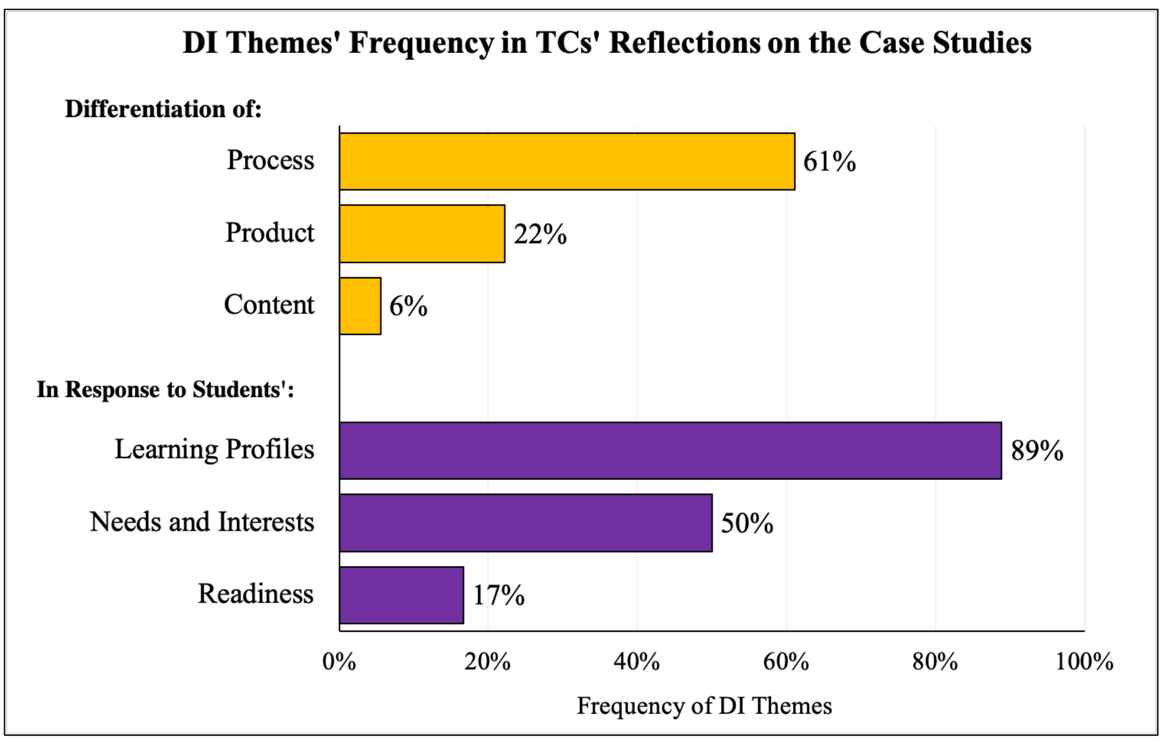


Figure 25: The Frequency of DI Themes in TCs' Reflections (n=18)

5.6 Discussion

First, I will address the RQ exploring how STEM TCs develop the curriculum to be inclusive of DI strategies using case studies as a teaching strategy. Based on the findings, TCs showed very good integration of DI principles and practices in most of the domains and sub-criteria of the DI matrix. In Domain 1 – Quality Curriculum and Lesson Design – TCs demonstrated a mastery level. In Domain 2 – Response to Learner Needs – TCs developed very good plans to pre-assess their students and prepare proactively. Yet, two major areas of improvement in this domain include developing activities that scaffold learning for struggling students and those that challenge advanced students. In Domain 3 – Planned Instructional Practices – TCs demonstrated exemplary lesson organization; variation in modes and strategies of instruction; high level of engagement capacity of activities; adequate grouping strategies; and a very good level of technology integration. Three criteria that need more attention within this domain are planning to address student intellectual development through activities that target their higher order thinking skills; providing students with more autonomy and choice; and integrating technology with a variety of solutions, and at the same time addressing inquiry and higher order thinking skills rather than only focusing on student engagement. In Domain 4 – Student Assessment – TCs adequately utilized formative assessment and rubrics. Yet, more variety and consistency in the assessment methods throughout the case study is a point of improvement that needs to be addressed. Domain 5 – Positive, Supportive, and Inclusive Learning Environment – is the domain in which TCs scored highest. TCs integrated EDI principles as stated in Ontario's Education Equity Action Plan (2017), emphasized respectful behavior, and planned lessons that develop a sense of community and collaboration between students. Finally, in Domain 6 – Evidence of Differentiation – TCs demonstrated the best evidence of differentiation in the process followed by the product, while the content differentiation lack evidence and thus require attention and improvement. Overall, TCs were successful to a high extent in developing differentiated curriculum using the case studies on SSI. TCs showed excellent performance on four of the six domains: quality curriculum and lesson design, planned instructional practices, student assessment, and positive, supportive, and inclusive learning environments. On the other hand, the domains related to responding to learner needs and content differentiation showed relatively low levels.

Overall, the DI-focused case study assignment was effective in enhancing TCs' conceptions and implementation of DI. This finding reiterates the importance of teacher preparation to integrate DI in their future practice (Dack, 2018; Goodnough, 2010; Valiandes & Neophytou, 2018). The findings also highlight the importance of PD programs in addressing the challenges documented in the literature, especially those related to lack of knowledge in implementing DI, lack of resources, and the perceived difficulty of this strategy (de Jager, 2017; V. Park & Datnow, 2017; Turner & Solis 2017; Wan, 2017). These findings show how the STEM course enriched with DI-focused strategies addressed TCs' PCK (Shulman, 1986). The course attended to most of Schneider and Plasman's (2011) science PCK components including TCs' knowledge about the orientation to teaching science, instructional strategies in science, science curriculum, and assessment of students' science learning. Moreover, the analysis of the case studies developed by the TCs demonstrated mastery of Lee's (2016) SSI-PCK framework including their knowledge of instructional strategies for teaching SSI; knowledge of curriculum; knowledge of assessment of SSI learning; and knowledge of learning contexts.

On the other hand, in terms of TCs' detailed DI skills, the relatively high scores on the assessment domain in the DI matrix contradicts what is documented in the literature related to teachers facing difficulties in differentiating their assessment strategies (Rollins, 2010; Wan, 2017). Yet, a major gap that this study reflected is TCs' inability to differentiate the content as it relates to teaching and learning. This finding parallels the conclusion of Turner and Solis (2017) that teachers usually understand the differentiation of the content component the least compared to other components. This finding is also in harmony with de Jager (2017) who maintains that the vast majority of teachers find it difficult to adopt a flexible curriculum and provide extra time for their students. According to Tomlinson (2001), the content is the input of teaching and learning. Hence, teachers have to adapt what is taught and modify how students access information and understandings. TCs' response to various student needs also reflected a gap in their understanding and implementation of this criterion, that is, content differentiation. TCs needed more guidance on how to scaffold learning for struggling students, attend to special need students, cater their teaching for various linguistic abilities, and challenge advanced students. This challenge has also been documented in the literature, whereby teachers indicate that the great diversity among students in the same classroom poses difficulty in their ability to attend to all learner needs (de Jager, 2017; V. Park & Datnow, 2017; Turner & Solis 2017; Wan, 2017).

These specific gaps in TCs' differentiated curriculum development require special attention and further reinforcement. Finally, it is important to note that while this analysis focuses on the ability of TCs to integrate DI strategies in their curriculum, DI was not the only focus of this assignment. Moreover, this course is a STEM curriculum and pedagogy course, with a focus on DI, amongst other components. As indicated before, the instructor facilitated a seminar on DI at the beginning of the course and provided explicit and reflective instruction with a focus on DI throughout the course. DI was only one component of the case study assignment rubric. Thus, TCs had to address several criteria which may have hindered their full implementation of DI. Although this notion appears to be a limitation, I believe that it fairly reflects TCs' future classrooms where they will be tasked with preparing STEM curricula and lessons addressing different concepts with a hope that they attend to various student differences in the classroom.

Second, as an extension to the RQ addressing the development of STEM/science curriculum using case studies on SSI topics with a focus on DI, I now assess the potential of case studies on SSI as effective tools to implement DI in secondary STEM/science classrooms. The overall analyses of the assignment design and requirements as well as coursework indicate that case studies on SSI are highly effective tools to differentiate instruction, with TCs differentiating the process and outcomes of learning, yet showing a need for more training in DI in order to attend to students' needs, backgrounds, and academic levels. Case studies and SSI present multiple perspectives and opposing arguments on debatable topics (Ekborg et al., 2009; Levin, 1995). Hughes (2000) maintains that SSI promote students' socioscientific awareness of the various dimensions to science and present science as accessible to various underprivileged groups.

Furthermore, since case studies allow multiple levels of analysis and interpretation (Levin, 1995), they proved to be adequate for differentiating instruction, as exemplified in TCs' coursework. This result was specifically facilitated by several components of the SSI case studies such as: 1) multiple stakeholders involved; 2) several sequenced lessons enabling the use of variety of teaching and assessment strategies; 3) multiple graphic organizers, note-taking frameworks, and sheets required in the analysis of the case; 4) presenting to different audiences; and 5) the debatable SSI and STSE topics that require attending to the rights and living conditions of minorities and underprivileged communities. Teachers can therefore capitalize on these components to embed DI practices within case studies on SSI, and thereby attain potential positive outcomes of both.

5.7 Chapter Summary

This chapter highlights the impact of integrating DI-focused strategies in a STEM curriculum and pedagogy course in teacher education on TCs' curriculum development practices. This impact is explored by presenting the analysis of one of the course tasks – case studies of SSI. Overall, the results show that the DI-focused task was effective in promoting TCs' curriculum development while attending to DI principles and practices. TCs were able to develop SSI case studies with a focus on DI strategies. Furthermore, case studies of SSI were effective tools to differentiate instruction, with TCs' performance ranked as satisfactory in differentiating the process and product of learning yet showing a need for more training in DI to differentiate the content to be able to attend to all students' needs, profiles, and academic levels. This chapter equips STEM teachers and curriculum designers with practical DI resources and strategies especially at the intermediate and senior levels. It also informs teacher educators and educational researchers about the effectiveness of similar professional development and teacher preparation opportunities that integrate DI in their practices and ensure equitable and high-quality education for all students.

Chapter 6

6 Findings – Embedding DI in Educative Curriculum Materials

Educative Curriculum Materials (ECMs) are materials that promote teacher learning (Davis & Krajcik, 2005). ECMs' designers must ensure that these resources are accurate, complete, and coherent in terms of content, and effective in terms of pedagogy (Davis & Krajcik, 2005). Krajcik and Delen (2017) note that these materials are scarce, and that we need to know more about how to design them so that teachers can effectively use them. Correspondingly, the lack of curriculum resources is one of the most common challenges for teachers to differentiate their instruction (de Jager, 2017; V. Park & Datnow, 2017; Turner & Solis 2017; Wan, 2017). Thus, it is essential to ensure that TCs are equipped with adequate curriculum resources that are DI-focused to facilitate their future teaching.

On the other hand, in the past few years we have witnessed rapid developments in technology and an abrupt shift to online teaching and learning due to the COVID-19 pandemic. Teachers consider integrating technology helpful in facilitating DI in secondary science classes (Heilbronner, 2013; Maeng, 2017), despite their belief that there is still a long way to go for optimizing the use of technology to support DI (Cha & Ahn, 2020; Valiandes & Tarman, 2011). Recent research findings indicate that STEM teachers face difficulties integrating DI in digital environments, which is mainly due to the lack of adequate teaching resources (DeCoito & Estaiteyeh, 2022b). Thus, it is crucial to advance teachers' and students' digital literacy by introducing and using digital resources effectively, while concurrently attending to student differences by integrating DI strategies.

Based on all of the above, this chapter explores how TCs create ECMs that are both DI-focused and digitally enriched. Findings in this chapter address the following RQs:

RQ2a. How do TCs develop curricula to be inclusive of DI strategies?

RQ2c. What models of technology-enhanced DI do TCs incorporate in their lessons?

The chapter presents TCs' course work, specifically the DVGs and the curriculum resource websites (explained in Chapter 3.3) and includes the analysis of eight DVGs and 18 websites.

6.1 Background

6.1.1 Digital Literacy in STEM/Science Education

Digital literacy is important for science learning as it promotes cognitive development, highlights relevance via relating science to students' real-life experiences, increases students' self-management of their own learning, and facilitates data collection and presentation (Webb, 2005). Digital media literacies allow participation and communication in science in ways that were otherwise unavailable to students (Doyle & Dezuanni, 2014). They also enable teachers to give more priority to cognitive and meta-cognitive skills and strategies especially by using information and communications technology (ICT)-supported formative assessments (Black & Wiliam, 2003).

ICT offers many ways to support science learning and teaching. These ways include Internet-supported student research projects, email for communications, games, simulations, and micro-worlds, modelling software, data-logging for data collection, text and multimedia-editing software, and collaborative online environments (Ng, 2013). For instance, students can use simulations in making predictions, visualizing processes, organizing material for particular purposes, collecting data, and graphing data. They can also use computer-based modelling in identifying relevant variables, hypothesizing relationships, and developing understanding of the scientific ideas that they are modelling. Students can use various electronic solutions to communicate and discuss results, synthesize knowledge through digital stories, display concepts in multiple representations, and demonstrate their understanding (Derman & Ebenezer, 2020; Ng, 2013; Webb, 2005). These digital resources, being dynamic and malleable, have the potential to support different learning needs (Hill & Hannafin, 2001).

Several factors may impede the integration of digital literacies in science classrooms. Research reports the lack of modeling by instructors due to gaps in their knowledge as one of these challenges (Hill & Hannafin, 2001). Similarly, Ng (2013) describes the current impact of ICT in classrooms as ad hoc and low due to two main barriers: teachers' lack of ICT related skills and knowledge and time required to develop said skills and knowledge. Thus, teachers need to plan to select appropriate pedagogical tools, and understand the potential of these technological affordances in order to support students' cognitive development, formative assessment, and new science curricula (Cox et al., 2004). Therefore, the effective integration of digital technologies in STEM/science teaching requires the intersection of pedagogy, technology, and content knowledge, as well as teachers' perceptions and beliefs about teaching and their instructional practices (Dipietro, 2010). The intersection of technology, pedagogy, and content knowledge is referred to as TPACK (technological, pedagogical, and content knowledge) (Koehler & Mishra, 2009). Research demonstrates that pre-service and in-service teachers need to attain high levels of TPACK in order to use technologies effectively in their classrooms (Baturay et al., 2017; Mouza, 2016). This effective use of technology requires targeted and continuous PD programs due to the rapid developments in technological tools.

6.1.2 Digital Literacy in Teacher Education

Research reveals that TCs' levels of self-efficacy (Bandura, 1995; Skaalvik & Skaalvik, 2008) and attitudes toward ICT determine whether or not, and how, they use it in their classrooms (Sasseville, 2004; Zhang & Martinovic, 2009). Dipetta and Woloshyn (2009) report that TCs believe that they will become more ICT literate; however, they believe that they do not possess the skills to integrate ICT in their future practices. DeCoito and Richardson (2018) investigated the use of technology by middle school teachers in Canada and noted a disconnect between their beliefs and practice. Teachers believed technology is important but did not implement it in their teaching. Teachers mostly reported utilizing technology for administrative and presentation purposes. Similarly, Russell et al. (2003) explored the use of technology by teachers in Massachusetts districts. They found that teachers generally use technology more for preparation and communication, rather than for instruction or assigning learning activities that require the use of technology. DeCoito and Richardson (2018) maintain that factors usually influencing teachers' use of technology can be categorized as both external such as availability of resources, training, and support; and internal such as personal investment in technology, attitude toward technology, and peer support.

These findings shed light on the importance of teachers' competencies to use technologies to maximize learning for their students, specifically their TPACK framework. For instance, the U.S. Department of Education Office of Educational Technology issued several expectations to focus on the active use of technology to enable learning and teaching through creation, production, and problem solving, and to enhance preservice teacher experiences with educational technology through deeper and wider programs rather than one-off courses, separate from methods courses (Borthwick & Hansen, 2017). Several studies confirm the need for more research on and tools for the effective preparation of preservice teachers to integrate technology in their classes (Gruszczynska et al., 2013; Zhang & Martinovic, 2009). In line with this, Ng (2013) also calls for better teacher preparation in order to harness the potential of ICT. Thus, teacher PD is essential if technology is to be used effectively, and the pedagogical and technical support for teachers and TCs need to address their daily challenges and responsibilities (DeCoito & Richardson, 2018; Ebenezer et al., 2012).

6.1.3 Technology-Enhanced DI

The COVID-19 pandemic created an unprecedented emphasis on technology in the form of online teaching. In a recent study of STEM teachers' engagement with online learning in Canada, teachers reported difficulties differentiating their instruction and attending to various student needs in online settings (DeCoito & Estaiteyeh, 2022a). On the other hand, based on the findings of a literature review (Estaiteyeh, 2021), the integration of technology with DI is promising despite limited and inconclusive research.

Technology is of assistance to teachers when differentiating their instruction in science classrooms (Boelens et al., 2018; Cha & Ahn, 2020; Heilbronner, 2013; Maeng, 2017; Valiandes & Tarman, 2011). This differentiation is feasible through modifying the instructional pace for students (Heilbronner, 2013; Karatza, 2019; Maeng, 2017); presenting the content in various modes using multimedia, and by supporting students individually and in groups (Karatza, 2019; Scalise, 2009; Siegle, 2014); facilitating content creation for teachers (Colombo & Colombo, 2007; De Lay, 2010); and offering several avenues for students to express their understanding (Heilbronner, 2013; Karatza, 2019; Maeng, 2017). On the other hand, from a student perspective, technology-enhanced DI is reported to result in 1) better student achievement in science (Haelermans et al., 2015; Zheng et al., 2014), 2) enhanced attitude towards learning (Collins, 2018), and 3) assisting students with special needs (Olsen, 2007; Shepherd & Alpert, 2015).

Yet, due to the emerging nature of this research area and the rapid advancements in technological solutions, teachers and TCs need training and professional support in technology-enhanced DI (Boelens et al., 2018; Karatza, 2019; Millen & Gable, 2016). Bellman et al. (2014) maintain that such training must be aimed at enhancing teachers' TPACK to advance their proficiency levels when it comes to integrating technology in their teaching practices.

6.1.4 TPACK

As an extension to PCK (Shulman, 1986), explained earlier, Koehler and Mishra (2005) add the technological knowledge construct and hence the TPACK framework. Thus, the three major constructs combined in this framework are technological knowledge (TK) – knowledge about technologies for use in teaching and learning; pedagogical knowledge (PK) – processes and methods of teaching and learning; and content knowledge (CK) – subject area understandings (Pringle et al., 2015). It is the intersection of the three types of knowledge that enables an effective integration of technology and hence moving beyond oversimplified approaches of technology use in teaching (Koehler & Mishra, 2009). Voogt et al. (2013) maintain that the TPACK framework enables better understanding of how teachers integrate technology in their practice to support student learning. In this study, the development of digital ECMs is centered around advancing TCs' TPACK in creating, choosing, and utilizing the resources.

6.2 TCs' Development of DVGs

TCs were tasked with designing and developing DVGs to teach STEM/science concepts. The analysis of TCs' design of the DVGs according to the CCP-RIP framework shows that TCs were able to successfully integrate DI principles and practices in their DVGs. In this chapter, TCs' best practices in technology-enhanced DI are showcased. For example, Angela and Robert created a DVG entitled "Spaceball" about projectile movement (Figure 26). The game displays a 2D field where the player, projectile, score, number of attempts remaining, and target are shown. The player adjusts how to launch the projectile from various angles, heights, and velocities while displaying these values. The screen also shows forces acting on the projectile such as gravity, wind, air resistance, and magnetic fields in numerical values and graphics. Level one consists of a simple projectile scenario in which the player is transported to the moon, and where they only need to consider gravity in their calculation. To level up, the player moves from the moon to Mars (gravity, bit of air resistance), then to Venus (lots of gravity, lots of air resistance) then Titan (gravity, wind, air resistance), and finally Earth (gravity, air resistance, wind, and magnetic field). Once the player successfully hits the target, the score is increased and an option to continue to the next level appears. If the player misses the target in a specific number of attempts, the game over screen will appear and the high score is recorded. The game is planned as a formative assessment for the kinematics unit in physics. It expands the player's knowledge on two-dimensional kinematics and allows them to connect their knowledge to various careers, such as correctly aligning explosive projectiles in the military, understanding the physics associated with throwing or kicking a ball as a professional sports player, or even space exploration and learning the different environment of each planet and accompany effects on objects.

Figure 26: Screenshots from the "Spaceball" DVG

As shown in Figure 26, Angela and Robert addressed the content differentiation in the "Spaceball" DVG by including three levels in the game with increasing difficulty in the concept explained, thus emphasizing scaffolding. They also addressed the product differentiation by providing varied assessment in each level. Furthermore, the DVG attends to students' profiles, especially cultural and racial diversity, by enabling students to choose the race and the shape of the avatar. Scaffolding is evident in this DVG, and additional support is offered to students, especially those who are at a lower readiness level. For example, struggling students can click for help if needed to obtain more hints and information. They can also use the toggle grid that would make their calculations easier. This game engages students with enjoyable sound effects and an interesting scenario that would increase secondary students' motivation. Additionally, the DVG offers instructions to students as written text and audio. Accordingly, students may choose what suits them better in terms of personal interest or learning need. Finally, the TCs created an accompanying sheet with specific follow-up questions that students can answer after playing the game, which also provides an additional phase for consolidating student understanding. Overall, this game is differentiated quite proficiently in terms of the content and product components, with several measures taken to address accessibility and variety in students' readiness, interests and profiles.

Scaffolding and differentiated assessments were also evident in another game developed by Nellie, who created an interactive quiz about kinematics and forces. A noteworthy additional aspect in this game is that students are provided with hints if they answer incorrectly. This strategy ensures effective scaffolding and hence better conceptual understanding as students move from one level to another.

Pam and Holly created a DVG about genetics (Figure 27). The objective of this game is for players to be comfortable differentiating between genotypes and phenotypes, and recessive and dominant traits. The game teaches students about homozygous and heterozygous traits and how Mendelian inheritance works. In each level, the player is provided with an offspring phenotype and must match that with the corresponding parents' genotypes. An extension to this task requires the player to create Punnett squares in determining offspring phenotypic and genotypic probabilities. Along the way, players are provided with embedded information describing each phenotype (e.g., disease). The goal is to answer all the questions correctly and achieve the highest score.

This DVG also attends to student diversity in terms of race and background and caters for students with specific needs through multimodal representation. In this game, students can either read or listen to the instructions. Moreover, the levels of difficulty address autosomal then sex-linked genes which requires a higher level of understanding and application. In all these DVGs students can work at their own pace and spend most or all their time on one of the levels, if needed. This measure showcases varied pacing for different academic levels of students which is crucial for differentiating the content. Finally, it is important to note that the games are very interactive, aesthetic, and integrates technology proficiently, although this was the first experience in coding to this extent for most of the TCs. In their description of the DVG, Pam and Holly stated the following:

> *Our DVG looks to include a pluriversal approach as it will require players to learn about disease distributions across different geographic regions and the different treatment options (e.g., Western medicine vs. Chinese medicine), to learn about different diseases and its distribution across different geographic regions. In terms of addressing equity, diversity, and inclusion, our game will showcase avatars with different appearances (e.g., race, body size, age group, eye color, etc.). We will address equity, diversity, and inclusion through providing differentiated instructions, multimodal instructions that accommodate different learning styles (i.e., using visuals, animations, written and voice-over instructions). In the game, we will ensure students' varied backgrounds and cultures are represented (pictures show people of different race, gender, age, and ethnicity).*

Pam and Holly provided a good introduction and clear instructions at the beginning of the DVG. This DVG highlights the importance of different levels of difficulty in differentiating the content, and the role of scaffolding students' knowledge in this regard. Students need to acquire sufficient understanding of autosomal genes before they address sex-linked genes. Furthermore, the game is aesthetically appealing which would engage students further in the learning process. Providing audio voiceover is an inclusive strategy that caters to the needs of a variety of students through multimodal representations. Overall, this game is differentiated to a very good extent in terms of the content component, with many measures taken to address accessibility and variety in students' readiness, interests, and profiles.

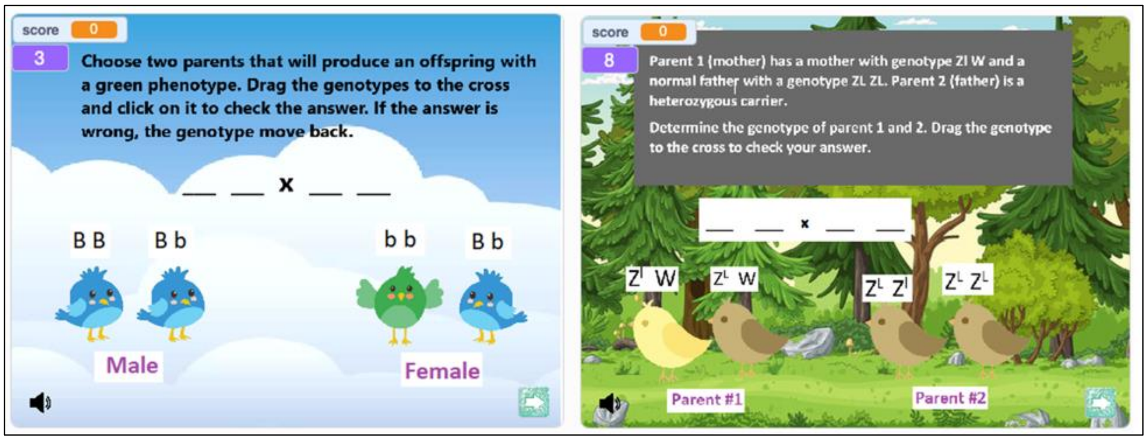


Figure 27: Screenshots from the "Genetics" DVG

Another example is a DVG, created by Gabe, on the topic of Projectile Motion (Figure 28). Figure 28-A highlights student choice, in terms of an avatar that reflects diversity (racial background, physical ability, skin color, gender, etc.) and EDI principles. Furthermore, different levels of difficulty are included in the game to attend to students' readiness levels. In this game, students can spend as much time as they want on a specific level before moving to another, which emphasizes different pacing for different students and the needed scaffolding to advance to higher levels of conceptual understanding.

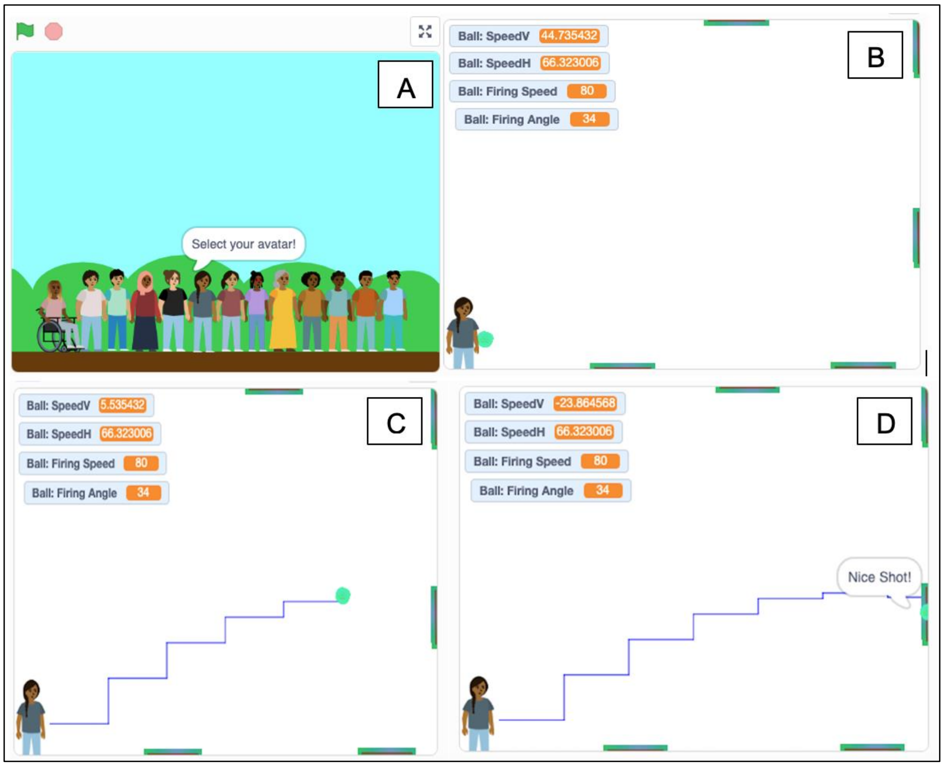


Figure 28: Screenshots from the "Projectile Motion" DVG

Finally, it is worth noting that several elements in the DVGs were planned to play a role in enhancing students' interest and engagement. This outcome was evident in Roy's DVG about chemical elements in the Periodic Table. As shown in Figure 29, Roy included several multimodal representations (audio, visuals, text, etc.) which are embedded within an interesting "solving a mystery" real-life scenario that would motivate secondary students. Students are kept engaged by searching for more elements with the inclusion of the reward element whenever they finish a level.

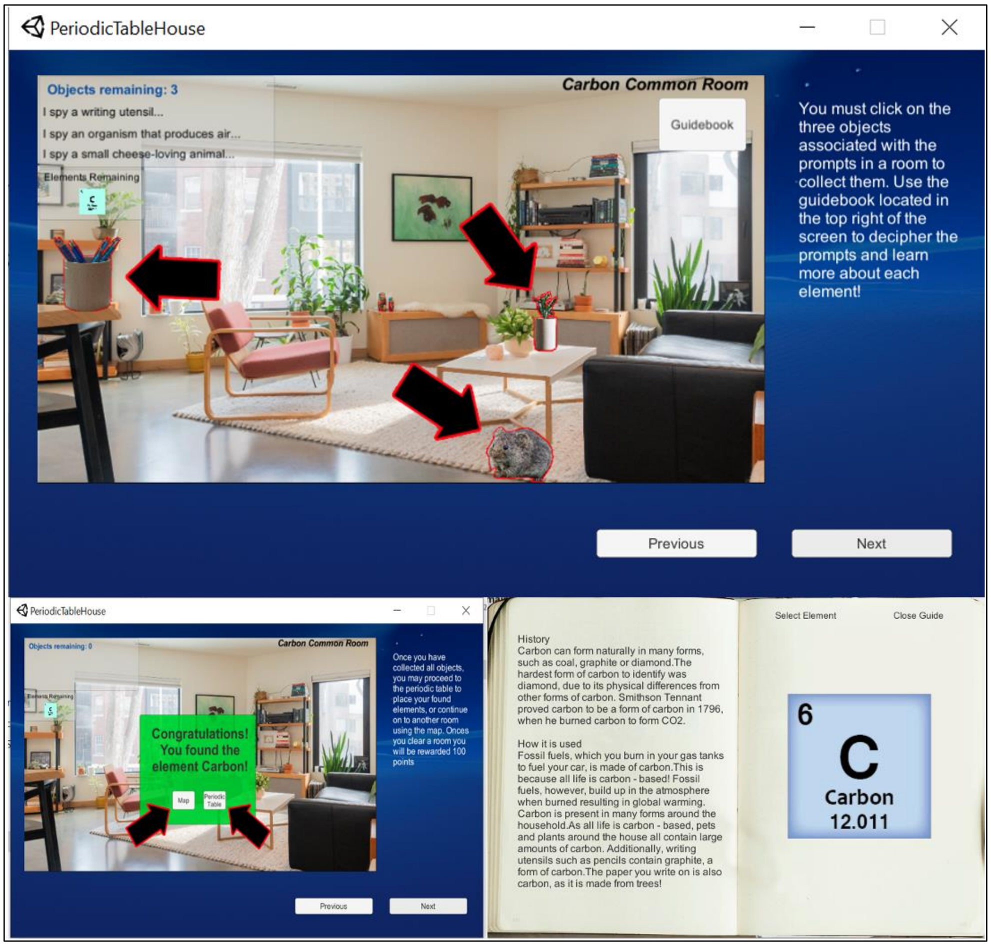


Figure 29: Screenshots from the "Periodic Table" DVG

Overall, TCs' DVGs reflect adequate levels of understanding of DI principles and practices, and also demonstrate how technology can facilitate DI. In differentiating the content, DVGs include increasing levels of difficulty that require higher levels of understanding of the concepts or application, in different contexts from prior levels. In planning these levels, scaffolding is emphasized which highlights an attention to the zone of proximal development (Vygotsky, 1978). Furthermore, DVGs allow students to work independently at their own pace, based on their readiness levels. Pacing is an important aspect of content differentiation that enables students to spend more time on specific aspects of the lesson if they need to. As such, students are not working in a "one size fits all" approach. This measure provides struggling students with additional time to comprehend the concepts, and at the same time provides advanced students with challenging tasks that match their intellectual abilities. This action would ensure that all students of different readiness levels are engaged in the classroom.

Another feature of the DVGs is the ability to provide additional optional support for students who need it. For example, this support is feasible through providing the gridline option for students who need it for better calculation of the angle or having a "Help" button for students to click if they require hints to tackle a problem. Finally, in terms of content differentiation, several TCs included informative introductions to the concepts, with some of them including links to available online resources that students can visit before starting the game. This practice takes into consideration students' prior knowledge and makes use of many available online resources that students can consult if they need additional assistance while playing the DVG. This add-on feature facilitated by technology is important as the teacher's time and effort during class can be dedicated to coaching or facilitating rather than providing factual information to students. In these roles, teachers can move among different groups of students posing questions and emphasizing conceptual understanding and application of the concepts and advancing students' higher order thinking levels.

In terms of process differentiation, the DVG can be used as a tool to differentiate the process of teaching, if combined with other teaching strategies. On its own, the DVG can include multimodal representations (audio, visuals, text, etc.) that would increase students' engagement and interest. Such visualization of concepts in real-life scenarios increase students' interest and understanding. Additionally, the DVGs included rewards that play an important role in increasing students' interest and competitiveness to achieve better by playing the DVG and progressing through the levels.

Pertaining to product differentiation, several DVGs offer the ability to conduct diagnostic assessment through guided questions, hence considering students' prior knowledge before the game commences. Additionally, formative assessments are more feasible at each level in DVGs, which requires completion before advancing to another level. Finally, DVGs offer the possibility for feedback by providing hints to students after incorrectly answering a question. These are practical examples of how assessments for learning, of learning, and as learning can take place utilizing one digital tool.

It is worth noting that in addition to these differentiation possibilities with respect to students' readiness and interest levels, DVGs are also particularly adequate in differentiating according to students' profiles. DVGs offer space to represent various students' backgrounds, genders, and abilities through avatar selections. As such, students would feel represented and valued. Additionally, DVGs can include information about specific ways of knowing or cultural contributions in a specific scientific domain while offering additional information about the concept. On the other hand, DVGs can provide additional support for ELLs or students with exceptionalities through audio voice-over or written text. Thus, DVGs offer several opportunities to differentiate the instruction taking into consideration students' readiness, interests, and profiles. Overall, many of the aforementioned advantages are facilitated by technology, which reiterates its importance in differentiating instruction in STEM classrooms and calls for further research to explore the full potential of technology in facilitating DI.

6.3 DI in STEM Curriculum Resources Websites

Each TC was tasked with creating a section of a STEM curriculum resources website incorporating a variety of teaching and assessment resources, with an emphasis on digital resources. TCs addressed DI principles in general in more than one section of their website such as the lesson plans, teaching strategies, assessment methods, societal implications, and foundations of professional practice.

In all websites, TCs showed adequate to high inclusion of DI principles and strategies, utilizing a wide array of creative and engaging tools. Overall, TCs' work shows that they were able to prepare lessons and compile a great number of resources while integrating a DI framework. As shown in Table 5, TCs demonstrated differences in their understanding and proficiency integrating DI in their resources, with some TCs showing a greater depth and variety in their DI-focused strategies. Moreover, their individual work was accompanied by peer feedback and sharing of resources which further advanced their expertise in this regard.

Despite individual differences between TCs, common features of DI were evident across the websites, facilitated by the sections required for the assignment. For instance, all TCs were required to include common student misconceptions related to their chosen science unit and researched specific strategies to address those misconceptions. Accordingly, TCs acknowledged student prior knowledge and expected levels of understanding and considered this item in their planning – an important feature in content differentiation. Second, the lesson sequence included five lesson plans, which enabled TCs to utilize a wide variety of teaching and assessment strategies – an important feature in process and product differentiation. Third, TCs were required to include sections for numerous student-centered and creative teaching strategies, ideas, and resources and assessment methods, which exposed them to a wide array of multimodal resources that are mostly digitally enriched to include in their lesson plans. All of these sections enabled students to attend to student differences in academic achievement levels, interests, cultural backgrounds, SES, linguistic abilities, and special needs. Finally, the societal implications section encouraged the TCs to explore how to include various topics related to EDI principles in their lessons in a profound manner. In this section, most TCs were capable of linking their science topics to equity matters, cultural differences, and social justice issues by highlighting real-life related scenarios.

In addition to the aforementioned common findings, Table 5 presents the analysis of a sample of five websites according to the CPP-RIP framework. These samples highlight novice, proficient and exemplary approaches in terms of how TCs incorporated DI in their websites. Each column highlights how TCs integrated specific strategies to differentiate each of the content, the process, and the product according to students' readiness, interests, and learning profiles. Table 5 is followed by screenshots from TCs' work to showcase how they integrated DI in their websites. Out of the 18 websites analyzed, five were selected to depict variation in TCs' levels of DI implementation by the end of the course. For instance, Jan and Pam showed an exemplary level of DI implementation. On the other hand, Roy and Nellie demonstrated a proficient level, while Robert reflected a novice level of DI implementation.

Table 5: Analysis of a Sample of TCs' STEM Curriculum Resources Websites

TC	Unit, Subject, and Class	Content Differentiation	Process Differentiation	Product Differentiation
Jan (Exemplary Level)	Sustainable Ecosystems and Human Activity-Science Grade 9	• In the Societal Implications, students are asked to explore and critically analyze articles on the disproportionate impact of climate change on developing countries, how wealthy consumption threatens species and habitats in developing countries, and relationship between environmental sustainability and poverty reduction is strong • In the lesson plans section, each lesson has the ability to be conducted in a digital way and utilize digital technology such as Google Read and Write to allow students of all capabilities to access the learning	• Students can choose to learn through videos, knowledge-based lectures by the teacher, simulations, debates, articles, case studies, experiments, hands-on activities, inquiry-based activities, and various other methods of learning • Students may work individually or in groups to work on independent or collaborative learning practices • Used rotating learning centers/stations • Used flexible grouping for various activities: randomization, mixed ability grouping, homogenous grouping, or heterogenous grouping	• Adopted a "low floor, high ceiling" approach, in which students are able to show what they know through any form of assessment • Students are offered choice for demonstrating their knowledge to be engaged and achieve their highest learning potential • Planned multiple assessment strategies for, as, and of learning across all lessons (e.g., lab reports, debates, literacy questions, worksheets for simulations, graphic organizers: Placemat, compare contrast, etc.) • Included rubrics for summative assessments • Included many virtual options for assessments e.g., Mentimeter, Plickers, Quizlet, and Socrative

Pam (Exemplary Level)	Cellular Biology-Biology Grade 11	• Culturally relevant content, e.g., how diets are influenced by culture and SES • Extending learning through a group research activity about the four macromolecules • Discussed how equity affects health (transgender hormone therapy, diabetes in urbanized areas) • Research about the historical discoveries: contributions of scientists of colour and women • Scaffolding students' learning by reviewing background knowledge • Familiarized ELLs with key-terms before the start of content explanation	• Included variety of active teaching strategies that are student-centered: simulations about diffusion, case studies, biochemistry memes, hands-on building macromolecules, etc. • Included learning through multimodalities: videos, songs, discussion, graphic organizers, pictures, and/or other tools to cater for different interests and learning profiles • Student choice in activities • Planned independent thinking activities (e.g., KWL charts) and group work (e.g., discussions or group activities)	• Different forms of assessments for students: provided through a list of suggestions, with other ideas are open to consideration. For example, options to present research on organelle function include a rap, poem, song, skit, poster, graphic organizer... Students are able to choose the medium • Included in the lesson plans varied forms of assessment *for* learning, assessment *as* learning, and assessment *of* learning • Rubrics included within each lesson
Roy (Proficient Level)	Microbiology Biology Grade 11	• In the creative piece, Minecraft DVG, students can customize their characters and represent themselves, hence accommodating to students of many different nationalities and races.	• Used a variety of tools and techniques such as YouTube videos, digital video games, readings, group discussion, and online research	• Students are given the opportunity to choose how to present material they research: Group PowerPoint presentation, verbal presentation of their research, or a written report

		• Highlighted the differences in gut microbiome between people of different nations • Highlighted contributions from female scientists	• Emphasized on collaborative work in various planned activities	• Planned diagnostic activities at the beginning and exit tickets at the end of the sessions • Planned multiple assessment strategies for, as, and of learning across all lessons
Nellie (Proficient Level)	Electric and Magnetic Fields- Physics Grade 12	• Included online dictionaries, translators, speech-to-text apps for students with special needs and ELLs • Highlighted scaffolding according to students' needs • Challenging content offered for advanced students	• Emphasized inquiry-based teaching and learning • Included cooperative learning formats: alternating sitting, peer helps, share-in-pair, and small group activities • Included interactive animations and simulations	• Included a diagnostic quiz to check prior knowledge levels and for students to overview their strengths and weakness • Included interactive evaluations like self-checks with Quizzet and Gizmos • Differentiated assessments with increasing difficulty • Included a variety of formative and summative assessments
Robert (Novice Level)	Gravitational Fields- Physics Grade 12	• Included resources that shows non-Western contribution to science such as the views obtained from a Chinese-made spacecraft • Emphasis on conceptual understanding	• Provided a variety of multimodal resources for students to choose what suits their learning needs • Included many videos, charts, and interactive simulations.	• The only aspect of differentiation included is varying the level of questions in the provided worksheets (knowledge based, application, and analysis)

In this section, samples from TCs' websites are illustrated to document the analysis presented in Table 5. For example, TCs included a wide variety of multimodal resources to differentiate the process. This form of differentiation is evident in Jan's website about Sustainable Ecosystems and Human Activity (Figure 30) and Pam's website about Cellular Biology (Figure 31).

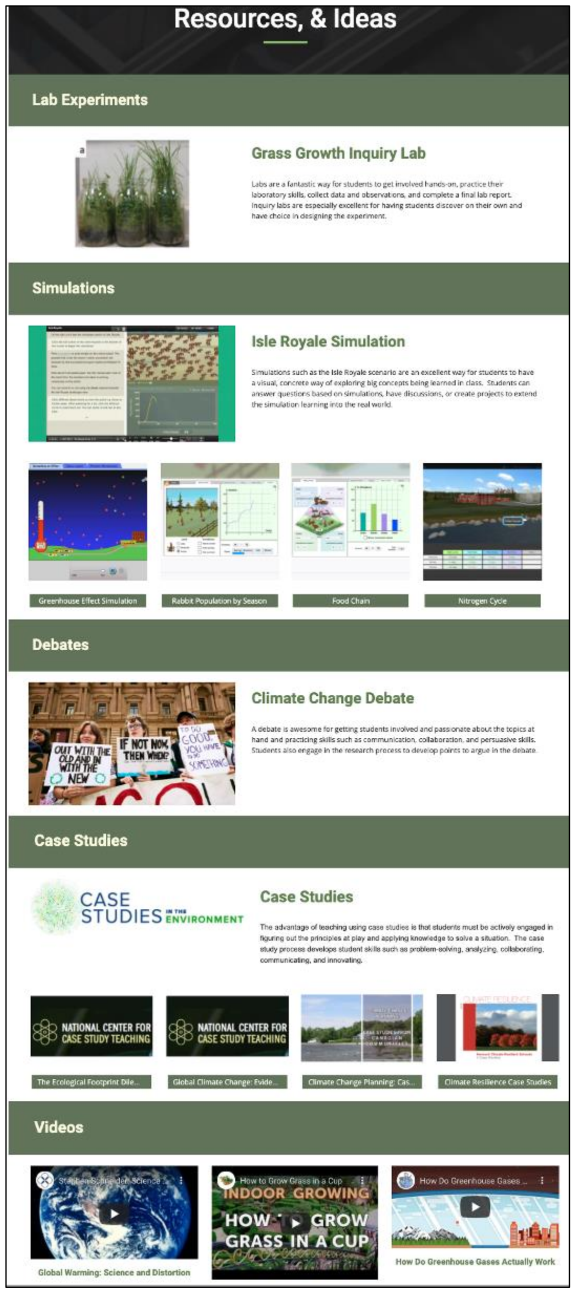


Figure 30: Screenshot of Jan's Website – Teaching Strategies Section

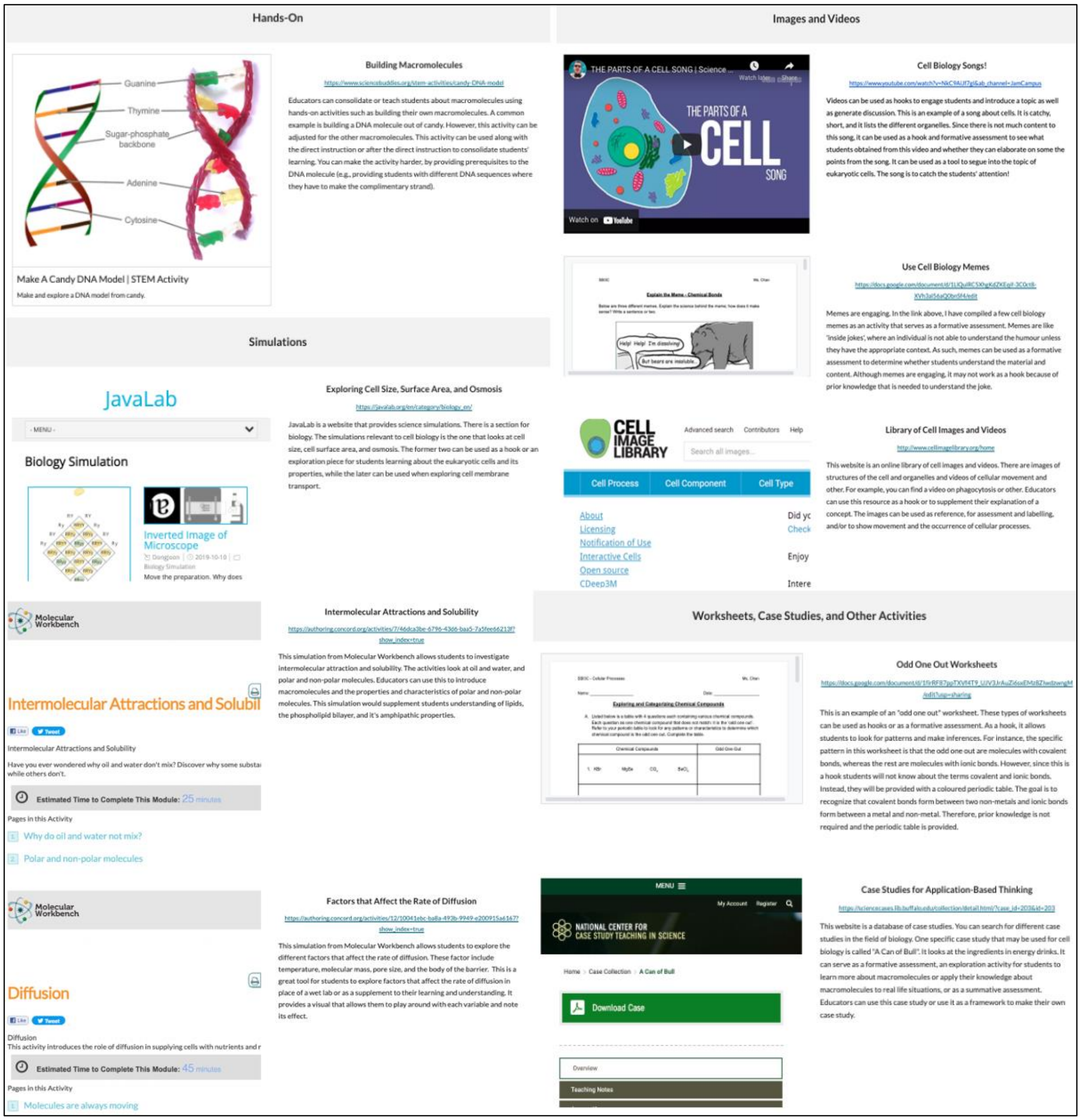


Figure 31: Screenshot of Pam's Website – Teaching Strategies Section

With respect to the product differentiation, Pam included many choices for students in the assessment tools section in her website on Cellular Biology (Figure 32). This sample shows how TCs integrated various assessment strategies for learning, as learning, and of learning. Gabe's website about Energy Changes and Rates of Reactions (Figure 33) shows an example of how to make use of technology to assess students and enable them to reflect on their knowledge. Accordingly, a specific form of grouping as well as varying the instructional pace can follow based on students' readiness and learning profiles.

Lesson 1 - Exploring Chemical Bonds

Assessment *of* Learning

- odd one out worksheet
- practice questions as a part of the direct instruction on Google Jamboard
- research activity on Google Slides about the interaction of shampoo with water and oil
- chemistry meme worksheet

Lesson 2 - Introduction to Macromolecules

Assessment *for* Learning

- class discussion and debrief following a video about "we are what we eat"
- hands-on building macromolecule activities (4 activities, 1 per macromolecule)

Assessment *of* Learning

- case study about the ingredients in a granola bar

Lesson 3 - Exploring the Organelles of Plant and Animal Cells

Assessment *for* Learning

- class discussion and debrief following a song about organelles
- research and present in groups about the functions of the organelles
- group Q+A research activity and class discussion

Assessment *as* Learning

- KWL chart

Lesson 4 - The Types of Transport Across the Cell Membrane

Assessment *for* Learning

- think-pair-share about why cells are so small
- digital video game on cell membrane transport
- practice questions within direct instruction
- dry lab worksheet about factors that affect the rate of diffusion

Assessment *of* Learning

- pre-recorded video of groups role-playing the different methods of cell membrane transport

Figure 32: Screenshot of Pam's Website – Assessment Strategies Section

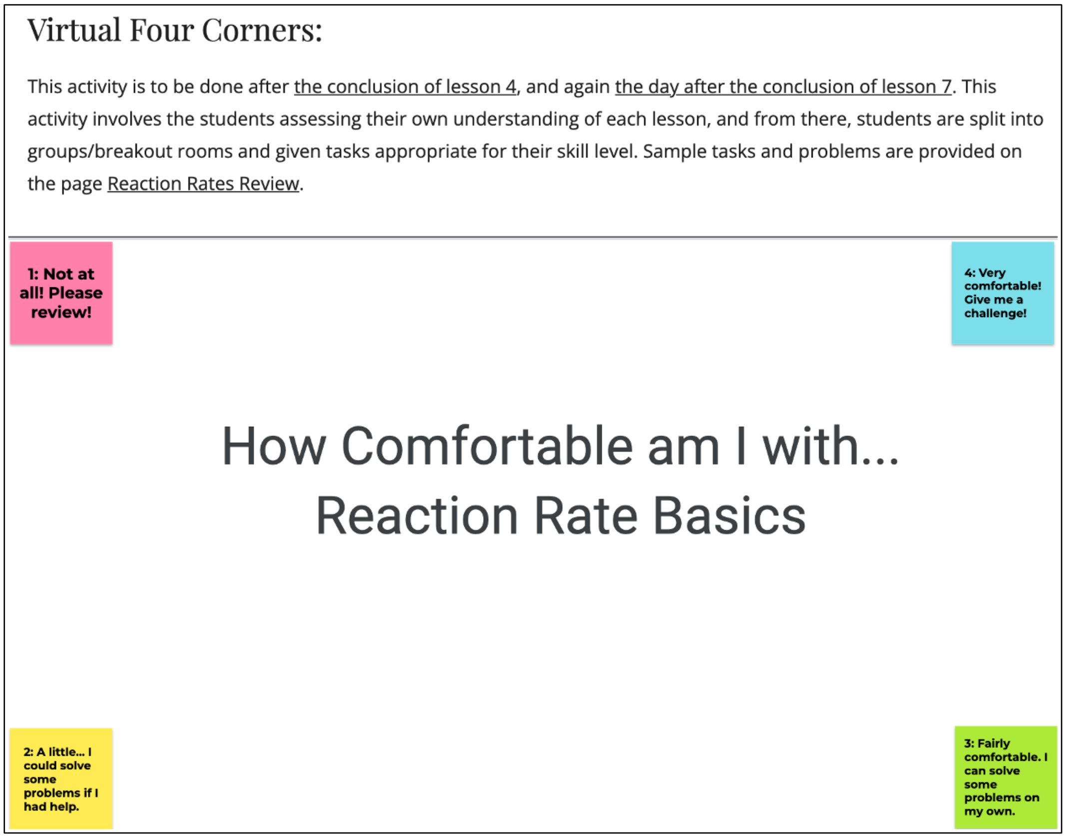
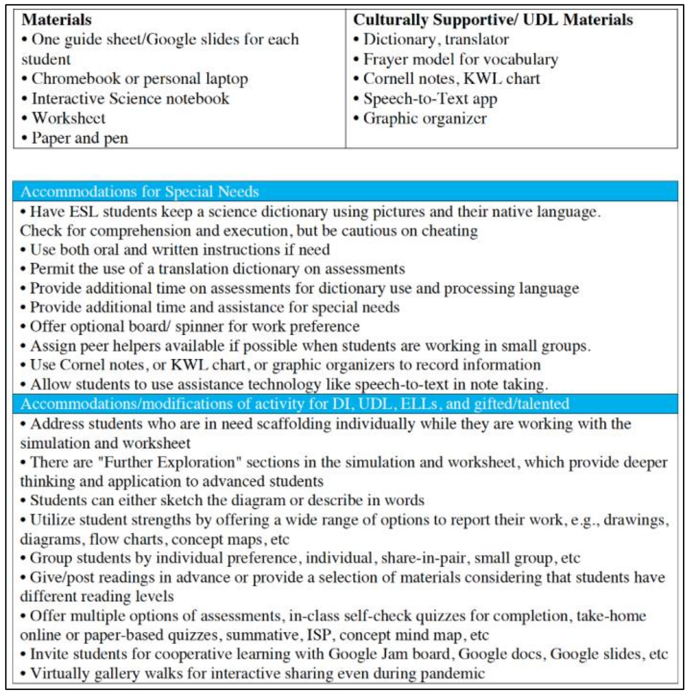


Figure 33: Screenshot of Gabe's Website – Assessment Strategies Section

TCs' commitment to integrate DI in their planning and attend to student differences was also reflected in other website sections. For example, Angela included a section on EDI on the front page of the website although this was not a requirement. Moreover, all Nellie's lesson plans included a section on culturally responsive teaching and accommodating students with special needs, ELLs, different academic levels (Figure 34).



Materials	Culturally Supportive/ UDL Materials
• One guide sheet/Google slides for each student • Chromebook or personal laptop • Interactive Science notebook • Worksheet • Paper and pen	• Dictionary, translator • Frayer model for vocabulary • Cornell notes, KWL chart • Speech-to-Text app • Graphic organizer

Accommodations for Special Needs
• Have ESL students keep a science dictionary using pictures and their native language. Check for comprehension and execution, but be cautious on cheating • Use both oral and written instructions if need • Permit the use of a translation dictionary on assessments • Provide additional time on assessments for dictionary use and processing language • Provide additional time and assistance for special needs • Offer optional board/ spinner for work preference • Assign peer helpers available if possible when students are working in small groups. • Use Cornel notes, or KWL chart, or graphic organizers to record information • Allow students to use assistance technology like speech-to-text in note taking.

Accommodations/modifications of activity for DI, UDL, ELLs, and gifted/talented
• Address students who are in need scaffolding individually while they are working with the simulation and worksheet • There are "Further Exploration" sections in the simulation and worksheet, which provide deeper thinking and application to advanced students • Students can either sketch the diagram or describe in words • Utilize student strengths by offering a wide range of options to report their work, e.g., drawings, diagrams, flow charts, concept maps, etc • Group students by individual preference, individual, share-in-pair, small group, etc • Give/post readings in advance or provide a selection of materials considering that students have different reading levels • Offer multiple options of assessments, in-class self-check quizzes for completion, take-home online or paper-based quizzes, summative, ISP, concept mind map, etc • Invite students for cooperative learning with Google Jam board, Google docs, Google slides, etc • Virtually gallery walks for interactive sharing even during pandemic

Figure 34: Screenshot of Nellie's Website – Lesson Plans Section

6.4 Discussion

This chapter captured how the STEM course supported TCs to design ECMs while integrating DI principles and practices. The analysis of TCs' work according to the CPP-RIP framework showed that TCs were able to design lesson plans and curriculum resources that are differentiated in content, process, and product. Compared to the case studies assignment, TCs showed significant improvement in the level of DI integration especially in terms of content and product. This improvement may be due to two reasons: 1) the feedback TCs received on the case study assignment, and 2) the nature of the ECMs which afforded DI integration to a greater extent due to their increased variation. Since this assignment was a culminating task in which TCs compiled a wide collection of resources for an entire unit in science, they were able to integrate more DI strategies. By creating and choosing ECMs focused on DI, TCs were able to address one of the most significant challenges that hinder DI implementation, that is, the availability of resources (Adlam 2007; Griful-Freixenet et al. 2021; Paone, 2017). The availability of these resources and TCs' mastery in developing relevant differentiated lesson plans can potentially reduce the required time for TCs' lesson planning in the future, which is also a common challenge reported by teachers for incorporating DI (Adlam, 2007; Brevik et al., 2018; Paone, 2017). TCs' ability to plan for differentiated content and product also addresses a major gap in teachers' practice as reported in the literature (Griful-Freixenet et al. 2021; Kendrick-Weikle, 2015; Rollins, 2010). On the product differentiation specifically, Griful-Freixenet et al. (2021) indicate that the ongoing assessment construct is the most important predictor for DI and other inclusive pedagogical practices. Accordingly, TCs need to master the design and implementation of different types of assessments that must be ongoing and integrated with instruction in teacher education.

Previous studies have documented the need for training both pre-service and in-service teachers to enhance their understanding and implementation of DI. For instance, Paone (2017) indicates that teachers have positive perceptions of DI, but several challenges hinder its implementation such as the lack of PD, required planning time, and lack of resources. Adlam (2007) maintains that the majority of teachers are familiar with DI and its strategies. Yet, they are not fully confident to use it as they need more resources and more knowledge of its tools. Garrett (2017) on the other hand indicates that self-efficacy is important for DI implementation, and that teachers often do not implement DI in their classrooms because they perceive it as too challenging. Similarly, studies with pre-service teachers and beginning teachers also report on the lack of DI implementation. Casey and Gable (2012) state that beginning teachers are more likely to be more confident in implementing surface-level differentiation rather than deep-structure differentiation. Additionally, Brevik et al. (2018) indicate that student teachers lack confidence in implementing DI, although they appreciate its importance. Thus, the positive outcomes in this study indicate that the STEM course and accompanying DI resources enhanced TCs' self-efficacy toward DI and understanding of it, which was reflected in their ability to utilize their conceptions in developing ECMs that focus on DI and integrate DI principles and practices in the content, process, and product of their teaching.

TCs' success in designing DI-focused ECMs reiterate the importance of PD in enhancing the implementation of DI for both in-service teachers (Paone, 2017; Taylor, 2018) and TCs (Casey & Gable, 2012; Rollins, 2010). The findings of this study are aligned with several recommendations to enhance TCs' preparation for DI. For example, Brevik et al. (2018) recommend that teacher education needs to offer more opportunities for TCs to practice differentiation. Similarly, Dack et al. (2019) stress the importance of supporting novice teachers in developing a practical vision of DI enactment rather than only a theoretical overview. Additionally, Dee (2010) reports a lack of preservice teacher education in the area of differentiation and suggests that TCs need explicit instruction and guidance in implementing differentiation skills. Findings of this study demonstrated TCs' ability to create a wide variety of DI-focused ECMs and related planning and affirms the need for and the importance of similar explicit training around DI to enhance TCs' self-efficacy, understandings, and thereby implementation of DI.

This chapter addressed the RQ 2c) *What models of technology-enhanced DI do TCs incorporate in their lessons?* Acknowledging the importance of digital literacy, and the potential of technology-enhanced DI, TCs were asked to integrate technology in their DI-focused ECMs. Analysis of TCs' work revealed the high level of digital literacy involved in the creation of DVGs and the STEM curriculum resources websites. Utilizing these resources in future classrooms would also enhance students' digital literacy. The collected resources address two dimensions in Ng's (2013) digital literacy framework: the technical dimension (operational literacy, critical literacy) and the cognitive dimension (information literacy, multiliteracies). One of the positive outcomes observed in TCs' work is their enhanced TPACK framework, which enabled them to choose digital resources and plan how to use them effectively. These competencies captured by TPACK are crucial in a 21st century classroom and aligns with recommendations calling for enhancing TCs' preparation to integrate technology in their practice and advance their TPACK levels (e.g., DeCoito & Richardson, 2018; Ebenezer et al., 2012; Ng, 2013).

Finally, it is important to note that TCs' work on DVGs and digital resources in the STEM curriculum websites corroborates research findings on the potential of technology for facilitating DI in secondary science classes (Heilbronner, 2013; Maeng, 2017). Levels in the DVGs, accompanying scaffolding, and multiple ways of presenting the content for students with different academic levels support research findings that new technologies can tackle content differentiation by modifying the instructional pace thus sparing time for teachers to work with gifted and/or struggling students (Heilbronner, 2013; Karatza, 2019; Maeng, 2017). Planning resources in ways that cater for student interests and backgrounds, combined with utilizing a STEM framework align with Milman et al.'s (2014) assertion that technology can offer various choices of the same content for students to engage with, and integrate content from various subjects in an interdisciplinary approach. Furthermore, the adopted strategies by TCs to differentiate the process using multimodalities; the wide array of simulations and animations addressing conceptual understanding; and the content creation by TCs also confirm research findings highlighting the importance of technology in process differentiation (De Lay, 2010; Colombo & Colombo, 2007; Karatza, 2019; Scalise, 2009; Zheng et al., 2014). Finally, the product differentiation evident in various forms of assessments utilizing digital solutions also corroborates research on how technology can help teachers offer several ways for students to express their understanding and keep the assessment ongoing, flexible, and interactive (Heilbronner, 2013; Karatza, 2019; Kassissieh & Tillinghast, 2014; Maeng, 2017). Therefore, based on the discussion technology seems inevitable in terms of offering appropriate opportunities for teachers to facilitate DI, thereby enhancing teachers' TPACK and students' digital literacies.

6.5 Chapter Summary

This chapter explored how TCs create ECMs that are both DI-focused and digitally enriched. Findings of this chapter address the following RQs: *How do TCs develop curricula to be inclusive of DI strategies?* and *What models of technology-enhanced DI do TCs incorporate in their lessons?* Through the analysis of TCs' course work, specifically a sample of four DVGs and five STEM curriculum resource websites using the CPP-RIP framework, it was evident that most TCs were able to proficiently integrate DI practices in digital ECMs. Technology has the potential to enhance DI by multiple ways including facilitating pacing variation for different students, presenting the content in different formats, integrating multimodalities, utilizing engaging and student-centered technological solutions such as animations and simulations that promote conceptual understanding, and by facilitating different forms of assessment.

Chapter 7

7 Conclusion

This research explored intermediate-secondary STEM TCs' teacher education training in terms of their views, understandings, and implementation of DI. The study highlighted the impact of integrating DI-focused strategies in a STEM curriculum and pedagogy course in teacher education at a Canadian university by 1) exploring how DI is understood and practiced by STEM TCs in Ontario; and 2) studying the impact of the course on STEM TCs' views, understandings, and implementation of DI.

The study addressed four main RQs:

1) What are intermediate-senior STEM TCs' views and understandings of DI?

2) a) How do TCs develop curricula to be inclusive of DI strategies?

   b) What successes and challenges do TCs encounter when developing DI-focused curricula?

   c) What models of technology-enhanced DI do TCs incorporate in their lessons?

3) How do TCs implement DI in their practicum?

4) What are TCs' intentions to integrate DI in their future careers?

The study adopted a mixed-method approach (Creswell & Creswell, 2018), specifically a case study (Yin, 2014). The study involved 19 intermediate-senior TCs in a curriculum and pedagogy course in STEM education. DI principles and strategies were integrated through seminars, assignments and resources using an explicit and reflective approach (Abd-El-Khalick & Lederman, 2000). Both quantitative and qualitative data were collected. Data sources include: 1) pre- and post-course questionnaires exploring TCs' views, understandings, and implementation of DI; 2) semi-structured interviews and post-practicum open-ended survey detailing TCs' implementation of DI in the course and their practicum; and 3) TCs' course work analysis which includes three major assignments, specifically case studies on SSI, DVGs, and STEM curriculum resources websites.

In this chapter, I consolidate the conclusions by addressing the RQs and present the research limitations and implications, as well as future research areas.

7.1 Conclusions

7.1.1 Impact of the Course, Successes, and Challenges

RQ1. What are intermediate-senior STEM TCs' views and understandings of DI?

Prior to the course, TCs had varied levels of exposure to DI principles and practices in some of their courses and practicum experiences (Section 4.1.1). TCs' initial views toward the importance of DI were generally adequate and positive. Research revealed that the effectiveness of the typical opportunities usually provided to TCs in teacher education program courses is debatable due to perceived lack of specific STEM contextualization, relevance, practical approach, and coherence among different courses or teacher education program components. Moreover, the emphasis on DI happens mostly in special education courses which in turn is impacting TCs' understanding of the applicability of inclusive practices in all conditions. Additionally, TCs have reported a lack of exposure to governmental policies such as Ontario's Education Equity Plan (2017), which reflects a disconnect between policy and practice. The results reiterate D'Intino and Wang's (2021) findings that the coursework in teacher education programs in Canadian universities is not sufficient to prepare TCs for DI. Results also relay the importance of the coherence between various courses within teacher education programs and between the coursework and the practicum experiences to ensure that TCs attain the expertise required to differentiate instruction in their future classes (Dack, 2019b; Massouti, 2019). Thus, the prior preparation of TCs provided an additional rationale for offering them contextualized and extensive training around DI, similar to the one offered in this STEM course with DI-focused integration.

The course played a pivotal role in enhancing TCs' views and self-efficacy (Bandura, 1993) toward DI with TCs expressing positive insights about the importance of DI and its benefits to students (Section 4.2.1). TCs also showed an improvement in their views that DI is applicable and feasible, and thereby more confidence, motivation, and willingness to implement it in the future. Additionally, the course positively impacted TCs' understandings of DI, with deeper and more profound understanding of the principles of DI, its applications in the classroom, and familiarity with strategies for process differentiation, and to a lesser extent for content and product differentiation (Section 4.2.2). Furthermore, TCs reflected on their improved ability to integrate DI practices in their course assignments (Section 4.3). This result highlights the positive impact of the course on their professional knowledge related to DI, and hence adequate preparation of teachers to implement DI in their future practices.

RQ3. How do TCs implement DI in their practicum? And RQ4. What are TCs' intentions to integrate DI in their future careers?

TCs reported implementation of DI strategies in the practicum after the course ended (Section 4.4), as well as clear and detailed intentions to practice DI in their future classrooms (Section 4.6.2). This result shows that providing training in an explicit reflective approach has helped TCs transfer their knowledge and skills to various contexts and made them more conscious of addressing EDI principles in their teaching. This finding highlights the positive impact of the course on their 1) learning, 2) PCK (Shulman, 1986) around DI, 3) professional knowledge, and 4) retention of DI knowledge and skills. These findings also confirm the direct relationship between teachers' self-efficacy and mindset on one hand and implementation of DI on the other hand. Despite these positive outcomes, instructors are advised to provide opportunities to dispel misconceptions that DI is individualized instruction and that it is an approach for students with special needs. Knowing that TCs' prior preparation on DI was mostly in special education courses, as indicated earlier, this concept must be addressed deeply in future research.

RQ2b. What successes and challenges do TCs encounter when developing DI-focused curricula?

In addition to the general positive impact of the course on TCs' views, understandings, and implementation of DI, TCs elaborated on specific successes (Section 4.5.1). They found the course helpful in 1) providing them with extensive knowledge about DI, 2) providing them with tools and resources to implement DI in their practicum and future classes, 3) motivating them to implement DI, 4) enhancing their confidence implementing DI in the future, and 5) making use of what they learned in this course in other courses and in their future practices. TCs expressed that the most helpful components and strategies in the course that prepared them to use DI included: learning community with peers, quality of resources provided, the holistic teaching approach and design of the course, course specificity and relevance, and the feedback provided (Section 4.5.2).

While some research studies show that novice teachers express less willingness to implement DI due to various challenges (Garrett, 2017; Rollins, 2010; Wertheim & Leyser, 2002), the STEM course with DI-focused elements highlights the importance of PD opportunities aimed at enhancing TCs' views, understandings, implementation of DI, and future career intentions. The STEM curriculum and pedagogy course adopted an intensive and explicit reflective approach in teaching about several elements, as well as DI through rounds of discussion, feedback about TCs' course work, and scaffolded course tasks to ensure advancement in TCs' understanding and skill mastery. The adopted strategies were rooted in socio-cultural learning theories and based on communities of practice through resource and expertise sharing. These collaborative strategies positively impacted TCs' self-efficacy and professional knowledge related to DI. This benefit calls for adopting similar training approaches in other courses in teacher education programs to ensure that DI principles and strategies are deeply understood and proficiently practiced by TCs. This finding is in accordance with research highlighting the importance of DI-focused training in teacher education programs on TCs' views, self-efficacy, and mindset toward DI (Coubergs et al., 2017; Goodnough, 2010; Wan, 2016), understanding of DI (Dack, 2018; Goodnough, 2010), and implementation of DI (Adlam, 2007; Wan, 2017).

Finally, challenges encountered and anticipated by TCs are worth noting (Sections 4.3.3, 4.4.4, and 4.6.3). Initially, TCs, mentioned time needed for preparation; resources; admin-related reasons such as support, funding, class size, and PD; student factors such as engagement and interest or special needs; teacher knowledge or skills; and online teaching during the pandemic as potential challenges that hinder DI implementation. In the post-survey TCs reflected on the challenges they faced while trying to implement DI in their course assignments. Two main themes emerged as challenges from eight TCs' responses: 1) specific content knowledge or skills related to an assignment, and 2) unknown students in the case of course assignments or having too many differences to account for in one classroom. In contrast to those reported in the literature such as the lack of teachers' knowledge or skills in DI (Adlam, 2007), low teacher motivation (Garrett, 2017; Rollins, 2010; Wertheim & Leyser, 2002), and lack of resources (de Jager, 2017; V. Park & Datnow, 2017; Turner & Solis 2017; Wan, 2017), the reported challenges do not reflect deep or profound obstacles that would impact TCs' implementation of DI in the future. Thus, when comparing TCs' pre-course survey reflections about the expected challenges to those in the post-course survey, the previously identified themes related to resource availability and TCs' knowledge and skills in implementing EDI strategies were not significant. The stated challenges at the end of the course revealed that resources and strategies provided by the course helped TCs surpass the perceived obstacle of preparing resources that reflect DI principles. The major challenge of being able to differentiate the instruction in online teaching environments warrant further research, especially post-COVID-19 pandemic, given online teaching and learning is gaining traction.

7.1.2 TCs' Development of Curriculum Focused on DI

RQ2a. How do TCs develop curricula to be inclusive of DI strategies?

Two chapters explored how STEM TCs developed curriculum to be inclusive of DI strategies using case studies on SSI, DVGs, and STEM resources websites. In the first assignment, TCs developed curriculum by creating case studies on SSI. TCs demonstrated proficient integration of DI principles in most of the domains and sub-criteria of the adopted DI matrix, with TCs differentiating the process most followed by the product of learning yet showing a need for more training in content differentiation in order to attend to students' needs, backgrounds, and academic levels (Section 5.4). These results are in accordance with the literature indicating that the content and product differentiation are the least understood by teachers, while differentiating the process is relatively more understood and implemented (Rollins, 2010; Turner & Solis, 2017).

Furthermore, the overall analysis of the case study assignment indicates that case studies on SSI are highly effective tools to differentiate instruction, especially since they present multiple perspectives and opposing arguments on debatable topics (Ekborg et al., 2009; Levin, 1995) and allow multiple levels of analysis and interpretation (Levin, 1995).

In the other two assignments, TCs developed ECMs with a simultaneous focus on DI and technology-enriched resources. In the DVGs, TCs showed adequate levels of understanding and implementation of DI principles and practices, especially content differentiation (Section 6.2). In differentiating the content, DVGs included increasing levels of difficulty highlighting scaffolding and varied pacing based on students' readiness levels. In terms of process differentiation, the DVGs included multimodal representations; yet they are required to be combined with other teaching strategies to ensure adequate differentiation. In terms of product differentiation, DVGs offered the room for diagnostic assessment before the game commences through guided questions as well as formative assessments and feedback throughout the levels. Additionally, the DVG offered space to represent various students' backgrounds, genders, and physical abilities through avatars involved in the game. Thus, DVGs offer several opportunities to differentiate instruction especially the content, taking into consideration students' readiness, interests, and profiles.

In the curriculum resources' websites TCs showed adequate to high inclusion of DI principles and strategies utilizing a wide array of creative tools (Section 6.3). TCs' work demonstrate that they were able to prepare lessons and compile numerous resources while integrating a DI framework. TCs addressed common student misconceptions, acknowledged students' prior knowledge, utilized a wide multimodal variety of engaging teaching strategies, and included various forms of diagnostic, formative, and summative assessment methods. TCs addressed student differences in academic achievement levels, interests, cultural backgrounds, SES, linguistic abilities, and special needs. TCs were also capable of linking their science topics to equity matters and social justice issues by highlighting real-life related scenarios. In agreement with the analysis of their course work, the majority of TCs stated in the post-survey that the curriculum resources website assignment was the most relevant to differentiate instruction when compared to other assignments.

The analysis of TCs' work according to the CPP-RIP framework showed that TCs were able to design lesson plans and curriculum resources that are differentiated in content, process, and product. By doing so, this research addresses the most pressing challenges that hinder DI implementation as reported by teachers, such as availability of resources (Adlam 2007; Griful-Freixenet et al. 2021; Paone, 2017), required time for lesson planning (Adlam, 2007; Brevik et al., 2018; Paone, 2017), and ability to plan for differentiated content (Griful-Freixenet et al. 2021; Kendrick-Weikle, 2015; Rollins, 2010). It is important to note that the three assignments were helpful in different ways, which is also a scaffolding approach used by the TCs. TCs were trying different DI approaches in each assignment and choosing what was of particular relevance. For instance, the case studies enabled TCs to take diversity and different perspectives into consideration. DVGs are of specific significance in differentiating the difficulty levels, scaffolding, and considering diversity and inclusion in race, gender, etc. On the other hand, the websites enable TCs to apply all their acquired knowledge and skills about DI to create teaching and assessment resources. Both the wide variety and required depth of DI implementation in various course tasks ensured an adequate exposure of TCs to various forms of DI. Thus, the course has addressed an important need for training TCs to enhance their understanding and implementation of DI (Casey & Gable, 2012; Rollins, 2010), by specifically offering them more practical and explicit opportunities to practice differentiation (Brevik et al., 2018; Dack et al., 2019; Dee, 2010).

RQ2c. What models of technology-enhanced DI do TCs incorporate in their lessons?

Finally, this study addressed how technology-enhanced DI can be incorporated in lessons and ECMs. The analysis of TCs' work reveals the high level of digital literacy involved in the creation of the DVGs and the websites and corroborates research findings on the potential of technology facilitating DI in secondary science classes (Heilbronner, 2013; Maeng, 2017), which would thereby result in enhancing teachers' TPACK and students' digital literacies.

7.2 Limitations

This study provides rich description of TCs' DI views, understandings, and implementation in the course from several data sources, thus ensuring data triangulation. Yet, the major limitation pertains to TCs' implementation of DI in their practicum and future practices. This limitation is due to the fact that this research relies on TCs' self-reporting to describe their practicum implementation of DI. Future research can further explore this aspect by observing TCs in their practicum to provide them with feedback and attain a more comprehensive understanding of their practices. Moreover, one of the limitations is the short duration of TCs' practicum after the course (six weeks) and the fact that TCs do not have full autonomy in the practicum since the classes are led by their associate teachers. This duration may not be enough for TCs to adequately implement all the strategies they would like to integrate. Accordingly, and to attain a clearer view of TCs' retention and implementation of the concepts, future research can entail a longitudinal design in which TCs can be followed in their first year(s) of teaching to assess the long-term retention and explore their success and challenges in teaching settings where they have full autonomy. Furthermore, one of the major challenges encountered in this study was the COVID-19 pandemic which led to the 12-week course being offered online. This shift required several amendments to the original course plan and affected the flow of the course to a certain extent. Finally, one of the study limitations is that many of the participants were not able to take part in the follow-up phase (post-practicum survey and interview) after the course ended. This limitation has not affected the rigor of the findings. Yet, having all the participants in all the phases of the study would have provided a more comprehensive and detailed view of the long-term impact of the course. Moreover, in general, the pandemic added a huge burden on TCs and can thus be perceived as a stressor that may have affected TCs' level of involvement in the study as well as the quality of work they produced.

7.3 Implications

This research advances knowledge about DI as an inclusive pedagogical practice. The adopted explicit, reflective, contextualized, and intensive approach of training is of great benefit to STEM/science teacher education programs as it addresses a gap in the literature related to preparing STEM TCs at the secondary level on how to address student diversity in their future classrooms. The study resulted in the development of a DI implementation framework, with an emphasis on Ontario's equity policies. This framework can be utilized in PD for in-service teachers and for TCs in teacher education programs. For example, TCs can use this framework to reflect on the level of integration of EDI practices in their coursework. Teacher educators can also refer to this framework to assess TCs' course work and provide them with relevant feedback.

STEM TCs in this study were provided with rich opportunities to engage with DI as a form of PD that enhanced their views, understandings, and implementation of DI. Thus, this research has the potential to equip STEM teachers and TCs with practical tools to differentiate their instruction and contribute to EDI in their classrooms by showcasing exemplary differentiated STEM curriculum resources and strategies – a major challenge to differentiating instruction in secondary classrooms. This implication is of particular importance as many educators perceive it to be challenging to integrate DI and broader EDI principles in STEM subjects, when compared to languages or humanities where open discussions occur more frequently. Additionally, this research informs teacher educators, heads of departments, and curriculum designers about practical measures to include DI practices in their trainings, as they may perceive the findings relevant to their future plans. This implication is of particular and timely importance as most teacher education programs are currently striving to integrate equitable and inclusive pedagogies in their curriculum and overall planning. The study shows that EDI practices such as DI must and can be woven into all requirements of teacher education programs. Teacher educators can integrate EDI principles and practices in an organic approach in all courses and program requirements, rather than restricting those principles to inclusive education or special education courses only. The study also informs policy makers and school administrators about the successes and challenges of similar PD initiatives, in the hopes that more of these PD programs are implemented with in-service teachers to revitalize their teaching practices. Now more than ever, and after the COVID-19 pandemic, schools must convene to adopt a curriculum that embraces diversity and 'walk the talk' surrounding equity and inclusion.

7.4 Future Research

Based on the study findings and limitations, future research can focus on how to develop strategies related to content and product differentiation specifically, which were noted as challenging for TCs in the early phases of the study. Moreover, future research can explore how inclusive practices such as DI and UDL can be integrated together into the design of all teacher education courses. This measure would help TCs and teachers contextualize these approaches as practices that are not restricted to special need students. Furthermore, research can follow-up with TCs or in-service teachers on the implementation of planned teaching strategies in their classes to attain the full picture of the real-life successes and challenges of the developed DI-focused curriculum arising from this study. Further research can also investigate the impact of the proposed DI strategies on students' performance and attitudes in STEM secondary classrooms. Finally, future research can focus on how to address DI in an online environment, especially that online teaching and learning will be more prevalent in the future. This study has shown how technology has the potential to facilitate DI. Yet, additional research is warranted to explore how technology can be employed and investigate teachers and students' experiences. On a related note, future research can also explore how the most recent trends in technology such as virtual reality, artificial intelligence, and other immersive technologies can facilitate DI and enrich students' experiences in diverse classrooms, assuming equitable access to these technologies.

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Appendices

Appendix A: Ethics Approval

Western Research

Date: 5 May 2020

To: Dr. Isha DeCoito

Project ID: 114831

Study Title: Science Pre-Service Teachers' Understandings and Implementation of Differentiated Instruction in Ontario High Schools

Short Title: DI Understanding and Implementation

Application Type: NMREB Initial Application

Review Type: Delegated

Full Board Reporting Date: June 5 2020

Date Approval Issued: 05/May/2020

REB Approval Expiry Date: 05/May/2021

Dear Dr. Isha DeCoito

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the WREM application form for the above mentioned study, as of the date noted above. NMREB approval for this study remains valid until the expiry date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Appendix B: Letter of Information and Consent

Project Title
Science Pre-Service Teachers' Understanding and Implementation of Differentiated Instruction in Ontario High Schools

Document Title
Letter of Information & Consent TCs

Principal Investigator + Contact
Dr. Isha DeCoito

Additional Research Staff + Contact
Mohammed Estaiteyeh, PhD Candidate

1. Invitation to Participate
You are being invited to participate in this research study about science teachers' understanding and implementation of differentiated instruction in Ontario high schools because you are currently a Year-2 science teacher candidate in a teacher education program at a university in Ontario, Canada.

2. Why is this study being done?
This study will explore how differentiated instruction (DI) is understood and implemented by science teacher candidates (TCs) in Ontario. The study will focus on five research questions: 1) What are secondary science pre-service teachers' views and understandings of DI? 2) How do TCs develop and implement the curriculum to be inclusive of DI strategies? 3) What successes and challenges do TCs face when developing and implementing DI focused curriculum? 4) What models of assessment, inclusive of technology, do TCs incorporate in assessing DI focused lessons? and 5) What are the impacts of DI on students' outcomes, as observed by TCs in their practicum?
The main problems addressed by this research are the fact that most of the research on DI has been done in literacy and mathematics for primary, junior, and intermediate classes. Hence, more information is needed about the applicability of DI in secondary science classes. In addition, research mostly indicate that teachers perceive DI as a difficult teaching approach and hesitate to implement corresponding strategies in their classrooms. Finally, research on teachers' implementation of DI in Ontario schools is scarce. Thus, we lack understanding about DI in the context of Ontario schools and teacher education programs.

3. How long will you be in this study?

It is expected that your time commitment in the study will be two hours. This will comprise: 15 minutes to complete an online Qualtrics pre-questionnaire, 30 minutes to complete an online Qualtrics post-questionnaire, and 15 minutes to complete an online Qualtrics questionnaire after your practicum. If you agree to participate in a follow-up interview, you will be required to dedicate an additional 60 minutes of your time. Thus, the maximum required commitment for participating in the study is 2 hours. All other activities will be part of the regular STEM/Science course you are enrolled in, and hence no extra time commitment is required on your part.

4. What will happen during this study?

All Year 2 TC participants in the STEM/Science course who have provided consent will be invited to complete an online pre-questionnaire at the beginning of their course. The pre-questionnaire items will explore TCs' understanding and views about DI. The STEM/ Science course will include a 3-hour seminar that is focused on DI, as well as assignments. This strategy is aligned with the Ontario Ministry of Education policies and practices. TCs will develop curriculum, develop and present micro-lessons, and a STEM project incorporating DI strategies.

At the end of the STEM/Science course, TCs will complete an online post-questionnaire, to check for any changes in their understandings and views about DI, in addition to their implementation of DI in their course.

Following TCs' practicum they will participate in a short online questionnaire, to explore the implementation of DI in their practicum. TCs who volunteer to participate in the follow-up interview will engage in a 1-hour audio-taped semi-structured interview. TCs will also be invited to share their course work as part of the study. This will include: 1) curriculum developed by TCs, such as concept lesson plans that are part of the course requirement; 2) micro-lessons which are class presentations; 3) a STEM project; and 4) peer evaluation. The course work will comprise data as they will be analyzed to determine the extent to which TCs explicitly incorporate DI into their curriculum development and practice.

5. What are the study procedures?

The research assistant Mohammed Estaiteyeh will visit the STEM/Science classes where instructors agreed to implement DI in their course at the beginning of Year-2 of the program. He will explain the study to the TCs, and they will be invited to ask questions about the study. Thereafter, the LOI will be shared with them, and consent will be obtained. Mohammed Estaiteyeh will be collecting all consent forms; hence, the STEM/Science course Instructors will not know which TCs are participating in the study.

For consenting TC participants, they will be invited to complete a 5-point Likert scale online pre-questionnaire (administered through Qualtrics online survey software). This questionnaire is composed of 15 questions will take up to 15 minutes to complete. The pre-questionnaire will explore TCs' initial understandings and views about DI. Thereafter, the Instructor will introduce DI through a seminar. DI will be integrated in assignments, and resources throughout the course. All TCs, regardless of their status with respect to the study, will be involved in all class activities, assignments, and regular teaching. The integrated DI material will be given to everyone in the course. There are no additional learning or assessment-related expectations from consenting TCs.

The course will include tailored tasks that require the application of DI principles and strategies. Course work will include micro-lessons taught by TCs to their peers, curriculum development in the form of concept lesson plans, a STEM project, and peer evaluations. All tasks will integrate DI at some level.

Observations will be conducted by the research assistant Mohammed Estaiteyeh. TCs will be observed while they present their micro-lessons and projects (regular components of their coursework). This will be done to check for the integrated DI components in their coursework using a designed rubric.

TCs who consent to participate in the study will be invited to share their course work with the researcher for analysis. The provided lesson plans, projects, presentations, and micro-lessons will be analyzed by the researcher. In addition, peers will be asked to evaluate each other during their presentations and micro-lessons. The peer evaluation rubrics/ protocols will also be analyzed. Only the consenting TCs' coursework will be analyzed (not their students'). Consenting TCs will be submitting an extra copy of their course work (artefacts) to the research assistant after submitting to the course instructor. This way, the research assistant will not request any copies from the instructor. The identities of participating TCs will thereby not be revealed to the instructor.

By the end of the STEM/Science course, TCs will be invited to complete a 5-point Likert scale online post-questionnaire (administered through Qualtrics online survey software) in order to explore changes in their views and understandings of DI. This questionnaire includes 39 questions and will require 30 minutes to complete and focuses on their understandings and implementation of DI as well as DI assessment throughout the course.

TCs who agree to participate in a 1-hour follow-up semi-structured interview will be contacted by email to arrange a time for either a face-to-face interview or an audio-conference using the "Zoom" application (both will be audio-recorded, with consent). The interview will follow-up on their responses in the pre-/post-questionnaires, in addition to few questions about their course work. The interview protocol is basically derived from the questionnaire. It will explore in greater depth certain elements of the questionnaire, such as details of how they understand and implement DI. The interviews will be transcribed by Mohammed Estaiteyeh. TCs who volunteer to be interviewed will be invited to contact the researcher to obtain the transcripts of their interviews and will also be sent a primary analysis of their data once the data analysis is performed (using Western University data management system: OWL).

By the end of Year-2 of the program (which includes TCs' practicum), TCs will be asked to complete an online post-questionnaire (administered through Qualtrics online survey software) to explore the details of the implementation of DI in the practicum and their reflections. This questionnaire includes 18 questions (5-point Likert scale and short-answer questions) and will require around 15 minutes to complete. The questions focus primarily on their implementation of DI as well as DI assessment, successes, and challenges.

6. What are the risks and harms of participating in this study?
There are no known or anticipated risks or discomforts associated with participating in this study.

7. What are the benefits of participating in this study?
Participating in this study will provide TCs with rich opportunities to engage with DI as a form of professional development, as well as additional support throughout their course in the form of teacher conferences, project development, and feedback on their work. Participants who take part in the study will enhance their understanding and implementation of differentiated instruction as a teaching approach. This will provide them with the chance to explore other teachers' practices which will play a role in their professional development and have a positive impact on their teaching practices.

In addition to the personal benefits, this research will advance knowledge about DI. It will inform policy makers and school administrators about the challenges that hinder DI implementation. Also, curriculum designers will be able to use the results to help teachers practice DI. Findings will be disseminated through publishing papers, conference presentations, and seminars with the education community especially the science teachers, heads of departments, school administrators, and teacher education programs across Ontario. This will have a positive impact on science teaching practices in general.

8. Can participants choose to leave the study?

a- Questionnaire:

- If you decide to withdraw from the study, you may do so at any time by exiting the questionnaire window.
- If you decide to withdraw from the study after your survey responses have been submitted, you have the right to request withdrawal of information collected about you (by email). You will be able to withdraw your information after one month of the survey completion. After that, the researchers will be unable to withdraw your data due to data analysis procedures.

b- Follow-up Interviews:

- If you decide to withdraw from the study, you may do so at any time by exiting the interview audio-conference "Zoom" window, or by stating this to the researcher if you choose the face-to-face interview option.
- If you decide to withdraw from the study after your interview has been recorded, you have the right to request withdrawal of information collected about you (by email). The related files will be deleted from Western University's Data Management System (OWL). You will be able to withdraw your information after one month of the interview completion. After the one-month period, the researchers will be unable to withdraw your data due to data analysis procedures.

9. How will participants' information be kept confidential?

9.1. Access to Information:

Participants' survey responses will be collected through a secure online survey platform called Qualtrics. Qualtrics uses encryption technology and restricted access authorizations to protect all data collected. In addition, Western's Qualtrics server is in Ireland, where privacy standards are maintained under the European Union safe harbour framework. The data will then be exported from Qualtrics and securely stored on Western University's server.

All digital data: audio recordings, digital documents obtained from TCs, and digital field notes taken by the researcher will be stored and saved on the same day using Western University's Data Management System (OWL). The data will not be stored on any personal device overnight.

All identifiable information, such as your: name, contact information, classes and subjects taught, highest degree, university name, and school location will be collected separately from study data and linked only by a unique ID code which will be assigned to you by the research team. The research assistant will assign a unique code (ID) to consenting TCs to be used in the surveys and all other collected coursework materials.

The master list linking your study ID and your identifiable information will only be available to the researchers. If the results of this study are published, only de-identified information will be made available. Your identity as a research participant in this project will not be released.

The email address will be needed to contact teacher candidates to agree on a time for the interview. Also, the email will be needed for communication through OWL which the TCs will use to send their coursework material. The research assistant will not be contacting consenting TCs during, before, or after course time, to avoid revealing to the instructor participating TCs. This is why the email will be requested in the consent form.

If the primary investigator in this study is your course instructor, he/she will not know who the participants are in this study and will not have any access to your information, until the course grades are published. Mohammed Estaiteyeh will be dealing with all the details in terms of obtaining consent, conducting the interviews, administering the questionnaires, and analyzing your submitted work.

Representatives of Western University's Non-Medical Research Ethics Board may require access to your study-related records to monitor the conduct of the research.

9.2. Identifiable information:

The following information are mandatory fields in the survey: the university, the school geographical area, the classes and subjects taught in the practicum. These are demographic information that are important for correlation with survey answers. The name of the university is also needed to evaluate the effectiveness of the intervention at each university as one group. The field "highest degree" is not mandatory but is needed for correlation with the study findings.

Only the researchers will have access to this data, as explained earlier. The results from the survey will be used for statistical analysis, and hence there will be no disclosure of specific cases in the dissemination. Thus, the identification of individual participants will be impossible. All digital data: audio recordings, digital documents, and digital field notes will be stored and saved on the same day using Western University's Data

Management System (OWL). The data will not be stored on any personal device overnight.

The identity of the participants will be known to the researchers only. First, all transcriptions will be completed by the researcher. Hence, the information will not be shared with any external party. Second, the findings will be presented using pseudonyms for the participants and their universities. This will maintain confidentiality. Knowing the number of teacher education programs in Ontario, it is nearly impossible for readers to link the data and identify the participants or their universities in the final report/dissertation.

9.3. Sharing the Information:
None of the identifiable information will be shared with others outside the study team. For the interviews, the identifiable information will be replaced with pseudonyms, and hence will not be shared with others outside the study team. The original collected data and documents will not be shared with others outside the study team.

9.4. Keeping Identifiable Information:
The researcher will keep all personal information about you in a secure and confidential location for 7 years. A list linking your study number/pseudonym with your name [and other identifiers, such as contact information and university information] will be kept by the researcher in a secure place, separate from your study file. Since all the information is digital, it will be stored using Western University's Data Management System (OWL) and will be deleted after 7 years. Only the researchers will have access to the stored information.

9.5. If the results of the study are published in any journal or conference presentation, your name and university name will not be used.

9.6. Personal quotes from the interviews, micro-class observation, and curriculum documents will be used within the publication. The quotes will not reflect any identifiable information as they will be deidentified.

9.7. Future use of data:
The future use of the data by researchers from outside the research team will not be permitted.

10. Are participants compensated to be in this study?
You will not be compensated for your participation in this research.

11. What are the rights of participants?
Your participation in this study is voluntary. You may decide not to be in this study. Even if you consent to participate you have the right to not answer individual questions or to withdraw from the study at any time. If you choose not to participate or to leave the study at any time it will have no effect on your performance, grade or employment status.
You do not waive any legal right by consenting to this study.
We will give you any new information that may affect your decision to stay in the study.

12. Whom do participants contact for questions?
If you have questions about this research study, please contact:

Dr. Isha DeCoito

Mohammed Estaiteyeh

If you have any questions about your rights as a research participant or the conduct of this study, you may contact The Office of Human Research Ethics (519) 661-3036, 1-844-720-9816, email: ethics@uwo.ca. This office oversees the ethical conduct of research studies and is not part of the study team. Everything that you discuss will be kept confidential.

13. Consent
Survey: Submitting the online survey is an indication of your consent to participate. This consent will be confirmed by checking a consent box at the beginning of the questionnaire.

Follow-up Interview: Joining the online audio conference is an indication of your consent to participate. This consent will also be confirmed orally at the beginning of the interview. This will be documented by having the interviews recorded through “Zoom”. If you choose to participate in a face-to-face interview instead, you will sign a written consent form.

This letter is yours to keep for future reference.

Written Consent Form

Project Title
Science Pre-service Teachers' Understanding and Implementation of Differentiated Instruction in Ontario High Schools

Document Title
Appendix A-Letter of Information & Consent TCs

Principal Investigator + Contact
Dr. Isha DeCoito, Associate Professor

Additional Research Staff + Contact
Mohammed Estaiteyeh, PhD Candidate

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.
□YES □NO
I agree to be audio-recorded in this research.
□YES □NO
I agree to have my course work and curriculum documents collected in this research.
□YES □NO
I consent to the use of unidentified quotes obtained during the study in the dissemination of this research.
□YES □NO
I agree to have my indirectly identifiable information; e.g. highest degree, class taught, and course taught used in the dissemination of this research.
□YES □NO

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Name of Participant	Signature	*Date (DD-MM-YY)*

Please indicate your email address: ---

My signature means that I have explained the study to the participant named above. I have answered all questions.

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Name of Person Obtaining Consent	Signature	*Date (DD-MM-YY)*

Appendix C: Pre-Questionnaire

DI Pre-Questionnaire Teacher Candidates
Project Title: Science Pre-Service Teachers' Understanding and Implementation of Differentiated Instruction in Ontario High Schools

*: Question can't be skipped

Q1 Please indicate your unique ID (given code).*

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Q2 Indicate your highest degree earned.
o Bachelors
o Masters
o Doctorate

Q3 Indicate the location of your assigned school for the practicum.*
o Central Ontario (Toronto, York, Peel…)
o East Ontario (Ottawa, Cornwall, Kingston, Peterborough…)
o West Ontario (Hamilton, London, St. Catharines, Waterloo, Windsor…)
o North Ontario (Nipissing, Parry Sound, Manitoulin, Timiskaming, Sudbury, Algoma, Cochrane, Thunder Bay, Rainy River, Kenora…)
o Not assigned yet

Q4 What class(es) are you placed in for the practicum? Please select all that apply.*
▢ Grade 9
▢ Grade 10
▢ Grade 11
▢ Grade 12
▢ Not assigned yet

Q5 What "STEM" subject(s) do you teach? Please select all that apply.*
▢ Biology
▢ Chemistry
▢ Earth and Space Sciences
▢ Environmental Sciences
▢ Physics
▢ General Sciences
▢ Math
▢ Technology/Computer Studies
▢ Other; Please indicate

Q6-16 Understanding of Differentiated Instruction: The questions below address your understandings and beliefs, and not your practices. Please answer these questions in reference to the context of secondary classes in Ontario schools.

	Strongly disagree	Somewhat disagree	Unsure	Somewhat agree	Strongly agree
I would describe my differentiated instruction understanding/knowledge as "Extensive"					
I can define and explain the term "differentiated instruction".					
Differentiated Instruction is individualized instruction.					
Differentiated Instruction is an approach for only students with special needs or certain disabilities.					
I believe that differentiated instruction is beneficial for students.					
Teachers should take into consideration all student differences when planning their lessons.					
I am familiar with at least 3 ways to differentiate the subject content for my students.					
I am familiar with at least 3 ways to differentiate my teaching strategies.					
I am familiar with at least 3 ways to differentiate my assessment strategies.					
It is okay that different students reach different levels of understanding and/or attain different skills regarding the same concept. Every student should work towards their own highest potential.					

Q17 Have you ever read the Equity plan issued by the Ministry of Education in 2017?
o No
o Yes. If yes, please elaborate on your understanding of the plan.

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Q18 Have you ever read the Differentiated Instruction handbook and/or its accompanying online resources issued by the Ministry of Education in 2010?
o No
o Yes. If yes, please elaborate on your understanding of the handbook.

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Q19 How would you describe the amount of resources at your disposal to assist you in differentiating instruction and being inclusive in your classroom?
o No resources available
o Minimal resources
o A fair amount of resources
o A great amount of resources

Q20 Reflect on any professional development you've had that would assist you teach through the lens of equity, diversity, and inclusion (e.g. students of various needs, academic levels, backgrounds etc...) in your future classes. Please describe. Was your experience effective?

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Q21 Based on your knowledge and personal experiences (such as the practicum and other), list some challenges that you anticipate would hinder the implementation of differentiated instruction or other inclusive strategies in your classes.

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Q22 Based on your knowledge and personal experiences (such as the practicum and other), list the advantages and successes of the implementation of differentiated instruction or other inclusive strategies in your classes.

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Appendix D: Post-Questionnaire

DI Post-Questionnaire Teacher Candidates
Project Title: Science Pre-Service Teachers' Understanding and Implementation of Differentiated Instruction in Ontario High Schools

*: Question can't be skipped

Q1 Please indicate your unique ID (given code).*
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Q2 Indicate your highest degree earned.
o Bachelors
o Masters
o Doctorate

Q3 Indicate the location of your assigned school for the practicum.*
o Central Ontario (Toronto, York, Peel…)
o East Ontario (Ottawa, Cornwall, Kingston, Peterborough…)
o West Ontario (Hamilton, London, St. Catharines, Waterloo, Windsor…)
o North Ontario (Nipissing, Parry Sound, Manitoulin, Timiskaming, Sudbury, Algoma, Cochrane, Thunder Bay, Rainy River, Kenora…)
o Not assigned yet

Q4 What class(es) are you placed in for the practicum? Please select all that apply.*
▢ Grade 9
▢ Grade 10
▢ Grade 11
▢ Grade 12
▢ Not assigned yet

Q5 What "STEM" subject(s) do you teach? Please select all that apply.*
▢ Biology
▢ Chemistry
▢ Earth and Space Sciences
▢ Environmental Sciences
▢ Physics
▢ General Sciences
▢ Math
▢ Technology/Computer Studies
▢ Other; Please indicate

Q6-16 Understanding of Differentiated Instruction: The questions below address your current understandings and beliefs, and not your practices. Please answer these questions in reference to the context of secondary classes in Ontario schools.

	Strongly disagree	Somewhat disagree	Unsure	Somewhat agree	Strongly agree
I would describe my differentiated instruction understanding/knowledge as "Extensive"					
I can define and explain the term "differentiated instruction".					
Differentiated Instruction is individualized instruction.					
Differentiated Instruction is an approach for only students with special needs or certain disabilities.					
I believe that differentiated instruction is beneficial for students.					
Teachers should take into consideration all student differences when planning their lessons.					
I believe that differentiated instruction is feasible and applicable.					
I am familiar with at least 3 ways to differentiate the subject content for my students.					
I am familiar with at least 3 ways to differentiate my teaching strategies.					
I am familiar with at least 3 ways to differentiate my assessment strategies.					
It is okay that different students reach different levels of understanding and/or attain different skills regarding the same concept. Every student should work towards their own highest potential.					

Q17-23 Implementation of Differentiated Instruction: The questions below address your practices as a teacher candidate in the course assignments, and not only your beliefs.

	Strongly disagree	Somewhat disagree	Unsure	Somewhat agree	Strongly agree
I would describe my differentiated instruction implementation as "Extensive".					
Students in my classes differ significantly in their backgrounds, academic skills, achievement levels, and/or attitude/motivation towards the subject.					
My understanding of all student differences impacts my teaching. I take deliberate efforts to create an environment that supports and values students' differences.					
I differentiate the content of the lesson by using three or more of the following or other strategies: (offering choices regarding where students can begin, extending the knowledge/ skills of advanced learners, providing supplemental support to candidates with difficulty, presenting the content at varying levels of complexity, reflecting students' interests or experiences, eliminating curricular material for some students, adjusting the pacing of instruction…)					
I differentiate the process of the lesson by using three or more of the following or other strategies: (offering multiple modes of learning, varying the instructional strategies, providing visual					

supports to my students, providing different prompts and cues, using flexible grouping, using independent study, using interest centers...)					
I allow my students to play a role in designing/selecting their learning activities.					
I use technology as a tool for differentiating my instruction.					

Q24-32 Assessment of Differentiated Instruction: The questions below address your practices as a teacher candidate in the course assignments, and not only your beliefs.

	Strongly disagree	Somewhat disagree	Unsure	Somewhat agree	Strongly agree
I pre-assess students before instructing (diagnostic assessment).					
I assess during the unit to measure understanding (formative assessment).					
I assess at the end of the lesson to determine knowledge acquisition (summative assessment).					
I differentiate my assessment tools by using three or more of the following or other strategies: (varying the types of assignments/assessments, providing students with choices for expression of their understanding, providing tiered assignments, utilizing rubrics that match varied ability levels, using student learning contracts...)					
I enable students to actively assess their own learning.					
I make use of the on-going assessments for forthcoming instructional planning.					

I evaluate the effectiveness of my teaching adjustments (e.g., monitor subsequent achievement and progress).					
I evaluate every student based on their improvement during the semester.					
I make use of technology in assessing my students.					

Q33-38 The questions below address the Differentiated Instruction seminar you had in this course. This includes the first presentation, provided resources, and all the accompanying support throughout the course.

	Strongly disagree	Somewhat disagree	Unsure	Somewhat agree	Strongly agree
The course provided me with extensive knowledge about differentiated instruction.					
The course provided me with tools and resources to implement differentiated instruction in my practicum and future classes.					
The course motivated me to implement differentiated instruction in my practicum and future classes.					
I am more confident implementing differentiated instruction in the practicum and future classes after this course.					
I will use the knowledge and skills provided by the course to implement differentiated instruction in my future teaching.					
I have made use of what I learned in this course in other courses I'm currently taking.					

Q39 Please indicate the value or the benefit of the following course components in terms of preparing you to differentiate your instruction in the future.

	Inadequate	Average	Excellent
The holistic teaching approach of the course (including the variety of offerings)			
The specific presentation on differentiated instruction			
The ongoing assessments and feedback offered			
Pacing/ time given to complete the assignments/tasks			
Level of support and guidance received from the instructors			
Learning community with peers; including class discussions, group work, and peer feedback			
Quality of resources provided (multimedia...)			
Case Studies Task			
Digital Game Task			
Curriculum Resources Website Creation Task			
Other course components; Please specify the most helpful ones:			

Q40 Which assignment in this course was the most relevant to differentiate instruction in? How did you achieve this?

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Q41 Describe the impact of the course on your teaching philosophy in terms of differentiated instruction and equity, diversity, and inclusion practices.

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Q42 Explain some of the challenges you faced while trying to integrate differentiated instruction and equity, diversity, and inclusion practices in your course assignments.

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Q43 List some teaching skills that still need improvement or reinforcement despite the material offered in this course (related to differentiated instruction and equity, diversity, and inclusion practices).

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Appendix E: Post-Practicum Questionnaire

DI Post-Practicum Teacher Candidates

Project Title: Science Pre-Service Teachers' Understanding and Implementation of Differentiated Instruction in Ontario High Schools

*: Question can't be skipped

Q1 Please indicate your unique ID (given code).*

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Q2 Indicate the location of your assigned school for the practicum.*
- o Central Ontario (Toronto, York, Peel…)
- o East Ontario (Ottawa, Cornwall, Kingston, Peterborough…)
- o West Ontario (Hamilton, London, St. Catharines, Waterloo, Windsor…)
- o North Ontario (Nipissing, Parry Sound, Manitoulin, Timiskaming, Sudbury, Algoma, Cochrane, Thunder Bay, Rainy River, Kenora…)

Q3 What class(es) were you placed in for the practicum? Please select all that apply.*
- ▢ Grade 7
- ▢ Grade 8
- ▢ Grade 9
- ▢ Grade 10
- ▢ Grade 11
- ▢ Grade 12

Q4 What "STEM" subject(s) did you teach? Please select all that apply.*
- ▢ Biology
- ▢ Chemistry
- ▢ Earth and Space Sciences
- ▢ Environmental Sciences
- ▢ Physics
- ▢ General Sciences
- ▢ Math
- ▢ Technology/Computer Studies
- ▢ Other; Please indicate

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Q5 Did you teach your practicum online or in-school?
- o Online
- o In-school

Q6 Please provide examples of how you differentiated instruction in your practicum (content, process, product).

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Q7 Please provide examples of how you integrated equity, diversity, and inclusion principles in your practicum classes.

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Q8 Explain the witnessed advantages/ successes of implementing differentiated instruction in terms of its impact on students during your practicum.

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Q9 Explain the witnessed advantages/ successes of implementing equity, diversity, and inclusion principles in terms of its impact on students during your practicum.

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Q10 Explain some challenges that hindered your implementation of differentiated instruction in the practicum.

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Q11 Explain some challenges that hindered your implementation of equity, diversity, and inclusion practices in the practicum.

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Q12 Did you use any of your STEM course assignments during your practicum? If yes, please describe how you incorporated them.

▢ DVGs. If yes, what feedback did you receive from your students or mentor?

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▢ Case Studies. If yes, what feedback did you receive from your students or mentor?

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▢ Curriculum Websites. If yes, what feedback did you receive from your students or mentor? ____

If you would like to share specific samples of your practicum lessons (reflecting our STEM course work), please send them by email to: mestaite@uwo.ca

Appendix F: Interview Protocol

Unique ID:

Interview Date:	Interview Start and End Time:
Class(es) in the practicum:	Subject(s) in the practicum:

Introduction: Hello X. My name is Mohammed Estaiteyeh. I am a PhD student at Western University. First, I would like to thank you for agreeing to participate in this research. I will try to discuss with you your understanding and implementation of differentiated instruction. Please note that this interview is being recorded as per your agreement. I want to confirm once again that your confidentiality and anonymity will be preserved. The interview transcription will be sent to you if you request it. Please elaborate on your answers to these items:

Understanding of DI:
1. Briefly describe your understanding of DI.
2. Do you feel that DI should be incorporated in all levels of science teaching? Why?

Course Evaluation:
1. Have you experienced/implemented DI in coursework and/or teaching prior to this course? Explain.
2. What was different between this course and other opportunities that made it particularly helpful (if so)?
3. Please recap how you DI in the 3 course assignments.
4. Would you have done the same if not this course mandate?
5. Do you feel that this activity/seminar is beneficial to teacher candidates? Why/why not? (knowledge, resources, motivation, confidence)

Implementation of DI in practicum:
1. Please provide examples of how you differentiated instruction in your practicum (content, process, product).
2. Did you use any of your STEM course assignments during your practicum? If yes, please describe how you incorporated them.
3. What feedback did you get from the mentor and students?
4. Explain the witnessed advantages/ successes of implementing differentiated instruction in terms of its impact on students during your practicum.
5. Explain some challenges that hindered your implementation of differentiated instruction in the practicum.
6. How did you make use of technology in DI? How did it help?

Implementation of DI in future career:
1. Will you utilize any of the course assignments in your future practice?
2. How do you plan to DI in your future classes?
3. List some challenges that may hinder your implementation of differentiated instruction in your future classes.

Final thoughts? Thank you.

Appendix G: DI Matrix

Differentiated Instruction Implementation Matrix-Modified2 (DIIM-M2) (Adapted from Maeng (2011) with permission)

	Criteria	Novice (1)	Apprentice (2)	Practitioner (3)	Expert (4)
Domain 1: Quality Curriculum and Lesson Design	1. Quality and clarity of the lesson objectives: What students should know, understand, and be able to do	Objectives are not clearly articulated for the lessons.	Objectives might be informed by national or state standards, but do not include big ideas meaningful to the content area.	Objectives include big ideas, issues, or problems specific and meaningful to the content area. Objectives are informed by national or state standards.	Objectives are informed by national or state standards and the important ideas, issues, or problems specific and meaningful to the content area. Objectives extend learning in authentic ways.
	2. Alignment of lesson objectives and lesson activities throughout the case study	The activities are mildly related to the objectives. It is not likely that students will master the objectives.	The activities of the lessons are unevenly related to the objectives. It is likely that only some students will master the objectives after successful completion of the activities.	The activities of the lessons are clearly related to the objectives. Most students are likely to master the objectives after successful completion of the activities.	The activities of the lessons are clearly and strongly related to the objectives. All students will master the objectives after successful completion of the activities.

Domain 2: Response to Learner Needs	1. Preassessment and Proactive Preparation	The case study demonstrates very little consideration of student needs.	The case study demonstrates that the teacher considered various student needs when planning the lessons.	The case study demonstrates that the teacher used preassessment data in advance of the lessons to plan for the needs of the students.	The case study demonstrates that the teacher used multiple sources of preassessment data and student learning profiles in advance of the lessons to plan for the needs of the students.
	2. Scaffolding for Struggling Learners; Spec. Ed., ELL, reading, etc.	Struggling learners are given irrelevant tasks of poor quality that do not require higher order thinking. Struggling learners may be grouped together most of the time.	Struggling learners are given tasks of moderate quality or better-quality tasks with little or no scaffolding and may not reach the lesson's learning goals, especially the big ideas and understandings of the lesson. Struggling students may be grouped together a lot of the time.	Struggling learners are given tasks of good quality and thoughtfulness with appropriate scaffolding and are expected to approximate the lesson's learning goals. Struggling learners experience may experience variety of grouping strategies.	Struggling learners are given tasks of high-quality and thoughtfulness with appropriate scaffolding to reach the same learning goals as other students. Multiple indicators are used when grouping students so that struggling learners experience a variety of grouping strategies.
	3. Challenging Advanced Students	Academically advanced students are assigned more or irrelevant work. They are used to	Advanced students may be challenged with probing questions and challenging tasks,	Academically advanced students are appropriately challenged at higher levels of quality, not	Academically advanced students are appropriately challenged at higher levels of complexity

		tutor less advanced students.	but are sometimes assigned more work. They may be used to tutor less advanced students.	quantity. Occasionally, they are used to academically anchor a flexible group.	and quality, not quantity. Experiences as an academic anchor in a flexible group enhance their understanding. Options are available for compacting into independent study on the topic.
Domain 3: Planned Instructional Practices	1. Lesson Organization	The lessons are unfocused and/or disorganized. The activities do not follow a logical progression.	The lessons have an identifiable structure, although the logic of that structure may be unclear. Progression of the activities is uneven.	The lessons are organized in a sensible manner, progressing in a fairly even manner.	The lessons are organized in a coherent (organized, unified, and sensible) manner, producing a unified whole.
	2. Modes and Strategies of Instruction	The lessons use a single mode of instruction that may meet the needs of some students in the class. The planned strategies or activities are not based on best practices in that content area.	The lessons use multiple modes of instruction on a limited basis, some of which may encourage active learning with the intention of providing variety for the students. Some of the strategies and	The lessons use multiple modes of instruction that encourage active learning and match the perceived learning profiles and needs of the students. Most strategies and activities reflect best	The lessons use multiple modes of instruction that require active learning and the exploration of the lessons' understandings. It intentionally matches the learning profiles and the

			activities planned in the lessons reflect best practices in that content area.	practices in that content area.	learning needs of the students. The strategies and activities reflect best practices in that content area.
	3. Engagement Capacity of Activities	Lesson components are not engaging and do not connect to the students' lives.	Lesson components are somewhat interesting to learners, but do not necessarily connect with students' prior learning, experiences, and/or goals.	Lesson components are engaging to learners and may be linked to students' prior learning or experience, and may connect with their lives and/or goals. The teacher helps students make connections between lesson content, practical applications, current events, the real world, or other aspects of the content area.	Lesson components are stimulating, motivating, and engaging to learners, linked to students' prior learning or experiences, and clearly connect to their lives and/or goals. Students explicate connections between lesson content, practical applications, current events, the real world, or other aspects of the content area.
	4. Intellectual Development	Activities are designed with little regard to student readiness, interest, and/or learning	Students with a particular readiness, interest, and/or learning profile will likely learn, but	Students with varied readiness, interest, and/or learning profiles have an opportunity to learn	Each student works at levels of readiness, interest, and/or learning profile that are

		profile. Few students are likely to learn as a result of the activities. The lessons' design does not provide work that is challenging for most of the students.	other students will find it difficult or impossible to learn. The lessons' design is inconsistent in its ability to challenge students at the highest level of which they are capable.	at some point during the lessons. A few students are able to find loopholes in the lessons' design which permits them to avoid completing their highest quality work.	appropriately challenging. The lessons are designed so that all students are compelled to do their best and complete high-quality work. The strategies and activities are planned to promote higher order thinking for all students.
	5. Flexible Grouping	Lessons may use a grouping strategy, but groups are not differentiated in any intentional way. Student groupings, which may have been created using some student data, are not flexible, but remain static over time.	Lessons use at least one grouping strategy that differentiates content, process, or product by readiness, interest, or learning profile. Flexibility is to accommodate variety in the lesson as opposed to matching student needs to the lesson's learning goals.	Lessons use at least one grouping strategy that differentiates content, process, or product by readiness, interest, or learning profile. Flexibility in grouping strategies is a planned response to student needs.	Lessons use various student groupings: individual, pairs, small groups. Students are grouped for a great variety of reasons to differentiate content, process, and/or product by readiness, interest, and/or learning profile. The lessons may combine grouping rationales (i.e., readiness and interest). Flexibility

					in grouping strategies is in response to a clear analysis of student needs.
	6. Teacher's Planned Role, Learner Independence, and Student Choice	The teacher's planned role is to only deliver content and/or direct student activity. Teacher will take the lead in most classroom activities. Students have no input or choice in lesson components.	Teacher's planned role is primarily deliverer of information and/or director of student activity. Teacher will invite occasional student input into lesson content and activities. Students have an opportunity to make a choice at some point in the lessons.	Teacher will play the role of deliverer of information and/or director of student activity, but will also act as coach or facilitator of learning at some point in the lessons. Students will have some input into lesson content and activities. There is a balance of student and teacher choice.	Teacher's overall planned role is primarily that of coach or facilitator in learning. Both students and teacher will have consistent input into lesson content. Students take on increasing responsibility for their own learning. There is a perfect balance of student and teacher choice.
	7. Technology Integration	The teacher plans a limited use of digital material. It is very difficult to implement the lessons in an online environment.	The teacher plans some use of digital material. With many modifications, the lessons can be implemented in an online environment.	The teacher plans a good use of digital material. With minor modifications, the lessons can be implemented in an online environment.	The teacher plans an excellent use of digital material. The lessons can be fully implemented in an online environment.
Domain 4: Student Assessment	1. Formative Assessment	Teacher does not plan to use formative assessment during	Teacher may plan to use some general informal assessment during the lessons	Teacher plans to use formative assessments embedded within	Teacher plans to regularly use formative assessments

		or at the end of the lessons.	(e.g., class poll) or at the end of the lessons (e.g., quiz, exit card). The data are used to gauge understanding of the lesson objectives and/ or to plan for future whole-class instruction.	the body of the lessons to make minor modifications to instruction (e.g. reviewing, clarifying misconceptions, adjusting lesson pacing) and to gauge student understanding. Assessment data are used to plan whole-class instruction.	throughout the lessons. Data from these lessons is used to: make modifications to instruction within a lesson, to gauge student understanding, and to plan future instruction for individuals and groups.
	2. Existence and Quality of Rubrics and Guidelines	Rubrics and guidelines have not been developed.	Rubrics and guidelines have been developed, but are not clear.	Rubrics and guidelines are developed with clearly articulated assessment criteria.	Rubrics and guidelines of clearly articulated assessment criteria and standards are developed. Students have the ability to participate in the creation of the rubric and guidelines and can actively plan next steps for learning.
Domain 5: Positive, Supportive,	1. Principles of Equity, Diversity, and Inclusion (EDI) as	The case study demonstrates an inadequate	The case study demonstrates an acceptable	The case study demonstrates an accomplished	The case study demonstrates a sophisticated

and Inclusive Learning Environment	stated in Ontario's Education Equity Action Plan (Ontario Ministry of Education, 2017)	understanding of EDI principles. The case study does not implement inclusive and culturally responsive pedagogy. Planned lessons do not reflect or attend to diversity (race, ethnicity, culture, religion, socioeconomic status, immigration status, Indigenous communities, Indigenous histories and ways of knowing, sexual orientation, gender identity...).	understanding of EDI principles. The case study partially implements inclusive and culturally responsive pedagogy. Planned lessons minimally reflect or attend to diversity (race, ethnicity, culture, religion, socioeconomic status, immigration status, Indigenous communities, Indigenous histories and ways of knowing, sexual orientation, gender identity...).	understanding of EDI principles. The case study implements inclusive and culturally responsive pedagogy. Planned lessons sufficiently reflect and attend to diversity (race, ethnicity, culture, religion, socioeconomic status, immigration status, Indigenous communities, Indigenous histories and ways of knowing, sexual orientation, gender identity...).	understanding of EDI principles. The case study excellently implements inclusive and culturally responsive pedagogy. Planned lessons fully reflect and attend to diversity (race, ethnicity, culture, religion, socioeconomic status, immigration status, Indigenous communities, Indigenous histories and ways of knowing, sexual orientation, gender identity...).
	2. Respectful Behavior Toward and Among Students	The lessons' structure discourages students' participation and questions. Students are not provided with opportunities	The lessons' structure does not encourage participation and questions from a broad range of students. Students are provided with	The lessons' structure fosters participation and questions from most students. Students are provided with enough opportunities to be	The lessons' structure fosters active participation and questions from all students. Awareness of students' strengths, successes, and

		to be aware of each other's strengths, successes, and contributions.	few opportunities to be aware of each other's strengths, successes, and contributions.	aware of each other's strengths, successes, and contributions.	contributions are cultivated and celebrated.
	3. Sense of Community and Collaboration	No apparent focus on individual or group excellence and growth. Students can not engage or support one another in learning.	Focus tends to be on competition among students rather than individual or group excellence and growth. There are minimal opportunities for students to engage and support one another.	Individual and group excellence and growth appear valued. Students can generally engage and support one another in learning.	Students and teacher can consistently focus on both individual and group excellence and growth. Students can consistently engage and support one another in learning. They are supported to work with any other student in the class.
Domain 6: Evidence of Differentiation	1. Content "The input of teaching and learning," adapting *what* is taught and modifying *how students are given access* to the information and understandings. (Tomlinson, 2001, p. 72)	Lessons are mostly about learning discrete facts and do little to address concept-based instruction. All students are working with the same materials.	Lessons are designed to be roughly a 50/50 split between concept-based instruction and learning discrete facts. There may be two options for material use that vary in readability, complexity, and/or interest. Lessons may include one of	Lessons are concept-based, but may contain some learning of discrete facts. There are several options for material use that vary in readability, complexity, and/or interest. Lessons include at least one or more of the	Lessons are highly concept-based and makes use of diverse materials at various levels of readability, complexity, and/or interest. Lessons include, but are not limited to, one or more of the following strategies: multiple ways to

			the strategies listed in the Expert column.	strategies listed in the Expert column.	access and organize information, learning contracts, curriculum compacting, flex-group mini-lessons, and varied support systems such as audio/video recorders, note-taking organizers, highlighted print materials, digests of key ideas, peer/adult mentors.
	2. Process "Process means sense-making… [and] is an essential component of instruction because, without it, students either lose the ideas or confuse them" (Tomlinson, 2001, p. 79).	Very little, if any, instructional time is spent on small groups of students or individuals working on various sense-making activities. All students tend to complete the same work with little variation.	Less than half of the instructional time is spent on small groups of students or individuals working on various sense-making activities that differ in their approach to learning or degree of sophistication. Sense-making activities do not always focus on essential understandings. The	More than half of the instructional time is spent on small groups of students or individuals working on various sense-making activities that differ in either their approach to leaning or degree of sophistication. All sense-making activities use essential skills and essential	Most of the instructional time is spent on small groups of students or individuals working with various sense-making activities that represent a diversity of approaches at varied degrees of sophistication to be completed in varying time spans with various levels

			lesson's sense-making activities may differentiate by readiness, interest, or learning profile.	information to understand the big idea or understanding of the lesson. The lesson's sense-making activities may differentiate by readiness, interest, or learning profile.	of scaffolding. All sense-making activities use essential skills and essential information to understand the big idea or understanding of the lesson. The lesson's sense-making activities may differentiate in one or more of the following ways: readiness by matching complexity of task to student's current level of understanding; interest by giving students choices and linking to personal interests and/or goals; learning profile by making sense of ideas in the students' preferred way of learning.

	3. Product “A product is a long-term endeavor… that helps students – individually and in groups – rethink, use, and extend what they have learned…[and] represent your students’ extensive understandings and applications.” (Tomlinson, 2001, p. 85).	Case study provides a single product option designed to explore the understandings of the unit’s goals. Guidelines provide a structure to focus and guide students and may provide limited choices OR guidelines may be overbearing. Students do not have input into the project requirements and assessment criteria. Teacher is reactionary and solves problems or answers as needed.	Case study provides at least two product options that are designed to explore the understandings of the unit’s goals. Products may differ due to curriculum requirements, interest, or learning profile. Guidelines provide a structure to focus and guide students and provide some choices. Students have limited input into the project requirements and assessment criteria. Teacher sometimes works as a coach to facilitate and scaffold students’ thinking, but is largely reactionary, solving problems and answering questions as needed.	Case study provides several product options that are designed to foster deeper understandings of the unit’s goals. Products may differ due to curriculum requirements or student readiness, interest, or learning profile. Guidelines provide a balance between structure needed to focus and guide students and freedom to support innovation and thought. Students have some input into the project requirements and assessment criteria. Teacher works as a coach to facilitate, scaffold, and expand the students’ thinking through flexible study groups, mini-	Case study provides several product options that are designed to foster deeper and richer understandings of the unit’s goals. Products may differ due to curriculum requirements or student readiness, interest, or learning profile. Guidelines provide the perfect balance between structure needed to focus and guide students and freedom to support innovation and thought. Students collaborate with the teacher to design the project requirements, timeline for completion, and assessment criteria. Teacher works as a coach to facilitate, scaffold, and expand

				lessons, and conferencing.	the students' thinking through flexible study groups, mini-lessons, and conferencing.

Curriculum Vitae

Name: Mohammed Estaiteyeh

Education:

Degree	University	Department and Emphasis	Year
PhD	Western University, Canada	Curriculum Studies- Faculty of Education Research: STEM Education; Equity, Diversity, and Inclusion in Education; and Online Teaching and Learning	April 2022
MA	American University of Beirut, Lebanon	Education Department Degree Emphasis: Science Education	2014
Teaching Diploma	American University of Beirut, Lebanon	Education Department Degree Emphasis: Science Education for Secondary Classes	2008
BS	American University of Beirut, Lebanon	Biology	2006

Recent Work Experience:

Date	Position	Department	Institution
January 2022-current	Research Assistant- Online Teaching and Learning	Ivey Business School	Western University
September 2021-April 2022	Course Instructor (Curriculum and Pedagogy in STEM Education- Year 2)	Faculty of Education	Western University
January 2021-current	Research Assistant- Interdisciplinary Medical Sciences Program Evaluation	The Schulich School of Medicine & Dentistry	Western University
May-August 2021	Research Assistant- Educational Technology and Online Teaching	Faculty of Education	Western University
September 2020-April 2021	Teaching Assistant (Curriculum and Pedagogy in STEM Education- Year 2)	Faculty of Education	Western University
August-December 2020	Conference Planner, Facilitator, and Researcher	Institute for Earth and Space Exploration	Western University

Honors and Awards:

2021	Ontario Graduate Scholarship (OGS), May 2021-April 2022. (15,000.00 CAD)
2021	Art Geddis "Learning About Teaching" Memorial Award, Western University, April 22, 2021. (500.00 CAD)
2020	"Jessica Jean Campbell Coulson Award" for Inclusive Education, Western University, May 13, 2020. (2,000.00 CAD)
2020	"Inclusive Education Research Award" by the Canadian Research Centre on Inclusive Education, Western University, February 20, 2020. (750.00 CAD)

Selected Publications:

DeCoito, I., & **Estaiteyeh**, **M.** (2022). Online teaching during the COVID-19 pandemic: Exploring STEM teachers' curriculum and assessment practices in Canada. *Disciplinary and Interdisciplinary Science Education Research, 4*(8). https://doi.org/10.1186/s43031-022-00048-z

DeCoito, I., & **Estaiteyeh**, **M.** (2022). Transitioning to online teaching during the COVID-19 pandemic: An exploration of STEM teachers' views, successes, and challenges. *Journal of Science Education and Technology*. https://doi.org/10.1007/s10956-022-09958-z

DeCoito, I., & **Estaiteyeh, M.** (in press). STEM teachers' transition to online teaching during the COVID-19 pandemic: A Canadian context. In H. Burgsteiner & G. Krammer (Eds.), *Impacts of COVID-19 pandemic's distance learning on students and teachers in schools and in higher education – International perspectives*. Leykam.

Estaiteyeh, M. (2021). Differentiated instruction in science classrooms: The potential role of technology. In D. Anderson, M. Milner-Bolotin, R. Santos, & S. Petrina (Eds.), *Proceedings of the 6th International STEM in Education Conference (STEM 2021)*. (pp. 116-123). University of British Columbia. https://dx.doi.org/10.14288/1.0402129

Patel, P., DeCoito, I., **Estaiteyeh, M.,** & Osinski, G. (2020). Space Explorer's Academy: A unique expert led outreach program to engage youth in space! *Proceedings of the 71st International Astronautical Congress – The Cyberspace Edition.*

Estaiteyeh, **M.,** & DeCoito, I. (in preparation). Preparing teacher candidates for online teaching by promoting their technological knowledge in STEM education. To be submitted to the *Journal of Science Teacher Education*.

DeCoito, I., & **Estaiteyeh**, **M.** (in preparation). A success story of STEM teacher candidates' creation of engaging and inclusive digital curriculum resources. To be submitted to the *Canadian Journal of Science, Mathematics and Technology Education*.

DeCoito, I., & **Estaiteyeh**, **M.** (in preparation). Online teaching and learning in STEM education: Enhancing teacher candidates' pedagogical knowledge in a digitally enriched course. To be submitted to the *Journal of Teacher Education*.

DeCoito, I., & **Estaiteyeh**, **M.** (in preparation). The impact of developing digital timelines on science teacher candidates' nature of science conceptions. To be submitted to the *International Journal of Science Education.*

Campbell, N., **Estaiteyeh**, **M.,** & DeCoito, I. (in preparation). Preparing graduate students for success: Validating interdisciplinary skill development needs. To be submitted to *Disciplinary and Interdisciplinary Science Education Research.*

Campbell, N., **Estaiteyeh**, **M.,** & DeCoito, I. (in preparation). Curriculum design process: The development of an interdisciplinary medical sciences master's program that fosters academic, professional, and personal skills. To be submitted to the *Journal of Curriculum Studies*.

Selected Academic Presentations:

Estaiteyeh, M., & DeCoito, I. (2022, May 15-19). *Tracking the development in STEM teacher candidates' conceptions and implementation of equity, diversity, and inclusion through reflective practice* [Paper Accepted]. Canadian Society for the Study of Education (CSSE) 2022 Conference, Virtual. https://csse-scee.ca/conference/ (First Author & Presenter)

DeCoito, I. & **Estaiteyeh, M.** (2022, May 15-19). *Addressing STEM teachers' challenges in online teaching by enhancing their TPACK and creating digital resources* [Paper Accepted]. Canadian Society for the Study of Education (CSSE) 2022 Conference, Virtual. https://csse-scee.ca/conference/ (Co-author & Co-presenter)

DeCoito, I. & **Estaiteyeh, M.** (2022, April 22-25). *Curriculum and pedagogy in STEM teacher education: Preparing teacher candidates for online teaching* [Poster]. American Educational Research Association (AERA) 2022 Conference, San Diego, CA. https://www.aera.net/Events-Meetings/Annual-Meeting (Co-author & Co-presenter)

Estaiteyeh, M. (2022, April 1-3). *Promoting STEM teacher candidates' understanding and implementation of equity, diversity, and inclusion in teacher education* [Paper]. 13th Robert Macmillan Symposium in Education (RMSE), Virtual. https://www.edu.uwo.ca/graduate-education/research__events/graduate-symposium/index.html

Estaiteyeh, **M.,** & DeCoito, I. (2022, March 27-30). *Enhancing STEM teacher candidates' understanding and implementation of equity, diversity, and inclusion through differentiated Instruction* [Paper]. National Association for Research in Science Teaching (NARST) 2022 Conference, Vancouver, BC. https://narst.org/conferences/2022-annual-conference (First Author & Presenter)

Campbell, N., **Estaiteyeh**, **M.,** & DeCoito, I. (2022, March 27-30). *Preparing graduate students for success: Validating interdisciplinary skill development needs* [Poster]. National Association for Research in Science Teaching (NARST) 2022 Conference, Vancouver, BC. https://narst.org/conferences/2022-annual-conference (Co-author & Co-presenter)

Estaiteyeh, **M.,** & DeCoito, I. (2022, January 6-8*). Case studies: Promoting STEM teacher candidates' understanding and implementation of differentiated instruction* [Paper]. Association for Science Teacher Education (ASTE) 2022 Conference, Greenville, SC. https://theaste.org/meetings/2022-international-conference/ (First Author & Presenter)

DeCoito, I. & **Estaiteyeh, M.** (2022, January 6-8). *Curriculum and pedagogy in STEM education: Exploring teacher candidates' preparation for online teaching* [Paper]. Association for Science Teacher Education (ASTE) 2022 Conference, Greenville, SC.

https://theaste.org/meetings/2022-international-conference/ (Co-author & Co-presenter)

Estaiteyeh, M. (2021, July 5-9). *Differentiated instruction in science classrooms: The potential role of technology* [Paper]. 6th International STEM in Education Conference, Virtual. https://stem2021.ubc.ca/

Estaiteyeh, M. (2021, July 5-9). *Differentiated instruction in science classrooms: A comprehensive literature review* [Poster]. 6th International STEM in Education Conference, Virtual. https://stem2021.ubc.ca/

DeCoito, I. & **Estaiteyeh, M.** (2021, May 29-June 3). *Science/STEM teachers' support and recommendations for successful online teaching during the COVID-19 pandemic: A Canadian context* [Paper]. Canadian Society for the Study of Education (CSSE) 2021 Conference, Virtual. https://csse-scee.ca/conference/ (Co-author & Co-presenter)

Estaiteyeh, M. (2021, May 29-June 3). *STEM pre-service teachers' understanding and implementation of differentiated instruction in Ontario secondary classrooms: Research design* [Roundtable]. Canadian Society for the Study of Education (CSSE) 2021 Conference, Virtual. https://csse-scee.ca/conference/

DeCoito, I. & **Estaiteyeh, M.** (2021, April 7-10). *STEM teachers' curriculum practices in online teaching during the COVID-19 pandemic: A Canadian context* [Paper]. National Association for Research in Science Teaching (NARST) 2021 Conference, Virtual. https://narst.org/conferences (Co-author & Co-presenter)